THE POTENTIAL ROLE OF AGRICULTURAL LAND DRAINAGE IN ECONOMIC GROWTH

Thesis for the Degree of Ph. D.

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MELVIN L. COTNER

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This is to certify that the

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presented by

Melvin L. Cotner

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of the requirements for

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ABSTRACT

THE POTENTIAL ROLE OF AGRICULTURAL LAND DRAINAGE IN ECONOMIC GROWTH

by Melvin L. Cotner

One of the main objectives of this study was to formulate general principles concerning the role of natural resources in economic growth. The thesis of this study is that the use and development of natural resources is and can be an important factor in economic development.

A review of literature found varying views about natural resources and their relationship to economic activity. Many scientists and laymen hold that the Malthusian doctrine still is applicable. Others argue that abnormal scarcity rents have not accrued to natural resources and therefore the Malthusian law is invalid. Scientists point to changes in the quality of resource inputs, thereby improving the productive capacity of our natural resources. Put another way, manmade substitutes developed through modern technology have lessened the pressure on the conventional natural resources.

An analytical model is developed which encompasses the agricultural resources of a 42-county region in lower Michigan. The model is designed to investigate the importance of natural resource development under specified alternative demand conditions and changes in the level of technology. The model developed is a minimum-cost formulation of a linear program. It is designed to simulate a partial economic equilibrium of the agricultural economy of the study area. By developing comparative static solutions with and without the test variables, the

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potential effects on natural resource rents and consumer benefits are determined. The basic linear programming model contains detailed information on soils, their quantity, productivity and location within the regions. The coefficients in the model are intended to be realistic estimates of conditions in 1980 for the region.

Without technological change, natural resource rents increase significantly as population increases. Alternatively, natural resource rents decrease as technology gains outstrip the food and fibre product needs. The adoption of field drainage provides significant efficiency benefits that accrue to producers or consumers depending upon demand elasticities. Owners of drainable land receive increased rents.

Two subareas of the 42-county region are studied in detail: the Thumb and South Central areas. According to the linear program, some 650 thousand crop acres have economic potential for additional field drainage. A survey of randomly selected farmers in the two areas indicated that farm operators felt additional drainage would pay on about the same number of acres. But only one-fifth of the farmers had plans for investing in drainage. Farm owners listed internal capital rationing as the principal reason for not undertaking the practice. Inadequate outlets for field drainage also were a significant factor in retarding drainage adoption.

The analysis provides insights as to the relationship of resource development in the form of drainage to economic growth. Implications for general policies and specific programs are developed.

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THE POTENTIAL ROLE OF AGRICULTURAL LAND DRAINAGE IN ECONOMIC GROWTH

By

Melvin L. Cotner

A THESIS

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Michigan State University
in partial fulfillment of the requirements
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ACKNOWLEDGEMENTS

The research reported here represents, in part, the agricultural land drainage study undertaken by both the Farm Production Economics Division and Natural Resource Economics Division of the Economic Research Service, USDA. The work was in cooperation with the Agricultural Experiment Station at Michigan State University. The drainage survey of farmers in the Thumb and South Central areas of Michigan was undertaken while the author was a member of FPE. Later, the author transfered to NRE at which time the agricultural production and drainage model was developed. The author expresses his appreciation to C. W. Crickman and W. B. Sundquist of FPE and W. A. Green and H. A. Steele of NRE who provided administrative and technical support as well as financial arrangements for the work.

A special thanks to Dr. David Boyne who served as thesis advisor. His suggestions and constructive criticisms, as well as those of the thesis committee, have improved the manuscript significantly. The assistance of A. Allan Schmid as chairman of the guidance committee, also is gratefully achnowledged.

The assistance of John Hostetler, a co-worker in the Natural Resource Economics Division, ERS, located at Michigan State is deeply appreciated. His help in the development of the basic data reported in Chapter IV and in checking computer runs was invaluable. R. D. Dunlap, another NRE employee, assisted in the computer runs made at the University of Illinois. Vernon McKee of the Program, Evaluation and Planning Staff, USDA, provided valuable assistance in interpreting and presenting results.

Pat Durst, NRE secretary at East Lansing, typed earlier drafts of the manuscript. Secretarial staff in the Department of Agricultural Economics and NRE assisted in typing and editing. To these--a debt of gratitude.

Finally, the encouragement received from an understanding family has been deeply appreciated as work on my graduate program was extramural, which served as a principal substitute for family life. My wife, Clara, typed the final manuscript, a task performed with more excellence than the manuscript deserves. Errors of omission and commission, of course, are the author's.

Melvin L. Cotner

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The world is finite, resources are scarce,
Things are bad and will be worse,
Coal is burned and gas exploded,
Forests cut and soils eroded.
Wells are dry and air's polluted,
Dust is blowing, trees uprooted.
Oil is going, ores depleted,
Drains receive what is excreted.
Land is sinking, seas are rising,
Man is far too enterprising.
Fire will rage with Man to fan it,
Soon we'll have a plundered planet.
People breed like fertile rabbits,
People have disgusting habits.

Moral:

The evolutionary plan
Went astray by evolving Man.

THE TECHNOLOGIST'S REPLY

Man's potential is quite terrific,
You can't go back to the Neolithic.
The cream is there for us to skim it,
Knowledge is power, and the sky's the limit.
Every mouth has hands to feed it,
Food is found where people need it.
All we need is found in granite,
Once we have the men to plan it.
Yeast and algae give us meat,
Soil is almost obsolete.
Men can grow the pastures greener,
Til all the earth is Pasadena.

Moral:

Man's a nuisance, Man's a crackpot,
But only Man can hit the jackpot.

(Written by Kenneth Boulding; inspired by the symposium on "Man's Role in Changing the Face of the Earth")

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CHAPTER I

THE POTENTIAL ROLE OF AGRICULTURAL LAND DRAINAGE IN ECONOMIC GROWTH

INTRODUCTION

The United States does not have a comprehensive natural resources policy. The current emphasis on comprehensive water resource management is a step in this direction.1/ But this policy pertains to only one of the several natural resources. Many divergent views exist concerning the role natural resources can play in economic growth. Even so, existing and expected population pressures within the United States and the world provide the impetus for a better defined policy on natural resource use and development.

While one would be optimistic to envision a monolithic resource policy under which all resource problems would be solved, a conceptual framework of the relationship of resource availability to economic growth should be developed. A resource policy is difficult in that goods and services from resources move in national and international markets. Resource use is conditioned by interregional and international resource supply and demand relationships.

A comprehensive resource policy is complicated from the institutional standpoint also. In our federal system, the local, state and national governments as well as individuals play interdependent roles in resource use and development. A resource development program at

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1/ Senate Document 97. Policies, Standards, and Procedures in the Formulation, Evaluation and Review of Plans for Use and Development of Water and Related Land Resources, 87th Congress, 2d Session, May 1962.

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The dynamic and complex physical, economic and institutional relationships make the work of the economist difficult. But economic principles and theories are held to be relevant in the allocation, development and use of resources for the benefit of society.

A. Purpose

In this research an examination of general principles concerning natural resources, their development and their potential influence on economic growth is made. Such principles should be useful to those involved in the policy formulation process.

Only one aspect of the natural resource-economic growth problem will be studied in depth; that of examining the potential influence of agricultural land drainage in a specific region on economic growth under varying assumptions. Even with the narrow focus of the analytical part of this work, not all of the relevant variables are studied. As will be pointed out, additional information is needed by policymakers if a comprehensive natural resource policy is to be formulated. Information on the economic potential of drainage, even though partial, should assist in the development of specific programs concerning land and water resources.

Analytical techniques and procedures will be developed which may be useful in the future analysis of agricultural resource development problems. The procedures are applied in a pilot study of lower Michigan and will be evaluated concerning their applicability and effectiveness.

B. Objectives

The general objectives of this study are to: (1) review literature relevant to the resource scarcity and economic growth problems,

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(2) articulate the theoretical relationships and public policy implications for alleviating the resource scarcity impacts on economic growth, (3) develop and test an analytical model for examining the potential contribution of agricultural land drainage to economic growth in selected areas of lower Michigan, (4) examine the critical variables in the analysis of land drainage potentials, and (5) analyze farmers' experience and plans for making field drainage improvements in the study areas.

With respect to the analytical model for selected areas of lower Michigan, the specific objectives are to: (1) determine the effect of increased food and fibre demands on the likely adoption of agricultural land drainage, (2) examine the aggregate effects of alternate public cost-sharing arrangements for field drainage, and (3) evaluate the substitution relationship between nondrainage technology gains and agricultural land drainage.

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CHAPTER II

ROLE OF NATURAL RESOURCES IN ECONOMIC GROWTH

The purpose of this chapter is first to review literature relevant to various resource scarcity doctrines, policies based on them and attempts to validate them. Then an attempt will be made to recapitulate the classical theory on resource scarcity and broaden it to represent new concepts about resource availabilities. Finally the public policy implications of the broader theory will be developed. Principles for public investment strategies for resource development and general technology development will be discussed. The material in this chapter provides the theoretical underpinning for the development of the analytical model to follow.

A. Resource Scarcity Doctrines

Both pessimistic and optimistic views can be found among laymen and scientists that nonreproducible natural resources are scarce and are becoming more so. The pessimistic view obviously leads to questions about natural resource limitations on economic growth and questions about the wise use of these resources over time.

Malthusian scarcity doctrine--During the early part of the 19th Century, Malthus postulated that population increases in geometric progression while means of subsistence increase arithmetically. Thus, in a matter of time, population eventually would begin to press on the means of subsistence. Modern theorists have classified this as the scarcity doctrine. According to this view, natural resources, being nonreproducible, ha

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nonreproducible, have a finite supply. According to this doctrine, as all of the available natural resources are brought into use the law of variable proportions comes into effect. The economy runs into diminishing marginal productivity of labor and capital as these factors expand against the fixed amount of natural resources.

As output per capita declines, the economic welfare of individuals is impaired. Likewise, if economic growth is measured by the increase in output, the diminishing returns slow the growth rate and ultimately, as output reaches a maximum, economic growth will cease.1/

Ricardian scarcity doctrine--In its rigorous presentation, the Malthusian scarcity view assumes homogeneous resources and absolute limits on their availability. The scarcity model attributed to David Ricardo relaxes these assumptions by postulating that resources are available but they have varying economic quality. As demand increases occur, resources of declining economic quality are employed. If in fact, a society does call in the more productive resources first, then the diminishing productivity associated with increased resource employment would have a dampening effect on economic welfare and economic growth just as in the Malthusian scarcity model.

Depletion scarcity doctrines--Nonreproducible resources can be depleted or destroyed over time. Stock resources and to a certain extent flow resources diminish with use. Soil nutrients, tree growth,

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1/ For a discussion of these points see Morse, Chandler and Harold J. Barnett. "A Theoretical Analysis of Natural Resources Scarcity and Economic Growth Under Strict Parametric Constraints," Natural Resources and Economic Growth, compendium of papers presented at conferences of Committee on Economic Growth of the Social Science Research Council, Joseph J. Spengler, editor, April 1960, p. 23.

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minerals, ores, etc., are depletable. Associated with maintaining the renewable or flow resources is the problem of ecological balance. Damage to a single resource or element may deplete the aggregate of the resources available for man's use. The depletion and impairment of the natural balance of the earth's resources allow the Malthusian and Ricardian scarcity doctrines to be more severe. Diminishing returns become more acute and economic welfare and growth more limited.

Faith in science doctrine--While at any given time the supply of a particular material or group of resources may be limited, there is reason to believe that over the long run the total supply of resources can be expanded. The technology and knowledge springing from science in effect can expand the supply of the resources either in developing more resources in the same form as the original or by developing substitutes.

The new concept of resources is a dynamic view. As science improves and man's knowledge grows, increasing proportions of our total environment can be used to provide food, shelter, clothing, tools, energy, etc. At the present time only a small proportion of our total environment is used for these purposes. Likewise,if we accept the view that there is an infinite amount of matter in total space then the horizons are unlimited. Furthermore, if matter is never destroyed by virtue of its being used, and only its current arrangement into useful resources is destroyed, then man needs only to resort to the process of science to develop some new (and perhaps improved) replacement or substitute resources.[1]

1/ For an excellent discussion of the technological advances on the horizon see Fisher, Joseph L., and Haus H. Landsberg, Natural Resources Projections and Their Contribution to Technological Planning, Resources for the Future, Washington, D. C., Reprint No. 32, January 1962, pp. 127-137.

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The implications of this view for economic growth and welfare are profound. There would be no resource limitation on growth. As pressures on resources mount and labor and capital experience diminishing marginal productivity, forces would be set off in the economy to develop substitutes for the resource. Economic welfare need not diminish because of resource scarcity as long as the forces of science and technology can be controlled and directed to this end.

This "confidence in science and technology" could lead resource users to proceed with reckless abandon. However, most individuals who hold the optimistic view also see the necessity of the wise use of existing resources over time. The wasteful use of resources would not be socially desirable. Rather than drift with population trends and technology this group holds the view that society should strive for increasing control over the key factors in the population-resource problem. This process involves a systematic appraisal of trends in population, resources, and economic activities so that emerging problems may be foreseen and plans made for meeting them.1/

Public opinion about scarcity doctrines--Many highly regarded officials, educators as well as laymen, voice concern about the resource scarcity problem. For instance, Admiral Rickover stated on a TV program,

> If we continue to use minerals and fuels at the rate we do, there is no question that within a generation or two there will be a shortage. It is my firm conviction that that nation which controls energy resources will become the dominate nation in the world.2/

1/ For a discussion of these views of "cautious optimism" see Fisher, Joseph L., Our Resource Situation and Outlook -- Public Policy and Individual Responsibility, Reprint No. 22, Resources for the Future, Washington, D. C., 21 pp.

2/ "See It Now," TV program manuscript, November 18, 1956, CBS.

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1/ Cook, Rober
1951, p. 296.

2/ Reese, Jim
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A geneticist, Robert C. Cook writes:

> The world's growing population will force the use of marginal lands, which in general are extremely expensive to exploit. More and more human energy will have to be devoted to the basic problem of producing food and the standard of living instead of going up, will remain at the subsistence level..., while the wealthier areas will find their standards of living declining. Already the pressures of population in most parts of the world have compelled an unwise exploitation of the good lands.[1]

An economics professor writes:

> Under these circumstances the Malthusian doctrine is not a theory but a reality in many parts of the world. We have only to think of China, Indonesia, Egypt, Java or even parts of Europe where food is scarce and the standards of living unbelievably low, to realise the seriousness of the problem.... Even in this country there is a growing concern as to how long our existing resources can continue to support an expanding population and rising standard of living. Furthermore, if we accept the concept of a finite supply of resources we are forced to admit there is no answer to the population problem. No matter how much we save or replenish it is only a question of time until the supply is exhausted. For the more pessimistic, it is a matter of years, for the optimist a little longer.[2]

These statements concerning the scarcity doctrines go on ad infinitum. Large numbers of our lay conservationists, as well as many of our more highly trained individuals, believe in the pessimistic scarcity doctrines.

1/ Cook, Robert C., Human Fertility, The Modern Dilemma, London 1951, p. 296.

2/ Reese, Jim E., "The Impact of Resource Decisions on America's Economic Development, Resource Use Policies: Their Formation and Impact (a series of background talks) Conservation and Resource-Use Educational Project, Joint Council of Economic Education, New York, May 1959.

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1/ See "An I
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2/ Ibid., se

Policies assuming scarcity--Many of those responsible for developing our national resource use programs tacitly assume the validity of the scarcity doctrines. Conservation policies aimed at maintaining the productivity of resources over time are devised with the purpose of maintaining economic welfare and fostering economic growth.

An example of the use of the implicit scarcity assumption is the recent conservation needs inventory for Michigan and the U. S.[1/] In the determination of Michigan soil and water conservation needs, one of the basic assumptions guiding technicians in developing the needs inventory was that the resources would not be able to supply the farm product needs of consumers in 1975. The assumptions were that aggregate demand for farm production in 1975 would increase about 40 percent over 1953 because of population increase and small increases in per capita expenditures. Since production currently is in excess of utilization, an increase of around 30 percent will meet projected requirements. For this inventory Michigan farm production is assumed to increase 25 percent between 1953 and 1975.[2/] The fact that there is a gap between requirements and the potential supply indicates that, implicitly, the scarcity doctrine must hold. With this as a basic assumption, technicians in the various counties when developing the needs inventory would tend to stress the use of more conservation inputs for the maintenance and development of agricultural land.

The productivity change of 25 percent has as one basis, at least,

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1/ See "An Inventory of Michigan Soil and Water Conservation Needs," Michigan Agricultural Experiment Station, November 1962, and Basic Statistics of the National Inventory of Soil and Water Conservation Needs, Statistical Bulletin 318, USDA.

2/ Ibid., see Michigan Experiment Station publication, p. 7.

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a study by USDA natural scientists and agricultural economists.[1] Two types of yield projections for 1975 were made. An "economic maximum" yield and an "economically attainable" yield were determined. Both projections were in terms of presently known practices. The "economic maximum" yield was estimated based on each farmer being completely rational. No noneconomic factor would retard the full economic adoption of current practices. The "economically attainable" projection was based on the assumption that certain limitations on management and incentives would influence and tend to retard the practice adoption rate. The latter projection was based primarily on past rates of adoption of improved practices. The 1975 agricultural production was projected to be 50 percent higher than the 1957 level if the "economic maximum" assumption is used and 25 percent higher than the 1957 level if the "economically attainable" level is postulated. The latter figure was used for developing the state conservation guide.

The "economically attainable" measure gives no weight to the development of new techniques of production during this period that would shift the production function upward. In this context the linear extrapolation of existing techniques seems unduly conservative. Regardless of its accuracy the projection as used by the conservation needs workers had an implicit assumption of resource scarcity.

B. Contemporary Theoretical Work

Professor T. W. Schultz at the University of Chicago has been instrumental in bringing about an awareness of the role of resources in economic growth and welfare. In looking at the performance of

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3/ Barton, G. T. and R. E. Daly. Prospects of Agriculture in a Growing Economy, paper presented at conference on Problems and Policies of American Agriculture, October 27-31, 1958, mimeograph, p. 13.

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2/ Ibid., p

Western countries as they have developed, he finds that natural resources receive a smaller proportion of the total national product as the nation develops. Further, as increased demands are placed on natural resources their unit prices have not increased relative to other prices. (These empirical generalizations will be discussed more fully in the next section.) His hypothesis supports the optimistic view developed in this section about resource scarcity, viz., advances in economic growth and welfare need not be limited by natural resources.

Schultz's thesis is that economists have not taken into account all of the resources used in production. There have been some new resources not considered and there have been some effective substitutes for the land resource in this set of new resources.1/

The characteristic of modern economic growth is that wholly new resources are developed and these resources play an ever increasing role in production and growth. Schultz states, "It is by adding to the stock of resources and, then, by employing them that we increase the national product."2/ Thus, increases in resources result in economic growth.

Schultz distinguishes two sets of resources - conventional and nonconventional. Conventional resources include labor, land and reproducible physical capital as conventionally treated and measured. Schultz labels the nonconventional set of resources as those that pertain primarily to the improvement in the quality of the conventional resources. Of primary importance is the concept of human capital. The quality of

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1/ Schultz calls this the "underspecification of resources." He developed this idea in his lectures given at the University of Illinois, June 17-20, 1958. See Schultz, T. W., "Land in Economic Growth," Agricultural Economics Research Paper No. 3816, Univ. of Chicago, August 26, 1958 (mimeograph), pp. 27-32.

2/ Ibid., p. 27.

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the labor force and the stock of useful knowledge have increased. In other words the nonconventional resource is increased knowledge. Schultz hypothesizes that these nonconventional resources are manifest in the improved quality of the old conventional resources.1/ He argues that his hypothesis is supported by the fact that the size of the stock of nonconventional inputs has increased relative to that of the conventional set and that the rate of return obtained from the productive services of these new resources has been relatively high.

Other workers are in major agreement with Schultz, Earl Heady writes:

> ...education will be important as it prepares human resources to be efficient managers in agriculture, but more so in providing education and training adapted to the skilled and professional fields of greatest demand derived from economic growth. Provision of more human resources to these fields will be a greater immediate contribution to national growth than upping the rate of output progress in agriculture. Improved education will be needed in agriculture so that diminishing returns won't be encountered in traditional inputs, with ratio of input to output in national food requirements increasing.2/

Thus Heady, too, is optimistic that the acquisition and application of knowledge will allow man to free himself from the grips of limited resources.

Harold J. Barnett, in a discussion of the static scarcity theories, indicates that by relaxing some of the rigid assumptions behind these models, the effects of natural resource scarcity might be indefinitely

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1/ Ibid., p. 37.

2/ Heady, Earl O., Agricultural Policy Under Economic Development, Iowa State University Press, 1962, p. 490.

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1/ Barnett, H... Economic Scarcity a... for the Future, Was...

2/ Ibid., p.

delayed.[1] He argues that if the static social production function is characterized by increasing returns to scale (presumably this is the management function on how to combine labor and capital inputs), the appearance of diminishing marginal returns to labor and capital due to resource scarcity can be indefinitely delayed depending upon the strength of the opposing forces. He further observes that the scarcity force would still be operational, and effects would still be experienced. If resources had not been scarce, then the improvement in the social production function could have generated even a much greater influence on the growth of the national product. Barnett thus develops the case where resource owners can receive increased scarcity returns while marginal productivities of labor and capital can remain constant or even increase.

Research by Resources for the Future--Recent work published by Resources for the Future represents attempts to measure the alleged changes in natural resource scarcity. In this work two measures are developed: (1) time series of product prices for minerals, timber and agriculture, and (2) time series of employment per unit of output.

The first measure reported by Harold J. Barnett,[2] is a price relative index. It is a ratio of the price index of the products produced by the resources to the wholesale price index for all products. The specific hypotheses that Barnett allegedly is testing concern the rising resource factor costs in the scarce resources sector. Presumably, the factor cost of a scarce resource in a competitive market would increase

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1/ Barnett, Harold J., Measurement of Change in Natural Resource Economic Scarcity and Its Economic Effects, Reprint No. 26, Resources for the Future, Washington, D. C., March 1961, pp. 87-88.

2/ Ibid., p. 93.

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Between 1870 and 1956 there was approximately a 10 percent increase in unit prices of extractive goods (agricultural, minerals, timber) relative to the BLS wholesale price index (Table 1). Barnett concludes that while this small rise would give some credence to the scarcity hypothesis, the short-term cyclical movements are so frequent and of such magnitude that the small long-term change raises doubt about its social significance. Individually, the agricultural and mineral components do not deviate much from the aggregate. Only the forestry products price relative shows a steady climb over this period. Barnett concludes that the forestry component is the only resource that appears to be receiving increased scarcity returns. He hastens to qualify his conclusions in view of the vagaries of the index number price weight problem and the paucity of data in the earlier periods.

However, Barnett presumably is making a dynamic measure of resource scarcity. He measures the price of product each year against the wholesale price level in each year. The problem concerns what is happening to the quality of the other nonresource factors of production such as labor, capital and management in the agricultural component as compared to the total wholesale goods industry over time. For his measure to isolate the scarcity effect for agricultural land over time, the nonland capital, labor, management-output functions have to be identical over time in both the individual component and the wholesale aggregate. To the extent that these diverge, the change in the price relative index would then reflect changes in nonnatural resource inputs as well as possible resource scarcities. The improvement of the capital, labor,

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1910-19	
1920-29	
1930-39	
1940-49	
1950-54	
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Source: N. Potter
Statistic

Table 1. Extractive Product Prices (1954 Weights) Relative to BLS Wholesale Price Index

Years	All Extractive	Agriculture	Minerals	Timber
		(1947-49 = 100)		
1870-79	70	65	93	28
1880-89	68	72	63	34
1890-99	68	71	65	38
1900-09	72	74	72	41
1910-19	82	84	83	42
1920-29	85	82	103	54
1930-39	77	71	96	57
1940-49	96	98	94	81
1950-54	95	91	102	106
1955	89	80	108	109
1956	87	77	110	109

Source: N. Potter and F. T. Christy, Jr., U. S. Natural Resource Statistics, 1870-1956.

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management-output ratios in agriculture has been phenomenal. Whether other BLS price components have experienced identical changes over time is questionable and therefore would tend to impugn Barnett's measure of resource scarcity. Alternatively, one could conclude that agricultural product prices have remained relatively constant over time because of increased productivities of capital and labor and would have been lower had the quantity and quality of resources been greater.

The second measure concerns labor productivity over time. The specific hypothesis tested here concerns the adverse effect of resource scarcity on the marginal productivity of labor. If labor becomes less productive, then labor costs per unit of output should increase. Potter and Christy demonstrate that labor costs per unit of output have in fact declined in all major resource components except forestry (Table 2).[1/] Therefore the conclusion is that the resource scarcity doctrine is not supported except possibly in the case of timber. Timber cutting and pricing is so integrally related to U. S. Forest Service policies and programs on public lands that the timber price rise may be an example of artificial scarcity resulting through the institutional forces involved.

Questions can be raised whether the assumptions behind the Potter and Christy analysis are valid and therefore allow the conclusion drawn. The difficulty with their measure (just as in Barnett's) is that to isolate the resource scarcity effect, they must assume, in the case of agriculture for instance, that the labor cost per unit of nonland capital is constant over time. If the marginal productivity of labor increases significantly with respect to nonland inputs, then there is a problem in

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1/ Potter, Neal and Francis T. Christy, Jr., Employment and Output in the Natural Resource Industries, 1870-1955, Resources for the Future, Washington, Reprint No. 26, March 1961, p. 128

Table 2

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Table 2. Indexes of Employment per Unit of Output

Years	Agriculture	Timber	Mining	All Extractive	Manufacturing	GNP
			(1947-49 = 100)			
1870-79	341	48	598	370	356	320
1880-89	291	58	440	320	236	230
1890	298	85	n.a.	310	233	226
1900-09	238	63	298	250	208	182
1910-19	214	73	233	220	176	167
1920-29	189	112	194	186	146	147
1930-39	170	111	157	173	132	138
1940-49	114	114	105	113	98	105
1950-54	81	100	84	81	87	89
1955	74	n.a.	70	73	80	82

Source: N. Potter and F. T. Christy, Jr., U. S. Natural Resource Statistics, 1870-1956.

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measuring the relative strength of these two forces. Neither of the measures developed by Barnett and Christy serve to refute the scarcity doctrines. Conclusions can be drawn only about how the scarcity effect has been modified.

Empirical studies of T. W. Schultz--Schultz has summarized historical data to show that land represents a declining fraction of our national wealth. In 1896 the total land component represented 38 percent of our total wealth. In 1920 it was 28 percent and in 1955 it had declined to 17 percent.[1/] Likewise, agricultural land shows a marked decline. This component represented about one-fifth of our national wealth prior to 1910 and was equal to one-twentieth in 1955.[2/]

Schultz offers two explanations for the apparent declining economic importance of land. On the supply side, progress in technology has tended to enlarge the production potentialities in agriculture as much as in other industries. On the demand side, the demand for agricultural products has not risen in proportion to the demand for the products of other industries. Low income elasticities for agricultural products and a decline in the rate of population increase in the industrialized Western countries account for the relatively smaller increase in demand for agricultural products. Thus, two complementary forces are in action in developing countries which explain the declining fraction of wealth and income accounted for by agriculture and other natural resources. This information is evidence that for the U. S., natural resources are not commanding an increasing share of the total product and have not inhibited economic growth in a significant degree at least.

1/ Schultz, T. W., Research paper 3816, op. cit., p. 5.

2/ Ibid.

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On this point, Abramovitz cautions about the generalizations possible for less developed countries based on this evidence.1/ He raises two questions. First, will rates of technological gains in productivity continue and will they have the same effect on other developing nations? Second, to what extent is the declining importance of resources simply a shift in the comparative advantage of the industrial sector over the primary product sector? Will all developing nations be able to expand their industrial component accordingly? A country involved in international trade and in protective tariff and subsidy programs may achieve a wealth distribution not possible in other countries.

The decline in the share of total national product attributable to natural resources does not in and by itself show that limited natural resources do not have a drag on the economy. The discussion of the measures reported by Resources for the Future is relevant here also. Would economic growth have been greater if there had been more plentiful natural resources? To the extent that this is true, the scarcity effect still is operational. The implication is that the highly developed countries to date have found means of counter-balancing the scarcity effect.

Abramovitz states:

> ...(The proposition) is not about natural resources at all, but rather one about the yield of technological progress and capital accumulation. To get the specific contribution of physical endowment to the generation of growth,...we need to pose the question somewhat differently. We ought to ask what the importance of differences in resource endowments is in accounting for differences in rates of growth among countries.2/

1/ Abramovitz, Moses, Comment on T. W. Schultz's paper, "Connections Between Natural Resources and Economic Growth," Natural Resources and Economic Growth, op. cit., pp. 9-14.

2/ Ibid., p. 14

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In other words, are some resource barriers harder to overcome than others? Conceivably resource endowment and the extent and speed by which the resource can be exploited would have some effect on per capita incomes, levels of education, attainment of skills and other factors such as savings, investment and incentives.

Schultz also looks at changes in relative prices of agricultural products and of farm inputs including the services of farm land. He compares two periods--1910-14 and 1956. The following summarizes his findings.[1]

1) Prices received by farmers for farm commodities declined about 15 percent relative to the index of consumer prices between 1910-56.

2) Prices of farm products at wholesale also declined about 15 percent relative to all commodities at wholesale between 1910-56.

3) Although satisfactory measures are lacking, the price of the services of farm land has been falling relative to that of all inputs used in farming between 1910-56.

4) The prices of all nonland inputs in agriculture have risen relative to farm product prices between 1910-56, except fertilizer.

5) Farm real estate prices and income attributed to farm real estate (excluding farm structures) have declined relative to farm product prices between 1910-56.

   a. Value of farm real estate per acre declined 33 percent relative to farm product prices.

   b. Income attributable to farm real estate, divided by an index of the quantity of farm land declined 29 percent relative to farm product prices.

Schultz states that this evidence strongly supports the view that the supply price of the services of land has been falling, not only relative to farm product prices but relative to consumer prices. On an economic basis, an influx of imported farm products could cause land

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1/ Op. Cit., T. W. Schultz, Research Paper No. 3816.

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prices to decline. Also, the physical supply of farm land could have increased, but neither of these are the case. Population pressures have shifted the demand for agriculture products considerably. Why is it then, that in view of the relatively small shift in the supply function, farm real estate prices fail to rise at a greater rate? In fact, they appear to have declined. He concludes that the Malthusian - Ricardian scarcity doctrines are inoperative and have not limited economic growth.

The data cited by Schultz as measures of the resource scarcity phenomenon can be subjected to the same questions about assumptions as those of the RFF studies. The nonland capital and labor-output ratios are assumed to be constant in the two periods. To the extent that nonland capital and labor have induced increasing agricultural output returns, the higher MVP's would have the effect of lowering farm product prices disproportionately in the second period, making the index smaller even if there were constant returns to the land input. In other words, the change in ratio of land rent to agricultural product prices in t_0 and t_1 would not be an accurate measure of the scarcity effect of a finite supply of land if the agricultural product prices in the second period were influenced by increasing returns in the labor and nonland input.

Further, the conclusion by Schultz that real estate values and income attributable to farm real estate are declining relative to farm product prices can be questioned. In an attempt to reconstruct and update the indexes, the index of farm real estate values per acre was found to rise 190 points between 1915 and 1960 (Table 3). The wholesale price index for farm products rose 123 points for the same period. Clearly, farm real estate prices have increased significantly in the last

Table 3. Indexes of
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Year	Wholesa
	All Commodit
1915	100
1920	237
1925	151
1930	125
1935	115
1940	122
1945	147
1950	21
1955	24
1960	24

Source: Historic
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Table 3. Indexes of Wholesale Prices for all Commodities and Farm Products, Realized Net Income per Acre and Value of Farm Real Estate per Acre, United States

Year	Wholesale Price Index		Index Realized Net Income per Acre	Index Value Farm Real Estate per Acre
	All Commodities	Farm Products		
	(1915 = 100)			
1915	100	100	100	100
1920	237	211	177	168
1925	151	153	161	125
1930	125	123	106	111
1935	115	110	103	74
1940	122	95	97	80
1945	147	179	263	121
1950	216	244	271	169
1955	241	224	233	218
1960	246	223	234	290

Source: Historical Statistics of the United States, Colonial Times to 1957 with Continuations to 1962, Department of Commerce Indexes of wholesale prices derived from Series E-26, 27. Realized net income index constructed from Series K-127 and K-2. Index of farm real estate value per acre constructed from Series K-7. Wholesale price index for 1915-50 period based on 1926 price weights; thereafter 1947-49 served as the base period.

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decade while farm product prices have declined somewhat. The wholesale price index for all commodities was slightly higher than for farm products in 1960 as compared to 1915. The rise in real estate values cannot be ignored. Real estate values were higher relative to wholesale prices for all commodities for the first time in 1960. The agricultural use of land is only one of many uses that gives land value. Regardless of the source, forces are in action to bid land prices up relative to other prices.

Many problems plague the analysis of changes in land prices. The price of stock resources, theoretically, is the present value of the prospective stream of incomes. The discount rate used influences price. A high discount rate represents a pessimistic view about the level and/or variability in the stream of revenues from the land. A low discount rate allows a higher capitalized value, indicating a more optimistic view about the income earning capacity of the resource. To the extent that the discount rate is affected differently by exogenous factors in successive time periods then actual prices may not be entirely relevant in measuring the true scarcity component in land price. In recent decades opportunities for investment in nonland capital ventures and the relatively high returns would tend to drive up discount rates and would lower the capitalised value of income streams from land. Even so, land prices have risen relative to other prices in the last decade.

In summary, the empirical evidence from the U. S. experience supports the optimistic view about resource scarcity. Forces have been released in many of the western industrialised economies which provide substitutes for natural resources as they become scarce. The theoretical analysis and empirical validation of these forces are the critical problems at the moment. However, the empirical data presented are not nvincing th

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C. The Theoretical Dependence of Economic Growth on Natural Resources

In this section the scarcity doctrines will be summarized in geometric form so the dependent relationships can be seen more clearly. The graphics are for explication only and are not meant to imply that broad resource problems have been refined for mathematical analyses. The primary purpose is to develop more explicitly the nexus between the "Malthusian - Ricardian scarcity doctrine," and "faith in science doctrine" and economic growth. Finally, the "faith in science" doctrine will be discussed in terms of conscious public policies to foster the long term economic growth function. Information requirements for policy makers to make rational and knowledgeable decisions will also be discussed.

For purposes of clarification of the theoretical exposition, the concepts of economic growth and natural resources are defined.

Economic growth--Economic growth is the added economic activity generated through the utilization of resources to provide goods and services. For economic growth to occur, capital must be invested to provide new income earning and, consequently, consumer demand activity. Not only must there be additional resources available for capital investment but there must be a demand for the goods and services from the resources--making the capital investment attractive. Gross National Product is the direct measure of economic activity; consequently, the rate of change in GNP is a measure of economic growth. Economic growth, just as with economic efficiency, does not necessarily imply improvements in individual economic welfare and income distribution. While these are rthy probl

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Natural resources--Resources are instruments of production that have economic usefulness. Natural resources are such nonreproducible and naturally replenished items as agricultural land, water, minerals and ores which can be depleted but cannot be reproduced in their exact form, at least with current technology. Natural resources can be manipulated in several ways, anyone of which can be a conscious policy objective. Resource use can be regulated so as to conserve, extend or sustain its use over time. Resources may be depleted and used at exhaustive rates. Resources may be developed so as to improve their quality and availability over time. Parts of the environment may be combined into entirely new resources for which there is new demand. The concept of natural resource use and development is dynamic.

The static theory of resource scarcity--Classical theory holds that limited resources will have the ultimate effect of restricting output in the economy. The presentation in this section has its roots in the writings of Adam Smith, Thomas Malthus, David Ricardo, John Stuart Mill and Alfred Marshall.[1/]

An aggregate production surface can be conceived where natural resources and nonnatural resources can be combined in varying proportions (Figure 1, chart 1). To be less abstract, one could conceive of an aggregate agricultural production process where units of land would be the

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1/ For an excellent summary discussion of the theories of these early economists see Harold J. Barnett and Chandler Morse, "Scarcity and Growth, The Economics of Natural Resource Availability," The John Hopkins Press, 1965, Chapter 3. The writer is indebted to these authors for ideas in diagramatic presentation.

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resource inputs and the nonresource inputs would be labor and capital combined as a joint input. In a similar manner, the production surface is a composite of agricultural products in this illustrative example. Each iso product curve from C_1 to C_6 represents larger amounts or levels of food and fibre production. An expanding population in a growing economy presumably would employ resource and nonresource inputs in some combination in some expansion path from C_1 towards C_6. The output in this illustration is measured in monetary terms while the inputs are measured in physical terms. To maintain rigor in the presentation of the concept, the inputs must be of homogeneous quality throughout the range of use and the ceteris paribus conditions pertaining to all other variables must hold. A fixed state of the technical arts is an important assumption.

As an expanding society demands more food and fibre, consumers and resource owners should be interested in production patterns that are efficient. Given the production possibilities illustrated in Figure 1, the least costly production pattern and expansion path, om, can be derived if prices of inputs are known. A given sum of production capital can be invested to buy all resources, or, or all nonresource inputs ol (see chart 1). An iso outlay curve, rl, can be derived representing varying proportions of the inputs that can be employed with the given sum of production capital. The C_2 iso product curve is tangent to the rl iso outlay curve at point j representing the highest product possible for the production capital considered. Alternatively, the production input mix at point j is the least costly way of producing the C_2 amount of food and fibre. The expansion path can be traced as increasing amounts of production capital are considered.

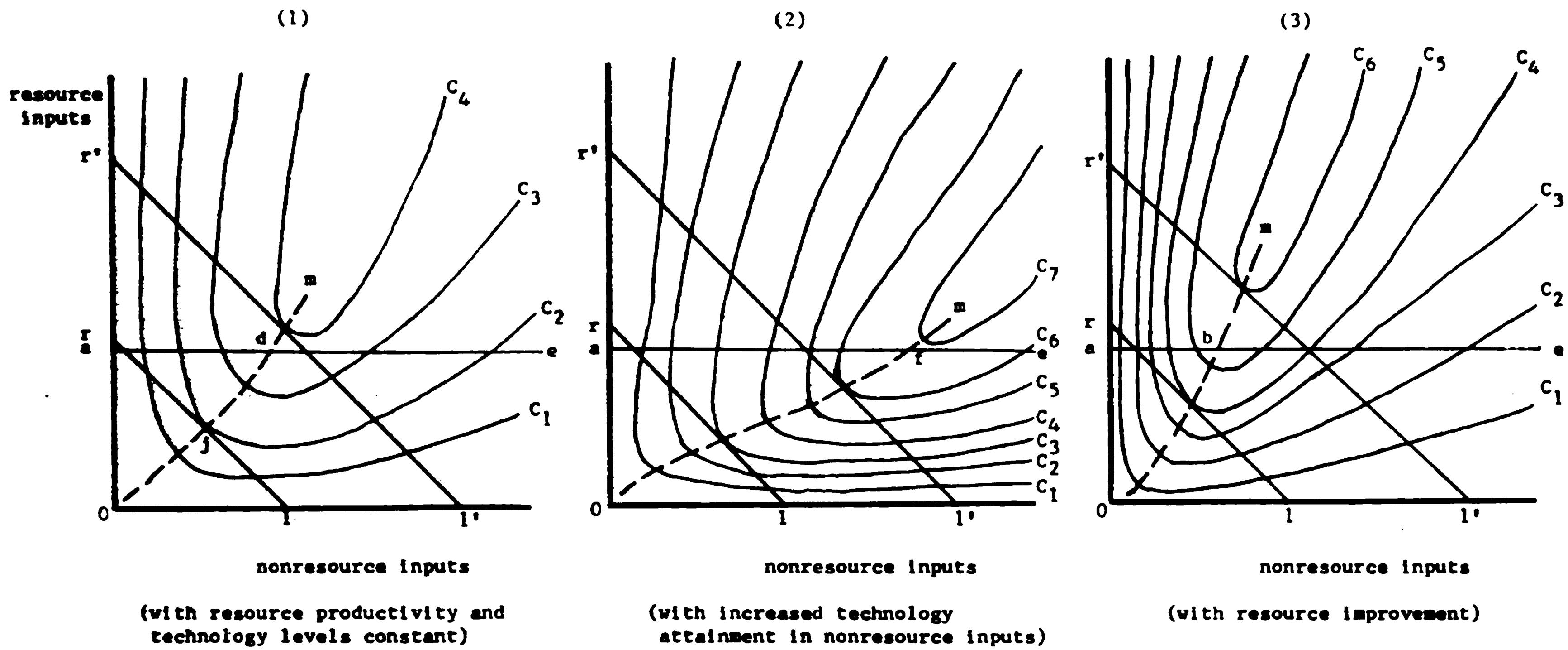

Figure 1. Theoretical Production Relationships from Various Combinations of Resource and Nonresource Inputs Assuming Various Levels of Technology and Resource Improvement

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With unlimited quantities of resource and nonresource inputs the expansion path in obtaining increased product is om. Resources would not restrict agricultural output. Output, of course, is limited, as the technology attainment assumed has a definite effect in shaping the production functions and their ultimate declining slopes. Output could exceed C_4 (see chart 1).

The imposition of a limit on available resources such as ae has a distinct limiting effect on output as more nonresource inputs are applied. The expansion path is od. Output rises to a point below C_4, then would decline if producers tried to combine more nonresource inputs with the resources. Clearly the nonresource inputs would be faced with declining productivity. Output in the producers sector would be limited as a result of resource availability. A case does exist where technology implied in the production functions could become limiting before resources would. In this instance maximum physical product would be reached on the od expansion path and would experience a decline before reaching the physical limit of resources.

With resources employed at their limit, two potential economic effects become prominent. As the effective demand for output increases and as attempts to combine more nonresource inputs with limited resources are made, scarcity rents accrue to resource owners. A reciprocal of this effect is reduced payments per unit of nonresource inputs. Resource rents per unit of output would increase and nonresource costs per unit of output also could increase as larger amounts of nonresource inputs are applied. As a result, the price per unit of output would increase, making the total bill for goods and services from the producers sector higher.

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One should note that there would be no economic incentive to push along the path de. Since this is in the declining total physical product stage which is in an irrational stage of production, knowledgeable producers would operate at point d. But atomistic producers face perfectly elastic demand functions thereby receiving erroneous economic signals to apply more nonresource inputs. If production was kept at d, the marginal productivity for nonresource inputs would not experience declining productivities.

The increase in rent to owners of limited resources implies an increase in asset values. Resource owners have control over a larger share of the wealth in the economy. Nonresource owners' earning capacity remains the same or is lower so they are not as well off relatively and perhaps on an absolute basis.

In summary, the static theory of production with all of the attendant assumptions of ceteris paribus conditions does support the view that limited resources would have a negative or dampening effect on economic expansion and growth. Resource owners would gain asset values while the earning power of other factor inputs would decline relative to that of resources.

Resource scarcity as related to propensities to consume and product demand elasticity--The ultimate effect of resource limitations on economic growth cannot be traced until the income recipients have utilized their income. Since nonresource owners have less disposable income and resource owners have more, there is potential for different propensities to consume which would have an effect on the economic activity generated through the income multipliers. One cannot say categorically that there would be less onomic activity wit

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If resource limitation involves a product for which there is an elastic demand, the decrease in economic growth may be short lived. An elastic demand suggests that alternate products could be used readily, thereby relieving the pressure on the product with limited resources. The effect on economic growth may be negligible also if the resource that is limited is small relative to the total of all resources used.

If the resource that is limited produces a product for which there are inelastic demand requirements and the product is a major one in the economy, then the effect on economic activity can be significant. In fact, an unstable situation would exist for major products having an inelastic demand and scarce resource inputs. Increased scarcity rents would provide income which when spent would create jobs which in turn would create demand for the product of the limited resources. If allowed to persist, the end effect would result in a concentration of wealth in the hands of resource owners.

The view that wealth would be concentrated in the hands of resource owners allowed the early Classicists to label economics as the "dismal science," to identify "subsistence theories," develop the "iron law of wages" and predict wide scale famines. These are logical conclusions given the static, changeless conditions believed to exist by these writers.

Relaxation of the technology assumption--If the state of technical arts is allowed to change, then resources can be less limiting in the production process (Figure 1 - chart 2). Under conditions of an increase in general technology attainment, the expansion path, of, calls for different combinations of resource and nonresource inputs

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than under the initial technology assumption (compare chart 1 and 2). The physical quantity of the resource remains the same in chart 2. Even so, higher levels of product requirements can be produced before the physical limit is reached. Technology has the effect of increasing the amount of product attainable with a given level of resources. In chart 2, the C_3 level of production is obtainable from the rl outlay function. In chart 1, the same outlay produces the C_2 level only. Economic growth is fostered as inputs are released to be employed in other productive measures.

Well known examples of technology advances in agricultural production in recent decades are hybrid corn and other improvements in seed varieties. Widespread availability and use of inorganic fertilizer is another. These measures in conjunction with mass mechanization have had a significant influence on the culture of crop and livestock production. General technology, as conceived in chart 2, comes about through education and other so-called expenditures in human capital. Productive capacity is influenced indirectly through the improved know-how of the human inputs in the projection process. Contrary to the views of the early theorists, the state of the arts does change. General technology has substituted for natural resources. In fact, technology has increased sufficiently so that abnormally high natural resource rent and product price rises have not come about.

Introduction of resource improvement--Improvements in the natural resources can have an effect similar to that of a general technology increase (Figure 1 - chart 3). Any measure that has the effect of improving the productivity of the natural resource also has the capacity of reducing the resource scarcity effect. The expansion path is g with resource imp

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ob with resource improvements. Again, higher levels of product are attained before the absolute limit on resources is reached. In the illustration, resource improvement allows output to be produced with considerably less inputs.

Resource improvement or development is another form of technology. The distinguishing feature of resource development is its physical link with the resource. Public expenditures can be applied directly to influence productive capacities of the resources. Agricultural land drainage is an example. Tile drainage is strictly a technological improvement but it is considered resource development because of its unique spatial location with the resource. The agricultural land resource has been improved. Large sums in both the private and public sectors have been spent to clear, drain and irrigate land. These improvements when coupled with general technological improvements have lessened the negative effect of resource scarcity on economic growth.

Dynamics of resource use--Schultz states that economic growth results from a dynamic disequilibrium.[1/] As demands shift, opportunities to utilize existing resources or develop substitute resources with a high payoff come into existence. As the resources are developed and the particular demand satisfied, rates of return on investment decline, thereby slowing the productive investments and deterring economic growth. To make a continuous positive function, new or expanding demands and new sets of resources or improved existing resources must be available for productive use. The maintenance of an ample and relevant set of resources in which

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1/ Op. cit., T. W. Schultz, Research Paper No. 3816, p. 27

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A product requirement of C_4 under the assumptions in Figure 1 - chart 1 is unattainable. As attempts are made to achieve this product, economic growth would tend to be dampened as labor and capital productivities decline. The degree that economic growth is slowed depends upon the elasticity of demand for the product from the limiting resource and the size of the product market relative to the whole economy. But this is a disequilibrium that will call for the corrective measures, providing of course an adequate institutional framework exists in the public and private sectors of the economy. The higher profits (rents) to the resource provide the incentive for technological inputs to capture some of the abnormal rents. With an increment of general technology as assumed in chart 2, resource earnings would be diverted to nonresource inputs. The new inputs, which are really manifestations of new resources are applied until the new demand requirement is satisfied. The new inputs also could become scarce, command abnormal rents and entice substitute inputs. Resource managers must be ingeneous and be innovators if measures to correct the dynamic disequilibrium forces are to be most effective. In fact, one could generalize the healthy economy as one in which there could be many resource barriers but knowledgeable entrepreneurs are adopting technology to circumvent the resource problems. Shifts in the productive capacity of resources such as shown in charts 2 and 3 must come about if economic growth and a full employment economy are to be sustained. Presumably, some desired mix of public expenditures for research, extension education and resource improvement will facilitate the dynamic adjustments process.

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One can conceive of a grand strategy to minimize the effects of resource limitations on economic growth. The theory summarized in this section suggests that as the original supply function of a resource becomes more inelastic, the scarcity returns potential becomes great. Further, the theory indicates that as the demand for the product of a limiting resource becomes more inelastic, the potential effect in limiting growth is greater. The strategy through time perhaps would be to concentrate public investments in the area of those conventional resources most likely to inflict diminishing marginal returns on other inputs; thus expanding productive capacity as conceptualized in charts 2 and 3 of Figure 1.

In the public sector, decisions about investments of public funds in general technology development and specific resource development can be subjected to the marginal calculus of economics. In general, the stream of social benefits from public investments in increasing the Nation's productive capacity should be equal to or greater than the stream of social benefits in the private purchasing power forgone in the investment.[1/] If the marginal increase in productive capacity and resulting stream of social benefits is smaller than the increment of public investment and its opportunity costs if left in the private sector, the expenditure would have a negative impact on economic growth. The above criteria relate only to the magnitude of economic activity and not to the effect on the distribution of personal utility streams. As indicated, wealth distribution is an extremely important problem but is not analysed in this work.

1/ The productivity criterion for public expenditures is advanced by James Buchanan in his book, Public Principles of Public Debt, Irwin, Inc., 1958.

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Presumably, there is a functional relationship between investments in research, education and extension activities and shifts in the productivity capacity of the Nation's resources. Likewise, public expenditures in making resources more productive are positively related. Public decisions can be improved if these functional relationships are known and meaningful information on costs and benefits developed.

D. Policy Implications

The principal policy implication to be drawn from the discussion in this chapter is that positive actions should be undertaken to insure that resource barriers do not become critical and that losses in economic activity are minimized. To achieve sustained economic growth, adequate institutional arrangements must be provided. Presumably, public investments to assist in the development and adoption of technology in relevant areas are justifiable uses of public funds.

But there are questions about the role that public agencies should play in directing the flow of resource creation. Some fiscal theorists argue that government should play a passive role in resource allocation and development schemes. In other words, the public programs should not alter the workings of the market in the private sector in calling forth resources and employment. In this view, the government would undertake only those measures necessary to soften temporary cyclical adjustments in the economy. Other fiscal theorists argue that there is a persistent and chronic gap between full employment and existing employment levels. With the Employment Act of 1946, this group feels that policy and responsibility of the Federal Government becomes one of coordinating and utilizing its functions and resources to achieve maximum employment, production and purch

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Those who argue for a passive role of government must concede that all public actions (even inaction) have a definite influence on resource allocations. Therefore, the acceptance of either political philosophy should not preclude research and analyses of the potential gains and losses of alternative public actions in the resource area and an analysis of constructive means of alleviating resource problems.

Policy for research and extension education investments--The public policy for research and extension education should be one whereby resource creation from such expenditures is adequate to maintain a near full employment economy. The criterion involves comparisons of the value of the public investment with the value of the employment created. As indicated previously, if the research and education investment is not productive of new streams of economic activity then the measure does not contribute to economic growth. Research and education investments should be compared with alternative investments to increase the productive capacity, such as direct public expenditures in resource improvements.

The ability to predict the increase in productive capacity associated with public research and extension educational expenditures is difficult. But if knowledgeable policy decisions are to be made about the use of public funds for research and extension education expenditures to develop and encourage the adoption of technology, estimates of these functional relationships are necessary. Research and extension education

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1/ For a presentation of the Heller-Burns arguments on these points, see the Morgan Guaranty Survey, Morgan Guaranty Trust Company of New York, August 1961, pp. 1-16.

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expenditures may well be a better use of available public funds in attempts to minimize the negative effects of limited resources on economic growth. The analysis in this study does not deal with the research expenditure question directly but the farmer survey reported in Chapter VI indicates opportunities for extension education investments.

Policy for public investments in natural resource improvements--Public policy for resource improvement should be one whereby the productivity of our stock of resources is adequate to maintain a near full employment economy. In a manner similar to that suggested for research and extension education investments, public resource improvement investments must be compared with the social benefit streams created. Federal, state and local governments now have specific responsibilities in facilitating natural resource improvements. As will be pointed out in the analysis chapter of this study, certain social benefits are associated with public cost-sharing arrangements with private resource owners to encourage agricultural land drainage. While drainage is only one of several resource improvement measures, the basic relationship with other resources is expected to be the same.

The theory presented in this chapter indicates that public resource improvement or development is clearly an alternative and complement to public research expenditures to promote general technology adoption in preventing negative impacts of scarce natural resources. In the final analysis, some combination of expenditure on research and extension education to indirectly influence productive capacity with direct investment on already-known techniques of resource improvements would be ideal. To properly apply these criteria, considerable information is needed on the functional relationships of the alternative uses of the public monies.

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Analytical schemes are needed to inventory current and potential resource problems. An analytical procedure is needed whereby resource problems can be placed in perspective and the effects of public resource development and assistance measures can be identified. In this study, only part of the functional relationship is analyzed; namely, the amount of added economic activity possible through resource improvement. In this case, resource improvement is land drainage for agricultural purposes. The exact nature of the analysis in this study follows in the ensuing chapter.

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CHAPTER III

METHODOLOGY AND ANALYTICAL PROCEDURES

The general methodological approach, formal analytical procedure and the farm survey used in the study are discussed in this chapter.

A. General Methodological Approach

Direct public investments in agricultural land improvement and indirect investments in agricultural research and extension activities are alternate means of increasing the Nation's capacity for producing food and fibre. The suggestion in the previous chapter was that some combination of direct and indirect public investments for purposes of resource creation would be optimum. Such investment patterns would make maximum contributions to economic growth. The decision concerning desired public investment patterns requires considerable information about the functional relationships. Only part of these relationships are analyzed here.

Public investments in land drainage historically have taken two forms. On one hand, river basin and watershed projects to deepen, straighten or extend streams and rivers so excess waters may have an outlet have been wholly or partially financed with public funds. Secondly, public funds have been used to share in the actual land owner costs of installing field drainage systems. These measures have the effect of increasing agricultural productivity.

The central focus of this analysis concerns the potential for and likely adoption of private agricultural field drain improvements. The effects of research and extension expenditures were not analysed in etail in th

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detail in this report, but various levels of general technology adoption were assumed in the analysis to determine the potential substitutional relationships with land drainage.

The basic approach in this study was to analyse the economic potential for farmers to adopt agricultural land drainage within a region. In other words, to what extent can land drainage increase the agricultural productive capacity as the expected population increases press against our conventional resources? Linear programming was utilised in this part of the study. Secondary data were used almost exclusively to determine the economic potential for drainage. A number of variations in yield and fertiliser use assumptions, and public cost-sharing in field drain installations were made to determine the sensitivity of these variables in economic growth. A survey of farmers in the region under study was made to determine the validity of the linear programming results and determine critical variables in the analysis. The survey also provides information on the necessity of public investments in outlet improvement to encourage field drainage investments by farmers.

A definitive policy for public resource improvement investments cannot be developed from the partial analytical approach used herein. However conclusions are drawn concerning the agricultural productive capacity possible through public measures to encourage farm drainage. The relative importance of direct investments in drainage to increase agricultural productive capacity can be compared with other measures such as general technology adoption. However the actual public costs of measures to encourage farm drainage or measures to obtain increased general technology adoption are not estimated. The analytical procedure used is considered a pilot study which can be expanded and improved for analyses in large

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B. Formal Analytical Procedure

Since the attempt in this study was to estimate the potential agricultural productive capacity that might be induced through public investment, the analytical model must take a special form. On one hand, the policy maker is interested in the normative public expenditure pattern. But in another respect, as an instrumental step in developing policy, the policymaker is interested in how private resource managers will in fact respond to alternate public expenditure patterns.

Linear programming was used in this study to simulate resource managers expected drainage practice adoption patterns. The programming technique provides optimum or normative resource use patterns under specified constraints. Certain constraints are built into the procedure in an attempt to make the results indicative of likely resource use.

The program model is set up in a minimum cost formulation for this study in what is commonly called the requirements approach. A minimum cost resource use pattern is derived in producing given levels of requirements under certain land availability constraints, drainage possibilities and other restraints. Requirements are derived from separate studies. The formal statement of the minimum cost primal problem can be generalized as follows:

Minimum cost primal problem --

$$\text{Min } z = p_1x_1 + p_2x_2 + \cdots\cdots p_nx_n$$

Subject to:

$$x_{1,2,\ldots n} \geq 0$$

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$$a_{m1}x_1 + a_{m2}x_2 + \cdots a_{mn}x_n = c_m$$
$$d_{11}x_1 + d_{12}x_2 + \cdots d_{1n}x_n \leq r_1$$
$$d_{21}x_1 + d_{22}x_2 + \cdots d_{2n}x_n \leq r_2$$
$$\cdots\cdots\cdots$$
$$d_{s1}x_1 + d_{s2}x_2 + \cdots d_{sn}x_n \leq r_s$$
$$h_{11}x_1 + h_{12}x_2 + \cdots h_{1n}x_n \geq w_1$$
$$h_{21}x_1 + h_{22}x_2 + \cdots h_{2n}x_n \geq w_2$$
$$\cdots\cdots\cdots$$
$$h_{v1}x_1 + h_{v2}x_2 + \cdots h_{vn}x_n \geq w_v$$

Where z = total production cost excluding payments to land

$p_{1,2,\ldots n}$ = costs of production per acre excluding land costs for various $x_{1\ldots n}$ land uses

$x_{1,2,\ldots n}$ = acres of various land uses (activities)

$a_{11\ldots mn}$ = amount of product requirement used in a unit of activity

$d_{11\ldots sn}$ = amount of land resource used in a unit of activity

$h_{11\ldots vn}$ = amount of minimum acreage requirement supplied by a unit of activity

$c_{1,2,\ldots m}$ = product requirements for various commodities specified from outside the model

$r_{1,2,\ldots s}$ = amounts of land resources available (extends to include land resources available for which additional drainage is possible)

$w_{1,2,\ldots v}$ = minimum acreages for individual crops

The two basic sets of constraints in the model are (1) product requirements ($c_{1,2,\ldots m}$), the food and fibre to be produced from the region, and (2) lanc

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region, and (2) land resources ($r_{1,2,\ldots s}$) -- the amount of land resource available to produce the product requirement. The land resource availability was extended by adding equations to allow for additional field drainage on specified land management groups. An additional crop rotation constraint was placed on the land resource to restrict the proportion of certain soil groups being devoted to row crops. These extensions in the land resource availability were not made in the preceding algebraic formulation but they are illustrated in Table 28 in Chapter V.

A minimum cropping pattern constraint for subareas of the region under study was imposed in the model. The constraint specified that a required acreage of each crop ($w_{1,2,\ldots v}$) be produced on each group of land resources representing a subarea. The minimum acreage constraint by subareas represents an attempt to partially reflect existing trends in production patterns. The constraint has the effect of placing a bound on production shifts among subareas in the study region. Since production pattern shifts and resource mobility are conditioned by many forces, this constraint is referred to as an institutional constraint.

The minimum cost program model as outlined is set up for a 42-county area in lower Michigan. Selected groups of counties representing the Thumb and South Central areas of the 42-county region are analyzed to determine the intraregional effect of agricultural land drainage on land use patterns and other economic parameters.

Data for the program model were developed from survey data, unpublished data from the Michigan Agricultural Experiment Station and from published sources. Basically, four sets of data are needed for the model: (1) information is needed on the extent and location of the land resources within the 42-county region to include information on additional

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drainage potential, row crop limitations and minimum acreage constraints; (2) cropping alternatives and productivity levels on each land resource are necessary; (3) production cost data for each crop alternative are needed; and, finally, (4) product requirements to be produced from the region also must be available. The nature and source of the data are discussed in Chapter IV.

The basic model was set up to reflect projected 1980 conditions with and without the extension of the drainage land use activities. In conjunction with the drainage comparisons, several computer runs were made assuming various level of product requirements and yield levels. Additional programs were run to reflect various drainage cost levels and public cost-share plans.

The solution to the primal problem provides estimates of total production costs excluding payments to land. Land use on each land resource is indicated. The land resource data utilized in the model are related to geographic locations, i.e. counties and groups of counties, therefore estimates of land use change and costs of production for subareas can be developed. Comparisons of total costs of production and resource use patterns provide a direct estimate of the effect of limited resources on the capacity for economic growth.

The linear programming procedure provides a basis for imputing rent values to scarce resources and marginal costs of production for each of the required products. This information stems from the dual of the primal problem formalized previously. The dual can be generalized as follows:

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Minimum cost dual (value imputation)--

$$\text{Max } z' = (c_1u_1 + c_2u_2 + \ldots c_mu_m) - (r_1y_1 + r_2y_2 + \ldots r_sy_s) + (w_1e_1 + w_2e_2 + \ldots w_ve_v)$$

Subject to:

$$y_{1,2,\ldots s} \geq 0$$

$$e_{1,2,\ldots v} \geq 0$$

$$(a_{11}u_1 + a_{21}u_2 + \ldots a_{m1}u_m) - (d_{11}y_1 + d_{21}y_2 + \ldots d_{s1}y_s) + (h_{11}e_1 + h_{21}e_2 + \ldots h_{v1}e_v) \leq p_1$$

$$(a_{12}u_1 + a_{22}u_2 + \ldots a_{m2}u_m) - (d_{12}y_1 + d_{22}y_2 + \ldots d_{s2}y_s) + (h_{12}e_1 + h_{22}e_2 + \ldots h_{v2}e_v) \leq p_2$$

$$\cdots\cdots\cdots\cdots\cdots\cdots$$

$$(a_{1n}u_1 + a_{2n}u_2 + \ldots a_{mn}u_n) - (d_{1n}y_1 + d_{2n}y_2 + \ldots d_{sn}y_s) + (h_{1n}e_1 + h_{2n}e_2 + \ldots h_{vn}e_v) \leq p_n$$

Where z' = total payments to nonresource inputs

$u_{1,2,\ldots m}$ = cost per unit of product requirement, $c_{1,2,\ldots m}$

$y_{1,2,\ldots s}$ = value imputed to limiting resource, $r_{1,2,\ldots s}$

$e_{1,2,\ldots v}$ = cost per unit of satisfying each minimum acreage restraint, $w_{1,2,\ldots v}$

The objective in the dual of the minimum cost primal problem as specified is to maximize returns to labor and capital without exceeding the specified production cost levels for each land use activity. The minimum acreage constraints, if restrictive, have the effect of raising production costs.

The $u_{1,2,\ldots m}$ coefficients represent marginal costs of production. The marginal costs of production when multiplied by their respective product requireme

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product requirement levels represent total production costs including payments to land. The $y_{1,2,...s}$ coefficient represents the scarcity payment or rent per acre of land. The rents when multiplied by their respective acreages in the program solution represent the total rent imputed to the land factor. In the application of the program formulation outlined, the land resources were first characterized into management groups. Each group contain soils of similar productivity yields and production costs were developed to reflect existing resource development and management requirements. In the program each land management group would compete in producing the product requirements. Land management groups with excess water as a management problem and with potential for new drainage development were allowed to compete in producing the product requirement in some of the program runs. In addition, land management groups with erosion problems were limited in the amount of row crops that could be planted. This restraint, along with the drainage and basic productivity restraints, provides identifiable rents that could be associated with each characteristic.

In addition to the resource rents, the $c_{1,2,...v}$ coefficients represent the cost per unit of satisfying the minimum acreage constraints in the model. When the minimum acreage becomes an effective constraint in the model, production patterns are less efficient; hence the negative rents are reflected in higher production costs.

In the several program runs, comparisons of marginal costs of production, changes in resource rents, drainage rents and negative rents due to minimum acreage requirements were made. The procedure provides a direct measure of change in production efficiency and change in asset value as a result of any variation in paired program runs. These procerns are explai

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dures are explained and discussed in greater detail in the analysis and conclusions portion of the report (Chapters V and VII, respectively).

General assumptions--The program model developed implies a general set of assumptions that must be considered in evaluating results. They are:

(1) Labor and capital inputs have unrestricted mobility and supplies are readily available at prices used.

(2) Owners of land resource groups seek to maximize profits and have full knowledge of cropping patterns that will maximize profits or alternatively minimize costs.

(3) Land resource groups represent a relevant basis for identifying homogeneous decision units in the program and input-output coefficients are constant within the relevant range considered.

(4) Total agricultural production in the region and subarea is limited only by the land resource available, drainage potentials, crop rotation limits and certain institutional factors implied in the minimum acreage constraint.

While the assumptions would appear to dampen the validity of the results, the program model is used primarily as a projective procedure to estimate economic relationships in a future period. A further assumption would be that some of the imperfections concerning resource mobility, knowledge and decision units unrelated to field boundaries and farms would be eliminated.

Specific assumptions and limitations concerning data used in the model are discussed in Chapter IV.

C. Farm Survey

A random sample of farmers in the Thumb and South Central areas of Michigan were surveyed to determine the extent of and potentials for drainage. T

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drainage. The survey schedule also was designed to obtain information on drainage practice adoption rates and to determine the critical factors that restrict additional drainage that otherwise would be economical. A description of the areas and counties involved in the survey and the survey schedule are discussed in Chapter IV and Appendix A.

Virtually no information is available concerning the extent of land drainage improvements. The decennial Drainage Census reports acreages in organized drainage districts only. The Agricultural Stabilization and Conservation Program Service of the U. S. Department of Agriculture publishes annual reports on drainage measures cost-shared but these data are incomplete with respect to the total picture.

Some estimates are available concerning acreages suitable for additional drainage. These estimates were developed in the Inventory of Soil and Water Conservation Needs conducted by the U. S. Department of Agriculture in 1958. The estimates were based on the judgment of county Soil Conservation Service personnel. The survey of farms in this study was designed to provide additional information concerning potentials. In addition, the survey provides information from the farmer concerning his plans for adopting and utilizing additional land drainage on his farm.

The survey also provides information on the general characteristics of the farm and the farm operator. Details on the management practices used in installing and improving field drainage systems and other criteria that influence the adoption of the drainage practice were also obtained. Through cross sectional analysis, the important variables with respect to the drainage practice are studied.

Survey schedule--The survey was undertaken as a part of the cooperative research between the Department of Agricultural Economics at igan State

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Michigan State University and the Economic Research Service of the U. S. Department of Agriculture. The survey was designed to provide information not only for the cooperative Michigan farm drainage study under the leadership of the author but to provide information for the Lake States Dairy Study under the leadership of George Irwin of the ERS staff. Consequently, some of the detail in the schedule is not necessarily germane to the drainage study.

The schedule along with summary instructions about the schedule and a definition of terms is reproduced in Appendix A (parts of the schedule not related to the drainage study are not included). Five enumerators were used in the survey. Each enumerator was given identical instructions concerning the study, the sampling plan and interview techniques.

Sample plan--A completely random sample of farms and farm managers was obtained. The Master sample of Agriculture was used. In this sample, geographic segments are selected at random throughout the United States. Each segment is selected to include three or more respondents; consequently, the size of the segments varies generally in proportion to the size of farms in the area. In lower Michigan, the segments generally contain 160 to 320 acres. The sample is divided into three groups: (1) primary sample, (2) alternative Sample A, and (3) alternative Sample B. The size of the sample can be expanded by combining two or more of the samples or by randomly selecting within the alternative samples.

The sample plan was to interview all eligible respondents from the primary and alternate A sample segments. Farm managers were interviewed if their gross income from farming exceeded $1200 the previous year. If 80 percent or more of the farm income was from poultry, fruit or truck farming, a schedule was not completed. The schedule was completed only r farms with

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on farms with 10 acres or more of cropland. Sections I and II of the schedule were filled out for all tracts of 10 acres or more regardless of the above qualifications.

All potential respondents living within the boundaries of the sample segment were contacted. At least two return calls were made in the event the respondent was not found at home. Farmers operating land in the sample segment but living outside of the segment were not contacted. However, land outside of the sample segments operated by eligible respondents was included on the schedules unless the land was outside of the two principal study areas.

Assuming that an adequate sample is taken under the completely randomized plan, statements about the universe can be made.

Sample size--A desired sample size can be estimated if the following information is known: (1) estimates of the standard deviation of the population,(2) an expression of the allowable error in the sample mean, and (3) an expression of the confidence limit the researcher is willing to accept that the sample is representative of the universe.

The required sample size at the 95 percent confidence level is derived:1/

$$n = \frac{4\sigma^2}{L^2}$$

Where: n = sample size

σ = standard deviation

L = allowable error in sample means

Information obtained in a survey of 43 farmers in northern Lapeer

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1/ George W. Snedecor, Statistical Methods, Iowa State Press, 5th Edition, 1956, p. 501.

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County and southern Gratiot County in 1961 provided an estimate of variance for one of the key variables in the present studies. The principal variable was the extent of land drainage on each of the farms surveyed. The standard deviation for the variable was estimated to be 26.6. A previous Lake States Dairy Study survey of the sample segments in the two study areas indicated that an average of 1.4 respondents could be expected from each of the 122 primary and alternate Sample A segments. The 177 expected respondents substituted into the formula indicated a possible error of four percent in the sample mean at the 95 percent confidence level. A four percent error was judged to provide sufficient precision; to include alternate Sample B would not appear to warrant the additional sampling costs. The results and conclusions of the survey will be presented in subsequent chapters.

The results of the survey are discussed in Chapter VI.

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CHAPTER IV

PHYSICAL AND ECONOMIC DESCRIPTION OF STUDY AREAS

In this chapter, the nature and source of the basic data used in the linear programming analysis are presented. As indicated in the previous chapter, four basic sets of data are needed, viz, (1) land availability, (2) cropping alternatives and yields, (3) production costs, and (4) product requirements. Each is discussed separately in this chapter.

In the cropping alternative section, two alternative sets of crop production and drainage yield estimates are developed to represent different levels of technology adoption. Corresponding fertilizer use, associated management practices, production costs, and drainage costs are presented. Cropping alternatives involving artificial drainage are developed separately so they may be included and excluded in paired program runs to determine the potential effect of drainage.

In the product requirement section, three sets of physical product requirements for the 42-county region in lower Michigan are developed. The product requirements or effective demands reflect increased population, changed personal income, and per capita consumption rates, livestock feeding efficiencies, and historical trends in regional production.

Several paired programs are developed from these data to test the sensitivity of the major assumptions in the model. While the alternative product requirements and production possibilities were not developed for the express purpose of making predictions, the coefficients used do represent possible relationships. Thereby the analysis can be useful in determining the elasticities of agricultural supply and drainage practice adoption.

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In addition to the presentation of the basic data for the linear program model, information about the agricultural characteristics of the two principal study areas will be presented. The study area characteristics will be presented first.

A. Agricultural Characteristics of Study Areas

The groups of counties representing the Thumb and South Central areas of Michigan approximate the geographic areas identified as Dairy and Cash Crop and Dairy and General Farming type of farming areas[1/] (Figure 2). Dairying is the most common type of farming in both areas. However, general livestock farming is second in the South Central area whereas cash-crop farming occupies this position in the Thumb area.

The soils in the Thumb area differ between the eastern and western portions. In the eastern counties, they are mostly loams and silt loams adapted to intensive cropping. These heavy, wet soils coupled with the high probability of late spring frosts limit the proportion of the land that profitably can be devoted to corn. Dry field beans, wheat, and sugar beets are the main cash crops. In the western counties of the Thumb, the land is more rolling and the soils range from sands to light loams. Dairy herds make good use of the forage, and milk is readily marketed in the nearby Detroit, Pontiac, Flint, and Saginaw markets.

The terrain in the South Central area is rolling and the soils are predominantly sandy loams, silt loams and loams of medium to high fertility. Most of the crops are feed crops--hay, pasture, corn, and oats. Farms generally have livestock of one type or another to utilise these feeds, making them general livestock farms. Wheat and soybeans are

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1/ Elton B. Hill and Russell G. Mawby, Types of Farming in Michigan, Michigan Agricultural Experiment Station, SB 206, September 1954, pp. 33-34.

Figure 2. Study areas in southern lower Michigan

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According to the 1964 Census of Agriculture, the Thumb area counties contain slightly over two million acres in farms 10 acres or more in size. Slightly less than three million acres are in farms 10 acres or larger in the South Central area (Table 4). Cropland in farms in 1964 was 1.5 and 2.0 million acres in the Thumb and South Central areas, respectively. The 1963 farm numbers for each area were developed through an expansion of the Farm Drainage Survey.[1] In 1963 some 13.2 and 16.3 thousand farms 10 acres or larger were estimated to be in the Thumb and South Central areas, respectively.

The average size of the farms in the South Central area was some 30 acres larger than the Thumb farm. In both areas, two-thirds of the land operated is owned by the farm operator.

About one-sixth of the farms in both the Thumb and South Central areas were cash crop farms; no livestock were produced (Table 5). About half of the farms in the South Central area were large livestock farms. The Thumb area had fewer of the larger livestock farms but more of the farms comprising smaller enterprises. The binomial distribution of farm types was significantly different at the 99 percent level.

Dry beans are the principal cash crop in the Thumb area (Table 6). However, corn production represents a larger acreage when corn for grain and silage are combined. Alfalfa and other hay, oats, and cropland pasture combine to represent a sizable proportion of the Thumb cropland devoted to uses to support livestock enterprises.

An analysis of the cropping trends in the Thumb area from 1949 to

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1/ The land in farms surveyed was 19,032 acres in the Thumb area and 23,604 acres in the South Central area, representing .971 and .840 percent of the 1963 acreages, respectively. These factors were used to expand the sample farm characteristics to the universe.

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Table 4. Characteristics of Farmland and Farms Over Ten Acres in Size, Thumb and South Central Michigan Study Areas

Item	Thumb	South Central
Land in Farms		
1964 Census acres	2,039,943	2,953,217
Cropland in Farms		
1964 Census acres	1,542,300	2,026,800
Total Farm Number		
1963 Survey Expansion*	13,176	16,303
Average Size of Farm**		
1963	180	213
	Percent	
Proportion of Farmland Owned by Operator	68	66

Source: 1964 Census of Agriculture and 1963 Farm Drainage Survey.

* Farm numbers estimated by expanding the random sample in the 1963 Farm Drainage Survey.

** Farm size relates only to those farms in the survey grossing $1,200 or more per year.

Table 5.

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Table 5. Type of Farming, Thumb and South Central Michigan Study Areas, 1963

Type*	Thumb	South Central
Cash Crop	16.9	15.6
Large Dairy	24.1	24.7
Large Beef	4.5	6.5
Large Hog	4.6	20.8
Large Enterprises, Two or More	9.8	3.9
Small Enterprises Only	40.1	28.5
Total	100.0	100.0

Source: 1963 Farm Drainage Survey

* For purposes here farms were classified:

Large Hog - if 30 or more pigs were raised and sold;

Large Dairy - if 20 or more dairy cows were inventoried;

Large Beef - if 25 or more beef cows were inventoried, or 30 or more feeders were raised or sold;

Small Enterprises - if one or more livestock enterprises existed with numbers under the limits above;

Cash Crop - if no livestock were produced or sold.

Frequency distributions were statistically different at the 99 percent confidence level.

Table 6. Cr

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Table 6. Cropland Use, Thumb Area Michigan, 1949-54-59-64 Census Years

Cropland Use	1949	1954	1959	1964
		(000 Acres)		
Corn for Grain	79.9	134.8	157.4	193.0
Oats	198.1	201.1	157.2	137.0
Barley	47.0	8.0	10.3	7.2
Dry Beans	1/	198.6	236.4	237.8
Soybeans	1.1	1.9	1.7	5.2
Wheat	227.0	199.0	221.6	182.7
Sugar Beets	32.2	33.4	38.0	36.4
Potatoes	4.4	3.3	2.8	2.1
Vegetables	9.0	10.5	11.3	13.2
Alfalfa - Mixtures	120.1	183.9	206.9	219.7
Clover - Timothy	155.5	124.0	64.1	48.8
Grass Silage	1/	1/	1/	19.0
Cropland Pasture	289.4	287.3	212.3	174.6
Corn Silage	47.9	64.9	55.6	73.3
Other Crops	297.6	41.5	34.0	23.2
Idle	110.3	153.7	174.8	169.1
Total	1,619.5	1,645.9	1,584.4	1,542.3

Source: Census of Agriculture

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1964 indicates that corn production is increasing while oats and barley production declines. Cash crop production appears to be fairly stable. Alfalfa production appears to be replacing clover-timothy production. Silage production is replacing cropland pasture uses. Idle acreage increased about 50 thousand acres during the 1949 - 1964 period.

Corn for grain and silage represent a half million acres in the South Central area (Table 7). Alfalfa and cropland pasture combine for another half million. Wheat is the principal cash crop. Feed grain production appears to be declining somewhat as corn acreages have been maintained in the last decade. Both dry beans and soybeans are increasing while wheat has declined. Shifts in cropland pasture use for silage production is apparent in the South Central area also. Idle cropland increased nearly 50 percent from 1949 to 1964 to a total over 350 thousand acres.

To summarize the cropping trends, the Thumb area appears to be undergoing internal shifts in cropping patterns. But, proportions of the cropland devoted to feed grains, roughages and cash crops remain the same. No shifts in type of farming seem evident. In the South Central area, there appears to be some shift in acreage from feed grains to cash crops, such as dry beans and soybeans. This may not mean a shift in type of farming away from livestock production. South Central area farmers produce corn as a cash crop; consequently, soybeans and dry beans may be a substitute for this crop. Idle crop acreage rose significantly in both areas.

One-third of the farmers in the Thumb area earned some money off the farm in 1962 while more than half the farmers had off-farm earnings in the South Central area (Table 8). Twenty percent of the farmers in

Table 7.

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Table 7. Cropland Use, South Central Michigan, 1949-54-59-64 Census Years

Cropland Use	1949	1954	1959	1964
		(000 Acres)		
Corn for Grain	359.1	417.9	468.3	420.4
Oats	316.1	285.3	191.0	146.8
Barley	5.6	12.4	28.5	6.4
Dry Beans	1/	32.2	49.4	72.8
Soybeans	6.6	18.8	32.4	59.4
Wheat	332.7	257.4	276.6	238.6
Sugar Beets	7.8	5.4	2.2	.4
Potatoes	5.7	3.8	4.5	3.9
Vegetables	12.9	10.8	11.9	13.5
Alfalfa - Mixtures	199.3	252.4	269.4	300.5
Clover - Timothy	168.8	164.8	84.4	44.6
Grass Silage	1/	1/	1/	30.0
Cropland Pasture	383.2	365.5	286.2	211.3
Corn Silage	59.1	61.3	61.9	84.6
Other Crops	129.5	98.7	67.9	37.8
Idle	234.0	196.3	263.8	355.8
Total	2,220.4	2,183.0	2,098.4	2,026.8

Source: Census of Agriculture

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Table 8. Distribution of Farm Operators by Gross Farm Earnings and Off-Farm Work

Off-Farm Work	Gross Earnings	Thumb	South Central
		--------Percent----------	
Full Time	$1,200 and more	55	37
	less than $1,200	11	7
Part Time*	$1,200 and more	25	38
	less than $1,200	9	18
		100	100

Source: 1963 Farm Drainage Survey. Frequency distributions were statistically different at the 90 percent confidence level.

* For purposes of this survey, farms were classified part-time if the farm operator grossed $200 or more per year off the farm.

Frequency distribution of part- and full-time work by area was statistically different at the 99 percent confidence level. The distribution of those earning less than $1,200 between areas was statistically different at the 70 percent level.

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the Thumb area grossed less than $1,200 in 1962. In the South Central area one of every four farmers grossed less than $1,200. Many of those grossing less than $1,200 on the farm, had off-farm income to counter the low farm income. But, both areas had approximately one of every 10 farmers who was classified as a full-time farmer yet had a gross income of less than $1,200. The frequency distribution of off-farm work by areas was statistically different at the 99 percent probability level. The distribution of farmers between areas earning less than $1,200 was not statistically different as the null hypothesis was rejected at the 70 percent confidence level.

The average farmer in both study areas was nearly 50 years of age (Table 9). One of every five farmers was over 60 years of age. The 45 to 60 age bracket represented the largest group in both areas, representing a skewness toward the older age groups. The distribution of age groups between areas was not statistically different. Male family workers per farm were essentially the same in each area. An average of about 1.5 men over 14 years of age worked on each farm.

B. <u>Land Characteristics and Availability</u>

About two-thirds of the rural land in both the Thumb and South Central areas of Michigan is cropland; pasture represents 10 percent or less (Table 10). The major land use of the two areas is quite similar even though large areas of the Thumb are level, flat farms that appear to be mostly cropland. Forest, woodland and miscellaneous acreages represent comparable portions of the rural lands in both areas.

The soils in Michigan have been categorized into seven major soil management groups by specialists at Michigan State University and the Soil Conservation Service of the U. S. Department of Agriculture. The

Table 9.

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Table 9. Demographic Characteristics of Farmers in the Thumb and South Central Michigan Study Areas, 1963

Characteristic	Thumb	South Central
Men over 14 years of age, per farm	1.4	1.5
Average age of farm operator, years	48.9	49.7
Age distribution, percent		
less than 30	8	5
30 - 44	31	30
45 - 59	39	47
60 and over	22	18
	100	100

Source: 1963 Farm Drainage Survey

Frequency distribution of age groups by area was statistically different at the 45 percent level.

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Table 10. Major Land Use in the Thumb and South Central Michigan Study Area, 1958[1/]

Land Use	Thumb		South Central	
	000 Acres	Percent	000 Acres	Percent
Crop land	1,705.1	70	2,205.3	62
Pasture	149.4	6	364.8	10
Forest	324.1	13	486.1	14
Other land	264.9	11	518.4	14
Total	2,443.5	100	3,574.6	100

Source: Inventory of Soil and Water Conservation Needs, USDA, 1958

1/ Land use pertains to all land areas except federal land, urban and built-up areas and water areas less than 40 acres in size.

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major groupings are related to the parent materials of the soils and soil texture. The texture of the soils varies from silty clays, clay loams, silt loams, sandy loams, loamy sands, sands to mucks.[1] The soils data in the Inventory of Soil and Water Conservation Needs provide a basis for estimating the acreage of each of the soil management groups in each county in the study areas (Table 11). Soil management groups 1, 2, and 2c represent clay loam and silt loam soils while groups 3, 4, and 5 are sandy loams and loamy sands. Over two-thirds of the Thumb cropland is in the clay and silt loams group. In the South Central area, only about half of the cropland soil is in this group which represents the more productive soils. Sandy loams are more prevalent in the South Central area. Nearly five percent of the cropland in the South Central counties is muck land.

Cropland available for future grain and row crop production--For purposes of this study an estimate of the soils that would be available for grain and row crop production in 1980 is needed. The current crop acreage is expected to be reduced for urban, industrial, highway and recreational development. Since these are higher economic uses, the land estimated for these purposes is reduced from the current inventory. The urban impact is related to the population projections for the Nation and the study areas by the Bureau of Census and Battelle Memorial Institute, respectively.[2]

All of the cropland can be planted to row crops but for part of each

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1/ For a detailed description of the soil management groups refer to Appendix B.

2/ "Agricultural Activity in the Grand River Basin: A Projective Study," Natural Resource Economics Division, ERS, USDA, January 1966.

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Source:

Table 11. Cropland Distribution by Soil Management Group in the Thumb and South Central Michigan Study Areas, 1963

Soil Management Group	Thumb Percent	South Central Percent
1	3.4	.6
2	35.9	39.2
2c	27.8	9.6
3	15.8	33.2
4	12.5	10.3
5	3.0	2.5
M	1.6	4.6
Total	100.0	100.0

Source: Distribution of soils among management groups based upon detailed soils mapping information listed on the sample segments in the Inventory of Soil and Water Conservation Needs.

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soil management group, the recommendation of Experiment Station and Soil Conservation Service technicians is to plant small grain crops only. In other words, a basic rotation involving a certain percentage of small grain crop is necessary to maintain soil productivity over time. The Conservation Needs Inventory indicates the acreage of each soil management group with slope or soil problems for which recommended row crop limits can be estimated (Table 12). By 1980, the assumption is that these recommendations will be followed rather uniformly; consequently, the row crop limits and total cropland availability after urban impact represent land resource restraints in the linear programming analysis.

C. Crop and Pasture Use, Alternatives and Production Potential

A productivity index of the soils in lower Michigan and the study areas was developed by staff members of the Crops and Soils Departments of the Michigan Agricultural Experiment Station, technicians of the U. S. Department of Agriculture Soil Conservation Service. For each study area, Statistical Reporting Service time series data on crop yields were utilised in a least squares regression analysis to predict current yield levels free of abnormal drouths, precipitation, frosts and other factors influencing crop failure. The area's current "normal" yield served as a base yield on which the productivity index was applied (Table 13). As a result, an internally consistent set of yields by soil management group was estimated for the current base period from which alternative technological yield projections could be derived.

The clay loam and silt loam soils clearly have higher productivity ratings over other soil management groups. Since two-thirds of the cropland in the Thumb area and only about half the cropland in the South Central area represent these more productive soils, the aggregate

Table 12.

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Source:

Table 12. Proportion of Cropland Recommended for Row Crop Production, Thumb and South Central Michigan, 1980

Soil Management Group	Thumb Percent	South Central Percent
1	73.9	62.5
2	86.2	70.3
2c	100.0	97.1
3	86.8	74.9
4	88.7	81.3
5	89.9	68.3
M	100.0	100.0

Source: Minimum crop rotation schemes based on estimates of staff members of the Crops and Soils Departments, Michigan State University and the Soil Conservation Service, U. S. Department of Agriculture.

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Table 13. Average Productivity Levels for Crop Alternatives on Soil Management Groups in the Thumb and South Central Michigan Study Areas, 1963[1/]

Soil Management Group	Wheat	Corn	Oats	Barley	Soybeans	Dry Beans
	--------------------Bu.				---------------------	Cwt.
Thumb						
1	31	68	53	41	24	11.9
2	32	65	53	43	24	14.3
2c	36	74	59	50	26	15.6
3	30	59	48	37	23	11.1
4	26	50	41	34	21	10.6
5	17	36	30	--	21	--
M	--	70	--	--	28	--
South Central						
1	30	66	50	40	23	11.7
2	30	63	54	41	23	13.6
2c	36	74	59	50	26	15.6
3	29	55	45	35	21	10.9
4	23	46	37	36	20	9.0
5	15	32	29	--	--	--
M	--	70	--	--	28	--

1/ Productivity levels reflect average management, average climatic conditions and present drainage conditions and existing improvements.

Table 13 Continued--

Table 13.

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Table 13. Continued

Soil Management Group	Potatoes	Corn Silage	Alfalfa Hay	Other Hay	Cropland Pasture*
	--Cwt.--	------------Tons----------			-AUD/yr.-
Thumb					
1	176	10.9	2.7	1.9	100
2	--	11.5	2.8	1.9	125
2c	--	14.0	3.2	2.1	145
3	192	10.6	2.7	1.7	113
4	174	9.3	2.1	1.4	92
5	--	6.0	1.4	1.0	55
M	240	12.0	--	--	--
South Central					
1	176	10.7	2.7	1.9	115
2	--	11.1	2.7	1.8	125
2c	--	14.0	3.2	2.1	145
3	187	9.9	2.6	1.7	111
4	169	8.9	2.1	1.2	87
5	--	6.4	1.3	0.9	54
M	240	12.0	--	--	--

Source: Unpublished material developed for the report, "Agricultural Activity in the Grand River Basin: A Projective Study," Natural Resource Economics Division, ERS, USDA, January 1966. John Hostetler, Agricultural Economist, Natural Resource Economics Division, USDA, primarily was responsible for the assembly of these data.

* Average yield on permanent pasture assumed to be 63 animal unit days per year.

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productivity potential of the Thumb area would be greater.

Technology attainment assumptions--For the economic analysis, an attempt is made to ascertain the effect of the adoption of different levels of crop production technology on the cropland use patterns, the rents attributed to the land resource prices of commodities produced, and the adoption of the farm drainage practice. Accordingly, two sets of crop and pasture yields that reflect different levels of production technology and management were developed (Tables 14 and 15).

The yield projections, of necessity, represent estimates of the possible adoption of known technology. The projected yields were developed by members of the Natural Resource Economics Division, ERS, in conjunction with the Michigan Experiment Station staff. The Statistical Reporting Service data on trends were used as the base yield projections for technology attainment number one for 1980 (TA_1). The second technology attainment (TA_2) was based upon assumptions of improved management and the more wide-spread application of near optimum uses of fertilizer. In the development of the estimates, each soil management group was analyzed with respect to its capacity to absorb additional technology. In all cases, the estimates developed are designed to reflect productivity levels under average management and climatic conditions. In both the TA_1 and TA_2 yield projections, no additional land drainage is assumed. Additional yield increases due to drainage will be discussed later.

The tabular material presented reflect yield projections for the 15 counties of the two study areas central to this study. Comparable data were developed for an additional 27 counties surrounding the study areas in lower Michigan and are not reported because of their voluminous

Table 14.

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Table 14. Average Productivity Levels for Crop Alternatives on Soil Management Groups in the Thumb and South Central Michigan Study Area, Assuming Technology Attainment 1, 1980[1/]

Soil Management Group	Wheat	Corn	Oats	Barley	Soybeans	Dry Beans
	---------------	---------------	Bu.	---------------	---------------	Cwt.
Thumb						
1	49	107	76	62	32	18.8
2	50	103	76	65	31	22.6
2c	56	116	84	76	34	24.6
3	46	91	68	56	30	17.6
4	40	78	58	51	28	16.7
5	22	56	43	--	28	--
M	--	110	--	--	37	--
South Central						
1	51	105	72	59	28	18.0
2	52	96	74	59	29	19.7
2c	60	114	88	73	33	24.0
3	48	84	65	51	27	16.4
4	39	71	52	45	25	13.8
5	26	49	41	--	--	--
M	--	107	--	--	35	--

1/ Productivity levels reflect average management and average climatic conditions and 1963 drainage improvements.

Table 14 Continued--

Table 14. Continued

Soil Management Group	Potatoes	Corn Silage	Alfalfa Hay	Other Hay	Cropland Pasture*
	--Cwt.--	-------------Tons-----------			-AUD/yr.-
Thumb					
1	--	17.1	3.8	2.9	138
2	281	17.9	3.9	2.9	173
2c	--	21.9	4.5	3.2	201
3	307	16.6	3.8	2.6	157
4	277	14.5	3.0	2.0	128
5	--	9.4	2.0	1.5	76
M	383	18.7	--	--	--
South Central					
1	--	16.1	3.7	2.9	159
2	265	16.6	3.8	2.8	173
2c	--	21.0	4.5	3.2	201
3	279	14.9	3.7	2.6	154
4	253	13.5	2.9	1.9	121
5	--	9.6	1.8	1.4	75
M	359	18.0	--	--	--

Source: Unpublished material developed for the report, "Agricultural Activity in the Grand River Basin: A Projective Study," Natural Resource Economics Division, ERS, USDA, January 1966.

* Average yield on permanent pasture assumed to be 88 animal unit days per year.

Table 15. Average Productivity Levels for Crop Alternatives on Soil Management Groups in the Thumb and South Central Michigan Study Area, Assuming Technology Attainment 2, 1980.[1/]

Soil Management Group	Wheat	Corn	Oats	Barley	Soybeans	Dry Beans
	--------------------Bu.				---------------------	Cwt.
Thumb						
1	59	126	90	76	37	23.5
2	61	121	90	81	36	28.2
2c	69	137	100	94	40	30.8
3	57	107	82	70	35	21.9
4	50	92	67	63	33	20.8
5	34	67	51	--	32	--
M	--	130	--	--	--	--
South Central						
1	62	119	86	72	33	22.5
2	63	114	92	74	34	26.2
2c	73	134	101	.90	38	30.0
3	59	99	78	63	31	20.6
4	49	84	62	56	29	17.3
5	32	58	50	--	--	--
M	--	125	41	--	41	--

1/ Productivity levels reflect average management and climatic conditions and 1963 drainage improvements.

Table 15 Continued--

Table 15. Continued

Soil Management Group	Potatoes	Corn Silage	Alfalfa Hay	Other Hay	Cropland Pasture*
	--Cwt.--	-------------Tons-----------			-AUD/yr.-
Thumb					
1	--	20.1	4.4	3.5	170
2	349	21.2	4.5	3.5	212
2c	--	25.7	5.2	3.9	246
3	381	19.5	4.4	3.2	192
4	344	17.1	3.5	2.5	156
5	--	11.0	2.4	1.8	94
M	476	22.0	--	--	--
South Central					
1	--	18.9	4.3	3.5	196
2	329	19.5	4.5	3.4	212
2c	--	24.7	5.2	3.9	246
3	347	17.6	4.3	3.2	189
4	314	15.9	3.4	2.3	148
5	--	11.3	2.2	1.7	92
M	446	21.2	--	--	--

Source: Unpublished material developed for the report, "Agricultural Activity in the Grand River Basin: A Projective Study," Natural Resource Economics Division, ERS, USDA, January 1966.

* Average yield on permanent pasture assumed to be 114 animal unit days per year.

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nature. As will be discussed later, all of the data for the 42-county region are used in the linear programming analysis of this study. Results discussed will relate to both the region and to the two subareas.

Fertilizer use assumptions--The fertilizer use implicit in the yield projections TA_1 and TA_2 represents approximately 30 and 60 percent increases in fertilizer nutrient use over 1959 estimates (Table 16). The alternative yield estimates represent increased levels of all management such as improved seed, use of insecticides, timeliness of operations, and so forth, as well as fertilizer uses.

In general the fertilizer applications represent maintenance applications. Fertilizer is assumed to be applied commensurate with the amount of the nutrient used, sufficient to maintain the basic soil fertility without mining the soil.

Drainage potential--In the 1958 Inventory of Soil and Water Conservation Needs, committees of local county agricultural leaders were formed to guide the inventory, interpret results and determine the conservation problems. Soils were characterized according to their primary and secondary conservation problems. One of the problems was excess water. The Thumb area has 1.1 million acres and the South Central area has .6 million acres where excess water is the dominant soils problem.1/

In addition to the estimate of acreages with an excess water problem, an unpublished estimate was made of the acreages that need artificial drainage in order that conservation measures and conservation farming could be undertaken (Table 17). These data were not published,

1/ Inventory of Soil and Water Conservation Needs, Michigan Report, pp. 49-50.

Table 16. Fertilizer Applications for Alternative Crops on Soil Management Group 3, Under Alternative Technology Attainment Levels, Thumb Area, 1959 and 1980 Projected

Fertilizer Estimate	Nutrient	Wheat	Corn	Oats	Barley	Soybeans
		Average Per Acre, Pounds				
Agricultural Sub-region 40, 1959	N	18	27	13	14	8
	P_2O_5	44	40	37	37	33
	K_2O	42	35	36	36	31
Technology Attainment 1	N	55	91	41	34	0
	P_2O_5	69	73	54	45	45
	K_2O	37	36	27	22	30
Technology Attainment 2	N	68	160	49	42	0
	P_2O_5	85	86	66	56	53
	K_2O	46	64	33	28	35

Table 16 Continued--

Table 16. Continued

Fertilizer Estimate	Dry Beans	Potatoes	Corn Silage	Alfalfa Hay	Other Hay	Cropland Pasture
	-------------Average Per Acre, Pounds-------------					
Agriculture Sub-region 40, 1959	8	74	1/	2/	26	2/
	34	131	1/	2/	45	2/
	32	136	1/	2/	43	2/
Technology Attainment 1	18	154	133	0	13	4
	53	123	50	76	52	14
	35	184	83	38	26	43
Technology Attainment 2	22	191	156	0	16	4
	66	152	59	88	64	17
	44	229	98	44	32	51

Source: Commercial Fertilizer Used on Crops and Pasture in the United States, 1959 Estimates, Statistical Bulletin No. 348, ERS and ARS, USDA, July 1964, p. 79.

Projected fertilizer use levels developed from estimates by members of the Michigan Agricultural Experiment Station. Yield estimates in Tables 12, 13 and 14 reflect the fertilizer estimates. In general, fertilizer estimates represent maintenance applications. Fertilizer is assumed to be applied commensurate with the amount of the nutrient used by plants, sufficient to maintain the basic soil productivity. Technology attainment levels 1 and 2 represent increases of 30 and 60 percent in fertilizer use over 1959, respectively.

1/ Fertilizer use included with corn for grain.

2/ Fertilizer use included with other hay.

Table 17. Cropland Tile Drainage Potential by Soil Management Group, Drainage Condition and Slope, Thumb and South Central Michigan, 1958

Soil Designation*	Thumb	South Central
	----------Acres----------	
1bcA	27,600	---
1bcB	---	5,200
2bA	219,400	103,300
2bB	---	3,800
2cA	257,400	91,800
3bA	91,000	68,400
3bB	---	1,600
3cA	2,300	3,000
4bcA	77,700	26,800
5bcA	12,500	6,500
McA	13,600	49,900
Total	701,500	360,300

Source: Unpublished estimates made by the county committee in the development of the Inventory of Soil and Water Conservation Needs.

* Soil designation symbols are defined as follows:

1, 2...5, M - soil management group

b - imperfect natural drainage

c - poor natural drainage

A - slopes less than 1 percent

B - slope between 1 and 3 percent

but were obtained from the Inventory of Conservation Needs' work sheets in the county Soil Conservation Service offices in the study areas. Presumably, the acreage estimate, as developed by the committee, represents cropland area where tile drainage would be physically feasible. In both areas, the feasible-to-drain acreage represents about two-thirds of the total land area having excess water as the dominant problem.

The feasible-to-drain acreage by soil management groups provides acreage limits for the linear programming model for determining the economic potential for drainage. As will be discussed later, the drainage activity is allowed to enter at various cost levels to determine the sensitivity of various cost-sharing arrangements on possible drainage adoption.

The potential yield increase obtainable through artificial drainage was based primarily on the 1963 Farm Drainage Survey. Individual crop production and acreages were obtained from each respondent in the survey.[1/] In addition, the actual drainage improvement, if any, was recorded. Thus, overall yield levels for the major crops were obtained for undrained and artificially drained conditions. However, these yield differences were not identified by soil management group. In a separate drainage study of the Ohio River Basin, Indiana and Ohio Experiment Station and Soil Conservation Service personnel developed drainage yield estimates for soil groups similar to those used in Michigan. One of the regions analysed in the Ohio study overlaps lower Michigan even though it does not lie in the Ohio river hydrologic boundary.[2/] The

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1/ See Section III, Appendix A.

2/ Land Resource Area 111 extends into lower Michigan. See the unpublished interagency report by the author, "Agricultural Activity in the Ohio River Basin: A Projected Study," Natural Resource Economics Division, ERS, USDA, February 1966, p. 16.

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index developed from these data was coupled with the yield differences found in the Farm Drainage Survey for the study areas to determine the average yield response that might be expected. The results were checked and adjusted by members of the Michigan Station (Table 18).

The drainage installation assumed for each soil management group reflects the recommended installation for each group by the Soil Conservation Service and the Experiment Station. At present, nearly all of the drainage installed in the study areas is done under technical assistance of the Soil Conservation Service and cost-sharing arrangements of the Agricultural Stabilization and Conservation Program Service. Consequently, the assumption is that future installations also will be according to recommendations.

Potential yield increases were developed for both technology attainment levels to be consistent with the yield projections developed earlier in this chapter. Practically no experimental information is available which relates the share of improved yields that can be imputed to drainage. In other words, the percent increase in yields through artificial drainage that farmers experience currently was used to determine the potential drainage increase from the TA_1 and TA_2 projections. The average yield levels for each commodity under the TA_1 and TA_2 assumptions were multiplied by the respective percent increase. Therefore, the drainage potential was assumed to be perfectly related to the projected yields for TA_1 and TA_2. The drainage input into the production process undoubtedly interacts with other technology inputs to command the higher yield. Fertilizer inputs, seeding rates, harvesting costs, etc., also would increase in conjunction with the drainage measure and may not be a constant proportion. While the constant proportion imputation of productivity is arbitrary, alternative

Table 18. Potential Yield Increases from Drainage for Crop Alternatives on Soil Management Groups in the Thumb and South Central Michigan Study Areas, Assuming Technology Attainment 1[1/]

Soil Management Group	Wheat	Corn	Oats	Barley	Soybeans	Dry Beans
	---------------	---------------	Bu.	---------------	---------------	Cwt.
Thumb						
1bcA	14	49	39	17	12	8.5
2bA	21	33	33	17	13	10.4
2cA	23	60	44	32	15	11.4
3bA	20	46	24	14	9	7.6
3cA	25	53	41	29	14	11.1
4bcA	23	46	36	--	15	8.7
5bcA	17	37	26	--	--	--
Mc	--	35	--	--	16	--
South Central						
1bcB	15	43	33	14	9	7.4
2bA	21	32	33	16	13	10.2
2bB	17	27	32	10	8	6.5
2cA	33	59	45	31	15	11.1
3bA	32	44	24	15	9	7.4
3cA	27	53	41	28	14	10.8
3bB	17	38	25	11	8	6.5
4bcA	25	45	36	--	15	8.4
5bcA	18	31	27	--	--	--
Mc	--	34	--	--	15	--

1/ Yield increases represent average changes in production above the averages listed in Table 14.

Table 18 Continued--

Table 18. Continued

Soil Management Group	Potatoes	Corn Silage	Alfalfa Hay	Other Hay
	--Cwt.--	---------------Tons---------------		
Thumb				
1bcA	--	7.8	1.4	1.3
2bA	--	5.4	2.1	1.4
2cA	--	10.1	2.3	1.5
3bA	88	8.1	1.7	1.3
3cA	144	8.9	2.1	1.4
4bcA	93	7.8	1.7	1.0
5bcA	--	6.6	1.0	1.1
Mc	224	5.8	--	--
South Central				
1bcB	--	6.7	1.0	1.1
2bA	--	5.2	2.1	1.4
2bB	--	4.5	1.5	1.1
2cA	--	9.7	2.3	1.5
3bA	82	7.8	1.7	1.3
3cA	90	8.6	2.1	1.4
3bB	90	6.9	1.7	.9
4bcA	87	7.5	1.7	1.0
5bcA	--	5.5	.8	1.1
Mc	211	5.6	--	--

Source: Information developed from the 1963 Farm Drainage Survey and from estimates of the Soil Conservation Service and Agricultural Experiment Station personnel in Michigan, Ohio and Indiana.

estimates are not available. The yield increases are in addition to the projected productivity levels presented in Tables 14 and 15.

D. Cost of Production

The production costs were developed on the basis of current input price levels and relationships. Their purpose in the model is to indicate the relative costs of producing various crops in the soils in the study areas. Current relative input prices are assumed to exist in 1980. All items of on-farm production costs were included with the exception of charges for crop and hay storage and interest costs for land or land improvements. The per acre production costs for each crop and soil were aggregates of the three major elements of costs: preharvest costs, harvesting costs and the cost of materials. The costs were designed to represent average costs of production that farmers would incur in the projection year 1980 (Table 19). Tillage operations, equipment size, and performance rates represent better than current average production methods. Unpublished Michigan Farm Account data were the principal sources of information for developing input budgets.

Preharvesting costs consisted of charges for land preparation, planting and general cultivation. Additional charges for side dressing with fertilizer and spraying with insecticides and herbicides for certain crops were made. Charges were made for clipping cropland pasture. A miscellaneous charge was made for equipment maintenance. Hired and family labor costs were figured at $1.58 per hour.1/

1/ Labor rates based on 1961 rates used in the farm business reports prepared by the Michigan Experiment Station and adjusted to 1963 by the wage rate index found in Agricultural Statistics, 1964, p. 445. See also Leonard A. Kyle, Michigan Farm Business Report for 1961, Michigan Experiment Station, M.S.U., Article 45-24, November 1962.

Table 19. Equipment and Labor Costs for Budgets, Michigan Farm Drainage Study[1/]

Item	Average Use Per Year	Cost Per Hour
	--Hours--	--Dollars--
Tractor, 3 plow	600	1.43
Plow, 3 - 14 in.	100	.88
Disk harrow, 10 ft.	100	.66
Drag harrow, 10 ft.	60	.13
Planter, 4 row	40	1.93
Rotary hoe, 4 row	40	1.43
Cultivation, 4 row	100	1.05
Sprayer, 8 row	40	.63
Corn picker, 2 row	100	3.85
Combine, 7 ft.	100	5.50
Mower, 7 ft.	60	1.10
Haybaler, P.T.O.	40	7.04
Hay rake, 7 ft.	60	1.21
Grain drill, 15 - 7 in.	60	2.20
Labor	--	1.58

Source: Developed from unpublished Michigan farm account data and material developed for the report, "Agricultural Activity in the Grand River Basin: A Projective Study," Natural Resource Economics Division, ERS, USDA, January 1966.

1/ Costs reflect 1963 machinery and salvage price levels. Capital charges were 6 percent. Labor costs, based on rates used in farm business reports prepared by the Michigan Experiment Station.

Harvesting costs include the time necessary to harvest the crop and, in addition, include the costs of equipment and labor needed to transport the crop to an on-farm storage facility. Off-farm transportation costs were not included.

The cost of materials varied among crops more than did the costs of planting and harvesting. Nitrogen, phosphorus and potassium fertilizer costs used were 12, 10 and 5 cents per pound of actual nutrients applied, respectively. Other material costs included such items as lime, seed, spray, twine for hay baling and bags for potatoes.

Production costs were developed representing the two technology attainment assumptions discussed previously (Table 20). Material and harvesting costs were the principal variants in costs of production from one attainment level to another. Material costs per unit were assumed constant over all levels of application. Harvesting methods were assumed to be slightly more efficient as yields increased. Preharvesting costs were assumed to remain unchanged.

Drainage costs--The investment in drainage was developed from unpublished information available from the Agricultural Stabilization and Conservation Program Service. Records of actual installation in the 1963-64 season provide a basis for determining typical tiling cost for the study areas. Average tiling costs were \$2.84 and \$3.85 per rod installed in the Thumb and South Central areas, respectively. Current ditching costs are 10 cents per cubic yard of earth moved. A survey of farmers by the author in Lapeer and Gratiot County in 1961 indicated that the useful life of tile installation averaged 30 years and open ditch installation 20 years. The amortization rate in determining the basic annual drain investments was 6 percent. The effect of varying

Table 20. Average Production Cost Levels for Crop Alternatives on Soil Management Group 3 in the Thumb Area under Alternative Technology Assumptions[1/]

Technology Assumption	Wheat	Corn	Oats	Barley	Soybeans
Technology Attainment 1					
Preharvest Costs	$ 5.88	$11.90	$ 9.25	$ 5.88	$12.77
Material Costs	23.42	23.77	16.62	17.66	11.25
Harvest Costs	12.41	12.45	10.96	13.79	9.58
Total	$41.71	$48.12	$36.83	$37.33	$33.60
Technology Attainment 2					
Preharvest Costs	$ 5.88	$11.90	$ 9.25	$ 5.88	$12.77
Material Costs	26.12	29.32	19.90	19.58	15.82
Harvest Costs	13.79	13.23	12.70	15.06	9.58
Total	$45.79	$54.45	$41.85	$40.52	$38.17

1/ Costs reflect 1963 machinery and salvage price levels. Capital charges were 6 percent. Costs do not reflect land charges or land improvement charges.

Table 20 Continued--

Table 20. Continued

Technology Assumption	Dry Beans	Potatoes	Corn Silage	Alfalfa Hay	Other Hay	Cropland Pasture
Technology Attainment 1						
Preharvest Costs	$12.77	$ 76.28	$12.03	$ .44	$ .87	$ .44
Material Costs	13.85	289.21	26.28	16.23	13.37	15.71
Harvest Costs	14.42	59.75	52.55	30.00	25.00	2.75
Total	$41.04	$425.24	$90.86	$46.67	$39.24	$18.90
Technology Attainment 2						
Preharvest Costs	$12.77	$ 76.28	$ 12.03	$ .44	$ .87	$ .44
Material Costs	18.36	345.61	34.25	17.99	15.92	18.35
Harvest Costs	15.26	72.09	57.32	33.00	27.10	2.75
Total	$46.39	$493.98	$103.60	$51.43	$43.89	$21.54

Source: Developed from unpublished Michigan farm account data and material developed for the report, "Agricultural Activity in the Grand River Basin: A Projective Study," Natural Resource Economics Division, ERS, USDA, January 1966.

drainage costs through alternate cost-sharing arrangements will be discussed in the following chapter.

The investment costs developed for this study represent the recommended tile and surface ditch spacing of the Soil Conservation Service and the Michigan Agricultural Experiment Station (Table 21). Grid tile systems are recommended on all soil management groups except on certain wet sandy soils (5bcA) where random spacing of tile laterals in depressions provide adequate drainage. The costs developed for each soil management group include costs for large on-farm open ditches for outlets. The cost presumably represents the farmers "on-farm" costs in draining an acre of land. Public drain costs or the cost-sharing of major channel improvements performed by federal agencies are not included.

E. Alternate Regional Food and Fibre Production Projections

For purposes of this study, three levels of product requirements for agricultural products in the region were developed. The term product requirements as used here refers to the amount of agricultural products consumers would be expected to purchase or require from the region. As discussed earlier, the aggregate requirements for agricultural production are exogenous variables in the study. The three levels of requirements were designed to reflect potential population levels and changes in per capita uses of agricultural commodities in the U. S. in the future. Assumptions also were made concerning import-export levels as well as livestock feeding efficiency and livestock feed composition. The production requirement developed can be considered as alternate projections for 1980 based on different growth rates, output ratios and per capita income. Alternatively, the requirement could be considered as projections into the future beyond 1980. At any rate, an

Table 21. Drainage Investment Costs Per Acre for Imperfect and Poorly Drained Soils in the Thumb and South Central Michigan Study Areas

Soil Management Group	Recommended Drainage System*	Amortized Annual Cost Per Acre **	
		Thumb	South Central
1bcA	4-rod grid	6.41	8.46
1bcB	4-rod grid	5.93	7.98
2bA	5-rod grid	7.27	9.69
2bB	5-rod grid	7.17	9.59
2cA	5-rod grid	7.22	9.64
3bcA	6-rod grid	5.93	7.91
3bB	6-rod grid	5.88	7.86
4bcA	7-rod grid	4.64	6.18
5bcA	random	.71	.91
Mc	7-rod grid	4.95	6.49

* Tile spacing represents recommendations of Soil Conservation Service and Agricultural Experiment Station technicians.

** Costs based on current drain investment costs in the study areas as recorded by the Agricultural Stabilization and Conservation Service. Tiling costs are $2.84 and $3.85 per rod installed in the Thumb and South Central areas respectively. The per acre costs also included necessary on-farm open ditch costs. Current ditching costs are 10 cents per cubic yards of earth moved. Tile costs were amortized over 30 years at 6 percent and open ditch costs over 20 years at 6 percent.

attempt is made to make the three estimates internally consistent and comparable. Whether the projections are alternative estimates for a given projection date or subsequent time period is immaterial as long as the estimates are within the range of possibilities.

Alternative national economic growth projections have been developed by the Ad Hoc Water Resources Council Staff[1/] (Table 22). These projections represent different assumptions about population growth, labor force participation and growth in Gross National Product. They were developed to represent expected 1980, 2000 and 2020 economic conditions but for this analysis the projections were labeled C_1, C_2 and C_3, respectively to reflect less emphasis on the time dimension. The symbol C represents the product that is assumed to be produced in the region or alternatively required.

The population and labor force assumed represented increases of about 40, 100 and 175 percent for the three levels C_1, C_2 and C_3 respectively. However, 2-, 4-, and 9-fold increases in GNP are expected. These rates are consistent with the population increase, the purchasing power of the labor force and the continued growth of the economy. Gross product per capita also increases significantly which influences per capita food consumption rates.

Expected per capita uses of agricultural commodities--An initial estimate of total U. S. agricultural product requirements of effective demands was determined by multiplying the expected per capita uses of the major farm products by the population assumed in C_1, C_2 and C_3. Per capita uses were developed by the Economic and Statistical Analysis

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1/ Economic Task Group of the Ad Hoc Water Resources Council Staff, National Economic Growth Projection, Washington, D. C., July 1963.

Table 22. Assumptions for Alternative Effective Demand Requirements for Analysis of Drainage Potential in the Michigan Farm Drainage Study Areas[1/]

Item		Average 1959-61	Alternative Assumptions C_1	% Increase Over 1959-61	C_2	% Increase Over 1959-61	C_3	% Increase Over 1959-61
Population	Mil.	180.1	254.0	141	358.0	199	502.0	279
Labor force	Mil.	73.1	104	142	147	202	206	282
Employment	Mil.	68.9	100	145	140	203	197	286
Gross National Product	Bil. $	515.3	1,096	212	2,232	433	4,518	877
Output per man hour	$	3.71	6.12	165	9.71	261	15.30	250
Gross product per capita	$	2,850	4,317	151	6,235	219	9,001	315

1/ Adapted from Table 3 and Appendix Table 61, Economic Task Group of the Ad Hoc Water Resources Council Staff, National Economic Growth Projection, Washington, D. C., July 1963.

Division, ERS, cooperatively with the Resource Development Economics Division (Table 23). In general, meat products are expected to have higher per capita uses, while cereal, dairy and egg products will have lower per capita uses. The increase in soybeans per person is expected to be most dramatic. Other commodity uses are not expected to change significantly. Alternative per capita uses were not projected since disposable personal incomes were expected to reach a level where additional incomes would not change the commodity mix in the U. S. diet significantly.

Livestock feeding efficiency and ration assumptions--To maintain consistency with the TA_1 and TA_2 technology assumptions, changes in feeding efficiency were estimated to correspond with the alternative product requirements (C_1, C_2 and C_3). Feeding efficiencies influence the amount of feed grains required for the livestock product estimated to be needed under the three situations.

Little statistical data are available to analyze feeding efficiency trends. The kinds and types of livestock fed have varied which tends to veil improvements in feeding efficiency. In fact, some projection models, in which favorable livestock-feed price relationships are assumed, indicate decreased aggregate livestock feeding efficiencies in the next 10-15 years.[1/] Nevertheless, livestock specialists estimate continued improvement in breeding, improved rations, less feed wastage, and increased parasite and disease control. Mechanization is expected to allow larger, more efficient organization and management of enterprise which in turn

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1/ R. F. Daly and A. C. Egbert, "A Look Ahead for Food and Agriculture," Agricultural Economics Research, January 1966, Vol. XVIII, No. 1, p. 4.

Table 23. Index Numbers of Projected Per Capita Uses of Major Farm Products, United States

Item	Projected
	(1959-61 = 100)
Meat (carcass weight)	
Beef	132
Veal	85
Lamb and mutton	71
Pork (excluding lard)	89
Total	111
Dairy Products	
Total milk equivalent (fats solid basis)	87
Poultry	
Chicken (ready to cook)	120
Turkey (ready to cook)	157
Total	127
Eggs	86
Soybeans	164
Flax	57
Wheat	87
Rice (milled basis)	106
Rye	78
Peanuts (farm stock basis)	103
Wool (apparel, scoured)	100
Sugar crops (raw equivalent)	100
Fruits	
Citrus (fresh basis)	102
Noncitrus	107
Tree nuts (in shell)	94
Vegetables (all, including melon)	103
Potatoes (fresh and processed)	102
Sweet potatoes	72
Dry beans	92
Dry peas	100
Tobacco	100

Source: Economic Framework Section, River Basin and Watershed Branch, Resource Development Economics Division, ERS, USDA. Unpublished memoranda dated March 29, 1965. Data developed cooperatively with the Economic and Statistical Analysis Division, ERS.

will encourage the adoption of newer technologies.

Feeding efficiencies have been estimated based on information prepared by the Ohio Experiment Station and the Michigan Agricultural Experiment Station [1/] (Table 24). In general, the feed requirements per pound of product of all livestock groups are reduced by one-third under the C_3 assumption.

Another factor in determining feed grain and roughage requirements is the mixture in the livestock feed ration. Roughages are expected to constitute a smaller share of the ration (Table 25). Feed grains also are expected to be a larger share of the concentrates fed. Increased pen feeding of beef and dairy cow confinement is expected to result in higher concentrate consumption. Even so, the projections do not deviate significantly from present rations.

<u>Projected regional product requirements</u>--Statistical Reporting Service data were summarized to develop a 1959-61 base for the production of the major farm products produced in the U. S. and in lower Michigan (Table 26). Following this step, the assumed population for C_1, C_2 and C_3 was multiplied by the per capita consumption rates to determine estimates of domestic food requirements. Livestock products were further translated into feed grain and roughage requirements. Net export requirements were added to the domestic requirements. Exports were entered at approximately double current rates for all three projection situations. The assumption is that developing countries are

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1/ C. J. Willard, Projected Crop and Pasture Yields, Associated Fertilizer Use and Feeding Efficiencies, Ohio River Basin, 1980-2010, unpublished report prepared for the Natural Resource Economics Division, ERS, USDA, 1964; and Project '80, Summary of Phase II Papers, Michigan Agricultural Experiment Station, March 1965.

Table 24. Feeding Efficiency Assumptions for Determination of Alternate Crop and Pasture Production Requirements, Michigan Farm Drainage Study

Commodity	Feed Units* Per Pound of Product			
	1959-61 Estimate	Projected		
		C_1	C_2	C_3
Beef and veal	11.5	10.5	8.8	7.2
Lamb and mutton	13.0	12.0	10.0	8.2
Pork	4.6	4.0	3.7	3.3
Milk	1.0	.85	.75	.65
Broilers	3.0	2.5	2.3	2.1
Turkeys	3.7	3.2	2.9	2.5
Eggs	3.6	3.1	2.7	2.3

Source: C. J. Willard, Projected Crop and Pasture Yields, Associated Fertilizer Use and Feeding Efficiencies, Ohio River Basin, 1980-2010, unpublished report prepared for the Natural Resource Economics Division, ERS, USDA.

* A feed unit is equivalent to one pound of corn.

Table 25. Projected Livestock Feed Ration Composition for Determining Alternate Crop and Pasture Production Requirements, Michigan Farm Drainage Study

Commodity	Ration Composition			
	Feed Units From Concentrates		Feed Units From Grain	
	1959-61 Estimate	Projected	1959-61 Estimate	Projected
	percent			
Beef and veal	21	25	14	19
Lamb and mutton	10	10	6	6
Pork	96	97	81	82
Milk	32	41	23	33
Broilers	100	100	55	57
Turkeys	95	98	58	62
Eggs	98	99	64	65

Source: Economic Framework Section, River Basin and Watershed Branch, Resource Development Economics Division, ERS, USDA, unpublished memoranda, dated March 29, 1965 and July 1, 1965.

Table 26. Production of Major Farm Products, U. S. and 42-County Region of Michigan, 1959-61 Average

Item	Unit	U. S.	42-County Region
		(1959-61 average)	
Beef and veal	Mil. Lbs. Live Wt.	28,206	372.1
Lamb and mutton	Mil. Lbs. Live Wt.	1,658	17.2
Pork	Mil. Lbs. Live Wt.	20,564	213.7
Chicken	Mil. Lbs. Live Wt.	7,571	37.8
Turkey	Mil. Lbs. Live Wt.	1,540	18.1
Milk	Million Lbs.	121,164	3,998.4
Eggs	Million	64,993	1,299.8
Wheat	Thousand Bushels	1,185,533	27,267.7
Rye	Thousand Bushels	28,143	619.1
Soybeans	Thousand Bushels	597,600	4,183.2
Sugar beets	Thousand Tons	17,047	1,108.0
Dry beans	Thousand Cwt.	18,710	6,585.9
Potatoes	Thousand Cwt.	258,230	5,681.0
Vegetables	Thousand Cwt.	416,640	11,665.9
Fruits, non-citrus	Thousand Tons	8,098	380.6

Source: Economic Framework Investigation Section, River Basin and Watershed Branch, Resource Development Economics Division, ERS, USDA and interagency report Agricultural Activity in the Grand River Basin: A Projective Study, January 1966, Natural Resource Economics Division, ERS, Table 11.

expected to provide larger shares of their own food and fibre needs.

A final step was to analyze the historical share of U. S. production that the lower Michigan area produced of each major commodity. A linear regression prediction for 1980 was used for allocating U. S. product requirements for the three projection situations. One slight modification in predicted shares was made in that corn production was increased to allow lower Michigan to be a slight surplus feed grain producing area for the three projection situations. Statistics were not available nationally or regionally to develop the estimated share of roughage production for pasture. Pasture production for lower Michigan was developed on the basis of existing and projected livestock production and expected pasture yields.

Based on the foregoing relationships and assumptions, indices of product requirements for the lower Michigan area were developed (Table 27). Feed crop projections were generally below current levels for C_1. All crop and livestock items were above current levels in the C_3 situation except for oats and barley which gave way to corn in the livestock rations.

Table 27. Indexes of Alternate Product Requirements for the Analysis of Drainage Adoption in Lower Michigan, Michigan Farm Drainage Study

Commodity	C_1	C_2	C_3
		(1959-61 = 100)	
Wheat	101	115	152
Corn	78	119	164
Oats	73	76	51
Barley	56	67	59
Soybeans	267	338	448
Dry beans	124	173	229
Potatoes	182	253	335
Corn silage	91	129	138
Alfalfa hay	75	120	140
Minor crops	96	118	136
Cropland pasture	132	140	131
Permanent pasture	129	145	119
Beef and veal	128	183	242
Lamb and mutton	92	130	172
Pork	122	170	225
Chicken	62	92	122
Turkey	154	213	282
Milk	118	163	215
Eggs	96	133	176

Source: Unpublished data from the Economic Framework Investigation Section, River Basin and Watershed Branch, RDED, ERS, USDA and working data for the interagency report Agricultural Activity in the Grand River Basin, A Projective Study, Natural Resource Economics Division, ERS, January 1966.

CHAPTER V

ECONOMIC POTENTIALS FOR LAND DRAINAGE

The results of the linear programming analysis are presented in this chapter. As indicated in Chapter III on methodology, a minimum-cost formulation of the linear programming technique is used to estimate the economic potential for agricultural land drainage under various assumptions.

One of the questions to be asked in the analysis concerns the role investments in agricultural land drainage by private resource owners and public agencies can play in economic growth. In other words, what are the expected changes in producer benefits? More specific economic questions can be raised. The linear programming model as used herein provides estimates for many of these questions. Information on production costs, marginal costs of production, resource rents, drainage rents, substitution of drained land for idle acres, etc., are provided.

A. Nature of the Linear Programming Model

The objective function for the linear programming model used herein is designed to minimize the costs of producing a given set of product requirements, given a specific set of restraints on the production process, within a producing region. The model was presented in Chapter III in both its primal and dual forms. A tabular illustration of the model is shown in Table 28. In the symbolic matrix, the p represents the per acre cost of the production activities and the a represents the per acre output or yield. The land requirement for each activity is one acre, to correspond with the per acre cost and yield coefficients. The product

Table 28. Tabular Illustrations of Minimum Cost Linear Programming Model with Drainage, Row Crop and Minimum Crop Acreage Extensions[1/]

Activities																										Restraints
p	p	.	p	p	p	.	p	.	p	p	.	p	p'	p'	.	p'	p'	p'	.	p'	.	p'	p'	.	p'	= Cost
																										Product Requirement
a				a				.	a				a'				a'				.	a'				= Wheat
	a				a			.		a				a'				a'			.		a'			= Corn
		.				.		.			.				.				.		.			.		= .
			a				a	.				a				a'				a'	.				a'	= Crop Pasture
																										Land Acreage Available
1	1	.	1										1	1	.	1										≤ 1
				1	1	.	1										1	1	.	1						≤ 2
								.													.					≤ .
									1	1	.	1										1	1	.	1	≤ s
																										Drainage Acreage Available
													1	1	.	1										≤ 1
																	1	1	.	1						≤ 2
																					.					≤ .
																						1	1	.	1	≤ s
																										Row Crop Acreage Limit
	1	.			1	.		.		1	.			1	.			1	.		.		1	.		≤ 1
	1	.			1	.		.		1	.			1	.			1	.		.		1	.		≤ 2
		.				.		.			.				.				.		.			.		≤ .
	1	.			1	.		.		1	.			1	.			1	.		.		1	.		≤ s
																										Minimum Acreage Requirement
1				1				.	1				1				1				.	1				≥ Wheat
	1				1			.		1				1				1			.		1			≥ Corn
		.				.		.			.				.				.		.			.		≥ .
			1				1	.				1				1				1	.				1	≥ Crop Pasture

1/ Identity Matrix omitted.

requirements are expressed as equalities meaning that all requirements must be met. The land availability restraint is such that not all of the land resources need be used in the production of the requirements.

The drainage potential extension provides additional activities in the model. The p' represents the per acre cost of producing an activity on drained land. The cost includes the amortized cost of the field drainage system as well as the regular production costs. The a' reflects the yields on an acre of drained land. The acres drained must be less than or equal to the acres available in the restraint column. Drainage activities compete with nondrainage activities in producing the required production. Either activity draws from the total land availability. In this formulation wet soils could be used in one of three ways: (1) drained, (2) undrained, or (3) left idle.

On certain soil or land management groups, limits on row crop use are recommended. Since these recommendations are expected to be followed in the time period assumed in the study, allowable acreages of row crops in any one production period were entered as a restraint. The row crop acreage on a given soil must be equal to or less than the recommended acreage.

An additional restraint is shown which requires at least so many acres of product be produced on the land resources available within subareas of the region. As explained in Chapter III, the minimum acreage constraint was included to partially reflect past production patterns in each subarea. In the actual computation of the program, a unique set of restraints was entered for each of the five subareas of the 42-county region. In other words, the five subareas competed in producing the required product. But each area had different resource availability.

including drainage acreage and row crop acreage availabilities as well as minimum crop acreage requirements.

The programming tableau as shown in Table 28 is directly related to the general model and matrix developed in Chapter III. The objective of the program is satisfied if the solution provides a land use arrangement that satisfies all of the requirements and restraints set forth, and total costs are minimized. In other words, the acreage of a specific land resource used in producing one of the requirements, multiplied by the per acre production cost for that use when summed for all land resources, represents total production cost, the sum to be minimized. By the same token, the acreages of various land uses when multiplied by their respective yields and summed for each product will exactly fulfill the product requirements.

The basic comparison made in the analyses is between program runs including and excluding the drainage activities. In runs excluding drainage, the drainage extension was left out. Alternative runs were also made where different levels of product requirements were entered. Different yield levels and production costs were entered to reflect varying amounts of technology adoption in another set of program runs. In a similar manner, production costs that included drainage were varied to reflect different public cost-sharing arrangements. Except for these variations, all other restraints in the model were constant in the various program runs.

The cropland base for the program model is developed from the Inventory of Soil and Water Conservation Needs conducted by the U. S. Department of Agriculture in 1958 (see Table 10 and 11). The cropland base for the model is reduced for expected urban and industrial buildup by 1980. Crop yields and fertilizer use represent projected average levels for 1980.[1/]

Only eleven cropland uses were considered in the model (see Table 13). Acreages for sugar beets and for minor crops such as vegetables were subtracted from the cropland base.[2/] Four of the eleven crops are row crops. Many of the soils cannot be used continuously for row crops and maintain productivity; consequently, a restriction was made to limit the amount of row crops on these soils (see Table 12).

Only cropping alternatives are considered in the program. Livestock requirements were not entered explicitly. However, feed grain, roughage and pasture needs for livestock production projected for the 42-county region are included in the product requirements along with a 10 percent surplus of feed grain (corn) for interregional export.

Cropland only is considered in the model. Native pasture is a near substitute for cropland pasture; therefore, a share of the grazing requirements was allocated to the native pasture acreage. Native pasture land was assumed to continue in pasture use. The remaining pasture requirement was included in the model to be provided via the cropland pasture activity.

B. Interpreting the Results

The nature of the computerized linear program solution is such that estimates of important economic relationships are readily available. Some 20 linear program runs were made for the 42-county region in this

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1/ For a discussion of these points refer to the corresponding sections in the previous chapter.

2/ Sugar beets are a significant crop in the Thumb area but have not been included because of their orientation to processing facilities.

study. Only four of the runs were made on the Michigan State computer using the CDM-4 system because of the problem size. The balance of the runs were made at the University of Illinois on the IBM 7094 computer using the LP 90 system. Both systems provide information for the primal and dual solutions to each problem (refer to chapter on Methodology).

Total production costs--One of the results of the linear program analysis is the total production costs necessary to produce the product requirements for the region. Total production costs in this study represent all nonland on-farm costs; in other words, all labor and capital costs except a capital charge for the land investment were included. Any return over the labor and nonland capital expenditures is assumed to accrue to the fixed factor, the cropland resource. Unpaid factors such as family labor were charged at an imputed value.

Changes in total production cost from one program solution to another indicate the size of the payment to the nonland factors. While the size of payment does not by itself indicate changes in individual welfare to labor and nonland capital owners, the payment does indicate the relative share these factors command in the production process. Changes in production costs have implication for those who supply and support the agricultural industry.

Production cost totals for the 42-county region are derived directly from the LP solutions without further calculation. However, the identical total cost can be derived by summing the product of the acreage used and the per acre cost for the use indicated in the program. Production costs for subareas of the 42-county region were derived in this manner.

Rent--Another result of the linear program is the earnings attributed to the fixed factor, in this case the cropland resource.

1) Resource rents: Resource rents, in the Ricardian sense, accrue to those soil management group acreages that are used completely and more could be used to minimize total costs of production. The linear program solution indicates the MVP resulting from the use of the last acre of a soil management group that is limiting. The sum of the products of the MVPs and their respective acreages in the program indicate the total rent accruing to the fixed resource. Resources as used here include existing capital improvements such as roads and existing drainage improvements. Since the soil management groups are identified by subareas within the 42-county region, changes in rents can be identified under alternative program runs for subareas as well as the region.

Changes in the earnings of the natural resource are of prime concern in this analysis. Again, changes in the magnitude of the earnings of the natural resource factor do not necessarily indicate individual welfare changes. But, earnings of the resource input relative to nonland capital and labor earnings can be compared.

2) Drainage rents: Rent accrues not only to the existing qualities of land but man-made improvements or developments as well. In the formulation of the linear program model, additional portions of selected soil management groups can be cropped under the drainage alternative (see previous chapter on acreage availabilities and crop yield potentials). Drainage allows selected soil management groups to have more productivity relative to lands not having a wetness problem. Depending upon costs of the drainage investment, artificially drained land may

have an additional rent earning capacity.

3) Negative institutional rents: A third rent concept is employed in this analysis. Negative rents accrue to acres of various crops forced into the linear program for each subarea to reflect to some degree the historical trends in production. If the minimum acreage restriction (see Appendix C for acreage restrictions) does in fact force a cropping pattern that is not consistent with efficient resource use, then the restriction forces a cropping pattern with higher production costs and rents. A measure of the negative rent is derived from the program results just as the natural resource and drainage rents were. However, the sign on the MVP is reversed. Total production costs and rents are increased if one more unit of the restriction is added.

The size of the negative rent is a measure of the effect that institutional forces have on production costs, rents and ultimately on the sales value of agricultural products. The measure is an indicator of the benefits that would accrue if public programs could be developed to improve resource mobility, eliminate capital limitations, etc. The negative rent concept is not the central focus of this study, but it does have implications for further analyses. For instance, any program that has the effect of changing cropping patterns or forcing land retirement in one subarea over another can be analyzed for the impact on production costs, rents and marginal costs of production.

Marginal costs of production--As indicated previously, programming is consistent with equilibrium theory in economics, therefore, marginal costs of production are obtained in the solution. The term shadow price is used in programming as each requirement in the model implies or has

a per unit cost associated with it. The concept is equivalent to marginal cost in economic theory. Since the model is set up in a cost minimization form in this study, the shadow price is considered the marginal cost of producing the last unit of product required.

Changes in production costs and marginal costs of production are important as they are estimates of payments made by producers as a result of the measures considered in this study. Marginal costs of production in the region and subareas indicate the relative costs of obtaining additional products.

Cropping patterns--Since soil management groups are identified by subareas within the 42-county area and crop uses of each soil group can be identified, cropping patterns for each subarea can be derived. The cropping patterns identified here are ones based primarily on the location and quality of the natural resource and then on farm costs of production. Transportation cost and market locations were not considered explicitly. The effect of transportation cost differentials are considered in part by the minimum cropping restrictions placed on each subarea in the model. In other words, the historical trends reflect market differentials.

Changes in cropping patterns may have significance in the type of farming of a subarea. There may be more or less cash crop farming. Comparative advantages in feed grain and roughage production also influence livestock production.

In the discussion of cropping patterns among subareas, crops will be grouped into cash, feed grain and roughage crops. No attempt is made to project individual crops.

C. Base Program Results

The base program run is the model with C_1 product requirements and TA_1 technology attainment levels. The population increases and the corresponding food and fibre needs assumed in C_1 are considered to be the most likely to occur by 1980. The technology adoption in TA_1 appears to be most consistent with current technology adoption and use rates.

In addition to the C_1 product requirements (Table 27) and TA_1 technology attainment or yield levels (Table 14), corresponding production costs for the TA_1 technology levels were used (Table 20). Land resource availability reflects the total cropland expected to be available for use in 1980 (Table 11) and the acreage that can be devoted to row crops (Table 12). The minimum crop acreage constraint was based on current trends in production patterns in the five subareas in the 42-county region (Table 61). In the paired drainage run, activities were entered to reflect yields with drainage and associated management and drain investment costs (Tables 18 and 21). Acreages on which drainage was a potential also were entered (Table 17). The basic model with the drainage extension contained 138 equations and 445 activities.

In the C_1-TA_1 solution with drainage adoption allowed to enter at full economic potential, crop production costs are estimated to be \$147.72 million (Table 29). Resource rents and drainage rents total \$6.78 million, making the gross sales value (less minor crops and native pasture) \$156.5 million. The resource rents capitalized at 5 percent represents land values in the 42-county region of over \$135 million. The negative rent of \$2.11 million indicates the increased production costs because of institutional constraints on resource mobility in one form or another. Without drainage the base program run indicates

Table 29. Labor and Capital Costs and Resource Rents Assuming C_1 Product Requirements, TA_1 Technology Adoption, With and Without Additional Land Drainage, 42-County Region, Michigan Farm Drainage Study, 1980 Projections

Item		Without Drainage	With Drainage
		---Million Dollars----	
Labor and Capital Costs		$153.35	$147.72
Rents:	Resource	6.18	4.59
	Drainage	--	2.19
	Institutional	(.85)	(2.11)
Total Production Costs		159.53	154.50

production costs at $153.35 million and gross sales at $159.53. Resource rents are $6.18 million and the negative rents are less than $1 million.

A comparison of the with and without solutions indicates that the adoption of the full economic potential for drainage in equilibrium would lower production costs $5 million. Producers' labor and capital costs would decrease $5.6 million but rents (both resource and drainage) to resource owners would increase $.6 million. Producers would be better off. Economic growth would be enchanced as fewer inputs are required to obtain an identical bill of goods; in other words, a shift in productive capacity similar to that illustrated in Chapter II (compare r'l' outlay in Chart 1 - Figure 1 with rl outlay in Chart 3 - Figure 1). Natural resource owner's purchasing power is increased by the net gain in rent and the efficiency gains. The negative rents due to forced minimum cropping pattern increased 2½ times, indicating that even larger producer gains would accrue if eliminated.

Additional drainage is a physical potential on 1,641.1 thousand acres. Under the assumption of this solution, farm drainage investment would be profitable to farmers on 743 thousand acres. The cropland available for use according to the USDA Inventory of Soil and Water Conservation Needs for the 42-county region is 7,249.2 thousand acres (Table 30). Of this total, slightly more than half is used in crop production. An examination of the 1949-64 trend in cropland harvested and cropland in farms indicates that the 3.9 million acres in crop use by 1980 would be consistent with current trends (see Appendix D). An extrapolation of the cropland harvested acreage trends for the 42-county region indicates that crop use would be between 4.0 and 4.5 million acres. The difference between the historical trend and results of the linear

Table 30. Major Cropland Use, Assuming C_1 Product Requirements, TA_1 Technology Adoption and Additional Land Drainage, 42-County Region, Michigan Farm Drainage Study, 1980 Projections

Item	Without Drainage	With Drainage
	----Thousand Acres----	
Cropland Acres		
Available	7,249.2	7,249.2
Used	3,867.5	3,473.8
Idle	3,381.7	3,775.4
Additional Acres		
Drainable	--	1,641.1
Drained	--	743.0

program is related to the assumption about technology adoption in crop yields for TA_1 and the assumed managerial capacity of resource owners. Cropland on farms has decreased significantly in recent years. Not only has idle cropland on farms increased but land in farms has decreased and there have been internal shifts on farms to new crop uses.

A comparison of the cropland use with and without drainage adoption indicates that drainage reduces the cropland used. The 743 thousand acres of drainage has the effect of idling 394 thousand acres of cropland. In theory, the idled land has no productive value, therefore income and capital values of idled land are written off and are not considered as social costs. In practice, however, idled land may be supramarginal thereby having a value representing a social cost. Also the relocation and re-employment of the resource owners on idled land may entail a social cost which should be considered in any benefit cost comparisons in program formulation.

The marginal costs of production in the C_1-TA_1 solution with drainage clearly are below current prices (Table 31). If current prices were to hold in 1980, farmers in the study area would appear to have economic incentive to produce agricultural products if acreage restrictions were not imposed. The implication is that the technology and drainage adoption assumed would increase farmer earnings. If efficiency is reflected in lower product prices, then consumers would gain from the technological advance, as smaller portions of their purchasing power would be spent for food and fibre.

If efficiency gains from drainage are reflected in producer earnings, then producers would be interested in investing in field drainage and drain outlet improvements. If efficiency gains are passed on to

Table 31. Marginal Costs of Production, Assuming C_1 Product Requirements, TA_1 Technology Adoption and Additional Land Drainage, 42-County Region, Michigan Farm Drainage Study, 1980 Projections

Crop	Unit	Marginal Costs Without Drainage	Marginal Costs With Drainage
		------Current Dollars----- 1963	
Wheat	Bu.	.85	.83
Corn	Bu.	.48	.47
Oats	Bu.	.51	.47
Barley	Bu.	.45	.45
Soybeans	Bu.	1.12	1.12
Dry Beans	Cwt.	2.04	1.89
Potatoes	Cwt.	1.31	1.15
Corn Silage	Ton	4.96	4.60
Alfalfa	Ton	11.49	11.14
Other Hay	Ton	13.43	13.13
Crop Pasture	AUD	.11	.11

consumers, society would be interested in policies and programs to finance the drainage measures. Likely, some of the efficiency gains will remain with the producer and part will go to consumers. Under these circumstances, cost-sharing of drain improvements in proportion to benefits received is implied. Cost-sharing arrangements will be discussed in more detail in the last section of this chapter.

The balance of this chapter will be a discussion of the several paired program runs designed to test the sensitivity of the major assumptions built into the model. The three assumptions to be analyzed are product requirements (C_1, C_2, C_3), technology adoption (TA_1, TA_2) and three levels of farm drainage investment costs (50%, 67%, 100%) to represent different levels of cost-sharing.

The implications for the 42-county region are discussed first, then the implications for the Thumb and South Central subareas will be discussed. Under each comparison of program runs, changes in production costs, resource rents, drainage rent, negative rents, marginal costs and cropland use will be analyzed.

D. Regional Analysis

Effect of product requirement changes--The linear programming model is designed so that only one set of product requirements are considered in each program run. However, additional programs were run to determine the sensitivity of product requirements on costs, rents, drainage adoption and per unit costs.

Three pairs of program runs were made to determine the likely effect of increased product requirements. Programs using C_1, C_2, and C_3 product requirements with and without additional drainage were run to show the influence of increased population pressure and consumption

requirements on a given resource base. In these comparisons, technology adoption was held constant at the TA_1 level (Tables 32, 33, 34).

Production costs rise nearly $100 million when product requirements are raised from the C_1 to C_3 levels. Without drainage, resource rents raised from $6.2 million for the C_1 requirement to $16.9 million for the C_3 requirement (Table 32). As a percent of total production costs, rents also rose from 3.9 percent to 6.3 percent for the two situations. With drainage, the sum of the rents was slightly higher than the no-drainage situation for the C_1 requirement but was slightly lower for the C_2 and C_3 requirements. One would expect resource rents to be higher under the no-drainage situation. The increased productivity through drainage has the effect of lowering the overall scarcity rents. However, on a percent of costs basis, the scarcity rents were 6.3 percent for the C_3 product requirement for both the with and without drainage runs. On the other hand, the negative institutional rent becomes larger on an absolute and percentage basis.

The sales value of the commodities increased nearly $100 million in the C_3 over the C_1 product requirement situation. The efficiency gains amounted to $5 million under the C_1 situation as compared to about $9 million under the C_3 case.

Marginal costs of production did not increase materially under the three product requirement situations. However, dry beans, potatoes, corn silage and alfalfa per unit costs were reduced about 10 percent when additional drainage was adopted (Table 33).

Without drainage, cropland used raised from 3.8 million to 6.1 million acres from the C_1 to C_3 situation (Table 34). Drainage reduced the cropland use about 400 thousand in the C_1 case and about 900 thousand in the C_3 case. In the C_1 case, one acre drained had the effect of

Table 32. Labor and Capital Costs, Resource Rents Assuming Changes in Product Requirements, Technology Adoption Held at TA_1 Levels With and Without the Adoption of Additional Drainage, 42-County Region Michigan Farm Drainage Study, 1980 Projections

Item	Assumptions: C_1-TA_1 Without Drainage		C_1-TA_1 With Drainage		C_2-TA_1 Without Drainage	
	Mil. $	Percent	Mil. $	Percent	Mil. $	Percent
Labor and Capital Costs	153.35	96.1	147.72	95.6	205.60	94.8
Rents						
Resource	6.18	3.9	4.59	3.0	11.37	5.2
Drainage	--	--	2.19	1.4	--	--
Institutional	(.85)	(*)	(2.11)	(1.4)	(1.72)	(.1)
Total Production Costs	159.53	100.0	154.50	100.0	216.97	100.0

*Less than .05 of 1 percent

Table 32 Continued--

Table 32. Continued

Item	Assumptions					
	C_2-TA_1 With Drainage		C_3-TA_1 Without Drainage		C_3-TA_1 With Drainage	
	Mil. $	Percent	Mil. $	Percent	Mil. $	Percent
Labor and Capital Costs	198.43	95.3	251.47	93.7	243.25	93.7
Rents						
Resource	6.69	3.2	16.90	6.3	12.47	4.8
Drainage	3.02	1.5	--	--	3.84	1.5
Institutional	(2.46)	(1.2)	(1.05)	(*)	(4.87)	(1.9)
Total Production Costs	208.14	100.0	268.37	100.0	259.56	100.0

*Less than .05 of 1 percent

Table 33. Marginal Costs of Production Assuming Changes in Product Requirements With and Without the Adoption of Additional Land Drainage, 42-County Region Michigan Farm Drainage Study, 1980 Projections

Commodity	Unit	Assumption					
		C_1-TA_1 Without Drainage	C_1-TA_1 With Drainage	C_2-TA_1 Without Drainage	C_2-TA_1 With Drainage	C_3-TA_1 Without Drainage	C_3-TA_1 With Drainage
		Dollars					
Wheat	Bu.	.85	.83	.87	.85	.87	.87
Corn	Bu.	.48	.47	.50	.49	.51	.50
Oats	Bu.	.51	.47	.52	.49	.52	.50
Barley	Bu.	.45	.45	.47	.45	.47	.47
Soybeans	Bu.	1.12	1.12	1.15	1.13	1.18	1.17
Dry Beans	C.	2.04	1.89	2.10	1.94	2.16	1.99
Potatoes	C.	1.31	1.15	1.32	1.17	1.32	1.17
Corn Silage	Ton	4.96	4.60	5.29	4.67	5.11	4.75
Alfalfa	Ton	11.49	11.14	11.81	11.44	12.23	11.74
Other Hay	Ton	13.43	13.13	13.82	13.42	14.26	13.81
Crop Pasture	AUD	.11	.11	.11	.11	.11	.11

Table 34. Major Cropland Use Assuming Changes in Product Requirements, Technology Adoption at TA_1 Levels With and Without the Adoption of Additional Drainage, 42-County Region Michigan Farm Drainage Study, 1980 Projections

Item	Assumption					
	C_1-TA_1 Without Drainage	C_1-TA_1 With Drainage	C_2-TA_1 Without Drainage	C_2-TA_1 With Drainage	C_3-TA_1 Without Drainage	C_3-TA_1 With Drainage
	Thousand Acres					
Cropland Acres						
Available	7,249.2	7,249.2	7,249.2	7,249.2	7,249.2	7,249.2
Used	3,867.5	3,473.8	4,913.0	4,412.4	6,130.3	5,206.6
Idle	3,381.7	3,775.4	2,336.2	2,836.8	1,118.9	2,042.6
Additional Acres						
Drainable	--	1,641.1	--	1,641.1	--	1,641.1
Drained	--	743.0	--	968.0	--	1,088.0

idling about one-half acre of cropland. The substitution rate was even higher in the C_3 case where the exchange is almost one-to-one. In the C_3 case, poorer cropland had been called into production, therefore, one would expect an acre drained to substitute for a larger amount of cropland at the extensive margin of production. The increased product requirements represented by C_3 would call in 350 thousand additional acres of drainage, a 50 percent increase over the C_1 situation.

A summary of the results of the three pairs of program runs with changes in product requirements indicates that a doubling of the population in the U. S. could have the effect of increasing the payments to labor and nonland capital $100 million; approximately a 67 percent increase. Rents would increase nearly 250 percent. The relationships support the conclusion of the scarcity doctrines. (Compare C_1-TA_1, and C_3-TA_1 program results in Table 32.)

The adoption of drainage reduces the total outlay necessary to produce the food and fibre requirement. Most of the reduction comes in the payments to labor and nonland capital. Resource and drainage rents together nearly equal resource rents without further drainage adoption. (Compare C_3-TA_1 with and without drainage adoption in Table 32.) Clearly, drainage adoption can have the effect of lessening the impact of resource scarcity.

Land used for crops under the C_3 product requirement, without drainage, would exceed that used in 1949. With drainage adoption, cropland use would be similar to amounts currently used. The implication is that the cropland base in the 42-county region could produce a reasonable share of the food and fibre requirement for a national population of 502 million with approximately 800 thousand acres returned to cropland, notwithstanding further technology gains or resource development. (TA_1 was held constant.)

<u>Effect of technology adoption changes</u>--Two pairs of programs were formulated to test the sensitivity of the farm technology adoption assumption on production costs, rents, marginal cost changes, and drainage adoption. The technology adoption change from TA_1 to TA_2 infers an approximate 20 percent increase in average crop yields. Fertilizer use and other management inputs increased accordingly. The C_1 product requirement was held constant in these comparisons.

The 20 percent increase in yield potential (TA_1 to TA_2) has the effect of reducing total production costs $6 million. The product requirement (C_1) can be produced with a smaller total outlay for labor and nonland capital. (Compare C_1-TA_1 and C_1-TA_2 without drainage in Table 35.) The decreased costs implies increased productivity of these inputs.

Under the without drainage assumption, resource rents were reduced both in absolute and relative terms (Table 35). The increased technology adoption in TA_2 reduces the scarcity value of the natural resource. Under the with drainage assumption, some of the scarcity value returns to the natural resource in the form of drainage rent. Drainage rents are slightly over $2 million per year. (Compare C_1-TA_2 with and without drainage.)

The technology change without further drainage adoption reduces total costs for the C_1 product requirement $9 million. If drainage is included, total costs reduce $12.5 million. Drainage yield increases range from 50 to 100 percent (see Table 17) as compared to 20 percent yield increases assumed in the TA_2 over the TA_1 situation. Yet larger efficiency gains accrue to consumers from the nondrainage technology change. The costs of obtaining production through drainage are high relative to these from nondrainage technology. The costs of developing the nonfarm technology are not fully accounted for in the labor and non-

Table 35. Labor and Capital Costs and Resource Rents, Assuming Changes in Technology Adoption, Product Requirements held at C_1 With and Without the Adoption of Additional Drainage, 42-County Region Michigan Farm Drainage Study, 1980 Projections

Item	Assumptions							
	C_1-TA_1 Without Drainage		C_1-TA_1 With Drainage		C_1-TA_2 Without Drainage		C_1-TA_2 With Drainage	
	Mil. $	Percent	Mil. $	Percent	Mil. $	Percent	Mil. $	Percent
Labor and Capital Costs	153.35	96.1	147.72	95.6	147.11	97.7	141.59	96.3
Rents								
Resource	6.18	3.9	4.59	3.0	3.54	2.3	3.38	2.3
Drainage	--	--	2.19	1.4	--	--	2.07	1.4
Institutional	(.85)	(*)	(2.11)	(1.4)	(2.19)	(1.5)	(2.06)	(1.4)
Total Production Costs	159.53	100.0	154.50	100.0	150.65	100.0	147.04	100.0

*Less than .05 of 1 percent

land capital inputs in the model. The development of general farm technology does have a cost to the consumer - taxpayer. Also, producers bear costs in acquiring management skills. In a complete analysis, research and extension program costs should be included in studies comparing benefits received by producers and consumers from public programs.

All per unit costs are lowered in the TA_2 case except for barley (Table 36). Barley production was forced to poorer quality land; consequently, marginal costs increased slightly. The technology assumed favored wheat, dry beans, soybeans, potatoes and corn silage production costs especially.

With the adoption of technology (TA_1 to TA_2), less cropland is needed to produce the C_1 product requirements (Table 37). Even without considering additional drainage, 700 thousand less cropland acres are needed. An acre of drainage displaces nearly two acres of marginal cropland under both the TA_1 and TA_2 technology assumptions. Through the adoption of technology at the TA_2 level, less drainage is economic. Approximately 120 thousand fewer acres would be drained. The reduction in cropland use and drainage adoption is consistent with the reduction in rents attributable to the natural resources.

Clearly, one can conclude that farm technology is a substitute for land just as drainage can be. The rent reduction of $6.18 to $3.54 million if capitalised at 5 percent represents an asset value loss of over $50 million. Rapid technology increases with stable demands for food and fibre can result in declines in the capital value of natural resources. In the previous section, the analysis of changing product requirements indicated that the increased food and fibre requirements assumed in C_2 would raise rents $5.2 million over the C_1 situation. The change in rents infer an upward pressure on land values. Thus, we see

Table 36. Marginal Costs of Production, Assuming Changes in Technology Adoption, Product Requirements Held at C_1, With and Without the Adoption of Additional Land Drainage, 42-County Region Michigan Farm Drainage Study, 1980 Projections

Item	Marginal Costs			
	C_1-TA_1 Without Drainage	C_1-TA_1 With Drainage	C_1-TA_2 Without Drainage	C_1-TA_2 With Drainage
	Dollars			
Wheat	.85	.83	.79	.75
Corn	.48	.47	.47	.47
Oats	.51	.47	.46	.44
Barley	.45	.45	.54	.53
Soybeans	1.12	1.12	1.07	1.07
Dry Beans	2.04	1.89	1.79	1.65
Potatoes	1.31	1.15	1.21	1.09
Corn Silage	4.96	4.60	4.61	4.21
Alfalfa	11.49	11.14	11.49	11.36
Other Hay	13.43	13.13	12.31	12.30
Crop Pasture	.11	.11	.10	.10

Table 37. Major Cropland Use Assuming Changes in Technology Adoption, Product Requirements Held at C_1 With and Without Additional Land Drainage, Michigan Farm Drainage Study, 1980 Projections

Item	Assumptions			
	C_1-TA_1 Without Drainage	C_1-TA_1 With Drainage	C_1-TA_2 Without Drainage	C_1-TA_2 With Drainage
	----------------Thousand Acres----------------			
Cropland Acres				
Available	7,249.2	7,249.2	7,249.2	7,249.2
Used	3,867.5	3,473.8	3,165.3	2,824.0
Idle	3,381.7	3,775.4	4,083.9	4,425.2
Additional Acres				
Drainable	--	1,641.1	--	1,641.1
Drained	--	743.0	--	624.4

the countervailing forces in the resource scarcity problem.

The C_2 product requirements and TA_2 technology adoption levels were matched in one program run with drainage adoption to measure the countervailing forces (not illustrated). The sum of the natural resource and drainage rents were \$9.8 million about \$3 million more than in the basic C_1-TA_1 solution with drainage. If the assumptions behind C_2 and TA_2 exist in the future, natural resource values probably would be pushed upward as the population increases.

<u>Effect of changes in drainage investment costs by resource owners</u>--In the last two decades, field drainage systems have been subsidized under the guise of conservation. In some instances up to 50 percent of the investment costs have been paid by the Federal Government. While the

stated purpose of Federal cost-sharing on field tile may be "for establishing conservation farming methods," the end result is a more productive natural resource. At a time when the capacity of the agricultural plant seems to be more than adequate, questions are raised concerning the efficacy of public investments in drainage. Alternative linear program runs have been made to test the effect of alternative cost-share arrangements on the overall productivity of the agricultural resource and other economic variables.

Four program runs were set up to test the sensitivity of various drainage cost-share assumptions. The drainage cost levels considered were 50 percent, 67 percent and 100 percent of the annualized drain costs (see Table 21). These alternatives represent one-half, one-third and no public cost-sharing respectively. In recent years the Federal cost-share rate in Michigan changed from a one-half to a one-third basis. Under current arrangements, resource owners pay about two-thirds of the cost. A comparison of these runs along with the no cost-share run (100% cost born by resource owner) will demonstrate the implications of such a shift. C_1 product requirements and TA_1 technology adoption are assumed throughout.

Production costs would be reduced $10 million if drainage adoption under the 50 percent cost-share basis is assumed (Table 38). Production costs are reduced less when the Federal cost-share decreases. As would be expected, production costs rise as the drainage costs increase. Interestingly, the resource rents and drainage rents have a reciprocal relationship. The lower the drainage investment cost of the resource owner, the higher the scarcity rent on drained land. The sum of the rent is essentially the same for each program. Consequently, natural resource rents substitute for drainage rents. When comparing the no

Table 38. Labor and Capital Costs and Resource Rents Assuming Changes in Drainage Investment Costs with Product Requirements at the C_1 Level and Technology Adoption at the TA_1 Level, 42-County Region, Michigan Farm Drainage Study, 1980 Projections

Item	Assumptions							
	C_1-TA_1 Without Drainage		C_1-TA_1 Drainage Costs @ 50%		C_1-TA_1 Drainage Costs @ 67%		C_1-TA_1 Drainage Costs @ 100%	
	Mil. $	Percent	Mil. $	Percent	Mil. $	Percent	Mil. $	Percent
Labor and Capital Costs	153.35	96.1	143.80	95.4	145.19	95.0	147.72	95.6
Rents								
Resource	6.18	3.9	2.72	1.8	3.96	2.6	4.59	3.0
Drainage	--	--	4.25	2.8	3.74	2.4	2.19	1.4
Institutional	(.85)	(*)	(2.81)	(1.9)	(2.48)	(1.6)	(2.11)	(1.4)
Total Production Costs	159.53	100.0	150.77	100.0	152.89	100.0	154.50	100.0

*Less than .05 percent

cost-share with the 50 percent cost-share arrangement, drainage rents rise $2 million while natural resource rents decline by almost an identical amount. Potentially, some natural resources that do not have the capacity for additional drainage could lose asset value with drainage adoption in other areas, implying that supramarginal land can be displaced by public land drainage programs.

The production costs under the 50 percent drainage cost arrangement are nearly $9 million less than without the drainage alternative (see Table 38). The drainage run assuming 100 percent drainage costs shows $5 million efficiency gain. The change from a no cost-share to a 50 percent plan increases efficiency gains $4 million. The one-third cost-sharing arrangement potentially could reduce production costs $6.5 million from that sold under the no-drainage situations. The per unit costs are lowest for the 50 percent drain cost run and gradually increase in the program solutions where drain costs born by resource owners rise (Table 39).

Nearly 1.2 million acres could be drained under the 50 percent drain cost run; an increase of about 450 thousand acres over the program where drain costs to resource owners are entered at 100 percent (Table 40). Cropland use drops 600 thousand acres in the 50 percent drain cost run which is about 200 thousand fewer acres than the amount used in the program with 100 percent drain costs. In general, two acres of drainage idle one acre of cropland.

If the cost-sharing arrangement is uniform for all soils and acres without differentiation (essentially this is the present policy), the annualized cost for drainage for the 50 percent arrangement would be $4.2 million (1.2 million acres @ $3.50) (Table 41). Under the 50-50 arrangement the efficiency gain would be $8.8 million. However, $5

Table 39. Marginal Costs of Production, Assuming Changes in Drainage Costs, With and Without the Adoption of Additional Land Drainage, 42-County Region, Michigan Farm Drainage Study, 1980 Projections

Commodity	C_1-TA_1 Without Drainage	C_1-TA_1 Drainage Costs @ 50%	C_1-TA_1 Drainage Costs @ 67%	C_1-TA_1 Drainage Costs @ 100%
	----------Dollars----------			
Wheat	.85	.81	.82	.83
Corn	.48	.46	.47	.47
Oats	.51	.46	.47	.47
Barley	.45	.45	.45	.45
Soybeans	1.12	1.10	1.12	1.12
Dry Beans	2.04	1.84	1.86	1.89
Potatoes	1.31	1.15	1.15	1.15
Corn Silage	4.96	4.53	4.57	4.60
Alfalfa	11.49	10.22	10.62	11.14
Other Hay	13.43	12.72	12.94	13.13
Crop Pasture	.11	.11	.11	.11

Table 40. Major Cropland Use Assuming Change in Drainage Investment Costs with Product Requirements at the C_1 Level and Technology Adoption at the TA_1 Level, 42-County Region, Michigan Farm Drainage Study, 1980 Projections

Item	C_1-TA_1 Without Drainage	C_1-TA_1 Drainage Costs @ 50%	C_1-TA_1 Drainage Costs @ 67%	C_1-TA_1 Drainage Costs @ 100%
	----------------Thousand Acres	------------------		
Cropland Acres				
Available	7,249.2	7,249.2	7,249.2	7,249.2
Used	3,867.5	3,271.6	3,345.5	3,473.8
Idle	3,381.7	3,977.6	3,903.7	3,775.4
Additional Acres				
Drainable	--	1,641.1	1,641.1	1,641.1
Drained	--	1,187.6	1,030.1	743.0

Table 41. Efficiency Gains, Producer's Rents for Drainage and Land Drained under Alternative Public Cost-Share Plans, 42-County Region, Michigan Farm Drainage Study, 1980 Projections

Item	Public Cost-Share Arrangement		
	50%	33%	None
	--------Million Dollars---------		
Public Costs Annualized	4.2	3.6	---
Efficiency Gains	8.8	6.6	5.0
Drainage Rents	4.2	3.7	2.2
Resource Rents	2.7	4.0	6.2
Acres Drained (000 acres)	1,187.0	1,030.0	743.0

million of the efficiency gain would have accrued without public cost-sharing. This being the case, the $4.2 million public investment nets only $3.8 million in efficiency benefits. Drainage rents increase to $4.2 million, nearly half of which are created by the 50 percent cost-share. The increase in drainage rent to the resource owner essentially is a transfer payment brought about by the cost-share.

The one-third cost-share plan has similar implications. The $3.6 million public investment is offset by a $6.6 million efficiency gain, however all but $1.6 million allegedly should accrue anyway. The increase in drainage rent from $2.2 to $3.7 million also is a transfer to the resource owner.

Proponents of the uniform cost-sharing plan argue that cost-sharing is an incentive plan to encourage farmers to undertake the drainage practice and thereby adopt conservation farming techniques. According to the model, farmers should be willing to drain 743 thousand acres without any public incentive (see Tables 30 and 41). As was pointed out in the discussion of the basic model, producers and/or consumers stand to gain $5 million with drainage adoption. Society should be concerned that the economic potential for drainage is adopted and should stand ready to provide the necessary incentives to obtain the efficiency gains. However, there is question whether a uniform cost-sharing arrangement is the proper incentive for the maximization of economic growth.

From a strict economic point of view in a private enterprise economy, public investments should be made in those activities that would not be made otherwise, but yet provide consumer gains equal to or greater than the public investment. Also, alternative investments of public monies must be considered. Micro-economic principles of choosing alternatives with the highest marginal returns must be applied if maximum economic growth is to be fostered.

If we assumed that the efficiency gains were passed on to consumers, the maximum allowable public cost-share would be $2 million in order that the additional $3.8 million in consumer benefits could be achieved. (Compare differences in drainage rents and efficiency gains under 50 percent cost-share and no cost-share - see Table 41.) Through selective cost-sharing with owners of the 444 thousand additional acres to be drained (difference between acres drained with 50 percent cost-share and solution with no cost-sharing), the identical consumer's benefit (efficiency gain) could be achieved at a saving of $2.2 million in public monies. The 444 thousand acres represents lands on which drainage would not be profitable unless there was a public cost-share equivalent at least to difference in drainage rents of the two situations.

A similar comparison can be made between the one-third cost-share plan and no cost-sharing. In this comparison the maximum allowable cost-share would be $1.5 million and the efficiency gain would be $1.6 million. Clearly, society would receive greater efficiency gains per dollar spent under the 50 percent cost-share arrangement. The data for the two cost-sharing arrangements suggests that other sharing arrangements may be optimum in a program designed to foster economic growth. As will be pointed out in the conclusions chapter these relationships may be modified as larger regions are considered and opportunities for interregional shifts are permitted. In addition, social costs of relocating and retraining users of resources idled have not been considered nor have asset value losses on supra marginal land been considered. In fact, the sum of the resource and drainage rents is reduced $1.5 million under the 50 percent cost-share plan (Table 41). While owners of drainable lands would receive increased rent, owners of marginal and supramarginal land idled would lose rent earning capacity. A complete analysis of cost-sharing arrangements should consider both gains and losses in returns to resource owners as well as efficiency gains.

The linear programming models developed in this study did not include the off-farm outlet improvement costs. For this reason the logic for cost-sharing as outlined above applies only to on-farm field tile systems. However, the size of the drainage rents does indicate the resource owner's ability to pay for outlet improvements or share in their costs.

The efficiency gains would be captured by the resource owner if he is faced with a perfectly elastic demand for food and fibre. In this case there would be no general consumer benefit. The public cost-share would represent a windfall gain to the resource owner. Under the 50 percent cost-share arrangement, the public expenditure would induce drainage rents and efficiency gains totaling $13 million. Without cost-sharing the comparable figure would be $7.2 million (Table 41). In other words the $4.2 million public investment would provide a net advantage to resource owners of $5.8 million. (8.8 + 4.2)-(5.0 + 2.2) = 5.8. But when the one-third cost-share arrangement is compared on a similar basis, the $3.6 million cost-share provides only a $3.1 million net gain. (6.6 + 3.7)-(5.0 + 2.2) = 3.1. If the cost-share program was intended as an income transfer to resource owners, a direct payment scheme would be more effective. Moreover, other effects should be considered. Resource rents decline as the cost-share increases, consequently the benefits above must be adjusted for these externalities to properly account for the program impact.

In summary, the current cost-sharing procedures on field drainage systems that treat all qualities of drainable soils alike, can be questioned. In fact, from an economic standpoint, cost-shares to resource owners on lands where drainage would be economic anyway, represent a transfer payment which can be capitalized into an asset value. Since one acre of land goes out of use with two acres of drainage, owners of idled land lose asset values, which in and by itself has a wealth redistribution effect. In fact the 50 percent cost-share plan reduces resource rents $1.9 million from rent levels under the no cost-share plan (Table 38).

Since fewer acres are required to produce the given product (C_1) under the 50 percent cost-share arrangement than under smaller public cost-shares, the productivity of the agricultural resource definitely is enhanced by the government program. Drainage adoption under the alternative cost-share arrangement also influence the aggregate use of cropland. While the drainage of agricultural land may provide a means to conservation farming, the drainage program increases the productivity capacity of agriculture as well.

E. Thumb and South Central Michigan Subarea Analysis

The analysis of the 42-county region program runs indicated that resource rents tend to shift from the nondrained to the drained acreage. Conceivably, the resource productivities and product requirements could be such that a positive or negative economic impact on a specific subarea within the region under a given program could occur.

To analyze the differential impacts, detail for three of the program runs were developed for the Thumb and South Central study areas. The three models selected were (1) base run without drainage, (2) base run with drainage costs at 100 percent, and (3) base run with drainage costs at 67 percent.

The South Central subarea contains more cropland that is found in the Thumb but a higher proportion of the Thumb cropland is used under the assumptions of the basic model. In comparisons with the present, cropland use increases in the Thumb area and is reduced significantly in the South Central area under the assumptions of the base program. If the minimum acreage constraints on individual crops had not been imposed, the concentrations in the Thumb area would have been greater. (Compare Table 42 with Tables 6 and 7.) With large acreages losing productive value, the impact on existing land resource ownership patterns could be significant.

Over half of the Thumb cropland in use is for cash crops such as drybeans, wheat and potatoes. Most of the South Central area cropland that is used is devoted to feed and roughage crops with only about one-fifth of the land in cash crops such as wheat and soybeans. With drainage, the land-use picture shifts. With private drain costs at 100 percent, less food crops and more feed and roughage crops would be profitable in the Thumb area. The reverse is true for the South Central area. The feed crop percentage remains the same but wheat and soybeans substitute for roughage production.

Nearly twice as much cropland in the Thumb has the physical potential for additional drainage than does cropland in the South Central area (Table 42). But the additional cropland drained in the Thumb is only slightly more than that drained in the South Central area. While a larger proportion of the cropland is idled in the South Central area than in the Thumb, the rate of drainage adoption would be greater in the South Central area.

When private drainage costs are reduced one-third, cropping patterns tend to revert to the proportions in the program run without drainage. The comparative advantage of producing cash crops in the Thumb area is

Table 42. Detailed Cropland Use Assuming C_1 Product Requirements, TA_1 Technology Adoption, With and Without Drainage Adoption at 100 and 67 Percent Cost Levels, Thumb and South Central Michigan Study Areas, 1980 Projections

Item	C_1-TA_1 Without Drainage				C_1-TA_1 With Drainage Costs @ 100%				C_1-TA_1 With Drainage Costs @ 67%			
	Subarea				Subarea				Subarea			
	Thumb	South Central	Other	Total	Thumb	South Central	Other	Total	Thumb	South Central	Other	Total
	----------				-----Thousand Acres-----				----------			
Cropland Acres												
Available	1,631.2	2,081.8	3,536.2	7,249.2	1,631.2	2,081.8	3,536.2	7,249.2	1,631.2	2,081.8	3,536.2	7,249.2
Used	1,515.8	774.3	1,577.4	3,867.5	1,313.8	542.2	1,617.8	3,473.8	818.2	938.3	1,588.7	3,345.2
Idle	115.4	1,307.5	1,958.8	3,381.7	317.4	1,539.6	1,918.4	3,775.4	813.0	1,143.5	1,947.5	3,904.0
Additional Acres												
Drainable	--	--	--	--	701.5	360.3	579.3	1,641.1	701.5	360.3	579.3	1,641.1
Drained	--	--	--	--	282.8	194.5	266.0	743.0	408.7	244.2	377.2	1,030.1
	----------				-----Percent-----				----------			
Cropland Use												
Food Crops	55	17			34	41			46	20		
Feed Crops	9	33			13	32			19	16		
Roughage	36	50			53	27			35	64		
Total	100	100			100	100			100	100		

maintained. Idle cropland would increase significantly in the Thumb area under the one-third drainage cost reduction assumption. South Central cropland use would actually increase over that in the base program without drainage. The comparative advantage in producing roughages would call in increased amounts of cropland.

The drainage adoption and cost-sharing arrangements would appear to provide definite influences in intraregional land use even to the extent of influencing the type of farming. The Thumb area would tend to become more of a livestock producing area if the full drainage costs were borne by the resource owner as feed crop and roughage production increased. The South Central area could move towards cash-crop farming. Even the policy on cost-sharing arrangements would tend to influence farming patterns among subareas if the assumptions in the analysis hold.

Rents increase with the adoption of drainage in the region as a whole but the Thumb area loses $1 million in rents in both drainage situations (Table 43). The South Central area loses resource rents but drainage rents more than offset this loss. In total, additional drainage tends to favor the South Central subarea. Rents increase which means that natural resources asset values would increase. But the asset values would be concentrated on fewer acres under the no cost-share arrangement. Production inputs and gross output values remain about the same. But the Thumb area would lose rents and asset values with drainage adoption. Drainage would provide the Thumb area with a comparative advantage in less intensive uses; consequently, the rents are not as large. Even gross output is less, especially for the case of no cost-sharing on drainage.

The negative rents due to the forced minimum cropping pattern are relatively minor in the study areas under the no drainage assumption.

Table 43. Labor and Capital Costs and Resource Rents Assuming C_1 Product Requirements, TA_1 Technology Adoption, With and Without Drainage Adoption at 100 and 67 Percent Cost Levels, Thumb and South Central Michigan Study Areas, 1980 Projections

Item	C_1-TA_1 Without Drainage				C_1-TA_1 With Drainage Cost @ 100%				C_1-TA_1 With Drainage Cost @ 67%			
	Subarea				Subarea				Subarea			
	Thumb	South Central	Other	Total	Thumb	South Central	Other	Total	Thumb	South Central	Other	Total
	Million Dollars											
Labor and Capital Costs	66.4	25.7	61.3	153.4	55.6	27.0	65.1	147.7	66.4	25.6	53.2	145.2
Rents												
Resource	2.6	1.2	2.4	6.2	1.5	1.0	2.1	4.6	1.2	.9	1.8	3.9
Drainage	--	--	--	--	.1	.4	1.7	2.2	.4	.8	2.5	3.7
Institutional	(.1)	(.1)	(.6)	(.8)	(.2)	(.6)	(1.3)	(2.1)	(.2)	(.8)	(1.5)	(2.5)
Total Production Costs	69.0	26.9	63.7	159.6	57.2	28.4	68.9	154.5	68.0	27.3	57.5	152.8

But with drainage, the negative rent increases and is highest in the South Central region where the minimum cropping pattern forced on the area is more restrictive on efficient crop production patterns.

Again the partial equilibrium analysis is for a small 42-county region. In the more general equilibrium case for the economy as a whole, the devaluation of assets and the idling of marginal cropland as drainage is adopted might occur in another region. On the other hand, drainage or other resource development and technological improvements in other regions might make the asset value and idle acre change even more dramatic in the study areas.

To summarize, the adoption of drainage by resource owners and the public cost-sharing program can have a definite influence on rent earning capacities. Wealth redistribution within and among areas can be significant. Also, cropping patterns would tend to shift especially under conditions of no cost-sharing.

As was pointed out in the methodology chapter, no constraints were placed on the adoption of drainage in the linear program. All other elements in the basic model were entered at levels expected to be consistent with reality. A minimum cropping pattern constraint was placed on each area to reckon with historical trends in production. While the minimum acreage constraint would affect drainage adoption indirectly, no direct or explicit constraint was placed on drainage adoption in the model. To determine the possible limitations to drainage adoption, a random sample of farmers in the study areas was interviewed to determine their plans with respect to drainage adoption and drained land use. The results of that survey will be discussed in the next chapter.

CHAPTER VI

CURRENT AND EXPECTED DRAINAGE ADOPTION BY FARMERS

In the previous chapter, the linear programming analysis indicated that there would appear to be economic potential to drain over 400 thousand more crop acres in the Thumb area and nearly 250 thousand in the South Central region. The linear programming estimates were developed primarily from secondary data. No direct information from farmers was used.

As has been pointed out, the linear programming analysis was an attempt to measure the economic potential for drainage, given that other variables are held at the levels as specified in the program. From the analysis, certain programs could be developed based upon the selective cost-sharing principles discussed in Chapter V. The consumer and producer gains, identified in the program results, were developed on the assumption that resource owners are perfect managers with respect to drainage adoption. Since perfect management is unlikely, then what management levels are likely? What factors tend to inhibit the adoption of the full economic potential? Can these factors be eliminated or minimized by explicit policy?

The initial section of this chapter will relate the potential for field drainage on farms in the Thumb and South Central area as viewed by farm operators.[1/] The farmer's estimate of the need for off-farm

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1/ The questionnaire used in obtaining information from farm operators for this chapter is contained in Part I of Appendix A. Part II of Appendix A is the instructions to the enumerators who contacted farmers to participate in the survey. Terms are defined and special interpretation of questions are also discussed. A discussion of the sample plan, sample size and statistical base for the sample is given in Chapter III.

channel improvement for outlets also will be discussed. Then, farmers plans for using the new drained land will be summarized as will be the reasons for not making drainage improvements.

A. Existing and Potential Field Drainage Improvements

The farm survey elicited information from 265 farmers in the Thumb and South Central areas. The determination of sample size and discussion of the questionnaire used are presented in Chapter III. The survey was taken in the spring of 1963. The land area on survey farms represents approximately one percent of the farm land in the study areas.[1/]

Of the 1.5 million acres of cropland in the Thumb, some form of artificial drainage exists on 1.2 million acres. Of the 2 million cropland acres in the South Central area, only about .6 of a million acres are artificially drained (Table 44). Random tile installations are most prevalent in the South Central area. Over half of the Thumb area drainage reported is surface ditch drainage only. According to drainage specialists, surface ditch drainage also needs to be supplemented with grid tile systems. For this reason, the acres reported represent varying degrees of drainage effectiveness.

On cropland on which there is no artificial drainage, farmers indicate that less than a fourth is potentially feasible to drain in the Thumb with even a smaller percentage in the South Central area (Table 45). Farmers were asked specifically concerning the acreage on their land that they thought it would "pay" to "artificially" drain. In each area a small percentage of the wet cropland is considered impractical to drain.

1/ For further information about the survey particularly as it pertains to the land market see, Cotner, M. L., M. E. Wirth and G. D. Irwin,"Participants in the Land Market," Michigan Agricultural Experiment Station, Research Report 12, May 1964.

Table 44. Amount and Kind of Field Drainage Installed on Cropland on Thumb and South Central Michigan Farms, 1963

Artificial Drainage Installation	Thumb		South Central	
	Acres	Percent	Acres	Percent
	(000)		(000)	
Random Tile	135.3	8.9	369.8	18.4
Grid Tile				
3-rod spacing	56.2	3.7	38.2	1.9
4-rod spacing	183.9	12.1	64.3	3.2
6-rod spacing	18.2	1.2	12.1	.6
Other spacing	56.2	3.7	22.1	1.1
Tile and Surface Ditch	60.8	4.0	20.1	1.1
Surface Ditch Only	655.1	43.1	49.0	4.5
None	354.3	23.3	1,434.4	69.3
Total	1,520.0	100.0	2,010.0	100.0

Table 45. Farmer's Estimate of Additional Drainage Potential on Cropland in the Thumb and South Central Areas of Michigan, 1963

Land Characteristics	Thumb		South Central	
	Acres	Percent	Acres	Percent
	(000)		(000)	
Potentially feasible to drain	82.5	23.3	225.7	16.2
Not feasible to drain	8.8	2.5	32.0	2.3
Naturally well drained	262.8	74.2	1,135.3	81.5
	354.2	100.0	1,393.0	100.0

The potentially feasible acreage presumably is an acreage where the respondent feels drainage would be profitable. The balance is acreage he considers well drained (see Appendix A, page 4 - Survey Schedule).

Farmers estimate that there is need for additional drainage on lands that already have some form of artificial drainage (Table 46). The tiling of land that presently has surface ditch drainage only represents 324.5 thousand acres in the Thumb and 49 thousand acres in the South Central area. Tiling between existing lines also would represent a sizable acreage. Often, farmers will lay out field grid systems but due to capital rationing will install laterals at wider than recommended intervals. When the farmer's estimate of potential on land with existing tile is added to his estimate of potential on undrained land the gross potential is 440 thousand acres in the Thumb area and 314 thousand in the South Central area (Table 47).

According to the Inventory of Soil and Water Conservation Needs estimates, drainage is physically possible on 700 thousand acres in the Thumb and 360 thousand in the South Central area (see Table 16).

Table 46. Farmer's Estimate of Additional Drainage Potential on Land with Existing Drainage Systems, Thumb and South Central Michigan, 1963

Type of Improvement	Thumb		South Central	
	Acres	Percent	Acres	Percent
Tile between existing lines	48.1	4.4	42.6	7.0
Tile land having surface ditch only	324.5	29.7	49.0	8.1
Relay existing tile	10.9	1.0	17.6	2.9
Surface ditch land already tiled	2.2	.2	.7	.1
None needed	707.0	64.7	496.8	81.9
Total drained land	1,092.7	100.0	606.7	100.0

Table 47. Summary of the Economic Potential for Tile Drainage as Estimated by Farmers, Thumb and South Central Michigan, 1963

Type of Improvement	Thumb	South Central
	(000 acres)	
Tiling undrained cropland	82.5	225.7
Tile between existing lines*	24.0	21.3
Tile land having surface ditch	324.5	49.0
Relay existing tile	10.9	17.6
Total	441.9	313.6

* Represents 50 percent of acreage reported in Table 46.

The linear program with the assumption of a one-third cost-share arrangement indicates that slightly over 400 thousand acres would have economic potential for drainage in the Thumb area and nearly 250 thousand acres in the South Central area. Farmers believe that the economic potential is from 10 to 20 percent higher than that indicated by the model. As will be pointed out later in this chapter, farmers may not have a clear concept of economic potential; consequently, the acreage may be overestimated. Even so, the two independent estimates of drainage potential are reasonably close.

Only one of five resource owners with drainage potential on their land have definite plans for making the improvement (Table 48). Eight percent indicated plans to make drainage investments within two years and 12 percent stated that they would invest in drainage within 3 to 5 years. In comparing estimates of Thumb and South Central area farmers, no statistical differences could be detected.

While the linear programming model indicates that there would be over 650 thousand acres of cropland on which drainage would be economic

Table 48. Plans for Making Field Drainage Improvement, Thumb and South Central Michigan, 1963

Time Period	Percent
Within 2 years	8
3 to 5 years	12
Indefinite	80
Total	100

in the two areas, the farm survey indicates that only about one-fifth of the farmers on that acreage have definite plans about undertaking the practice. If public investments are made to provide outlets and the time lag in farmer adoption is great, the social benefits would be discounted considerably. Farm owners indicate a variety of reasons why the drainage practice is not adopted or given priority. These reasons will be discussed in the final section of this chapter.

B. Existing Nonfield Drains and Improvement Needs

Nonfield drains for outlets for field systems can be provided either through the County Drainage District organization or private individual or group action. An inventory of nonfield drains indicates that there are approximately 2 million rods of open and closed ditches in each of the two areas (Table 49). Over one-third of the drains are private drains in the Thumb area while only one-fourth of the drains in the South Central area are private drains. (Sum the open and closed percentages in each of the two areas in Table 49.) County drains require group action for clean out and other improvements while private drains can be accomplished usually with the initiative of a few resource owners. Closed county drains are most prevalent in the South Central area as there are nearly a half million rods. Usually, less maintenance is required on closed drains.

Slightly more than half of the drainage potential in the Thumb and South Central areas is dependent upon outlet improvements (Table 50). Farmers would not be expected to install field tile with inadequate outlets. In the Thumb, one-third of the drainage potential is dependent upon new outlets. Some of the outlets can be provided through private investments but many of the new outlets must come from actions of a

Table 49. Amount of County and Private Open and Closed Nonfield Drains, Thumb and South Central Michigan, 1963

Nonfield Drains	Area			
	Thumb		South Central	
	Rods (000)	Percent	Rods (000)	Percent
County				
Open	1,256.2	62	936.0	49
Closed	30.5	1	498.2	26
Private				
Open	704.3	35	396.4	20
Closed	49.3	2	87.0	5
Total	2,040.3	100	1,917.6	100

Table 50. Proportion of Drainage Potential Dependent Upon Outlet Improvements, Thumb and South Central Michigan, 1963

Type of Outlet Improvement	Thumb		South Central	
	Acres	Percent	Acres	Percent
	(000)		(000)	
Clean and repair existing outlet	115.2	24.6	100.7	30.0
Establish new outlet	157.3	33.6	82.2	24.5
None needed	195.7	41.8	152.7	45.5
Total drainage potential	468.2	100.0	335.6	100.0

Drainage District or a group of individuals.[1/] The establishment of Drainage Districts and the petitioning for improvements is time consuming and often is met with opposition by those who benefit little.

In many instances the drainage outlet must cross a neighbor's property. Easements for a drainage ditch on the neighbor's property are necessary. Often these are not granted. Drainage Districts can be established to get access to outlets across neighbor's property but these are hindrances in field drainage adoption. In the Thumb area nearly three-fourths of the drainage potential dependent upon new outlets also is dependent upon access through a neighbor's property (Table 51). In the South Central area, nearly 60 percent of the drainable land without outlets will require easements on adjacent properties.

C. Reasons for not Making Field Drain and Outlet Improvements

Field drainage--Self imposed capital rationing appears to be the principal reason for not investing in farm drainage even though farm owners indicate that the practice is profitable and outlets are available (Table 52). One-sixth of the farmers indicate that other improvements have priority over drain investments. A similar group judged that the drainage problem was not serious enough to merit investment at this time. Undoubtedly, the productivity gained and the return on the investment on some cropland would be low, causing investors to be cautious and indifferent. In other words, there is more risk to the point where there is indecision. But this can involve up to 10 to 15 percent of the area that the program model, and farmer too, identify as economic

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1/ For a discussion of procedures for establishing a Drainage District see Cotner, M. L. and A. Allan Schmid, "Drain Law for Michigan Land Owners," Farm Science Series, Michigan State University, Extension Bulletin E382, September 1963.

Table 51. Proportion of Drainage Potential Dependent Upon Outlet Access Across Neighboring Property, Thumb and South Central Michigan, 1963

Location of Outlet	Thumb		South Central	
	Acres	Percent	Acres	Percent
	(000)		(000)	
Outlet must cross neighboring property	116.1	73.8	48.4	58.9
Outlet need not cross neighboring property	41.2	26.2	33.8	41.1
Total requiring new outlet	157.3	100.0	82.2	100.0

Table 52. Reasons for not Making Potential Field Drainage Improvements on Cropland now Served with Adequate Outlets as Related to the Expected Use of Credit[1/]

Reason for Not Making Investment Now	Plan to Use Credit To Finance Drainage Investment	
	Yes	No
Funds not available	57.1	58.1
Making other improvement first	14.3	19.3
Problem not serious enough	8.6	17.2
Nearing retirement and other factors	20.0	5.4
	100.0	100.0

1/ Frequency distributions were statistically different at the 95 percent confidence level.

potential. The point here is that farmers belief about the economics of the practice is not necessarily followed by a decision to adopt the practice.

Resource owners' expected use of credit for drainage investment is related to age (Table 53). As would be expected, a larger proportion of the younger farmers would incur indebtedness for drainage. Less than 5 percent of the farmers over 60 would borrow and only one out of eight of the farmers in the 45 to 59 age bracket would borrow. The two groups, "45 to 59" and "over 60", control over half the farm land area in the two areas. If credit will not be used, then capital for the improvement accrues only through personal savings; a procedure which creates a considerable time lag in drainage adoption. Also as farmers approach retirement in these age groups, they are less apt to invest in drainage. There was no statistical difference in the expected use of credit for drainage between the Thumb and South Central areas.

Table 53. Expected Use of Credit for Making Field Drainage Improvements as Related to Age of Operator, Thumb and South Central Michigan, 1963[1/]

Expect to Use Credit	Age of Operator			
	Less Than 30	30-44	45-59	60 and Over
Yes	57.1	35.7	13.6	3.3
No	42.9	64.3	86.4	96.7
	100.0	100.0	100.0	100.0

1/ Frequency distributions were statistically different at the 99 percent confidence level.

The drainage potential is concentrated on 40 percent of the farms (Table 54). Most of the farmers having economic drainage potential have less than 25 percent of their holdings in this category. However, one-tenth of all farmers have from 25 to 49 percent of their acreage in the potentially drainable category. If a large proportion of the farm has drainage potential, the size of the capital investment to drain all of the land at one time would appear formidable to the decision maker.

In the survey, a historical record was made of the field drainage adoption on farms after outlets were made available. Two-thirds of the farmers with all of their drainage completed required nine or more years to complete the job (Table 55). In contrast, of those who were only half completed in 1963, nearly 50 percent reached this level in less than two years. However, 15 percent of those half completed took nine or more years to accomplish that amount. The time lag for field drainage adoption after the outlet is developed is significant.

Outlet improvement--The resource owners who responded that existing drain outlets needed improvement or cleaning were asked their reason for not making the improvement at this time. Over half indicated that they could not get financial support from their neighbors to make the improvement (Table 56). One-fourth indicated internal capital rationing as a reason for not improving the outlets. Many of the existing outlets were originally improved as early as the turn of the century. Many of the older farmers attest that little or no maintenance has been accomplished since the original improvement. In most cases, outlet improvements cannot be made on an individual basis. Usually the entire drainage ditch or channel improvement must be made for any of the farm outlets to be effective. Often, there is a disassociation of costs and benefits.

Table 54. Proportion of Farms with Farmland Drainage Potential, Thumb and South Central Michigan, 1963

Portion of Farm With Potential Drainage	Proportion of Farms
------Percent-------	------Percent------
None	58.6
1-24	25.4
25-49	11.1
50-74	2.9
75-100	2.0
	100.0

Table 55. Average Time Lapse Between the Establishment of Outlet and the Installation of Field Drainage, Thumb and South Central Michigan, 1963[1/]

Time Lapse	Farmers Reporting	
	All Field Drainage Complete	One-Half Field Drainage Complete
---Years---	-----------Percent---------	
Less than 2	16.3	48.8
2 - 4	4.7	16.3
5 - 8	10.5	19.8
9 and more	68.5	15.1
Total	100.0	100.0

1/ Frequency distribution statistically different at the 99 percent confidence level.

Table 56. Reason for Not Improving or Cleaning Existing Drains at the Present Time

Reasons	Proportion of Farmers Reporting
	--Percent--
Finances, lack of cash, other priorities	27.6
Not interested in intensifying problem not serious	17.2
Neighbor won't share costs	55.2
	100.0

One farm may be adequately served by a nonfarm drainage ditch but the whole ditch must be dredged to adequately serve a neighbor. If the drain is a County Drain, the improvement expense does not need to be, but often is, spread among property owners in the same proportion that the original expense was spread. Improvements in the County Drain are initiated by petition of the resource owners. An identical problem exists with private group drains. Neighbors cannot reach agreement on the relative benefits, hence cost-sharing arrangement.

D. Farming Changes Planned With Drainage Adoption

In the previous chapter the linear programming model which incorporated drainage at the 100 percent level indicated that the Thumb area would experience a shift in cropland devoted to roughage production. Presumably there would be increases in livestock production to utilize the areas comparative advantage in producing roughage. The South Central area would shift to increased cash-crop farming as more wheat and soybeans would be produced. However, under the one-third cost-share arrangement the cropping patterns remained much as they are now (see Table 43). Since the one-third cost-share arrangement presently faces resource owners, one would expect the resource owners to maintain existing basic farm plans in the two areas.

When asked whether they would change their livestock system upon completing their drainage, more than 90 percent of the farmers had no plans for changing or establishing a livestock system (Table 57). There were no statistical differences in the response from the two areas. While the response tends to confirm the linear program results, one can question whether resource owners respond with carefully calculated management plans. Since drainage investments for most farmers obviously are not in the immediate future, livestock management plans at best would be tentative. Nevertheless, the response does indicate that significant immediate shifts in livestock production would not be expected.

Nine out of ten farmers indicated that they would follow the same cropping pattern after they made their drainage investment. Again, there was no statistical difference in response between areas (Table 58). One out of 20 farmers planned to increase the acreage devoted to cash-crops. In view of the sample size and the expected accuracy of the results (+ or - 4 percent) the increase estimated for cash-crops would appear to have little significance.

The current cropland use on artificially drained land in the Thumb area is distributed nearly equally among food, feed and roughage crops (Table 59). Corn grain production on drained land in the South Central area makes the feed grain distribution larger in that area. The projected use of drained land in both the Thumb and South Central areas indicates increased uses of cash or food grain crops. Thus the plans

Table 57. Changes Planned in Livestock System with Additional Field Drainage Installed, Thumb and South Central Michigan, 1963

Change Planned	Proportion of Operators Reporting
	--Percent--
Same livestock system	93.4
Increase dairy	2.5
Increase beef	2.0
Increase hogs	.4
Decrease dairy	1.3
Decrease beef	.4
	100.0

Table 58. Changes Planned in Cropping System with Additional Field Drainage Installed, Thumb and South Central Michigan, 1963

Change Planned	Proportion of Operators Reporting
	--Percent--
Same cropping pattern	92.1
Increase cash-crop	5.8
Increase feed and roughage crops	1.7
Other	.4
	100.0

Table 59. Current and Projected Use of Artificially Drained Lands, Thumb and South Central Michigan, 1963

Cropland Use	Thumb	South Central
	---------Percent---------	
Current*		
Food crops	30	35
Feed grain crops	36	44
Roughages	34	21
Total	100	100
Projected**		
Food crops	49	68
Feed grain crops	21	26
Roughages	30	6
Total	100	100

*Farm Drainage survey.

**Assuming C_1, product requirements, TA_1, technology adoption and field drainage at 67 percent (one-third cost-share arrangement).

of farmers to maintain existing farm plans with some overall increase in cash-crop farming appears to be consistent with the results of the linear program model.

CHAPTER VII

SUMMARY AND CONCLUSIONS

A. Summary

One of the main objectives of this study was to formulate general principles concerning the role of natural resources in economic growth. The thesis of this study is that the use and development of natural resources is and can be an important factor in economic development.

A review of literature found varying views about natural resources and their relationship to economic activity. Many scientists and laymen hold that the Malthusian doctrine still is applicable. Others argue that abnormal scarcity rents have not accrued to natural resources and therefore the Malthusian law is invalid. Scientists point to changes in the quality of resource inputs, thereby improving the productive capacity of our natural resources. Put another way, man-made substitutes developed through modern technology have lessened the pressure on the conventional natural resources.

An analytical model is developed which encompasses the agricultural resources of a 42-county region in lower Michigan. The model is designed to investigate the importance of natural resource development under specified alternative demand conditions and changes in the level of technology. The model developed is a minimum-cost formulation of a linear program. It is designed to simulate a partial economic equilibrium of the agricultural economy of the study area. By developing comparative static solutions with and without the test variables, the potential effects on natural resource rents and consumer benefits are determined. The basic linear programming model contains detailed information on soils, their quantity, productivity and location within the regions. The coefficients in the model are intended to be realistic estimates of conditions in 1980 for the region.

Without technological change, natural resource rents increase significantly as population increases. Alternatively, natural resource rents decrease as technology gains outstrip the food and fibre product needs. The adoption of field drainage provides significant efficiency benefits that accrue to producers or consumers depending upon demand elasticities. Owners of drainable land receive increased rents.

Two subareas of the 42-county region are studied in detail: the Thumb and South Central areas. According to the linear program, some 650 thousand crop acres have economic potential for additional field drainage. A survey of randomly selected farmers in the two areas indicated that farm operators felt additional drainage would pay on about the same number of acres. But only one-fifth of the farmers had plans for investing in drainage. Farm owners listed internal capital rationing as the principal reason for not undertaking the practice. Inadequate outlets for field drainage also were a significant factor in retarding drainage adoption.

The analysis provides insights as to the relationship of resource development in the form of drainage to economic growth. Implications for general policies and specific programs are developed.

B. Conclusions and Implications

Resource scarcity rents--The alternative product requirements used in the linear programming analysis in this study were based upon increases in U. S. population. The C_1 product requirement was based on a U. S. population of 254 million. The C_3 product requirement was based on a 502 million population; approximately double the C_1 assumptions. The assumed populations are representative of the intermediate and long term projections developed by the Bureau of Census. Per capita consumption patterns used were estimates projected for 1980.

With all other variables held constant, the shift in product requirements for the C_1 to C_3 assumption caused resource rents in the 42-county region to increase from $6.2 to $12.5 million; a 100 percent increase. Clearly, without corresponding increases in technology and natural resource development, larger shares of consumers purchasing power will go to resource owners in the form of resource rent. But perhaps more important is the finding that resource use in the region could be expanded to provide increased food requirements.

The technology attainment assumptions were based upon estimates of likely adoption of technology in future time periods. The TA_1 level represents the expected productivity level in 1980. The TA_2 level reflects possible adoption in 1980 under an intensive research and extension program or adoption at some later date. With all other variables held constant, the increase in technology from TA_1 to TA_2 reduced resource rents from $6.2 to $3.5 million with a C_1 product requirement; a 43 percent reduction. The C_1 - TA_1 and C_2 - TA_2 program runs indicated that the technology attainment in TA_2 would not be sufficient to keep pace with the product requirements in C_2. Resource rents would rise $3.6 million or 60 percent under these assumptions.

If the assumptions in the two programs do have a semblance to expected reality and if the income distribution effects are not satisfactory, then specific policies and programs for the development of technology and resource development are needed or may be needed. Presumably increases in agricultural research and extension activities would increase technology adoption.

Resource rents in total rise $1.5 million for the 42-county region when the full economic potential for drainage is adopted under the one-third cost-share arrangement and C_1 product requirements and TA_1 technology attainment. Through drainage the quality of the resource improves, consequently increased scarcity rents accrue. Rents on drained land appear to substitute for rents on nondrained land when drainage is entered as an option. Such substitution could have an impact on asset values both within and among regions. Some resource owners conceivably could lose natural resource value and yet the basic market forces remain unchanged. The equilibrium analysis used in the study is for a small region, thus the rent substitution was forced to occur within the region. Even in a larger region the principle holds. The idling of land is a direct measure of the devaluation phenomenon.

The size of the resource rents generated under the assumption of the alternative programs indicates that the average agricultural value of the natural resource is relatively small. On a per acre basis the rents average from $2 to $4 per acre which when capitalized at 5 percent represent only one-tenth of the census estimate of the value of land and buildings as reported in the 1964 Census. Even at a lower capitalization rate the capitalized agricultural land value is but a small fraction of reported value. The rent estimates are in terms of 1963 constant dollars. (1963 input price levels were used.) The rents discussed here pertain only to the qualitative differences in productivity of the fixed factor - the cropland resource. In other words, the MVP measures the Ricardian rent that accrues to land because of its varying quality. In the small regional model developed in this study, transportation costs were not considered explicitly. Subareas with significant transportation advantage would earn rent also. Undoubtedly, other factors not considered contribute to agricultural value. But even so the average agricultural value of cropland appears to be below reported values. Farm lands may be purchased in view of their marginal value to a farm unit rather than the average productivity presented above. Undoubtedly, land values are influenced by factors other than agricultural.

Another difficulty in capitalizing the calculated MVP into values concerns the relevant agricultural product price level to use. Prices received for agricultural products currently are higher than the marginal costs of production indicated. The MVP derived from the linear programming analyses are based on the assumption that the marginal costs of production are market clearing product prices. Government programs to pay product prices at higher levels obviously would increase the residual rent to resources. But the MVP as shown herein should be a valid measure of the use value of the resource in the food and fibre production process.

If product prices are pegged at higher levels, rents attributable to land would be higher. Under these circumstances, a problem occurs in estimating relevant measures of benefits for public drainage channel improvement projects. Should benefits be calculated on the basis of their use value or should the institutionalized prices be used? This particular question was not the subject of this research but it is relevant to further studies. Subsequent linear programming runs could be made in maximizing formulations using various assumed price levels. Comparisons with the existing minimum cost solutions would indicate the relative share of the rent that is attributable to use value and price support programs.

If the product components in the supported prices and marginal costs of production derived in this study have the same relative values, then certain results will be unchanged. Land use patterns to produce a given mix of product will not change if prices are increased by a constant. Likewise, acreages identified as having an economic potential for drainage in the minimum cost formulation would remain the same with higher but constant relative prices.

Role of drainage development in economic growth--The results of the linear program analysis indicate that a sizable return in efficiency benefits could accrue if all of the economic drainage potential is adopted. Benefits can be in the form of lower prices for agricultural commodities, higher resource rents or some combination of the two. If consumers are confronted with lower prices they can purchase an identical bill of goods using less of their purchasing power; then, society presumably is better off. If the saved purchasing power is diverted to other productive uses, then economic growth would be enhanced. If the purchasing power represented in increased rents is diverted to productive uses, economic growth is affected similarly.

The basic linear programming model indicates that there would appear to be economic incentive for resource owners to install field drainage systems on some 743 thousand acres additional without any public cost-sharing. Assuming that efficiency gains are passed on to consumers in the form of lower product prices, the cost for primary agricultural products from the 42-county region would be reduced some $5 million. Under a one-third cost-sharing arrangement with resource owners, the consumers gain would be $6.6 million or $1.6 million more than under the no cost-share arrangement. Under a uniform one-third cost-share arrangement on all lands drained, the annualized public outlay would be $3.6 million (excluding administrative costs). Clearly, the public outlay for drainage would not be rational from the public viewpoint if the $3.6 million investment provides a $1.6 million increment in benefits at large. Resource owners receive increased rents in this example. But these gains are the basis for cost-sharing by the resource owner and other local beneficiaries. The relationship suggests selective cost-sharing on those drainable lands that would not otherwise be drained. A similar example can be shown using the data derived for a 50 percent cost-sharing plan.

The linear programming models used to depict alternative cost-share plans indicate that owners of nondrained land lose rent-earning capacity as the public cost-share is increased and more land has economic potential for drainage. Improving the productive capacity of the resource through drainage lessens the aggregate scarcity value of the resource in the production process. Public resource development programs do have important income earning and redistribution impacts. If the cost-sharing policy is to be equitable, all of the gain and loss relationships must be considered.

Many factors influence the adoption of the economic drainage potential. Resource owners in general recognize that the drainage potential as identified by the linear program exists on their farms. But only one of every five resource owners has definite plans for draining additional land in the Thumb and South Central subareas. Slightly over half of the drainage potential in the two subareas surveyed is dependent upon outlet improvements. Much of the outlet improvement must come from group actions either on a private basis or through the Drainage District. Federal legislation exists to provide financial support for major channel improvement and flood control measures. In the analysis of benefits to be associated with the public costs, the lags in drainage adoption must be considered. Time delays in the realization of consumer and resource owners benefits could influence the discounted benefit-public cost comparison significantly.

Approximately half the drainable lands require improvement of group outlets. On this portion, three-fifths of the resource owners claimed that capital availability kept them from making the drainage improvement now. The balance either were making other improvements first, nearing retirement or thought the problem on their farm was not serious enough. Based upon the survey, one could conclude that at least one-fourth of the drainage potential would not be adopted because of farmer's age, attitudes and indifference to the drainage practice.

Farmers will not use credit to overcome the capital limitation they indicate confronts them. Farmers over 45 control half the land but only one of 10 will borrow funds for drainage. Resource owners are loathe to mortgage their resource for this purpose. If capital for drainage investments must accumulate through personal savings, one can question if even the three-fifths who claim capital limitations will drain land during their tenure.

The cross sectional analysis in this study on drainage adoption has direct implications for the benefit determination procedures used by federal agencies in estimating time lags in actual adoption. Adoption rates usually are somewhat arbitrary based upon the informed judgment of agency technicians on the likely practice adoption in the area. Empirical studies on past and expected adoption rates would assist agency personnel in these decisions.

Policy implications--The analysis herein supports the hypothesis that technology adoption and natural resource development are substitutes in the production of the nation's food and fibre needs. But more importantly, the two can be complementary and matched in appropriate combinations to enhance economic growth and development. But what principles should govern the policies and programs to achieve the ends of maximum economic growth? The policy is difficult as the programs have wealth distribution or redistribution implications and each program involves an investment of public monies. In other words, benefits from publicly induced drainage adoption are not entirely "at large". Specific benefits do accrue to resource owners in the form of increased rents and asset values.

The decision to redistribute wealth among resource owners is largely a political decision. But the economic consequences of different resource development programs, wealth distribution and ultimate effect on economic growth is within the purview of economics. The economic purist would argue that the economic relationships should guide the politician in the development of institutional arrangements for resource use.

If maximizing economic growth is a goal, then guides for public investment programs in the technology-resource development area can be developed. The principal criterion for such a policy is the productivity test. The program to follow would be one that produces the largest net gain in economic growth. Marginal analysis procedures are held to be directly applicable in the analysis of alternative measures and in designing the scale of public involvement in the development of technology.

Public investments in research and extension indirectly influence the productivity of natural resources. Public investments in incentive programs or other cost-sharing activities also improve the productive capacity of natural resources. Research, extension or direct incentive programs, have (alone or in combination) a functional relationship with the desired end--economic growth. These "social production functions" allegedly can be treated in principle the same as production functions in individual farm management. Admittedly, the quantification and measurement of these relationships seem formidable. But the analysis in this study is one attempt to quantify parts of the input-output relationships with respect to field drainage and general technology adoption.

The complete social production function would trace the input-output relationships resulting from a public investment through both the production and consumption sectors of the economy. Changes in Gross National Product stemming from alternate levels of public expenditures on and combinations of resource programs would be the direct measure of economic growth.

Each of the alternative policies considered by society concerning resource development would imply a certain wealth distribution within the producing sector. For instance, technology improvements that are not tied to the land resource would tend to reduce natural resource rents and increase rents to the technology adopted. Another program could stress natural resource development with increased earnings accruing to users of these resources. Clearly, one combination of these inputs would maximise the contribution to economic growth. To deviate from the wealth distribution implied would be at the expense of economic growth.

Such a scheme may seem grandiose, especially when problems of measurement, analytical techniques and computer capacities would appear to limit the application of the principles suggested. But researchers continue in their attempt to improve the analytical procedures. Currently, the Office of Business Economics, U. S. Department of Commerce, is developing a national interregional model of the U. S. economy. Presumably, input-output matrices will be developed for the 16 major water resource regions. The Economic Research Service of the USDA is developing a national interregional model for agriculture. In the current emphasis on comprehensive water resource development, models are being developed to project mineral and energy production. Improvements in computer technology are being made. Recent developments in the LP 90 system on IBM equipment provides almost unlimited capacity for linear program studies. We are soon approaching the point where the effect of public investment programs on a national basis can be traced and compared with alternative uses of public investment funds.

The uniform cost-sharing practice on field drainage would appear to involve the uneconomic use of public monies on some lands. The net gains in producers rents and consumer benefit in reduced product prices over what would accrue with no cost-sharing is smaller than the public investment cost. The procedure also has implications concerning transfer payments and wealth redistributions. An analysis of the linear program results indicates that selective cost-sharing on drainable soils that would not otherwise be drained would be a rational policy. Even then, the program should be compared with alternative means of obtaining the food and fibre needs before final decisions on cost-sharing arrangements are undertaken. The costs of administering a selective cost-sharing program probably could be high relative to current administrative costs but actual program costs should be reduced in view of the reduced cost-share payments.

The general resource development policy outlined in this section has implications concerning the political philosophy held by many in the U. S. In the above outline, the role of government would be one of full partner with the private resource owners. Presumably, the goals of the resource owner and the goals assumed for society are mutually compatible; one of maximum individual economic welfare and maximum national economic growth. Since some hold the political value that the government should have a passive role in individual's decisions about resource use, the active role of government in manipulating resource use to enhance economic growth may not have full support.

One further policy implication concerns the negative attitude of resource owners towards the use of credit. Consideration should be given to expanding the research and extension programs to improve farmers' knowledge and use of financial management. Such a program would be of value not only in individual decisions to borrow money for drainage but would assist in all decisions involving capital investments.

Since the drainage practice is one that normally will pay for itself in 5 to 10 years, intermediate term credit is needed. Public programs that could encourage intermediate loans might speed up drainage adoption materially.

Current agency procedures in analyzing potential water resource development measures involves a budgeting analysis of primary benefits to resource owners only. Secondary benefits to consumers through reduced product prices are not considered. Often the size of the individual project being considered is so small, its impact on consumer's benefits is not considered significant. With price supports, the efficiency gains are not realized by consumers. In fact, the efficiency gains foregone make the opportunity costs of a price support program to society even larger.

The complexion of water resource development programs is changing. Whole water resource regions are being studied. Alternative uses and development of the water resource are being considered. The implication is that micro-individual project analyses do not consider all of the relevant relationships. Problems cannot be considered in isolation. Clearly an analytical model is needed to examine the producer-consumer gains and losses and keep the relationships in perspective. The linear programming technique used in this study with further modification could be an important part of such an analytical model.

Usefulness of analytical procedures in study--The minimum cost formulation of the linear programming technique appears to be useful in analyzing future resource use and for determining the likely effect of alternative policies. But, as with all techniques, the use of linear programming is not without conceptual and operational problems. The problems are not intrinsic to linear programming but mostly a problem of how the technique can be used in a study such as this. Conceptually, difficultues arise when we assume that we can make a comparative static analysis of two partial equilibrium situations at the aggregate level. In one application we are asking the model what will happen. How will resource owners use their resources and produce the products expected to be needed? In another application we try to impose an additional variable-drainage to determine what should happen with respect to this variable. A technique is needed to predict reality and at the same time allow the isolation of a single variable to permit normative prescriptions.

The linear programming approach provides solutions showing the economic system in equilibrium given the constraints placed upon it. One of the conceptual difficulties concerns the time dimension and path to equilibrium of the economy. Conventional theory suggests that long-run adjustments within an economy are towards equilibrium. In other words, the basic drive of decision makers in the capitalistic system at least is to prefer more rather than less economic goods. In this regard, the use of equilibrium theory should provide meaningful results concerning intermediate and long-term adjustments in an economy. Even so, the equilibrium solution for the 1980 projections indicated rather sharp concentrations in resource use among subareas; more than an analysis of historical trends would support. To make the model more realistic for 1980, additional constraints on the perfect management assumption implied in the linear programming system must be made. Herein lie the operational problems.

Further constraints could be placed on resource use to reflect capital rationing, labor availability and management constraints. Such constraints would have the effect of modifying the perfect management assumption in the basic linear program system. But to do so would increase the equations and vectors in the LP matrix beyond the useable capacity of computer systems available for this study. At least the analyses could not be made for the 42-county region. A one step recursive constraint was placed on cropping patterns in this study. A minimum cropping pattern was forced on each subarea to reflect historical trends which of course represent the realities of the decision process. This restriction required 11 equations in each subarea which kept the problem within limits of computer capacity. Conceptually, then, part of the projection for 1980 (approximately 50 percent) is based on trend and the balance is based on the efficiency aspects of equilibrium theory. The problem in the application here is the determination of the proper balance of these two forces. Interestingly, the formulation here allows determination of efficiency gains forgone through the imposition of minimum cropping patterns.

A dilemma exists in the aggregation problems of the analysis. On one hand, more detail is wanted in the model so more realism and increased accuracy in results can be obtained. But as the detail in the model is increased, the validity of the coefficients that represents small micro elements in the system are questionable. In other words, accuracy may not be gained by becoming more precise. The accuracy-precision relationships suggest guides for the incorporation of precision in the model. The development of precision represents an expense to the decision maker. Marginal analysis again would be useful. The marginal cost in developing precision in the model should be weighed against the marginal benefit obtained through increased accuracy in results.

Another conceptual problem concerns the dynamic path to equilibrium. The actions of decision makers in making adjustments may in fact influence the ultimate equilibrium. In other words, a sequence of imperfect decisions on the part of resource owners might have a feedback effect on the quality of the resources and even the nature of the problem being analyzed.

The stochastic variables in agriculture such as weather may be such that significant discounting for risk and uncertainty should be accounted for in the model. The yield coefficients in the model developed represented expected averages as influenced by "normal" climatic conditions. While the effect of climate was considered in determining individual crop yields, no special constraint was placed on the overall farm management function for risk and uncertainty except for the minimum cropping pattern restriction imposed on each subarea.

Additional work is needed in designing and improving a projection model to accomplish the purposes set forth in this study. Historical climatological data developed recently by the Weather Bureau on a Crop Reporting District basis provides key variables in a study of the climate-crop yield relationships. Probability distributions of yields can be derived from which a range of outcomes in the projection year could be obtained. There is some promise that the climate-yield probability distributions could serve as a driving force for a computer-simulation analysis of the dynamic growth path in agriculture.

One final note concerns the farm survey analysis. In the past agencies have depended upon informed judgement as to resource owners' response to a public development measure. Public investments have been made based on these estimates which do not have an objective measurement. No claim is made that the design of the questionaire used in this study provides most of the relevant answers. But the survey results do indicate relationships that must be considered in any project analysis.

Much of the research in water resource development work has been on a case study basis. The problem with case studies concerns the relevance of results to other areas. Often the number of observations are such that statistically meaningful relationships cannot be made. More cross sectional analyses are needed to provide improved information of resource users response to public resource development investments.

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APPENDIX A

PART I

SURVEY SCHEDULE

Schedule No. ____________ Budget Bureau No. 40-6339
Date ____________ Approval Expires October 31, 1963
Enumerator ____________
Checked by ____________

Michigan Agricultural Experiment Station
in cooperation with
Farm Production Economics Division
Economic Research Service, USDA

FARMING ADJUSTMENTS IN LOWER MICHIGAN

IF GROSS INCOME FROM FARMING IN 1962 DID NOT EXCEED $1200 OR 80 PERCENT OR MORE WAS FROM EITHER POULTRY OR FRUIT AND TRUCK, COMPLETE ONLY SECTIONS I AND II. DO NOT TAKE ANY INFORMATION UNLESS FARM HAS AT LEAST 10 ACRES CROPPED.

Schedule Code	
1962	1958

Operator: Name ____________ Address ____________

I. The Farm - Size, Control and Tenure

(1) Location of farm: County ____________ Sample segment ____________

(2) Was this farm operated in 1962 by:

		Comments
An owner	☐	1 ____________
A tenant	☐	2 ____________
A partnership	☐	3 ____________
A corporation	☐	4 ____________
A hired manager	☐	5 ____________
Tenant and landlord jointly	☐	6 ____________
None of these	☐	7 ____________

(3) How long have you operated this farm? ________ years Farmed? ________ years

(4) IF MORE THAN ONE PERSON, other than hired and family workers, participated in the management of this farm in 1962.

(a) How many additional participated? ____________

(b) What is the relationship among the persons who jointly participated?

____

(5) Acres in farm: Total ____________ Owned ____________ Rented in __________ Rented out ____________

(6) IF LAND WAS RENTED IN, what was the leasing arrangement in 1962:

(a) Percentage share to tenant of each crop ______________________________

____

(b) Percentage share to tenant of each class of livestock ______________

____

(c) Cash rent paid per acre ______________________________________

(d) Percentage share of operating expense (tenant-crops and livestock) ______

____

(e) Relation of tenant to landlord? ______________________________

II. Farm Drainage

(1) When have field drainage improvements been made:

(a) tile: year	acres served	(b) surface ditches: years	acres served
____	____________	_____	____________
____	____________	_____	____________
____	____________	_____	____________

(2) Do you have a drainage sump pump installation? Yes ☐ No ☐

(a) Year installed ____ (b) Installation cost $______ (c) Annual maintenance costs $______

(d) Annual operating costs $______ (e) Acres of land served by pump: Tiled: _____ Other; _____

(f) Do you plan to install a sump pump in the next two years? Yes ☐ No ☐

(3) Amount of large drain ditch improvement on or along side your property:

	Rods	Year estab.	Year last cleaned or repaired	Working conditions	
(a) County or Inter-County open drains	____	____	____	good ☐	poor ☐
Closed drains	____	____	____	good ☐	poor ☐
(b) Private non-field open drains	____	____	____	good ☐	poor ☐
Closed drains	____	____	____	good ☐	poor ☐

(4) Since 1958 what kind of improvement, new drains, maintenance, repairs have been made on your non-field drains (include information on county drains on or next to your farm).

Year	Kind of improvement or repair	Type drain			Financed	
		County	Private	Partnership	Tax	Private
___	___	☐	☐	☐	☐	☐
___	___	☐	☐	☐	☐	☐
___	___	☐	☐	☐	☐	☐
___	___	☐	☐	☐	☐	☐
___	___	☐	☐	☐	☐	☐

(5) On your most recent clean out or repair of a non-field drain:

(a) What was the total cost $________

(b) Your share of the total cost $______ (indicate ASC payments received, in addition $________)

(c) Description of work done: ________________________________

____

____

(d) When had this drain been cleaned out or repaired before? Year ______

(6) If a new open ditch drain was constructed in 1961 or 1962:

(a) What was the total cost $________

(b) Your share of total cost $________ (indicate ASC payments received, in addition $________)

(c) Number of acres served ________acres

(d) Description of work done ________________________________

____

____

Comments:

(7) Field Drainage improvements, existing and possible acreages

	Cropland		Permanent pasture and other	
(a) TOTAL ACRES [ ] (Sect. I (5))	[ ] acres		[ ] acres	
(b) Field drains installed	(acres affected only)			
1. Tiled				
a. Random *	rods ( ) ____ ac.		rods ( ) ____ ac.	
b. Grid				
(1) 3 rod	____ ac.		____ ac.	
(2) 4 rod	____ ac.		____ ac.	
(3) 6 rod	____ ac.		____ ac.	
(4)__ rod	____ ac.		____ ac.	
c. Tiled plus surface ditch	(____) ac.		(____) ac.	
2. Surface ditch only	____ ac.		____ ac.	
3. TOTAL DRAINED LAND	[ ] ac.		[ ] ac.	
(c) Potential drainage of undrained land				
1. Drainage not needed or will not pay 1. Naturally well drained	____ ac.		____ ac.	
2. Wet but will not pay	____ ac.		____ ac.	
			Plan to convert to cropland	Plan to use in existing use
2. Drainage will pay and can use present outlet (with outlet drains in existing condition)				
a. random tile*	rods ( ) ____ ac.		rods ( ) ____ ac.	rods ( ) ____ ac.
b. Grid tile	____ ac.		____ ac.	____ ac.
c. Surface ditch only	____ ac.		____ ac.	____ ac.
d. Tile and surface ditch	____ ac.		____ ac.	____ ac.
3. Drainage will pay, but only with new outlets (requiring new or cleaned outlet drains)				
a. Random tile*	rods ( ) ____ ac.		rods ( ) ____ ac.	rods ( ) ____ ac.
b. Grid tile	____ ac.		____ ac.	____ ac.
c. Surface ditch only	____ ac.		____ ac.	____ ac.
d. Tile and surface ditch	____ ac.		____ ac.	____ ac.
4. TOTAL NOT DRAINED	[ ]		[ ] acres	

(d) Additional potential drainage on drained land

	(Cropland)	(Pasture and other)
1. Tile between existing lines	____ ac.	____ ac.
2. Tile land having surface ditches	____ ac.	____ ac.
3. Surface ditch land having tile	____ ac.	____ ac.

*Landowners frequently will report random tiling in terms of feet or rods. If his random tile acreage estimate is not readily available we will use the factor 500 feet or 30 rods serves 1 acre. Include county tile that cross land farmed.

(9) If you have insufficient outlet at your farm boundary: (relate to Sect. 7, part c (3))

(a) How many acres can be drained by deepening and cleaning the existing drain? _________ acres (Include acres that could be served with sump pump.)

(b) How many acres can be drained only by the establishment of a new drain to your property __________ acres

(c) Will this new drain have to cut across a neighbor's field requiring a new channel? Yes ☐ No ☐

Comments: ______________________________

____

(10) ONLY ASK OF OWNER OPERATORS
If you can drain more of your fields now with existing outlets,

(a) What are the reasons for not making the improvements at this time?

____

____

(b) When do you plan to make these drain improvements? ______________

____

(c) Would you expect to use credit? Yes ☐ No ☐ . If so, what kind do you expect to use? (Specify length term and type of security)

____

____

(11) As you drain more land, what change could you make in your: (Indicate magnitude)

(a) Cropping system ______________________________

____

(b) Livestock system ______________________________

____

(12) If you have insufficient outlet because of a clogged open ditch drain (public or private), (a) Why hasn't this been corrected? ______________

____

(b) If this is a private ditch when do you expect to make this improvement?

____

Comments: ______________________________

____

____

III. Land use, crop production and drainage conditions, 1962

(1) Land use	(2) Acres	(3) Actual yield per acre	(4) Drainage Indicate drainage conditions: wet land not drained, naturally well drained, 4 rod grid, 6 rod grid, surface ditch. (Indicate if more than one condition is present)
Corn for grain 1st year		bu.	
2nd year		bu.	
Corn for silage		ton	
Soybeans		bu.	
Drybeans		cwt	
Sugarbeets		ton	
Potatoes		bu.	
Oats		bu.	
Wheat		bu.	
Barley		bu.	
Grass silage		ton	
Hay: Legume		ton	
Grass		ton	
Mixed		ton	
Rotation pasture			
Feed Grain Program			
Conservation Reserve			
Idle			
Total Cropland	owned / rented		

VI. Family Inventory, Off-farm Work and Labor Hired during 1962

(1) Family inventory and off-farm work

Member of family	Age	Highest school grade completed	Major occupation in 1962	Work off-farm in 1962			Expectation of future occupation
				Days	Income	Where worked	
Operator				1/			
Wife							
Children							
Partner				1/			
Wife							
Children							
Other (specify)							

1/ For operators and partners record only work hired out to other farmers. For all other family members, record all off-farm work.

(2) Labor hired 1962

(a) Total hired in 1962 ______ days

(b) Seasonal distribution: January-March ______ days April-May ______ days June-July ______ days
August ______ days Sept.-Oct. ______ days Nov.-Dec. ______ days

(c) Total cost ______ dollars

(3) Machinery hire 1962. Total cost $______, including operator time (if charged).

VII. Nonfarm Employment of Operator, 1962

(1) **Did you have a nonfarm job at any time in 1962?** Yes [ ] No [ ]

IF NO, skip the rest of this section.

(2) What kind of work did you do? ____________________

(3) Who was your employer? Name ____________________ Location ____________________

(4) How many miles was your job from home? ____________________

(5) Were you employed year around [ ] or seasonal [ ]

(6) IF SEASONAL, (a) How many weeks were you employed? ____________________

(b) Which months did you work? ____________________

(7) To get some idea of time you had available for your farm work we would like to know: (a) What time of day you left for work? ____________________

(b) What time of day you arrived home from work? ____________________

(c) How many days did you work per week? ____________________

(8) Did you work overtime anytime in 1962? Yes [ ] No [ ]

(9) IF YES, when and for how long? ____________________

(10) IF NOT SHOWN IN QUESTION 7, did you work night shift anytime in 1962? Yes [ ] No [ ]

(11) IF YES, when and for how long? ____________________

(12) What was your wage rate per hour? Regular $________ Overtime $________

(13) What were the total take-home wages received in 1962? $________

(14) How many days of paid vacation did you have during the year? ____________________

(15) IF ANY, could you choose your vacation period? Yes [ ] No [ ]

(16) IF YEAR AROUND, were you laid off at any time in 1962? Yes [ ] No [ ]

IF YES, (a) What was the reason? ____________________

(b) How long and in which months? ____________________

(17) Why do you work off the farm rather than expanding your farming operations?

____

____

APPENDIX A (CONTINUED)

PART II

SELECTED PORTIONS OF INSTRUCTIONS TO ENUMERATORS

Major Parts of Schedule

The schedule includes seven parts as follows:

I. The Farm - Size, Control and Tenure

II. Farm Drainage

III. Land Use, Crop Production, Sales and Purchases

IV. Livestock and Livestock Facilities

V. Change in Farm Organization since 1958

VI. Family Inventory, Off-Farm Work, Labor Hired

VII. Nonfarm Employment of Operator

Comments and interpretation of individual sections and questions follow:

I. The Farm - Size, Control and Tenure

(1) Sample segment is the number indicated on the enumeration map.

(2) Owner - may be a full owner or an owner with additional land rented.

Partnership - may be owners or tenants.

Corporation - applies only when a member or an officer of the company performs the management.

Tenant and landlord - may include father-son and other family agreements, but the landlord must participate in the management more than merely specifying land use.

(3) Acres in farm applies to the land operated as a single unit. It

may include both owned and rented land and should include land temporarily rented out.

(4) In recording rent and expenses, show the rent paid to the landlord and the share of the expenses paid by the landlord. List crops, kinds of livestock and items of expense separately.

II. Farm Drainage

The purpose of this section is (1) to determine the extent of artificial drainage, (2) to determine the potential drainage on farms both with and without additional off-farm outlets, (3) to determine the rate that drainage practices have been adopted and (4) to determine the critical factors that restrict additional drainage that otherwise would be economical.

Definition of Terms

Field drainage: Any artificial drainage on cropland fields, meadow or pasture.

Tile drainage: Tile laid underground either on a systematic grid basis or a random basis which drains underground water into open ditches. Tiles are normally 4 to 5 inches in diameter and usually are 2½ to 3 feet deep. Tile lines are spaced 4 to 6 rods apart, if on a grid basis, and are connected to a system of mains.

Surface ditches: Any shallow ditch to move surface water off the fields. Surface ditches can be crossed by farm machinery and normally are cropped. Ditches normally are 10 to 12 feet wide and 12 to 18 inches deep.

Open ditches: Are large ditches that cannot be crossed by machinery and equipment readily. These ditches normally are 4 to 10 feet deep and 10 to 15 feet wide. Open ditches can be private

ditches or part of a system of public drains (County or Intercounty drains).

Public drains: Individual drainage areas are organized into Drainage Districts. The County Drain Commissioner is an elected official who administers the business of the Drainage District. Landowners petition for the construction of new drains or clean out of existing drains. Public drains are normally large open-ditch drains. Often, existing stream beds are enlarged as public drains. Sometimes new channels are constructed to go along side a farm adjacent to the road or cut across a farm. Open ditches become clogged with tree and brush growth and silt, thereby reducing the outlet for drainage.

Outlet: Refers to the ability to drain water from the surface ditches or the tile system of the farm without stoppage due to clogged ditches off the farm or water in ditches backing up because of clogged drains further away. In many cases, additional outlet can be obtained by cleaning out the off-farm drains or constructing new drains.

Sump-pump: Some landowners do not have an outlet at the boundary of their farm to serve their field tile which are 2½ to 3 feet deep. In some cases these farmers install a cistern at the end of their mains, then pump the drainage water into the public drain.

(1) In this section the rate of adoption is sought. Some farmers will not be able to relate the early drainage history. Go back as far as this operator can give, then list acreages with dates unknown.

(2) Installation costs should include material costs, excavation costs (including the building of dams or dikes) and all hired labor costs.

Since there will be a few sump-pumps falling into our sample, estimate the annual maintenance costs and operating costs based on the last three year's records (1960-62).

(3) In determining the length of the open ditch and large closed non-field drains, include those drains that cross the farm and also those that are contiguous to the farm boundary. For instance a public drain or private drain that follows a road ditch between the farm and the road would be included. If the drain was across the road in the opposite road ditch it would not be included. If a segment of the large drain actually separates two farms only one-half the length of this segment is reported. In this manner sample estimates can be expanded to area estimates.

(4) Occasionally landowners prefer to clean out small portions of the public drain on their own rather than follow the legal procedure specified in the drain law.

(5) Describe the work in terms of total yards excavated or in terms of added depth, width or length of excavation. Agricultural Stabilization and Conservation payments are available in some instances on private drains. Show ASC payment separate from actual direct cost to the farmer.

(6) Same as (5) above.

(7) All of the acres in the farm are considered in this section. Subsection (b) + (c) must total to (a). Only those acres where the drain is actually effective should be entered in subsection (b). A 10-acre field with a random tile system which really drains 3 acres of the field will be credited in the schedule as 3 acres random tile drained. Much tile was installed 30-40 years ago and is

now ineffective. These acreages should not be listed.

Subsection (c) elicits information on potential drainage. Not all drainage is practical. The question in section (c) and (d) relates to drainage investments that would pay as estimated by the farmer.

In subsection (c) the permanent pasture and other land acreage that has drainage potential is divided into land that is (1) to be converted from pasture or other use such as woodlots to cropland and (2) to remain in its existing use. If there are other kinds of changes anticipated such as converting cropland to permanent pasture after drainage, indicate this in the margin. Subsection (d) refers to additional drainage investments on land reported in subsection (b) above.

(8) This section is relevant only if the farm operator has existing tiledland with which to compare yield potentials.

(9) This section is a further breakdown of section (7) (c) 3. The acreage listed for (a) and (b) in this section should equal the acreage listed for (7) (c) 3.

(10) In part (a) there may be more than one reason for not installing drainage. List all reasons. In part (c) we are interested if the farmer expects to get short, intermediate, or long-term credit. List the length of term in years. Also we wish to find out if he prefers to use his land, his livestock, machinery, or other assets as security.

(11) In this section indicate as precise as possible the kind of change and the magnitude of change planned when more land is drained (i.e., increase 10 acres of white beans - decrease oats 5 acres, decrease

barley 5 acres or increase dairy herd from 30 to 45 cows).

(12) The outlet is one of the important restrictions on additional land drainage. Since the public drain and private large ditch drains involve group action, the reasons for the inaction in this area are important. If there are additional comments on this or any other part of this section on drainage,please list at the bottom of this page.

III. Land Use, Crop Production, Sales and Purchases, 1952

(1) Account for all of the land operated in this farm as recorded on page 1. Write in additional crops or other uses as needed. "Corn for grain, 1st year" is corn that was grown on land that was used for some crop other than corn in 1961. "2nd year" is corn that was grown on land that was in corn in 1961. If grass silage was cut on land which was used for rotation pasture or from which a hay crop was harvested, in 1962, circle the acreage of grass silage to indicate double cropping.

(3) Write in unit for crops added.

(4) The purpose of this column is to relate the drainage improvement to the actual yield for each crop. Frequently there will be a combination of drainage improvements existing on the land used for a specific crop in 1962. When this is the case, try to get the farmer to estimate the actual yield per acre in 1962 for each drainage condition. Make marginal notes to explain any entries in this column. Note if there were different fertiliser rates and different cultural practices.

VI. Composition and Occupation of Operator's Family

This section concerns the migration situation and expectations which have a bearing on trends in adjustments on farms.

(1) List the members of the operator's family even though they may be grown and away from home. The age of each is important information. Obtain the highest grade completed only for the persons who have discontinued attendance at school. Major occupation for persons with more than one occupation may be determined on the basis of relative time spent. The expectation question may apply to the operator and his wife as well as the children if they have expectations to discontinue farming.

(2) Record labor hired by days for each period of 1962.

VII. Nonfarm Employment of Operator, 1962

The purposes of this section are (1) to ascertain when and how much time part-time farmers have available for work on the farm, (2) what is the nature of off-farm employment and income, and (3) why part-time farmers prefer to work off the farm rather than expand their farming operations.

APPENDIX B

CHARACTERISTICS OF SOIL MANAGEMENT GROUPS

Table 60. Significant Characteristics of Large Soil Management Groupings, 42-County Region, Lower Michigan[1/]

Soil Management Groups	Relief and Drainage	Parent Materials and Management Problems	Native Vegetation	Land Use and Major Crops
0a, b, c 1a, b, c	Nearly level to rolling with moderate to poor drainage characteristics.	Developed in clay loam or silty clay parent materials. Problems of soil structure and drainage exist.	Relatively wet and swampy, heavily timbered with elm, ash and soft maple.	Suitable to general cropping when adequately drained if soil structure is maintained.
2a, b	Level to hilly, well to imperfectly drained, poor drainage in depressional areas and natural drainways.	Deep and durable soils developed in loam, clay loam, and silty clay loam drift. Associated wet areas influence size and shape of fields. Slope, erosion and drainage are problems.	Generally hardwood forest consisting of sugar maple, oak, ash, hickory, elm and soft maple.	Dairy and livestock with associated general crops and some cash cropping.

1/ Clarence A. Engberg, State Soil Scientist, Michigan SCS, USDA and Dr. Eugene P. Whiteside, Professor of Soil Science, Michigan State University, assisted in developing this table.

Table 60. Continued

Soil Management Groups	Relief and Drainage	Parent Materials and Management Problems	Native Vegetation	Land Use and Major Crops
2c	Nearly level to depressional areas which are naturally poorly drained.	Relatively high in organic matter, nitrogen and lime, moisture retentive. Developed in loams, silt loams and clay loams; have high natural fertility but problems of drainage.	Heavily timbered primarily with elm, ash and soft maple.	Generally used for high-value crops such as corn, field beans and sugar beets but suitable for general cropping.
3a, b, c	Level to hilly with slow to rapid surface drainage.	Surface and subsoils slight to strongly acid, sandy loams with moderate water-holding capacity underlain with sand and gravel in places, water erosion a serious problem in some areas, drainage needed in others.	Largely hardwood forest of oak, hickory, elm, ash and soft maple.	Moderate natural fertility adapted to a wide range of crops, especially potatoes and all types of livestock production. Gravel and sand sources, hilly areas suitable for recreation and forestry.
4a, b, c	Level to hilly and rolling to extremely rough with lakes, swamps and marshes in the basin-like	Open and loose loamy sands with a finer textured subsoil. In some cases there is loam to silty clay at depths of 18 to 42 inches. Some	Hardwood forest of oak, hickory, elm and ash, marsh and short grasses.	Diversity of soils and unfavorable topography result in a wide range of field crops, fruits and special crops. Many hilly areas are

Table 60. Continued

Soil Management Groups	Relief and Drainage	Parent Materials and Management Problems	Native Vegetation	Land Use and Major Crops
	cont. associated areas, surface drainage good to rapid.	cont. with seasonally high water tables require drainage. Drouthiness, low productivity and erosion on steep slopes are problems on others.		cont. unsuitable for farming and are used for forestry, recreation and sand or gravel enterprises.
5a, b, c	Level to extremely hilly uplands, with some dunes along Lake Michigan, generally well drained, but some poorly drained areas are included.	Mainly deep sands to more than 66 inches, strongly acid, low water holding capacity and low fertility. Level areas respond to irrigation and fertilization, wind erosion is a problem where the soil is tilled.	Hardwood forest of oak, hickory, elm and ash, sedges and short grasses.	Some general cropping, pasture, truck crops, small fruits, second growth forest, public recreation areas and rural residences.

Table 60. Continued

Soil Management Groups	Relief and Drainage	Parent Materials and Management Problems	Native Vegetation	Land Use and Major Crops
Mc	Level to depressional with poor to extremely poor natural drainage.	Mucks and peats of variable thickness developed from the partial decomposition of plant remains, with water level management, fertility, frost and wind erosion problems.	Marsh and bog vegetation, short grasses, scrubby trees, elm, ash, soft maple, brush and shrubs.	Production of onions, mint, celery, potatoes and truck crops, small acreages of pasture and blueberries where the soil is very acid.

Source: Whiteside, Schneider and Cook, Soils of Michigan, Michigan Agricultural Experiment Station, Spec. Bulletin 402, December 1959 and Hill and Mawby, Types of Farming in Michigan, Michigan Agricultural Experiment Station, Spec. Bulletin 206, September 1954.

APPENDIX C

MINIMUM ACREAGE REQUIREMENT

Table 61. Minimum Acreage Requirement Used in Analytical Model to Reflect Historical Production Shifts, Michigan Farm Drainage Study

Commodity	42-County Region		
	Thumb	South Central	Other
	--------Thousand Acres----------		
Wheat	52.2	68.3	102.2
Corn	31.2	101.2	153.5
Oats	36.5	42.7	59.4
Barley	1.9	4.3	5.0
Soybeans	1.0	29.0	131.6
Dry Beans	71.5	15.1	79.9
Potatoes	.4	1.1	5.5
Corn Silage	10.4	12.7	21.0
Alfalfa Hay	43.4	55.1	99.7
Other Hay	6.8	7.7	14.4
Crop Pasture	53.3	81.9	121.2

Source: Based on trends in cropland use found in 1949-64 Census of Agriculture reports.

APPENDIX D

MAJOR CROPLAND USE, 42-COUNTY REGION

Table 62. Major Cropland Use, 42-County Region of Lower Michigan, 1949-64

Year	Cropland Harvested	Cropland Pastured	Cropland Not Used	Total
		(000 acres)		
1949	6,024.6	1,424.9	910.5	8,360.1
1954	5,957.9	1,338.9	879.3	8,176.2
1959	5,666.4	982.9	1,026.8	7,676.2
1964	5,374.9	770.2	1,203.7	7,348.8

Source: Census of Agriculture