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Title: SELECTED FACTORS AFFECTING THE PATTERN OF AGRICULTURAL LAND CONVERSION IN WASHINGTON COUNTY, OREGON, 1963-1973

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In recent years the conversion of agricultural lands to more intensive non-rural land uses has become a focus of increasing public awareness and concern. The growing attention to farmland conversion is manifested in increasing public policies and legilsation to protect agricultural and forestry land uses. Nevertheless, our understanding of the farmland conversion process is restricted. Although agricultural land conversion has been descriptively addressed, little consideration has been given to defining and analyzing the factors affecting the spatial pattern of rural land conversion.

The purpose of this investigation was to analyze the impact of selected variables on agricultural land transition to more intensive non-agricultural uses. The research tested the reliability of a composite site characteristic model, and individual submodels for explaining land conversion patterns in Washington County, Oregon. Within the

framework of the site characteristic model, specific objectives were:

(1) to determine those site factors which exhibited a significant influence on agricultural land conversion,

(2) to estimate empirically the influence of each factor on agricultural land conversion, and

(3) to determine differences in the effect of individual factors and composite models on agricultural land conversion in areas with varying stages of urbanization.

The site characteristic model examined in the investigation included twenty-three predictor variables drawn from four sets of site factors. These four broad categories of site characteristics are accessibility indices, infrastructural-policy factors, social factors, and environmental factors. Individual regression models were developed for each set of site characteristic variables, as well as, for the composite site characteristic model. Published government documents, planning reports, and manually calculated information from aerial photographs provided the primary sources of these data.

Following the collection of farmland conversion data from 1963 and 1973 aerial photography for Washington County, a series of multiple regression analyses were undertaken. The results of these analyses showed that the hypothesized site characteristics proved important factors in explaining farmland conversion patterns. The composite site characteristic model, with fourteen predictor variables, accounted for 78 percent of the variation in farmland conversion for the county. Geographically, the composite model was most effective in explaining land conversion in urban sections of the county (R^2 = .676), while achieving its lowest precision in urban-rural fringe areas (R^2 = .627).

As expected, the effectiveness of individual submodels varied extensively with respect to explaining land conversion. Several of the hypothesized variables were consistently strong performers accounting for much of the variation in farmland transition. Conversely, numerous variables proved of only peripheral value during the modeling. The modeling results showed the most powerful set of variables to be the infrastructural-policy factors. This submodel, with four significant variables, was able to explain 70.7 percent of the variation in farmland transition for the entire county. Conversely, the weakest set of site characteristics were the environmental factors. With five significant variables the environment submodel accounted for 49.2 percent of the farmland conversion in the study area. As in the case of the composite model, the relative effectiveness of the submodels varied extensively between urban, urban-rural fringe, and rural portions of Washington County.

The research results of the investigation found that the site characteristic model provided a consistently powerful tool for understanding farmland transition in all sections of Washington County, Oregon. The strong measure of reliability associated with the site characteristic methodology, viewed within the framework of concern for farmland conversion, suggests that the conclusions of this investigation may have broad policy implications. The linkage between farmland development and site characteristics provide insight regarding the operation of agricultural land conversion process. Drawing on the relationships pointed out in the investigation, Washington County and other governmental units may find that the study findings can assist in improving mechanisms for controlling land conversion.

Selected Factors Affecting the Pattern of Agricultural Land Conversion in Washington County, Oregon, 1963-1973

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CHAPTER I

INTRODUCTION

The issue of agricultural land conversion has emerged in the 1970's as a major focus of interest and concern among state legislators, land planners, environmentalists, and agricultural interests. This concern has its origin in a divergent set of values; however, the prospect of the continued loss of agriculture land uses has generated extensive public sentiment for conserving this resource. Responding to public demands, decision makers and legislatures across the nation have developed policies to reduce the conversion of agricultural lands. Currently, forty-two states have enacted some form of legislation, primarily differential assessment laws, to protect agricultural and forestry lands. Moreover, in many areas, local governments (counties, townships, and cities) have adopted specialized legislation or policies to protect agricultural resources within their political jurisdiction.

In most cases, the effectiveness of strategies to reduce land conversion has not been determined. However, *ex post* studies in several states indicate, at best, only limited success in reducing losses in agricultural land (Hady and Sibold, 1974; Gustafson and Wallace, 1975).

In reviewing the failure of existing methodologies to decrease agricultural land conversion, a number of possible explanations arise. One problem area surrounding the land conversion issue is a lack of understanding regarding the spatial configuration of agricultural land conversion. What are some of the factors affecting the conversion process? To what extent do these factors influence the location, magnitude, and type of development? The research reported in this study has focused on these issues, in the hope that the data generated can assist in the development of effective land management policies.

Background and Issues

In the past thirty years, the thrust of a variety of social and economic forces has created an urban demand for rural lands that is unparallelled in United States history. Since the Second World War, America has experienced a massive population redistribution. This demographic shift is characterized by twin movements: population concentration on a national scale, and population decentralization on a metropolitan scale. The decentralization of urban areas has occurred through areal expansion, commonly called suburbanization.

In discussing postwar suburbanization, Marion Clawson writes:

> In the decade beginning with 1948, more than 10 million new households were formed, partly because of a high marriage rate, partly because of the accumulated backlog of unfilled or potential demand for separate households that had built up through depression and war. In many older cities there was relatively little vacant land on which new residential structures could be built... The obvious direction to do, in providing the new housing, was toward the suburbs... Postwar cars and postwar highways went far toward freeing an urban worker from the necessity of living near his job. He could live nearly anywhere within the urban area and work at any other location... At the same time, changes underway in industrial plants tended to take them too to the suburbs... retail shopping stores and districts moved from downtown to the suburbs... Movement of customers to the suburbs induced many department stores to open suburban branches and the availability of convenient shopping areas certainly was another force leading families to move to the suburbs... This combination of shifts in job location, changes in transportation, and development of new modes of communication has led toward a major expansion of the city at the periphery. This expansion conceivably could have been in a relatively solid and blocked-up fashion. It was not--discontinuity and dispersion were its marked characteristics... (Clawson, 1971, p. 40-41).

Although descriptive discussion of the suburbanization process are easily developed, identification of the causal factors stimulating the loss of farmland is difficult. The roots of the problem are diverse and defy simplistic analyses. In a probing review of background and beginnings of the agricultural land conversion problem, Phillip Raup has suggested that three root causes are the automobile, affluence, and advertising (Raup, 1975, p. 372). Raup believes that this triumvirate has provided the bases for our urban life style which concentrates demands upon space. In summarizing the American lifestyle, Raup has stated:

> The taste for space that we have encouraged ... is drug-like in intensity. It has been integrated into a lifestyle in which the age-old search for food, clothing, and shelter is supplemented by demands for space and mobility... The automobile becomes both a mode of dress and an inseparable component of housing, subject to turns in fashion that in an earlier day were confined to simpler forms of personal adornment... These determinants of our urban pattern have supported a feedback system that has been powerfully re-enforced by mass media advertising. Expenditure patterns built around the single-family home and the automobile define target audiences to which the majority of advertising messages are directed. The most sophisticated use of powers of persuasion in our culture are designed to create wants whose satisfaction requires space. This has generated construction, service, and supply industries that must have space to succeed (Raup, 1975, p. 374).

This sprawled lifestyle described by Raup is not singularly a product of private enterprise, but rather has been encouraged and subsidized by governmental policies and large scale investments. Extensive investments in infrastructure by the Federal government has stimulated the surbanization of urban centers and conversion of agricultural lands to higher uses. One of the most massive of these investments has been in highways. New urban highways have been characterized as the destroyers of inner cities. Radial freeways built to facilitate access to central cities have led to an exodus from the city to the suburbs. Circumferential highways, designed to let traffic by-pass congestion, became congested because of businesses and households which located along them. Similarly, public investments in sewer and water lines, mass transit, and other infrastructural elements have also encouraged our low density settlement pattern, necessitating increasing amounts of agricultural land for urban purposes.

Beyond direct public investment in infrastructure, governmental housing and taxation policies have subsidized the demands for space to an even greater degree. Beginning with the G.I. Bill after the Second World War, the Federal government has taken an active role in financing housing. A variety of government insurance and mortgage guarantees are available. However, these subsidies are almost entirely restricted to suburban or rural single-family detached houses. In other words, we are subisidzing suburban sprawl and agricultural land conversion by the way in which we finance housing. Other financial incentives for suburbanization are contained in numerous governmental financial policies, especially taxation procedures. Raup suggests that, in many ways, the income tax deduction allowance for property taxes and interest, the tax-exempt status for municipal bonds, and tax exemptions for real estate provide a form of subsidy for suburban sprawl and expand the demand for agricultural land conversion (Raup, 1975).

The combined impact of an American lifestyle that requires increasing amounts of space and sympathetic government policies has been an increasing rate of agricultural land conversion. Only recently, however, has the threat to agricultural lands been recognized as an issue of major importance. During the 1950-1960's, the major problem in American agriculture was thought to revolve around agricultural surpluses and government remedies to take land out of production. However, more recent data regarding agricultural land resources have portrayed a different type of "farm problem". A 1975 study by Krause and Hair noted that from 1944 to 1969 land classified as cropland (excluding cropland pasture) has declined by 5% (22.7 million acres) (see Table 1). They also pointed out that from 1950 to 1970 urban areas took 13.5 million acres of rural land to accomodate an increase of 53 million urban residents. "Urban" was defined using the Bureau of the Census criteria which encompasses all places with population greater than 1,000. A particularly noteworthy aspect of this datum is found in an increase in the acreage per person for urban population. This acreage requirement rose from .207 acre in 1950-60 to .312 acre in 1960-70. One might infer from this increase that the space requirements of the American lifestyle, so vividly described in Raup, are continuing to increase.

The 1975 findings of Krause and Hair have been reaffirmed by a number of government scientists and other researchers. For example, the Economic Research Service estimates that 2.2 million acres (of agricultural land) are shifted annually to other uses. About

Table 1. Cropland acreage changes, 1944-64.[1/]

Region	Total Cropland		Counties showing		Net regional change
	1944	1964	Decrease	Increase	
			Million acres		
Northeast	22.7	15.8	7.0	0.1	-6.9
Lake States	41.3	39.5	2.9	1.2	-1.8
Corn Belt	80.9	82.1	3.3	4.6	+1.3
Northern Plains	92.3	93.5	3.5	4.7	+1.2
Appalachian	26.7	18.8	8.1	0.1	-8.0
Southeast	24.5	15.0	10.6	1.0	-9.5
Delta	18.7	15.1	5.2	1.6	-3.6
Southern Plains	45.4	38.3	9.9	2.8	-7.1
Mountain	30.5	36.9	1.5	8.0	+6.4
Pacific	20.2	21.4	1.4	2.6	+1.2
48 States	403.2	376.5	53.5	26.7	-26.8
Per Year			-2.7	+1.3	

[1/] Excludes cropland pasture. Totals may not add due to rounding.

Cropland acreage changes, 1964-69.[1/]

Region	Total cropland		Counties showing		Net regional change
	1964	1969	Decrease	Increase	
			Million acres		
Northeast	15.8	13.3	2.5	0.1	-2.5
Lake States	39.5	37.2	2.6	0.2	-2.4
Corn Belt	82.1	82.6	1.5	2.0	+0.5
Northern Plains	93.5	92.0	3.4	1.9	-1.5
Appalachian	18.8	17.5	1.7	0.5	-1.2
Southeast	15.0	14.2	1.4	0.6	-0.8
Delta	15.1	17.3	0.4	2.7	+2.3
Southern Plains	38.4	38.6	1.5	1.7	+0.2
Mountain	36.9	36.7	1.4	1.2	-0.2
Pacific	21.4	20.9	1.0	0.5	-0.5
48 States	376.5	370.5	17.5	11.4	-6.0
Per year			-3.5	+2.7	

[1/] Excludes cropland pasture. Totals may not add due to rounding. Source: Krause and Hair, 1975, p. 3.

1.2 million acres are used for urban development, transportation, reservoirs, and flood control. Only about half of this was cropland before it was converted to other uses. About 1 million acres are shifted annually to recreation and wilderness areas with very little coming from cropland (Council for Agricultural Science and Technology, 1975, p. 7).

In spite of the extensive annual conversion of agricultural lands, the national inventory of active cropland has not dropped precipitously, owing to an annual 2.2 million acre shift of unused land to farming (Economic Research Service, 1974). The majority of these new agricultural lands are brought into production through the use of irrigation or drainage. Some observers have cited the conversion of formerly unproductive acreage to agriculture as a solution to the withdrawal of agricultural land by urbanization (Hart, 1976). However, critics are quick to note a number of problems with this potential panacea.

Spatially, much of the land brought into production is situated far from existing population centers and existing processing centers. Often the new agricultural land is also of lower quality than the land it is replacing. Finally, the creation of new agricultural lands requires heavy technological inputs and extensive amounts of energy. Howard Odum observed in a U.S. government study of the world food problem that American agriculture, "...is largely accomplished with aid of machines, chemicals, special varieties of plant and livestock and various kinds of industrial aids... This is an entirely new system in which vast new flows of potential energy are made available from fossil fuels so that all the things that once had to be done as drains from the central (energy) budget may now to done with outside fuel" (Odum, 1967, p. 60-61). In his summary, Odum warns that plans should be made for future contingency of failing fossil and nuclear energy flows, as the survival of man could be threatened by reduction in our energy base (Odum, 1967, p. 70).

Some more cynical observers, have suggested that United States agriculture already depends too much on a cheap supply of energy to maintain high productivity (Gale and Yompolsky, 1975, p. 18). One recent study shows the aggregate U.S. farm output, as a function of total energy inputs, has leveled off in the past decade (Steinhart and Steinhart, 1974, p. 310). Thus it would seem that dependence on technology and energy subsidies to bring new agricultural lands into production to offset land conversion is an ill-advised response to the problem.

Agricultural Land on the Rural-Urban Fringe

The greatest pressure for land conversion occurs in the areas surrounding large urban places. This trend is especially significant in that agricultural production and the quality of agricultural land resources in these areas is higher than the national average. Robert C. Otte, in a study entitled Farming in the City's Shadow, pointed out that 15 percent of the total acreage classified by the U.S. Soil Conservation Service in Land Capability Classes I, II, and III occurs in the 242 Standard Metropolitan Statistical Areas (SMSA) comprising only 13 percent of the total land area. Even of more critical importance than the quality of agricultural land in urban areas, is the agricultural production data for urbanized counties. Otte reports that 60 percent of all vegetables sold in 1969 were produced in SMSA's, as were 43 percent of the fruits and nuts (Otte, 1974, p. 12). However, as one might expect, SMSA's share of total U.S. agricultural production has decreased slightly during the 1960's from 22.6 percent total value of farm product sold in 1959 to 21.5 percent in 1969.

The Federal Response to Decreasing Agricultural Acreage

The seriousness of the problem surrounding the conversion of agricultural land has brought about increased Federal concern in the past three years. One of the most significant actions taken thus far is the Secretary of Agriculture's Memorandum No. 1827, Supplement 1. This document, entitled, Statement on Prime Farmland, Range, and Forest Land, expresses official concern over the conversion of agricultural resources. In the memorandum, Acting Secretary, John A. Knebel, notes that:

> The continued loss of lands well suited to the production of food, forage, fiber, and timber, and the degradation of the environment resulting from those losses is a matter of growing concern to the Nation. Major consideration must be given to prime lands and the long-range need to retain the productive capability and environmental values of American agriculture and forestry...
>
> The concerns about wise use of prime lands are local, Statewide, and national in scope. The loss of land suitable for sustained crop and wood production in a region or locality can influence the viability of supporting supply, processing and marketing facilities. Continued loss of farmland, range, and forest land production affects the economy locally, influencing employment and income levels. In addition, it limits other qualities essential to the well-being of our people.

Memorandum 1827 requires the Department of Agriculture, through its national and state Rural Development Committees, to "... advocate the protection of prime and unique farmlands, range, and forest lands from premature or unnecessary conversion to non-agricultural land uses." Departmental personnel are directed to give "particular concern" to potential conversion to urban or built-up land uses. Finally, the document establishes as departmental policy:

> 1. Advocate the protection of prime lands from premature or unnecessary conversion to other land uses. Priority will be given to prime lands threatened by conversion to irreversible land use.
>
> 2. Assure that environmental impact statement procedures and review processes thoroughly consider and evaluate the impact of major Federal actions on prime farmland, range, and forest lands...

4. Cooperative efforts with States, local governments and universities will be initiated to assure concerns for food, fiber, and wood production are recognized and emphasized in the identification of prime lands.

Indications are that the tone and policy set forth in the Secretary's Memorandum No. 1827, Supplement 1 may be expanded to all Federal agencies. The preliminary draft of President Carter's message on the environment, to be issued later this year, will expand Federal protection of prime agricultural lands. The April 4, 1977 issue of Land Use Planning Report, an independent planning and environmental newsletter, notes,

> The administration is expected to oppose strip mining on prime farmland and ranchlands as designated by the Department of Agriculture... According to a tentative outline of the message, Carter will issue an executive order 'discouraging Federal support of construction in prime agricultural lands'. According to White House aides, Carter believes that development has needlessly destroyed considerable wetland and farmland acreage (Land Use Planning Report, April 4, 1977, p. 108).

If Carter does issue an Executive Order restricting Federal support for construction on prime farmland, this policy would become mandatory throughout the Federal government.

Government's increased recognition and attention to the issue of agricultural land conversion is especially significant in light of new demographic data. The latest population information gathered and analyzed by the Economic Research Service for the U.S. Senate, Committee on Agriculture and Forestry indicates evidence of a reversal in population distribution trends. Between 1970 and 1973 population growth in non-metropolitan areas exceeded that of metropolitan areas by 1.3 percent (Committee on Agriculture and Forestry, 1975, p. 2). In reviewing the strength of this new population shift and its potential impacts, the Committee report noted:

> In the period 1940 to 1970, the United States was characterized by both rapid population growth and rapid urbanization. But in the 1970's, both of these trends have diminished... there is firm evidence of shift in population distribution toward the non-metro areas and small cities... There is also evidence of considerable residential discontent on the part of many metro urban and suburban people. Surveys of recent years have shown sizeable numbers of such people expressing a preference to reside in a rural area or a small town and an intention to do so. Thus, economic trends that created net growth of jobs in non-metro areas have coincided with noneconomic preferences for residence in such areas. The result has been net immigration of people into nonmetro areas since 1970, in sharp contrast to trends of just a few years ago.

If the population shift noted above remains strong, as the early data would seem to indicate, pressure for agricultural land conversion will increase. This scenario would mean accelerating losses of farmland and increasing demands for food and fiber. Current data makes it incumbent that government and the private sector cooperate to restrict farmland conversion. "The fact that land is both a finite resource and the basic resource for the nation's food production capability make the need even more pressing" (Blobaum, 1974, p. 27).

Problem Statement

As noted earlier, agricultural land conversion has only recently emerged as a land use issue. Owing to rapid rise in public concern and calls for resolution of the problem, governmental decision-makers have been required to develop legislation for this complex issue in very short periods of time. Forced to design measures that were politically feasible, administratively operable, and fiscally possible, legislatures chose differential assessment mechanisms to assist agricultural land owners.

Beginning in 1957 with Maryland, forty-two state legislatures have enacted legislation which grant preferential tax treatment to farm and other types of underdeveloped land. These laws were usually enacted to serve the dual purpose of reducing tax burdens for farmers and preserving current agricultural and other open space land uses. The underlying rationale in this strategy is the assumption that reducing the tax burden on such lands will reduce the rate of conversion to higher intensity uses.

Unfortunately, the effectiveness of differential assessment mechanism as a land use tool is limited. Early studies of states which have adopted differential taxation laws are almost universal in negative appraisal of their value (House, 1967; Gustafson and Wallace, 1975). Differential assessment provisions are viewed as "weak holding actions at best" (Blobaum, 1974, p. 23). In the most complete analysis of differential assessment to date, researchers from the Regional Science Institute, working for the Council on Environmental Quality, concluded:

> With respect to the goal of retarding the conversion of farm and other open land, differential assessment is marginally effective and its cost in terms of tax expenditures is high, in most cases so high as to render it an undesirable tool for achieving this goal...we conclude that differential assessment is not very effective in maintaining current use in urban areas, even in the short run. In the long run, death and retirement will bring almost all properties on the open market, and, as a rule, the demand for land for urban uses will increase. In this longer run perspective, differential assessment is of little significance in maintaining farm or other open uses (Council on Environmental Quality, 1976, p. 115-116).

An alternative approach to control of agricultural land conversion involves the regulation of the land development process through existing planning techniques and the provision of public facilities. This is to say, one may preserve farmland by restricting infrastructural and public improvements to active agricultural acreage. A main objective in this strategy is to influence the functioning of the real estate market in such a way so as to fulfill general public welfare considerations, i.e. preserving farmland.

Research surrounding the land use decision making process would seem to indicate the inherent applicability of this approach for guiding development. Clawson has noted:

> Another power of local government is the power of the purse, or the spending power, especially for public improvements. Cities and counties construct and operate a wide variety of public improvements--school, roads, parks, sanitary and water facilities. The location and the quality of the service provided can be influential in guiding or inhibiting private land development. In the urban and suburban locations, there has been relatively little use of the direct and conditional subsidy to induce private action ...but the technique has major applicability to urban problems which has not as yet been utilized... Indeed, it is in the articulation of various programs to a defined goal that the management possibilities in local government are the most exciting and important (Clawson, 1971, p. 67).

Empirical research by Chapin and Weiss (1962) in North Carolina, Czamanski (1966) in Baltimore, and Milgram (1967) in Philadelphia have produced evidence which support Clawson's thesis that infrastructural derived land use controls can be effective mechanisms for guiding development.

A major deficiency, however, which restricts the usefulness of this strategy for preserving farmland is the lack of precise information surrounding the agricultural conversion process. Because of the complexity of issues surrounding the process of urban growth, the body of current research dealing with urban expansion is far from comprehensive.

The land development pattern of an area at any particular point in time can be conceived as the cumulative effect of a myriad of decisions and actions by individual and groups, consisting of households, institutions, corporate interests, and government. The attitudinal basis of these actions have been broadly categorized as stemming from profit making, livability, and culturally rooted values (Chapin, 1957, pp. 67-68). To sort out the factors that individually and in combination exert an influence on farmland conversion will require a great deal of research and study. It is unlikely that all factors that are operative in any area can be identified; nor is it probable that if all factors were identifiable they would function in an identical fashion in all communities. Nevertheless, it is the premise of this investigation that in any particular community the key factors are identifiable and, given adequate data and analytical techniques, it is possible to establish empirically the relative importance of these factors as determinants of the present day pattern of agricultural land conversion.

The research reported here has examined the effect of selected governmental policies, social conditions, and natural environmental variables on the development process in Washington County, Oregon. Many of the variables examined have not been previously analyzed for their effect on farmland conversion.

Washington County was selected as the study area owing to a number of factors, including (1) demographic-economic characteristics, (2) data availability, and (3) local government cooperation. The location of Washington County in the rapidly growing Portland metropolitan area, as well as the productive agricultural resource base in the County has precipitated a classic conflict between agricultural land uses and expanding suburban development. Between 1964-1972, the Census of Agriculture has recorded a 35, 628 acre decline in agricultural land in the County (U.S. Census of Agriculture, 1964 and 1972).

The unique locational situation and dynamic land conversion process in Washington County provide excellent opportunity to examine empirically the spatial pattern of farmland conversion and analyze how and why it takes the form it does. While recognizing the geographic limitations of this empirical research, the findings generated should provide valuable insight into the process of urban development and the forces and decisions which produce change.

Study Objective

The primary objective of this study is to analyze the degree to which the spatial patterns of agricultural land conversion are related to selected policy, social, and physical factors in Washington County, Oregon. In the context of this objective, the research will examine and test the reliability of several models designed to evaluate the relationship between land development factors and patterns of agricultural land conversion.

As a part of the research objective, differences in the effect of development factors on differing types of agricultural land are explored. Farmland conversion in areas with varying degrees of urbanization is examined in three separate regression models. Finally, data developed from empirically derived models are examined for applicability to land use planning methodology and policy.

Research Hypothesis

The research hypothesis of this study is that the distribution of agricultural land conversion is correlated with selected policy, social, and environmental variables. The hypothesis to be tested is stated as:

Ho: No significant relationship exists between the amount of agricultural land converted to more intensive uses and selected variables.

H_a: A significant relationship exists between the amount of agricultural land converted to more intensive uses and selected variables.

Expected Contributions of the Study

In an attempt to control agricultural land conversion, many state and local governments are exploring alternative techniques and management strategies for addressing the problem. Most state governments have attempted to ameliorate the problem by providing tax relief to agricultural land owners. One management option available to local governments is control of agricultural conversion through traditional planning techniques. Most states have empowered local units of governments to regulate land use through zoning, planning, subdivision regulation, sanitary codes, and official maps.

Despite the interest and efforts at controlling agricultural land conversion, however, a clear understanding of the forces operating and factors affecting farmland conversion patterns remains elusive. The current strategies for reducing farmland transition have emerged with minimal analysis of the conversion process.

The research and scope of this investigation were discussed with members of the Washington County Planning Department. The reaction of the Planning Department, as expressed by staff members, is one of enthusiastic support. According to county planners, this study complements an ongoing research effort by the Washington County Planning Department to comply with the Oregon Land Conservation and Development Commission's (LCDC) Planning Goals. As a part of their compliance to LCDC directives, the Planning Department is developing an Urban Growth Evaluation System, to control rural land conversion, modeled after the Ramapo methodology. It is the opinion of the staff that the identification of variables influencing land conversion will greatly assist in the establishment of their proposed Evaluation System. Beyond its applicability to Washington County planning efforts, the findings and conclusions of this investigation may have practical value to many local governments in the Willamette Valley and throughout the nation.

CHAPTER II

LITERATURE REVIEW

Any review of the published literature surrounding the land development process necessitates a broad inter-disciplinary search, including a survey of geography, land economics, planning, and sociological publications. Efforts to restrict one's focus to agricultural land conversion, however, meets with a dearth of published research. It would seem most investigations surrounding land conversion have prescriptively categorized nondeveloped lands on the urban fringe as "open space", "vacant land", or "idle land". Many times the type of land use prior to development is noted only in passing. It would appear that an *a priori* assumption of uniformity of all land converted to urban usage exists among researchers.

Owing to the lack of specific literature addressing farmland conversion, this chapter will focus primarily on published research concerned with development processes on the rural-urban fringe and in rural areas. Those studies which have specifically discussed agricultural land conversion will be so noted. The emphasis of this chapter will be a review of theoretical and empirical literature regarding the spatial pattern of land development and the influence of key variables on development patterns. The purpose of this review is to present research and outline material that will be incorporated in subsequent discussions.

Theoretical Literature

The classical economists have provided the foundation of most current land development theory. David Ricardo, the English economist, developed a general theory of agricultural rent, noting that the most fertile areas are put into use first with less fertile lands used as demand increases (Richardo, 1817). Richardo's work is considered by many as providing the groundwork for location theory. He recognized the concept of locational advantage and that the competition for the use of land would insure that full advantage go to the landlord in the form of rent. Ricardo also perceived that crops produced on land nearer to markets bear lower transportation costs than those produced on more distant land, and that this advantage accrues to the land owner in the form of rent as a result of competition.

Ricardo's concepts of location theory were refined further by the German, Johann Von Thunen. Von Thunen wrote that various agricultural land uses around a market place bid for the use of land, and that land is assigned to the highest rent bidder (Von Thunen, 1826). According to Von Thunen, the rent each crop can bid at any location will be determined by the savings in transportation of production that the site accords in contrast with more distant sites. Von Thunen's theory of economic rent is portrayed graphically by a series of concentric rings of agricultural land use surrounding an urban place. The innermost circle represents the highest or most intensively farmed zone. The outer circles receive lesser amounts of labor and transportation effort as the net returns will be lower. Von Thunen hypothesized that the rent at any location is equal to the net revenue or value of the product minus transportation costs. Von Thunen's approach has most recently been developed further by Dunn, Isard, and Alonso (Dunn, 1954; Isard, 1956; Alonso, 1965).

Sinclair, however, has suggested that owing to urban pressures not operating during Von Thunen's time, agricultural land patterns around urban places are reversed (Sinclair, 1967). Sinclair's theory relies on distance from the city as the primary determinant for agricultural land use. Simply stated, the relationship of his model is:

> As the urbanized area is approached from a distance, the degree of anticipation of urbanization increases. As this happens, the ratio of urban to rural land values increases. Hence, although the absolute value of the land increases, the relative value for agricultural utilization decreases. Consequently, the capital and labor investment in agriculture, i. e., the intensity of agricultural land use, decreases. The result of this process is a basic agricultural land use pattern which is the reverse of that found in Von Thunen's time (Sinclair, 1967, p. 78).

Beginning with formalized city planning in the 1920's, research surrounding urban land use increased. The principal tenets of this literature were developed by Robert Haig. Haig's hypothesis stated that rent was a charge which can be imposed on an accessible site because of the savings in transportation costs which useage of the site makes possible (Haig, 1926, p. 422). The especially innovative aspect of Haig's work was its strong support of the complementarity of rent and transportation costs. According to Haig, transportation is a device to overcome the "friction of space". The more accessible a location, the less friction. Thus, the user of a site pays the "cost of friction" transportation costs in rent, which is the savings in transport cost. Regarding the application of theory to the real world, Haig concluded, "...the layout of the metropolis... tends to be determined by a principle which may be termed the minimizing of the cost of friction" (Haig, 1926, p. 423).

Lowden Wingo has incorporated Haig's theoretical analysis with his own analysis of traffic flow into an explicit mathematical model of the residential land market (Wingo, 1961). In the Wingo model, transportation costs, including the value of commuting time in dollars, are determined by the marginal value of leisure time. Thus Wingo's research supports Haig's view of the complementarity of rent and transport costs in the urban environment, and parallels closely Von Thunen's agricultural model.

Alonso, however, challenges the premises upon which Haig's hypothesis is based. He charges that the logic of minimizing costs of friction is not valid in strictly economic terms and is faulty as a planning objective (Alonso, 1965, p. 105). Instead, Alonso proposes a general model of land rents based on the multiple regression equation

$$pg = a + by - ct$$

where

Pg is obtained by multiplying the quantity of land per family (g) by the price of land per square foot (p) for each census tract. Y is income, using the median family income in the census tract. T is distance, measured in straight line miles from a city center, and a, b, c, are estimated parameters (Alonso, 1965, p. 168).

The relationship tested, as indicated by the above equation, states that the expenditure for land by a family is determined by their income and their distance from the center of the city. A major advantage of this model, according to Alonso, is its simplicity and testability.

Beyond the analyses in economic literature, the issues surrounding urban land use and development patterns have been actively addressed in human ecology and geography. In 1925, Burgess developed his concentric zone model for urban land use. This model states that at any given point in time land use in a city is organized into zones differing in age and character and situated in a definite order from the city center (Burgess, 1925). Burgess' research was largely based on Chicago, with five zones identified for the city. The outermost zone in the concentric zone model contained satellite communities composed of people working in the central city. Although no explanations were presented by Burgess for this particular arrangement of land use, Berry (in Garrison, 1959) and Isard (1956) provide a partial understanding in terms of the substitution of rents for transportation costs.

An alternative land use model that incorporates accessiblity factors is Hoyt's sector theory. Hoyt theorized that urban growth follows along major arteries of transportation. Differences in accessibility between radials cause marked sectoral variation in land values and arrangement of land uses.

In most urban areas, land use patterns are not built around a single city center; rather they are developed around several discrete centers. In response to this pattern, the theory of multiple nucelii was developed by Harris and Ullman (1945). The number and location of the nucleii within the urban area vary with city size.

Perhaps one of the greatest contributions to land use theory has come from the German geographer, Walter Christaller.

Christaller's central place theory is a multivariable hypothesis concerning the spatial distribution of urban settlements (Christaller, 1966). Briefly, this theory states that there is a hierarchy of urban service centers which are evenly spaced, and that their neighborhoods are hexagonal in shape. Christaller's theory has been generalized by Losch to show that a complete economic landscape can be generated using the heirarchial concept (Losch, 1954). Losch postulates that a system of hexagonal central places and trade areas exists, which is characterized by six densely settled and six sparsely developed sectors radiating from the metropolis. Losch's asserts that those sectors most heavily settled coincide with minimized transportation costs and maximum local supplies of goods.

The theories of Christaller and Losch have primarily dealt with steady state equilibrium systems. Berry and Garrison, however, have shown these theories apply to the dynamic sequence of urban growth (Berry and Garrison, 1958). Their contribution has stimulated numerous empirical studies in this area. Among the more notable studies have been Knos' (1962) investigation of rental patterns in Topeka, Kansas; Marble's (1959) study of distance theory and rent; and Yates' (1965) and Bourne's (1976) analysis of land use change in Chicago and Toronto, respectively.

The Land Conversion Process

The process of urban physical growth and change is an extremely complex phenomenon involving constantly changing interrelationships among a great variety of interacting institutions and decision-makers, all in turn, continually subject to many conditions and forces. Our lack of knowledge concerning the land conversion process is reflected in the statement by Clawson, "... suburban land conversion is a field notably lacking in solid data of clear meaning" (Clawson, 1971, p. 3).

While this subject has been characterized as being "largely overlooked," there have been several important publications dealing with the subject. An especially innovative analysis of the land development process was undertaken by the Twin Cities Metropolitan Planning Commission in 1962. Their report, Selected Determinants of Residential Development, was focused on expansion of urban land use in the Minneapolis-St. Paul, Minnesota area and the factors and forces influencing this development. Despite its geographical restrictions, the findings of this study have had nationwide application among planning agencies.

Another empirical study with widespread following is Milgram's investigation in Philadelphia. Published in The City Expands, this research looked at the development of 5,200 acres of northeast

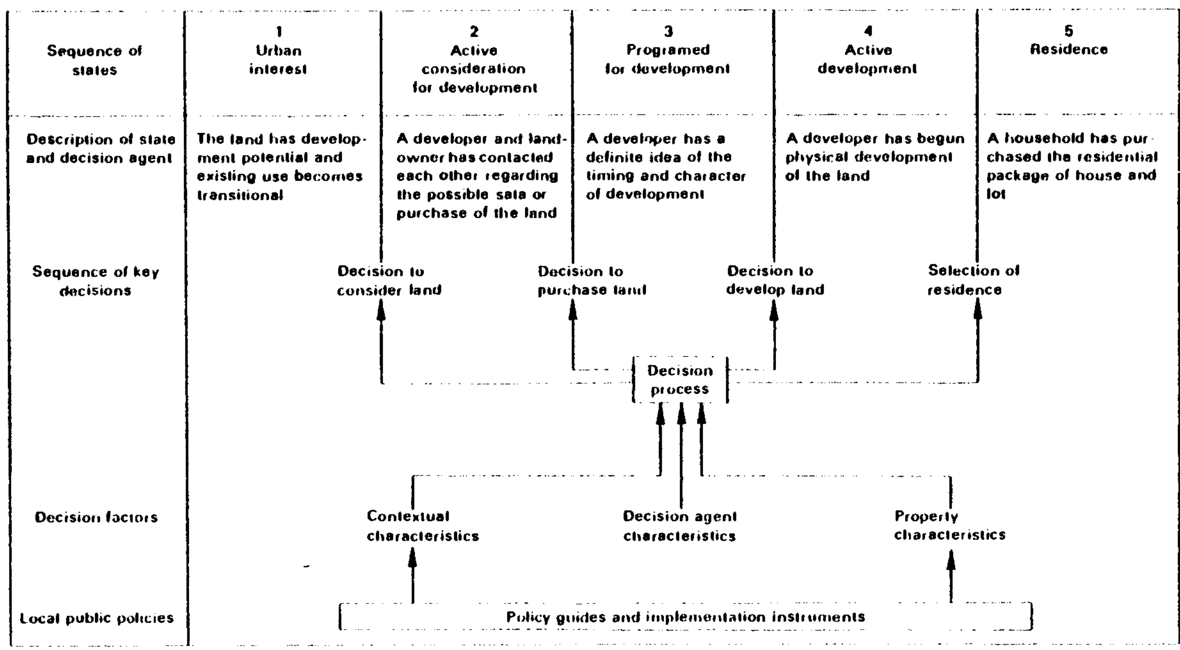
Philadelphia from 1945 through 1962 (Milgram, 1967). Over this 18 year period, more than three-fourths of the study area was converted to residential uses and land value increased by 13 fold. Factors identified as having influenced the conversion process included accessibility to the central city through roads, the intensity of accompanying uses, the availability of sewers, and location of parcels relative to the main roadways.

Beyond the individual authors noted above, the land development process is a research focus among investigators at the Center for Urban and Regional Studies, University of North Carolina - Chapel Hill. As an integral component of its research program, the Center has funded and published numerous investigations regarding the decision-making process for land development and modelling the urban growth process. Among the studies published have been Weiss's (1966) analysis of the residential development decision process, Kaiser's (1968) producer model for residential growth, and Kenny's (1972) analysis of the land developer's decision process.

Largely based on research conducted through the Center, a descriptive model of the land development process has been developed by Kaiser and Weiss. They have characterized the land transition process as a series of steps influenced by a complex set of decisions (see Figure 1). According to Kaiser and Weiss, the decision-making process is influenced by three types of decision factors: contextual,

Figure 1.

The Residential Land Conversion Process



Source: Kaiser and Weiss, 1970, p. 33.

decision agent, and property characteristics.

Contextual factors provide the macro-environment for development decisions; the broad areawide considerations which limit and determine the general type and amount of development. There are two types of contextual characteristics, socioeconomic and public policy. Examples of socioeconomic contextual factors include economic structure and growth prospects, competition in the construction industry, and the prevailing psychology of the period. The public policy context may include annexation powers; capital improvement and service policies affecting the quality, spatial pattern, and costs of transportation, water, sewerage, and schools; and subdivision regulations, land use policies and planning strategies for the area (Kaiser and Weiss, 1970).

Property characteristic factors provide an operational means to describe the land unit about which decisions are being made. Kaiser and Weiss identify three types of property characteristics: physical, locational, and institutional. Physical characteristics are those factors inherent in the resource, such as soil type and topography. Locational characteristics, on the other hand, are not inherent but rather derived solely from the relative location within the spatial pattern of urban activities. For example, accessibility measures are derived from locational characteristics. The third category, institutional characteristics, represents attributes that are applied to a site by societal actions. This might include the zoning or planning classification for the individual site. According to Kaiser and Weiss, property characteristics are the most important variable to a household in the decision-making process (Kaiser and Weiss, 1970, p. 33).

The final decision factor identified is decision agent characteristics. These characteristics reflect the attitudes and perceptions of the actors involved in the land development process. Participants included in this category are the individual landowner, the developer, and the individual household. Unlike contextual factors and property characteristics, decision agent characteristics are largely independent of influence by public policy. However, "they play a large role in determining the direction and strength of the impact of contextual and property characteristics, and hence of public policy" (Kaiser and Weiss, 1970, p. 34).

The dynamics of the land conversion process revolve around the key decisions, as influenced by decision factors. Mathematical notation states the process succinctly,

Land Development (changes in the state of land or decisions)
= fn (Contextual Factors, Property Characteristics,
Decision Agent Characteristics)

One can analyze the process through the investigation of the relationship between key decisions and the three sets of decision variables. Thus, the task of analysis becomes the specification of the relationships and interactions among the factors. In this way, one can approach the study of the uniformity and variation in the process both within and among metropolitan areas.

The Chapin-Weiss Model

The land conversion model reported by Kaiser and Weiss was developed from an earlier research project entitled the "Five Cities Land Development Study". This study, funded by the Center for Urban and Regional Studies and the U.S. government, was a pilot investigation by Stuart Chapin and Shirley Weiss for prediction of land development patterns by means of land use models. More particularly, this research investigated... "the spread and intensity to the pattern of land development in a cluster of cities, identifying the major factors that appear to influence the form of these patterns" (Chapin and Weiss, 1962, p. 426).

Viewing the land conversion process as the cumulative effect of a myriad of decisions and actions, Chapin and Weiss hypothesize that these actions can be characterized as either priming actions or secondary actions. Within the context of this classification, land development can be conceived of as a consequence of selecting priming actions which precondition and establish a broad framework for a mass of secondary actions that follow and make up the bulk of the pattern observed.

Priming actions are characterized as "triggering" mechanisms which may have a structural effect (i.e. impacting the distribution of land development) or a timing effect (i.e. fixing the sequence of development) on the conversion of "vacant" land. Priming actions may develop out of both private and public decision-making. For example, an industrial location decision may generate a chain of decisions or actions by other businesses and government. Alternatively, a highway location decision can serve to prime numerous governmental and private actions to accommodate the generated impacts.

Secondary actions are more numerous and more complex to trace and examine with regard to the land conversion process. Operating within the framework of the priming actions, secondary factors reflect behavioral and environmental constraints and opportunities for land use. Aggregated, the effects of secondary actions may account for the bulk of land conversion patterns, with location and intensity of the pattern preempted by priming variables.

With respect to spatial location, the separate influences of priming and secondary actions may complement each other in some areas undergoing land conversion and be in opposition in other areas.

Moreover, if the effect of location decisions were considered for each point in space, the problem would have no limits. Fortunately, the locations where the effect of such decisions might be investigated can be narrowed.

By observing the impact of priming and secondary factors in selected areas undergoing development, "...especially locations which exert a structuring effect on land development and control", sufficient evidence may be provided to determine cause and effect relationships in the land conversion process (Chapin and Weiss, 1962, p. 430-431). The Chapin-Weiss model places a premium on identifying and studying how and why priming actions occur. Their rationale is that, if the structuring actions of land development can be isolated and a relationship perceived regarding the direction and intensity at which development later proceeds; it may be possible to achieve a significant working knowledge of the impact of all factors (priming and secondary) without identifying all of them, even if that were possible.

The Chapin-Weiss model was tested in a 103 square mile area in North Carolina, containing five cities, with a combined population of one half million. Multiple regression analysis was employed as the modelling technique. After testing several mixes of independent variables, Chapin and Weiss arrived at a final model consisting of fourteen "priming variables" (see Table 2). These factors were

Table 2. Relative Influence of Selected Variables in Explaining Land in Urban Use Greensboro, Winston-Salem, and Lexington, North Carolina.

Independent Variables	Greensboro 1960 "t" values	Winston-Salem 1960 "t" values	Lexington 1960 "t" values
Marginal land not in urban use	-15.30	-1.63	-9.45
Travel distance to nearest major street	-10.06	1.92	XXX
Availability of sewerage	5.09	15.03	-1.01
Distance to nearest available elementary school	-8.40	-5.37	.57
Zoning protection	7.02	5.99	5.09
Assessed value	9.47	XXX	XXX
Accessibility to work areas	1.56	-2.85	1.51
Proximity to nonwhite areas	2.06	1.31	- .46
Proximity to blighted areas	.30	1.91	8.00
Total travel distance to high value corner	2.84	-7.30	-8.76
Proximity to mixed uses	23.49	15.70	22.27
Distance to nearest playground or recreation area	-7.07	2.33	XXX
Distance to nearest convenience shopping area	-4.40	-1.77	XXX
Residential amenity	11.67	XXX	XXX
Multiple Regression Coefficient (R^2)	.667	.503	.801

XXX-Variable not included in the model.

Source: Chapin and Weiss, 1962a.

then analyzed against the observed pattern of land conversion in three urban centers, Greensboro, Winston-Salem, and Lexington.

As one might expect, there was a variation in explanation among the three study areas, ranging from 80.1 percent explanation in Lexington to 50.3 percent in Winston-Salem. However, the summary data depicted in Table 2 shows that the model has highly significant explanation power.

The findings generated in the North Carolina tests suggest the Chapin-Weiss model could have applicability for analyzing the land conversion process in other areas. The multiple regression model provides a suitable framework for testing various combinations of variables and sifting out strong influence factors. In discussing the potential value of their model, Chapin and Weiss stated, "the present form of the model...enable(s) the user to make comparative studies of the generalized pattern of residential development which reasonably could be expected...with respect to various priming actions" (Chapin and Weiss, 1962a, p. 33).

Other Empirical Studies

Research regarding the impact of priming and secondary factors on the land conversion process has been largely ignored until recently. As a study by the President's Council On Environmental Quality noted, the link between priming actions and land use change "has long been recognized in a general way" but the implications have not been analyzed (Council On Environmental Quality, 1976, p. 5). The concluding portion of this chapter will introduce and discuss research efforts which have examined the linkage between individual or sets of priming actions on land conversion.

Certainly the most widely examined type of priming actions are increased accessibility as generated by highway construction or improvement. A number of researchers have analyzed empirically the effect of highways on land use with almost unanimous findings. Highways have been shown to be a significant factor in land conversion.

Highways promote the conversion of agricultural and "vacant" land to commercial and industrial uses. Case studies by Wilbur Smith and Associates (1968) in Maryland, McKain (1965) in Connecticut, Adkins (1959) on urban fringe areas in Texas, Cribbins et al. (1965) in North Carolina, and Philbrick (1961) in Michigan show that increased accessibility provided by highways introduces pressures for commercial development of land. According to several researchers, commercial land use changes are most rapid and most intensive around road intersections and interchanges (Connally, 1968; University of Kentucky, 1960; Lemly, 1959). Moreover, Stein (1969) reports that industry, commerce, and high density residential users appear much more frequently than highway related businesses at interchanges along circumferential highways.

The relationship between residential land use and highway development is not as direct as with commercial land use. Several researchers have suggested that low density, single family development is often independent of highway priming action, with policy factors the predominate influence (Philbrick, 1961; Adkins, 1959; Cribbins et al., 1965). However, research by Carroll et al. (1958), University of Kentucky (1960), and Environmental Impact Center Inc. (1975) suggests that highways promote low density residential uses at the expense of farmland at the urban fringe. Carroll's study in the Minneapolis area found that the land use impacts of highways were most pronounced on agricultural land, with later more intensive land use changes occurring independently of highway improvements. High density residential development appears to be promoted by highways, especially at or near interchanges (Connelly, 1968). Connelly particularly noted the development of multi-family apartments on former agricultural land along circumferential highways.

As one might expect, the value of land adjacent to new or improved highways increases substantially. An increase in value from 100 to 400 percent over control areas in a ten year period is typical. Land value increases most substantially in farmland converted to commercial use (Wilbur Smith and Associates, 1968).

Mass transit affects urban activities through the same mechanism as highways--accessibility. However, the differences between cars and mass transit modes of travel have inherently different effects on land conversion. Those studies that are available indicate no evidence of mass transit stimulating land conversion (Gannon et al., 1972; Heenan, 1968).

Until quite recently, the influence of water and sewer facilities on urban land conversion land use patterns has received little attention. The impact of water lines and sewerage treatment facilities and trunk sewers on patterns of development was all but ignored. An extensive search of recent literature identified only a few empirical studies. Those studies which are available would support the hypothesis that sewer investments can be a principal determinant to land conversion in metropolitan areas today (Environmental Impact Center, Inc., 1975).

A main conclusion of Milgram's 1967 study of Philadelphia was that the lack of sewers acts as a negative constraint on development. Stansbury's (1972) study of Fairfax County, Virginia makes a strong case for sewer lines as a major factor in land conversion. In his study, Stansbury documents the rapid expansion of interceptor sewers into agricultural lands with resultant noncontiguous urban sprawl. By far the most comprehensive analysis of water and sewer facilities impact on land use is the study conducted by the Metropolitan Council of Governments (Washington, D. C.). This investigation, Analysis of the Joint Interactions of Water Supply, Public Policy, and Land Development Patterns in an Expanding Metropolitan Area (1973), quantitatively examined relations between sewer and water extensions and population growth in the Washington metropolitan area. Statistical analysis showed that the amount of farmland converted to residential use was highly correlated with straight distance to sewerage trunk lines (Metropolitan Council of Governments, 1973).

CHAPTER III

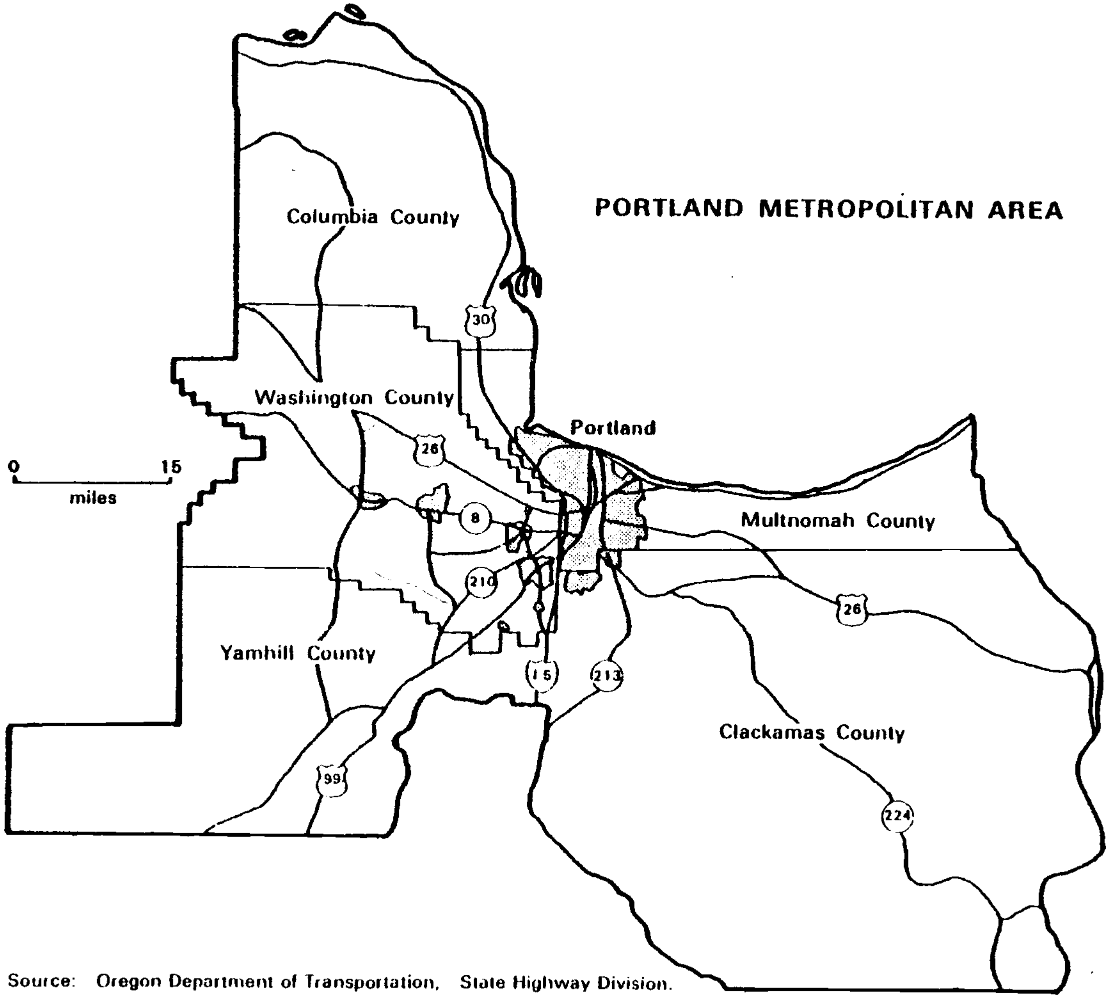
THE STUDY AREA: WASHINGTON COUNTY

Washington County Oregon is located in the northwestern part of the state, on the western edge of the Portland urban area (see Figure 2). One of the smaller counties in Oregon, it covers an area of 731 square miles or 467,840 acres. The Washington County landscape is characterized by gently rolling hills, flat lowlands, and flood plains, surrounded by low mountains. The mountainous areas rimming the county form the Tualatin drainage system and the Tualatin Valley.

The Tualatin Valley dominates the eastern and central quadrants of the county. It occupies one-fourth of the total county area. The elevation of the Valley ranges from 140 to approximately 275 feet above sea level. The broad valley slopes gently from the surrounding foothills to the meandering Tualatin River, which drains it and passes out of the County near the southeastern corner.

The Tualatin Valley lies encircled by the Coast Range and two low ranges, spurs of the Coast Range (Watson *et al.*, 1923). To the west, the main Coast Range forms the County's western boundary and is the source of the Tualatin River. Elevations average between 1,000 and 2,000 feet, with a few peaks that rise to 2,600 feet above sea level. The northwestern edge of the Valley is blocked by a long spur of the Coast Range which borders the Columbia River on the

Figure 2.



Source: Oregon Department of Transportation, State Highway Division.

south bank and extends to Portland. This spur, the Tualatin Hills, has elevations ranging from 800 to 1400 feet above sea level. The southern end of the Valley is bounded by the other spur, the Chehalem Mountains. The Chehalem Mountains also have elevations averaging from 800 to 1400 feet. The mountainous sections of the County are very similiar in character. The slopes are smooth and rounded, and only moderately steep in higher areas. The crests of the hills have gentle slopes or are rounded. A few of the mountains are stony, but usually the rocks are very weathered and a deep mantle of soil covers the mountains (Watson et al., 1923, p. 6).

Soils in Washington County have developed in response to topographic related variables, former vegetation, and climatic factors, especially the high seasonal fainfall (Watson et al., 1923, p. 16). The most recent soil reconnaissance indicates six general soil groups in Washington County. Those soils which have developed along watercourses in the Tualatin Valley are characterized as soils derived from recent alluvium. Included in this category are the Camas-Chehalis-Wapato group, Newberg, Cloquato, Maytown, Reed, Cove, and Tangent series.

A second category is soils derived from silty material on terraces. These soils are formed on the higher terraces adjacent to alluvial soils. Comprising this group are Hillsboro, Willamette, Woodburn, Amity, and Dayton soils. Soils derived from loess on terraces are the third group. This grouping of soils has the same situational location as the terrace soils discussed earlier; however, the parent material is loessial (i.e. wind deposited) and was laid down by aeolian action. Examples of this category include the Cornelius, Quatama, Helvetia, Aloha, and Huber series.

Loessial soils on uplands are the fourth category of soils. These soils were derived from glacial outwash plains and are found in depths to 100 feet in the Tualatin Hills and Chehalem Mountains. Soil types include Laurelwood, Kinton, Cascade, and Delena series. The fifth grouping are soils developed from igneous materials. This categorization is limited to higher areas in the Coast Range. Estacada, Nekia, McCully, Olympic, Viola, and Kinney series are soils of this type in Washington County. The final general soil group is soils formed from sedimentary rocks. These types of soils are also limited to the Coast Range and are formed from weathered marine micaceous and tuffaceous sandstone, siltstone, and shale. Soil series in this category are Willakensie, Peavine, Melbourne, Dupee, and Panther.

The generally favorable climatic conditions and rich soil resource base have facilitated agricultural development in the County. Historically, since 1834 the Tualatin Valley and Washington County has been one of the major agricultural areas in Western Oregon (Watson *et al.*, 1923, p. 6). The County has been sheltered from the urbanizing influence of Portland by the Tualatin Hills. The Hills posed a natural barrier to the low cost extension of municipal services into the Tualatin Valley. However, highway improvements in the 1950's and increasing development pressures from Portland have negated the barrier effect of the Hills. In assessing the current and future land use situation in the County, a Washington County planning report of 1965 stated, "...Washington County, traditionally agricultural, is undergoing a transformation toward more urban development and represents perhaps one of the largest and most promising residential and industrial areas within the Portland metropolitan region" (City-County Joint Planning Department, 1965, p. A-1).

Population

During the period from 1960 to 1970 Washington County experienced the sharpest population change in Oregon. During this period when the statewide growth rate was 18 percent, the County grew from 92,000 to 158,000 persons, an increase of 71.7 percent in ten years (Washington County Planning Department, 1973, p. 11). The magnitude of the population increase surprised even the most liberal demographers. For example, the 1962 Metropolitan Planning Commission's Population Prospects forecast that Washington County would have the highest population growth rate in the four county Portland metropolitan area over the next fifteen years. They projected, however, a 44 percent increase to 133,018 by 1970.

A rapidly expanding population is not a new phenomena to Washington County. During the past thirty-five years the County's annual growth rate has averaged 5.27 percent. Historically, from 1910 through 1940, Washington County maintained a relatively constant growth rate, increasing in population an average of 2 percent per year. Population increased from 21,522 to 39,194. Starting around 1940, however, the urban growth of Portland began to spread into the eastern portion of the County. Accordingly, the annual growth rate jumped to 4.6 percent, and the population climbed to 61,500 persons (56.9 percent) between 1940 and 1950 (City-County Planning Department, 1965, p. B-2). During the 27 year period since 1950, urban pressures and expansion have accelerated as has population growth in the County.

A primary factor in the recent rapid growth of Washington County has been the emergence of a new regional demographic trend in the Portland metropolitan area. Over the past 15 years population in the Portland area has been undergoing a shift from the central city (Portland) to suburban areas. Census data indicates that Portland experienced a 3 percent growth rate from 1960 to 1970, whereas incorporated suburban areas grew by 54 percent and rural areas by 35 percent during the same period (Washington County Planning Department, 1973, p. 12). This disparity in growth rates resulted in a decline in the percentage of metropolitan population residing in Portland from 45.5 percent in 1960 to 37.8 percent in 1970. During this same period Washington County's portion of the metropolitan population increased from 11.2 to 15.6 percent (Washington County Planning Department, 1973, p. 12).

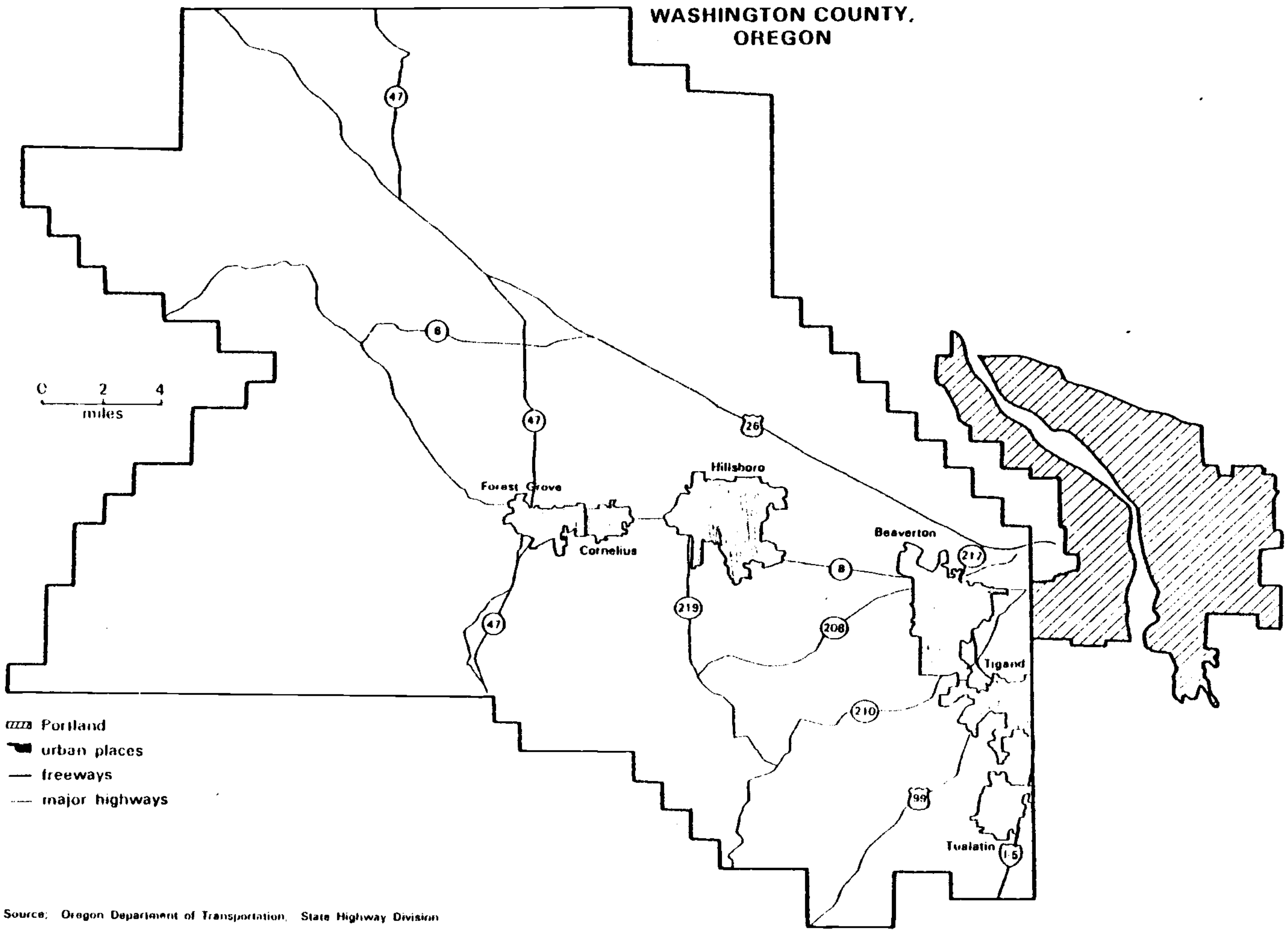
Land Development and Its Impact

The lure of relatively inexpensive land, lower taxes, and a pristine rural environment have produced massive, low density land development in Washington County in the past 25 years (see Figure 3). A summary report of the Washington County Planning Department, for the period 1960 through 1965, in describing the land conversion situation, noted:

> ...the largest home building growth activity in the State of Oregon accompanied by the fastest population growth in the Portland metropolitan area is occurring...the subdivision of heretofore open lands has been taking place at an average annual rate of .72 square miles (Washington County Planning Department, 1965, p. 16).

Most observers would agree that the overall impact of urban development on Washington County has not improved the quality of life. Urban sprawl, particularly low density residential development, has been the dominant development trend in the county. Residential densities are extremely low, varying between 3.3 and 6.1 persons per acre in most of Washington County (City-County Joint Planning

Figure 3.



Source: Oregon Department of Transportation, State Highway Division

Department, 1965, p. S-1). In describing the character and pattern of development in Washington County, one planning study noted:

> But much of the urban development of the county has taken place on a spotty, or intermittantand dispersed basis, suggesting that extensive amounts of vacant land are being held out of use for speculative purposes. This kind of development tends to be a burden on public services: water and sewage facilities, schools, fire and police protection ...all of the public services that provide the structure for urban living must be spread over a larger area, and cannot be operated as efficiently or as economically as the more uniformly developed areas (City-County Joint Planning Department, 1965, p. S-1).

As the Council on Environmental Quality has noted, sprawl is the most expensive form of development in terms of economic, environmental, and personal cost (Council on Environmental Quality, 1974, p. 7). The impact of sprawl in Washington County has not been atypical. Rapid low density development has strained water and sewerage facilities in the county. Prior to 1972, water and sewerage treatment was "balkenized" with 60 different cities and special districts administering a proliferation of small systems. A 1969 engineering study noted that a seasonal shortage of domestic water existed in the central Tualatin Valley (i.e. Hillsboro, Forest Grove, Cornelius, and Banks). According to this report, the water situation varied "...from apprehensive to critical depending on the weather" (Stevens, Thompson, and Runyan, Inc., 1969, p. 2).

Beyond the problem of providing adequate potable water supplies, rapid growth rates in the county created an even more alarming problem: inadequate sewerage treatment facilities. As the population expanded, the county's response to increasing sewerage disposal requirements was the construction of sewers and sewerage treatment plants with effluent discharge into streams which are practically dry in the summer. Moreover, during the winter months high infiltration into sewerage collection systems caused excessively high flows at treatment plants resulting in the discharge of inadequately treated sewage into streams.

The seriousness of the problem related to inadequacies in treatment facilities in Washington County was demonstrated in an action taken by the Oregon State Sanitary Authority in September 1966. Owing to the increasing deterioration of water quality in the Tualatin River caused by waste discharges, the Authority adopted the following policy regarding waste treatment in the Tualatin Basin:

1. That until a master plan of sewerage is developed and adopted, no new sewerage or waste facilities and no expansion of existing facilities other than those previously committed be approved for construction in the Tualatin Basin unless provisions are included to prevent discharge of the effluent to the Tualatin River or its tributaries during the low-flow season--normally June 1 to November 1--and

2. Those in charge of existing facilities located on tributaries of the Tualatin River be instructed to start immediately to comply through improved operation and/or upgrading of treatment facilities with the Sanitary Authority policy directive adopted June 24, 1965, namely, to maintain plant effluents within the limits of

> 20 parts per million BOD and suspended solids and to achieve proper disinfection before said effleunts are released to the receiving stream (Stevens, Thompson, and Runyan, Inc., 1969, p. 22).

A number of other deleterious impacts have resulted from the inefficient development patterns which characterize the County. These include higher costs for infrastructural improvements (e.g. roadway construction and maintenance) and public facilities (e.g. physical facilities for schools). As one might expect, one sector of Washington County which has suffered most extensively from sprawled urban development is the agricultural community.

Agriculture in Washington County

Historically, agriculture and agricultural related industrial activities have been the most important economic activity in Washington County. The land development process, however, has generated a number of direct and indirect spillover effects threatening agriculture. Non-contiguous urban development requires large amounts of farmland, and simultaneously surrounds operating farm units. Police powers used to protect suburban residents from noxious conditions restrict routine farming activities. Speculation discourages farm consolidation and encourages farm abandonment. As the number of farmers declines, agricultural infrastructure declines as well.

As recently as 1954, over 50 percent of Washington County was classified as land in farms. However, in the past 23 years agricultural land use has declined. As land development has increased in Washington County, lower value agricultural land uses have been converted to urban uses. As depicted in Table 3, the total acreage in farmland has decreased by 64 percent from 1954-1974. During the ten year period analyzed by this study, the decline has been approximately 19 percent. This decrease in agricultural land does not compare favorably with the state trend, as data for the same period shows a decrease of 11 percent for Oregon.

While the decline is symptomatic of agricultural land conversion, there is also an apparent consolidation of smaller farms into larger more efficient enterprises. The average Washington County farm has increased in size from 81.2 acres in 1964 to 98 acres in 1974. Indicative of farm enlargement is the changing composition of farm size in Washington County. The Census of Agriculture notes that in 1964, 711 farm units were under 10 acres in size; however, by 1974 small farms in this category had dropped by over 80 percent to 232 units. Conversely, the number of farm operations with over 500 acres increased from 11 to 67 during the same period. As one might expect, the average value of farms has increased dramatically from $48,377 to $128,661 in the ten year period from 1963 to 1973.

Beyond farm enlargement, another trend apparent from the Census of Agriculture is a shift in agricultural products raised. An

Table 3. Farms, Land in Farms, and Land Use: 1954 to 1974.

	1974	1969	1964	1959	1954
OREGON					
Land in Farms	18, 241, 445	18, 017, 850	20, 509, 500	21, 236, 298	21, 047, 340
Total Number of Farms	26, 753	29, 063	39, 757	42, 573	54, 441
Proportion of Total					
Land in Farms	29.6	29.3	33.3	34.5	34.1
Average Farm Size	682	620	516	499	387
Cropland Harvested	3, 213, 399	2, 893, 632	3, 050, 250	3, 118, 451	3, 265, 385
WASHINGTON COUNTY					
Land in Farms	161, 050	172, 055	200, 345	211, 108	458, 240
Total Number of Farms	1, 649	1, 976	2, 468	2, 785	3, 676
Proportion of Total					
Land in Farms	35.1	37.5	43.7	46.0	51.5
Average Farm Size	98.0	87.0	81.2	75.8	64.3
Cropland Harvested	98, 908	92, 525	99, 313	105, 767	112, 902

Source: U. S. Census of Agriculture

examination of the "value of products sold" reveals a shift in the composition of agricultural products marketed. In the 1964 census, the income from all crops sold comprised 62.3 percent of the total value of products marketed, while livestock and livestock products accounted for 36 percent. By 1974, however, the percentages had changed to 77 percent from crops and 22 percent for livestock. During this same period forest products dropped slightly from 1.7 to 1.0 percent.

This change of fourteen percent would seem to infer that agriculturalists in Washington County are shifting their land utilization patterns toward raising crops rather than livestock husbandry. This supposition is affirmed in the limited 1974 Census data. While acreage dropped for most commodities between 1964 and 1974, as one would expect with a 35,000 acre decline in farmland during the period, the numbers of cattle, hogs and pigs, sheep and lambs, and chickens and hens declined even more sharply. Especially hard hit were the numbers of chickens, and hens and pullets of laying age. In these two categories there was a decrease from 274,365 animals to 12,738 (95 percent decline) and 237,137 animals to 12,106 (95 percent decline) respectively. The only exception to the overall decline among the number of livestock raised was an 8 percent increase in dairy herds.

Increases in acreage during the 10 year period were limited to vegetables, sweet corn, and melons. The land devoted to raising these crops for sale increased by 71 percent, from 2,232 acres in 1964 to 3,827 in 1974. Conversely, the amounts of farmland devoted to grains and silage declined. But decreases were not as dramatic as the drop in livestock. These limited data would seem to support the hypothesis that agriculture in Washington County is shifting to more intensive cropping patterns and abandoning those agricultural activities requiring more extensive holding or with higher "nuisance" potential.

Despite the decreasing acreage devoted to farmland, agriculture remains an important part of the county's economy. Between 1964-1974, the value of agricultural products sold by County farms increased from $19,721,376 to $41,598,000. The estimated finished product value of Washington County agriculture in 1974 was $100,000,000 (Washington County Planning Department, 1973, p. 39).

Despite the encouraging economic indicators, agriculture in Washington County should not be perceived as totally immune to the effects of land conversion. The continued loss of extensive amounts of farmland place even greater pressures on the resource base. If population increases and development pressures continue at the same levels, the future of the agricultural economy in Washington County will be questionable.

CHAPTER IV

HYPOTHESIS AND MODEL FORMULATION

The purpose of this chapter is to describe the theoretical basis, methodology, and research procedures of this investigation. Accordingly, the chapter will cover variable identification and selection, methods of data acquisition, and model development. In the interest of facilitating review of the study and its findings, selected issues (i.e. derivation and definition of study variables and data sources) are briefly addressed in this chapter, with more comprehensive documentation and discussion in the Appendices.

Theoretical Framework

The transformation of the rural landscape as a result of the effects of urbanization has come to be regarded by many Americans as a "normal" part of land use decision-making. To the casual observer, the process of farmland conversion is a simple sequence from the initial state of urban interest to the final state of developed use. The intermediate period is generally conceived of as a series of decisions among land owners, developer-entrepreneurs, and land buyers, all operating solely within the constructs of profit and loss goals.

Previous research, however, has demonstrated that total reliance on criteria used in land market models to explain land conversion is incomplete. This is to say, the land conversion process is affected by a number of social, governmental policy, physical, and economic factors. Social and physical conditions provide a matrix in which farmland conversion occurs. For example, soil conditions may make physical development costs prohibitive precluding land development in one area, while contiguous upper income housing may spur demand for development of nearby agricultural areas. Similarly, it is possible for public policy decisions to redirect demands toward formerly "un-economical" parcels. For example, the construction of high capacity arterials and freeways, the development of public recreation facilities, or the "up-zoning" of land parcels can be stimulants to development of nearby agricultural land. Conversely, government can effectively restrict urban development in other areas through the establishment of special zoning categories, such as exclusive agricultural use zones or conservation/preservation districts, by the declaration of a building permit moratorium, or through restrictions on connections to public sewer and water systems.

On the basis of previous research discussed in Chapter II, especially the work developed at the Center for Urban and Regional Studies, University of North Carolina, a descriptive model of agricultural land conversion is hypothesized. The formulated model theorizes that the conversion of agricultural land is influenced by the

the site and situational characteristics surrounding individual parcels.

Within the context of this study, site characteristics include physical or human attributes which apply to a parcel of land. These characteristics focus on the unique character of any given point in space. Site characteristics may be inherent in the land, such as topography and soil type, or they may be determined by society, as in the case of zoning or accessibility. Four broad categories of site characteristics are hypothesized to influence decisions: accessibility characteristics, infrastructural-policy characteristics, social characteristics, and environmental characteristics.

Several earlier researchers have suggested the land conversion decision-making process is influenced by a larger set of factors: contextual factors (i. e. market conditions), participant characteristics (i. e. seller-buyer characteristics), and site characteristics. However, research by Kaiser (1968) and Kenny (1972) which utilized this three factor model found that site characteristics were the most critical set of variables impacting the land development process. Drawing on the conclusions of Kaiser and Kenny, the model developed and examined in this investigation focused on importance of site characteristics. The inclusion of nonsite variables in data modeling and analysis was not within the scope of this study.

The investigation reported here was designed to explore the importance of selected site characteristics on the magnitude of agricultural land conversion in Washington County, Oregon. It was the hypothesis of this investigation that site characteristics are primary factors influencing the pattern and magnitude of agricultural land conversion. Consequently, the study analyses focus on the relationship between the location and amount of farmland converted to urban uses and selected site characteristics, including policy, social, assessibility, and environmental variables. Beyond the analysis of conversion magnitude, the research design permits inference regarding the spatial distribution of converted farmland in urban, rural, and urban-rural fringe areas of the county.

The Functional Model

The model developed and tested in this study is similar in methodology to earlier studies which have been concerned with conversion of "vacant" land and the estimation of factors affecting land values. However, one significant difference from earlier research is the larger number of variables included in the scope of analysis. With minor exceptions, previous studies have tended to focus attention on the role of accessibility, social amenity variables or economic criteria in influencing land conversion. Most studies have not considered infrastructural improvements, planning policy, or environmental factors.

In line with the earlier descriptive model, a statistical model was formulated to analyse the influence of site characteristics on farmland conversion. The model postulates that the distribution of farmland converted to urban uses is a function of four types of site characteristics: accessibility, intrastructural-policy, social, and environmental factors. The following equation depicts the theory behind the model:

$$_i = f\,(A_i,\ I_i,\ S_i,\ E_i)$$

where $_i$ = farmland converted at any particular site

A_i = accessibility

I_i = governmental infrastructure and policy

S_i = social desirability

E_i = environment

Variable Selection

In accordance with the research objective, a number of site related variables were identified and examined with regard to their impact on land conversion. Ideally, all possible site characteristics which influence the transformation of agricultural land should be introduced into the research; however, total inclusion would be nearly impossible. Moreover, data requirements for regression modeling would preclude the inclusion of some of the possible factors.

Consequently, the approach for selecting variables was to review the findings of previous investigations and examine variable requirements in terms of the study hypothesis.

A final criterion which restricted the number of variables examined was data availability. Owing to the nature of the research problem and the time period used in the study (i.e. 1963-1973) appropriate data for some variables were unavailable.

Dependent Variable

The dependent variable examined in data analyses was units of agricultural lands converted to urban land uses in Washington County between 1963-1973. The study identified 456 parcels which represented a transformation of 10,433.5 acres of agricultural land. Each observation was a contiguous unit of farmland which was physically developed to a non-agricultural use during the study period. Parcel ownership was not considered except for verification purposes. The methodology used for determining the dependent variable is similar to procedures used by Carroll *et al.* (1958), Environmental Impact Center Inc. (1975), and others in previous research.

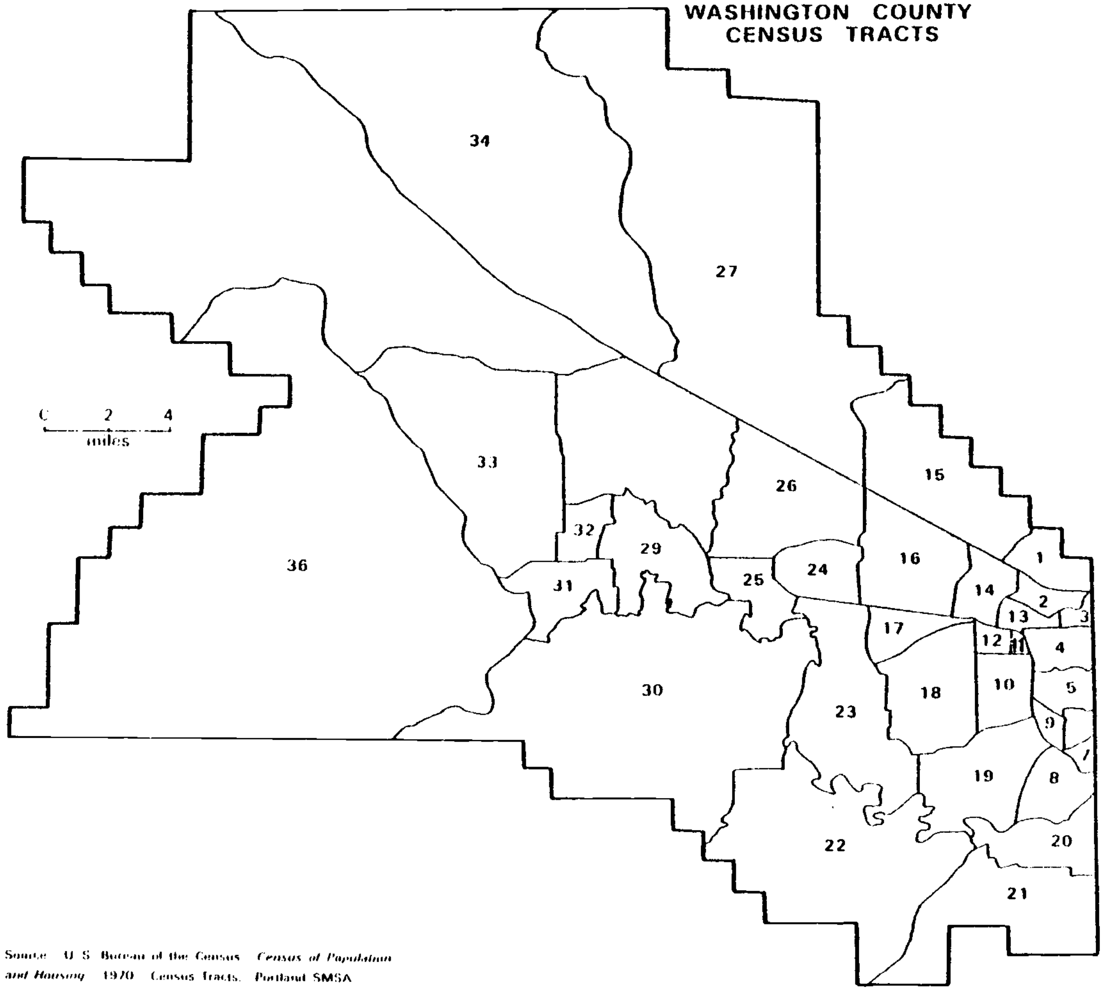
The dependent variable (Y) depicts the scale of agricultural land conversion as measured for each observational unit. The Y variable as used in this analysis does not represent an aggregate spatial value. Rather, the regression analyses present the statistical relationship between the entire set of land conversion observations and the set of independent variables. What is portrayed in the regression model is, however, any tendency of the Y variable to vary with the independent variables in a systematic fashion. Hence, the investigator is able to observe the set of land conversion activity and draw inference with respect to the spatial pattern of conversion as measured against the independent variables included in the model. In this way, the Y variable serves to suggest the overall spatial behavior of land conversion in Washington County.

Among the observational units, three subsamples were identified: (1) urban Washington County, (2) Washington County rural-urban fringe, and (3) rural Washington County. This grouping of dependent variables permitted regression models to be developed for each subunit so that those factors influencing agricultural land use changes were examined for the entire county (Y_1) and for areas with varying degrees of urban pressure.

The subsamples were identified utilizing Federal and local government reports. Urban Washington County (Y_2) was defined as Census Tracts 1-14, excluding Census Tract 8, by the U.S. Bureau of Census. The Census Bureau classification was adopted by this investigation (see Figure 4).

The rural-urban fringe (Y_3) was defined as Census Tracts 1, 8,

Figure 4.



Source: U.S. Bureau of the Census, *Census of Population and Housing*, 1970, Census Tracts, Portland SMSA

10, 14, 15, 16, 17, 18, 19, 24, 25, 26, 29, 31, and 32. Rural Washington County (Y_4) is comprised of Census Tracts 20, 21, 22, 23, 27, 28, 30, 33, 34, 35, and 36. The designation of both of these subsamples was developed following discussions with staff members of the Washington County Planning Department and examination of the Washington County Framework Plan (1973).

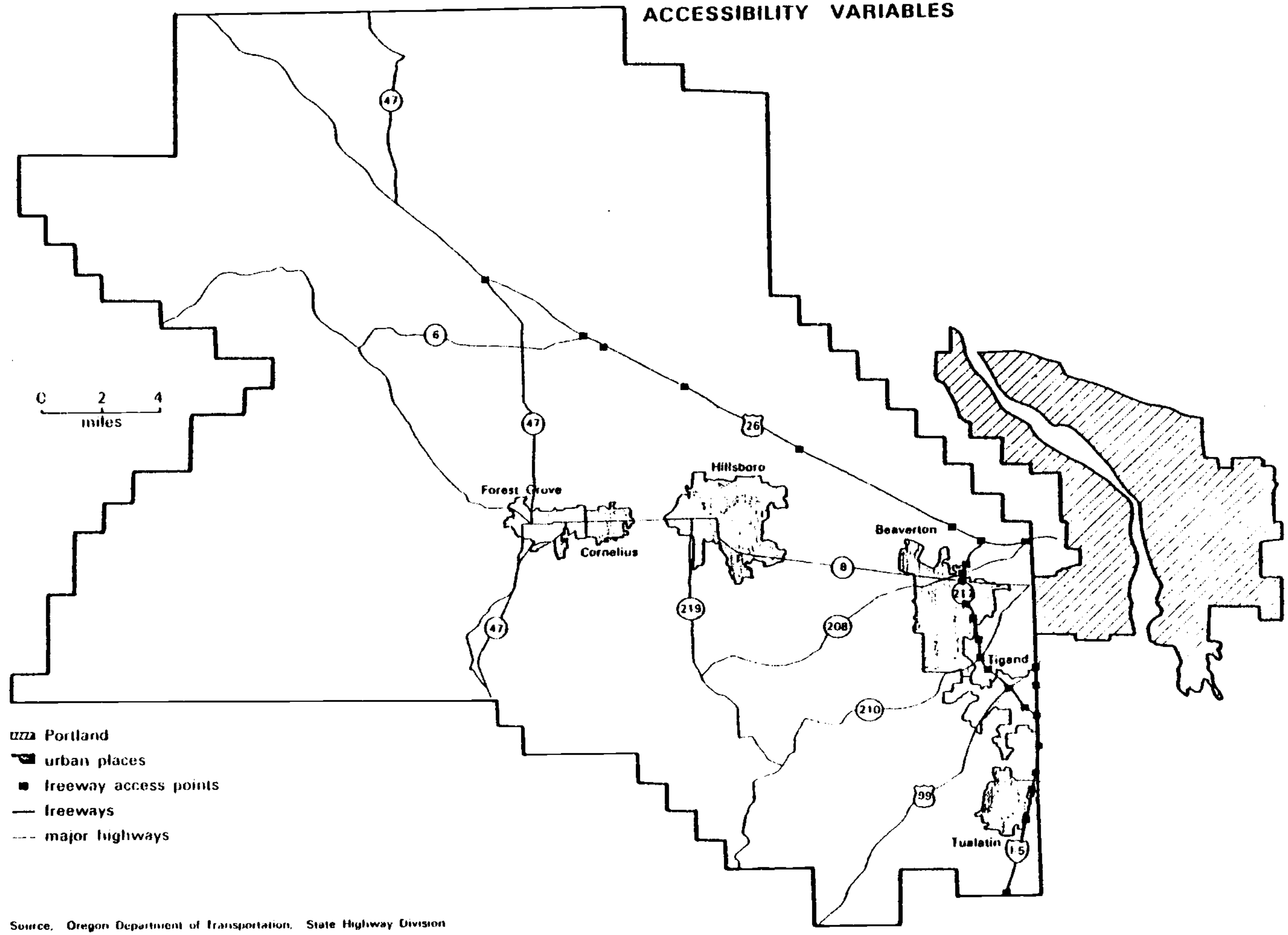
Independent Variables

Twenty-three site characteristics were identified and used as predictor or independent variables. It was hypothesized that these variables influenced the conversion of farmland in Washington County. Variables were clustered into four groupings based on whether they were accessibility factors, infrastructural factors, social factors, or environmental factors (see Table 4). This grouping procedure permitted regression analyses of the individual components of the agricultural land conversion model, as well as the full model. The following four sections provide a brief description of each variable and a statement of hypothesis.

Accessibility Variables

Location theorists generally consider accessibility to be a major factor in the areal distribution of land use. Isard states that two of the major factors which determine land use in an urbanizing area are:

Figure 5.



ACCESSIBILITY VARIABLES
0 2 4
miles
Forest Grove
Cornelius
Hillsboro
Beaverton
Tigard
Tualatin
47
6
26
8
219
208
210
217
99
5
Portland
urban places
freeway access points
freeways
major highways
Source, Oregon Department of Transportation, State Highway Division

Table 4. Independent Variables for Washington County Agricultural Land Conversion Model.

	Site Characteristics
	Accessibility Factors
X_1	distance to the Portland city center
X_2	distance to the nearest urban place
X_3	distance to the nearest freeway access point
	Infrastructural-Policy Factors
X_4	distance to the nearest sewerage trunk line
X_5	distance to the nearest water line
X_6	distance to the nearest developed area
X_7	distance to the nearest elementary school
X_8	planning and zoning designation
	Social Factors
X_9	median family income
X_{10}	median value of housing stock
X_{11}	amount of substandard housing
X_{12}	median education
X_{13}	population change
X_{14}	elevation
	Environmental Factors
X_{15}	soil capability class
X_{16}	slope
X_{17}	irrigation suitability
X_{18}	drainage
X_{19}	effective root zone
X_{20}	available water holding capacity
X_{21}	erosion hazard
X_{22}	septic tank drain field limitation
X_{23}	shrink-swell potential

"1. effective distance from the core (city center); 2. accessibility of the site to potential customers..."(Isard, 1956, p. 200). A number of empirical studies of land conversion have demonstrated that improved accessibility, generated by improvement to existing arterials or construction of limited access freeways, dramatically increases land conversion (Adkins, 1959; Corroll _et al._, 1958; Connelly, 1968; Philbrick, 1961; Wilbur Smith and Associates, 1968; Environmental Impact Center Inc., 1975).

In light of earlier research and the research objectives of this investigation, the following accessibility variables are hypothesized to be associated with increasing farmland conversion:

x_1 -- _decreasing distance to the Portland city center:_ measures the travel distance, using the most direct public road or highway, to the Portland city hall, measured to the nearest .01 mile.

x_2 -- _decreasing distance to the nearest urban place:_ measures the travel distance, using the most direct public road or highway, to the nearest urban place (i.e. U.S. Census Bureau definition of population greater than 2,500), measured to the nearest .01 mile.

x_3 -- _decreasing distance to the nearest freeway access point:_ measured by the most direct road or highway. Freeway are defined as limited access, multilaned, divided roadways. Included in this category are Interstate Highway 5, State Route 217, and portions of U.S. Route 26.

Infrastructural-Policy Variables

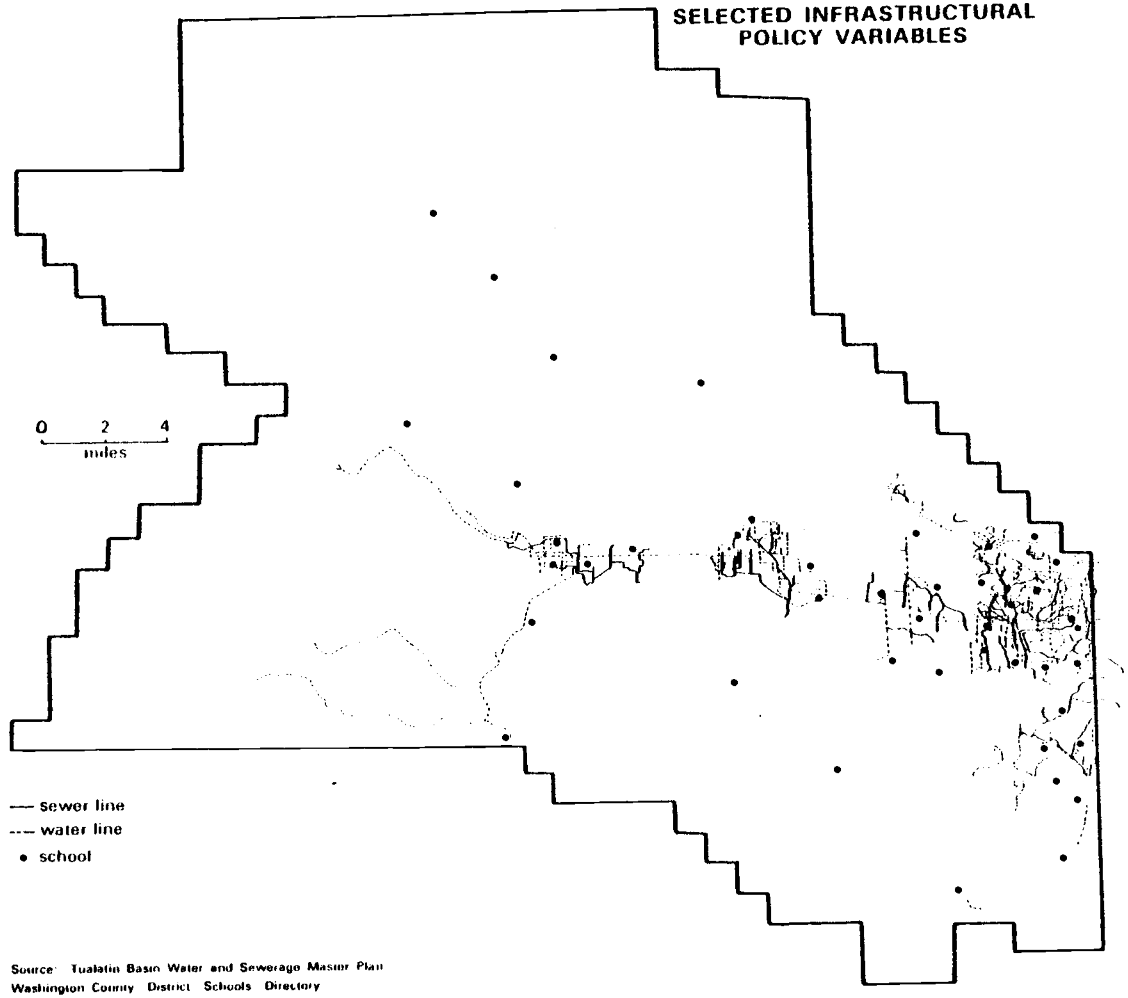
Until quite recently the impact of governmental policy and regulatory actions on land conversion rates was generally acknowledged, but rarely examined quantitatively. Recent efforts by communities to guide development patterns through infrastructural mechanisms have generated intensive interest in the functional relationship between governmental infrastructure and policy and land development.

Within the context of the previous research findings and discussion surrounding the impact of policy factors, it is hypothesized that increasing farmland conversion is related to the availability of governmental infrastructure and land regulation policy. Variables examined include:

x_4-- decreasing distance to the nearest sewerage trunk line: measures the "digging" (aerial) distance, to the nearest sewerage trunk, to the nearest .01 mile.

x_5-- decreasing distance to the nearest water line: measures the "digging" distance to the nearest .01 mile to the nearest public water line.

Figure 6.


SELECTED INFRASTRUCTURAL POLICY VARIABLES
0 2 4
miles
sewer line
water line
school
Source: Tualatin Basin Water and Sewerage Master Plan
Washington County District Schools Directory

x_6-- decreasing distance to the nearest developed area: measures the straight-line distance to the nearest developed area, to the nearest .01 mile. A developed area is defined in this investigation as any urban development or rural aggregation of five residential units or more with a density of greater than one unit per acre. It was hypothesized that "precedent setting" public policy which permitted the introduction of urban development into rural areas serves to increase the propensity for additional farmland conversion on adjacent lands.

x_7-- decreasing distance to the nearest elementary school: measures the travel distance, using the most direct public road or highway to the nearest elementary school in the school district in which the observational unit is situated. X_7 is measured to the nearest .01 mile.

x_8-- planning designation is an indicator of whether an observational unit was zoned and was situated in an area where an adopted land use plan existed during the period of study. It is hypothesized that those farms operating in areas with planning and zoning guidance will have greater "protection", and thus exhibit a propensity to remain in agricultural land use.

Social Variables

Behavioral scientists have long held that social conditions and variables are important factors influencing land values and uitlization (Park and Burgess, 1925). Recent empirical studies have partially affirmed the theoretical suppositions of early cultural ecologists that proximity to blighted or deprived areas has an arresting influence on land development (Chapin and Weiss, 1962; Brown, 1966).

In including six social variables in this investigation, it is hypothesized that social values, as expressed by the following variables, influence agricultural land conversion in Washington County. This is to say that agricultural land in proximity to "desirable" areas or having aesthetic value was converted to urban use to a greater degree than farmlands situated in less desirable areas. Social variables analyzed include:

x_9-- increasing median family income: measured by the U.S. Census Bureau (1960) for the census tract population in which the observational unit is located.

x_{10}--increasing median value of housing stock: measured by the U.S. Census Bureau (1960) for the census tract population in which the observational unit is located.

x_{11}--decreasing amount of substandard housing: the percentage of housing defined by the U.S. Census Bureau (1960) as either "dilapidated" or "deteriorated" (i.e. a measure of substandard housing) for census tract in which an observational unit is situated.

x_{12}--increasing median education: measured by the U. S. Census Bureau (1960) among all persons over 25 in the census tract in which the observational unit is situated.

x_{13}--increasing population change: measures the percentage change in census tract population from 1960-1970. In including this variable, it is hypothesized that population increases in areas near farmland create increased psychological and physical pressures on land conversion.

x_{14}--increasing elevation: measures elevation above sea level of the center proint of each observational unit. It is hypothesized that lands situated at higher elevations have greater scenic and aesthetic attributes, thus demands for land conversion are more intense.

Environmental Variables

Most previous models of land conversion have primarily restricted their research focus to analyzing the impact of "human" factors on land conversion rates. Few researchers have reported on the role of physical factors. Chapin and Weiss examined the influence of "marginal soils", a composite variable, which included flood prone areas, poorly drained areas, and land with slope greater than 15 percent. They found, however, that this factor added little precision to their analyses (Chapin and Weiss, 1962a, p. 11).

Nevertheless, the current study hypothesized that environmental variables (i.e. soil characteristics) influence farmland conversion rates. In the context of this hypothesis, soils which have the highest potential value in agriculture also have the best qualities for urban development. Thus, agriculturalists and developers are competing for the same land resources. The following is a listing of environmental variables and a short description of each:

x_{15}--<u>higher soil capability class:</u> the U.S. Soil Conservation Service rating for predominant soil (i.e. the soil type comprising the largest area) in each observational unit. Soil classes show, in a general form, the suitability of soils for most kinds of field crops. Soil capability Class I represents the highest quality of agricultural soils, while Class VII soils have the most severe limitations.

x_{16}--<u>decreasing slope:</u> the mean slope measured from U.S. Geological Survey topographic maps for each observational unit. Soils possessing minimal amounts of slope are usually most conducive to large scale agriculture. Severe slopes present significant problems for soil use and management.

x_{17}--<u>increasing irrigation suitability</u>: an index of the irrigation potential of a soil series as established by state and Federal soil scientists for use in the Columbia-North Pacific region. The scale is from 1 to 5, with 1 connoting excellent potential and 5 very poor or nonirrigability. Soils in group I have excellent irrigation suitability. The soils in group V are very poorly suited for irrigation, and "...may be considered to be nonirrigable" (Oregon Water Resources Board, 1969, p. 41).

x_{18}--<u>improving drainage:</u> an index of drainage classes indicating the degree of wetness under natural conditions. Developed by soil scientists, for the Willamette Valley, six drainage groups are established. Values range from "moderately well drained soils" in group 1 to "poorly drained to very poorly drained" soils in group 6. The hypothesis of this investigation suggests that soils in group 1 would have a greater probability of being converted to urban land uses.

x_{19}--<u>increasing effective root zone:</u> the upper layer of the soil which is useable for root growth. The effective root zone may be thinner than the soil profile, and should not be confused with depth of soil profile. The effective root zone for soil in Washington County ranges from 10 to 60 inches. Soils with greatest agricultural potential are those with the deepest effective root zone. It was hypothesized that these soils would be least subject to farmland conversion.

x_{20}--increasing available water-holding capacity (AWHC): the total quantity of water available for plant growth that is stored in the effective root zone or upper 60 inches of the soil profile. Five classes are identified by the U.S. Soil Conservation Service, ranging from 1, a "very high AWHC", to 5, "very low". A high AWHC is a soil property which facilitates increased agricultural productivity; thus it was hypothesized that these soils would be less prone to conversion.

x_{21}--decreasing erosion hazard: an estimation of how susceptible a soil series is to erosion when the surface is left bare. The U.S. Soil Conservation Service has established five hazard classes, with values ranging from 1 for "low" to 4 for "very high". Values at the lower end of the scale were hypothesized to correlate with low rates of farmland conversion.

x_{22}--decreasing septic tank drain field limitation: an index of the restrictions on the utilization of septic disposal systems. Developed by Soil Conservation Service scientists for the Willamette Valley, the scale ranges from 1 (slight limitations) to 4 (very severe). It was hypothesized that soils with few limitations to septic tank utilization would experience larger amounts of transition to urban use.

x_{23}--decreasing shrink-swell potential: a measure of the soil volume change to be expected with changes in the moisture content of a soil. Shrink-swell is an important consideration when using a soil for construction sites and as fill material. Ratings range from 1 (low shrink-swell) to 3 (high shrink-swell). Low ratings were hypothesized to be associated with larger quantities of farmland conversion.

Data Acquisition

Data requirements for quantitative analysis and hypothesis testing were satisfied using a number of diverse information sources. The following section provides an overview of data sources, with more detailed discussion found in Appendix B. As noted earlier, aerial photographic interpretation was the data source for the dependent variables, individual units of agricultural land converted to higher uses. U.S. Agricultural Stabilization and Conservation Service photography (Scale: 1:20,000) was used for the 1963 data and National Aeronautical and Space Administration color infrared photography (Scale: 1:30,000) was employed for 1973. The photographic scales for both sets of photography facilitated the required interpretation. The interpretative procedures utilized for aerial photo identification and interpretation incorporated earlier research and classification systems.

Data for the accessibility variables (i.e. x_1 distance to the Portland city center, x_2 distance to the nearest urban place, x_3 distance to the nearest freeway access point) were developed from Oregon State Highway Division data, in conjunction with aerial photography. Following the identification of roadway networks which were in operation during the study period, the travel distance from the center point of each observational unit to the point of interest was calculated using a map measurer. This procedure was also utilized for calculating x_7, i.e. distance to the nearest elementary school. Information regarding the location of elementary schools and their respective school district boundaries was derived from the twelve public school districts in Washington County.

The calculation of variables x_4 (distance to the nearest sewerage trunk line), x_5 (distance to the nearest water line), and x_6 (distance to the nearest developed area) was completed using a modification of the above methodology. Straight-line distances were tallied from the center point of observations to the point of interest, with locational data provided by the Washington County Planning Department.

U.S. Census Bureau data for the Portland Standard Metropolitan Statistical Area provided a source of data for x_9 (median family income), x_{10} (median value of housing stock), x_{11} (amount of substandard housing), x_{12} (median education), and x_{13} (population change). The 36 census tracts in Washington County provided the enumerating areas. The remaining social factor x_{14} (elevation), was derived from U.S. Geological Survey topographic maps for the county.

The source of information for the environmental variables was the Washington County Soil Survey field maps and report. These documents, completed in 1974, provided current pedalogical data for variables x_{15} through x_{23}. These data sources are presently unpublished, but are available in the Washington County Soil Conservation District Office.

Statistical Treatment of Data

In order to develop the model described earlier and examine the significance of data variables generated, statistical analysis of data was required. Following a review of procedures used by previous researchers and consultations with Oregon State University faculty, multiple linear regression analysis was selected as an analysis technique.

Multiple Regression Analysis

Multiple regression analysis has been used widely by geographers to analyze the degree and direction of relationships between a particular distribution considered as a dependent variable and selected independent variables (King, 1969, p. 151). Regression analysis "is a statistical tool which utilizes the relation between two or more quantitative variables so that one variable can be predicted from the other, or others" (Neter and Wasserman, 1974, p. 21).

Stated simply, the regression approach consists of those techniques employed to summarize the "average relationship" between variables. When two variables are involved, the procedure is referred to as simple regression; when three or more variables are included, the analysis is known as multiple regression. The basic process employed is one of estimating the best fit to a series of observed data. The equation describing the optimal curve approximation is the regression equation. The relationship and strengths of the variable associations are represented by the equation.

The general linear regression model, with normal error terms, used in the current investigation is:

$$Y = B_0 + B_1X_1 + B_2X_2 + \dots + B_{p-1}X_{p-1} + E$$

Where:

Y is the value of the dependent variable (acres of farmland converted to urban uses)

B_0, B_1, . . . B_{p-1} are parameters

X_1 . . . . X_{p-1} are the values of the independent variables

E is the random error term with mean E = 0 and variance

$^{2}(E) = {}^{2}$

As noted previously, four separate multiple regression models were fitted for the entire data set (i. e. Washington County) and subsets (i. e. urban, urban-rural fringe, and rural Washington County). These models are represented by:

$$Y_i = B_0 + B_1X_i + \dots + B_{p-1}X_{i,p-1} + E$$

The use of multiple regression models provides a descriptive tool for analyzing the relative influence that site characteristics have on farmland conversion. Moreover, regression facilitates the statistical testing of the hypothesis postulated by this investigator. Hypothesis testing procedures permit a test of "overall" goodness of fit of the regression equation, testing for a specific regression coefficient, and a test for a subset of regression coefficients. Throughout this hypothesis, testing the F test statistic was employed.

Search for the "Best" Model

The selection of the set of independent variables which "best" explain the behavior of the dependent variable is a difficult process. Neter and Wasserman (1974) remark that "One of the most difficult problems in regression analysis often is the selection of the set of independent variables to be included in the model" (p. 371). The researcher, in selecting a "best" set of variables, is faced with a contradiction in needs--"small enough so that maintenance costs are manageable and analysis is facilitated, yet...large enough so that adequate description, control, or prediction is possible" (Neter and Wasserman, 1974, p. 372).

Owing to the limited number of independent variables considered in this investigation, extensive search procedures for screening variables were not needed. However, a search procedure was established as a component of the research design in order to select the model which most efficiently (i.e. with the least number of variables) explained with the greatest precision the variation in cropland conversion.

The search procedure was twofold. Initially models were constructed using a forward selection regression search method and a backward elimination procedure. The Statistical Interaction Programming System (SIPS) was employed for this data manipulation

(Guthrie et al., 1974). Finally, the Cp criterion (total squared error) was calculated and used to select the "best" model.

The forward selection procedure is employed widely for model building. This approach involves adding one independent variable at a time and generating a series of intermediate regression equations. The first variable added to the model is the one which has the highest simple correlation with the dependent variable. Following the initial regression, partial correlations between the dependent and all other independent variables are computed, and the variable which contributes most to understanding unexplained variations is added. At each step, the adjusted partial regression coefficients and multiple correlation coefficient are obtained. The forward selection procedure continues until all the specified independent variables are included in the model.

The backward selection procedure is a complementary technique to the forward selection approach. Following the addition of all specified independent variables to the model, this procedure, in a stepped approach, strips a model of the most ineffective independent variable. This search procedure is the opposite of the forward selection procedure.

Following backward and forward selection procedures, the resultant models were evaluated for effectiveness using Cp criterion. Cp provides a quantitative indicator of model effectiveness. Cp, a relatively new technique, is an estimator of the total squared error in a regression model. In using the Cp criterion, the researcher has a procedure for selecting the model with the smallest bias component (Neter and Wasserman, 1974, p. 380). Cp is calculated using:

$$Cp = \frac{SSE}{6^2} - (n-2p)$$

Where

p = number of parameters in the model

SSE = error sum of squares

6^2 = the estimate of variance from the full model

n = number of observations

The result of the dual model construction procedure and Cp evaluation was the selection of the most "powerful" model for explaining the variation in agricultural land conversion in Washington County.

The use of regression models for analyzing land conversion provided this investigation with precision that would not have been possible without this statistical procedure. Regression analysis facilitated the development of the hypothesized land conversion model, in that variables could easily be included, evaluated, or dropped from the model and the statistical testing of hypotheses was made possible. Centering on regression techniques, the methodology employed in this study sought the strongest possible analysis of the association between agricultural land conversion and the selected contextual variables. Without the employment of these techniques, evaluation of the model's effectiveness would have been reduced to supposition and qualitative evaluation.

CHAPTER V

MODELING RESULTS AND HYPOTHESIS EVALUATION

The purpose of Chapter V is to present the descriptive data developed by this investigation, discuss the results of the regression modeling, and to test the research hypotheses. As noted earlier, multiple regression models were chosen to test the combined effect of site characteristic variables on agricultural land conversion. The derived regression equations were used to determine, initially, whether the relationship outlined earlier as a functional model is statistically significant, and, if so, the quantitative measure of farmland conversion associated with changing values in predictor variables.

The discussion of analyses is restricted to multiple regression models. However, simple correlation was a component of early data manipulation. The findings of these preliminary analyses are presented only as necessary.

The presentation of data analysis is divided into five sections conforming to the research components of the land conversion model outlined in Chapter IV. Separate multiple regression equations were fitted for accessibility factors, infrastructural-policy factors, social factors, and environmental factors, as well as for the full model.

These units comprise the subheadings for data analysis. This structuring procedure was adopted in an effort to better analyze and judge the importance of these factors individually, and within the context of the hypothesized full model.

As a second component of data analysis, multiple regression models were fitted separately for three geographical subunits within the study area. These areas are urban, urban-rural fringe, and rural Washington County. The purpose of the individual models is to examine the consistency in land conversion behavior in varying geographical areas of the county with differing degrees of development pressure. The geographical divisions of the county provide the conceptual framework for the presentation of the individual submodels noted earlier. That is, individual site characteristic submodels and a full composite model are presented for each geographical area in the county. Proceeding in this manner, each set of site factors (accessibility, policy-infrastructure, social, and environmental) is analyzed and variable performance is compared with other sections of the county. This approach facilitates the analysis of relationships and is useful for testing hypotheses.

Characteristics of Converted Farmland

Using aerial photography of Washington County for the period from 1963-1973, 293,000 acres were surveyed for evidence of agricultural land conversion. This search, which included 62 percent of the total land area of the county, excluded only those portions of Washington County that were publicly owned timberland or land owned by large lumber companies. It was presumed that these areas are already effectively removed from the land market.

Using established aerial photographic interpretation procedures, it was determined that 10,433.5 acres of agricultural land were transformed to urban uses during the study period (1963-1973). In an effort to examine data accuracy, the converted acreage, as identified by aerial photographs, was compared to the best available U.S. government data. The results of the comparison show that the study findings and the Federal data are generally consistent. The *U.S. Census of Agriculture* reported that in the period from 1964 to 1974, the total cropland in Washington County dropped by 8,712 acres. Because of definitional divergence and differences in study periods, data unanimity is impossible; however, the lack of significant variance between the published data and study findings is viewed as significant.

As one would expect, the variation in individual units of farmland being converted was quite significant. Observational units ranged in size from 717.5 acres to .25 acres. The average unit of converted farmland was 22.88 acres, with a standard deviation of 2.50. As indicated in Table 5, extensive variance was also exhibited in the types of agricultural land converted to urban uses. Of the 456 observational units, 196 units (43 percent) were lands formerly used for cropland. Cropland, as defined in this investigation, consists of land from which crops were harvested or hay was cut, and acreage devoted to nursery and greenhouse products. One hundred thirty two observational units (28.9 percent) were farmland previously utilized for pasture. In the context of this study pasture is identified as land used for rotation pasture and grazing, and land in cover crops, legumes, and soil improvement grasses. Land formerly planted in orchards occurred in 59 cases of 12.9 percent of the total observations. The remaining 69 observations were forest land, 15.1 percent of the total units. This category includes all woodlots, timber tracts, and cutover and deforested land with young timber growth.

Table 5. The Structure of Converted Agricultural Land.

	Frequency (Observational Units)	Percent	Acreage Converted	Percent
Cropland	196	.430	4818.35	.486
Pasture	132	.289	3195.80	.306
Orchard	59	.129	1679.25	.160
Forest	69	.151	486.10	.047
Total	456	1.00	10,433.50	1.00

In terms of the magnitude of conversion among agricultural land uses, 48.6 percent of the transformed farmland was formerly cropland (see Table 5). This figure is significantly higher than the frequency of cropland conversion (43 percent), suggesting that the mean parcel size of converted cropland was larger than the 22.88 acre county average. Pasture and orchard lands converted to urban use comprised 30.6 and 16.0 percent of the total acreage, respectively. These data were also larger than their frequency percentage, indicating the average parcel size was larger than the Washington County mean. In the forest category, however, only 4.7 percent of the total land converted was included in this class. This is significantly smaller than than the 15.1 percent of the observational units that were forestry lands. This implies that the mean unit of forest land was substantially smaller than the mean county observational unit. One can infer from these data that, in terms of the farmland land conversion process in Washington County, cropland and orchards were the preferred type of land for larger scale development activities whereas forest areas were targets of small scale urban development. The frequency and scale of converted pasture lands were almost identical, suggesting that the scale of development occurring on former pasture was near the county mean.

With regards to post-conversion land uses, residential land use was the dominate product of converted farmland. Examination of Table 6 shows that 77.9 percent of the observational units were transformed to residential usage. Residential land use, in this investigation, is defined as land utilized for housing, including single family dwellings, apartments, and mobile homes. Nineteen point one percent of the observational units were transformed to commercial land uses. In the context of this study, commercial land use included areas of retail and wholesale trade, services, and manufacturing activity. Public land uses comprised .031 percent of the total parcels. Included in the public land use grouping were public and quasi-public facilities, transportation, and utilities.

Table 6. Post-Conversion Land Use.

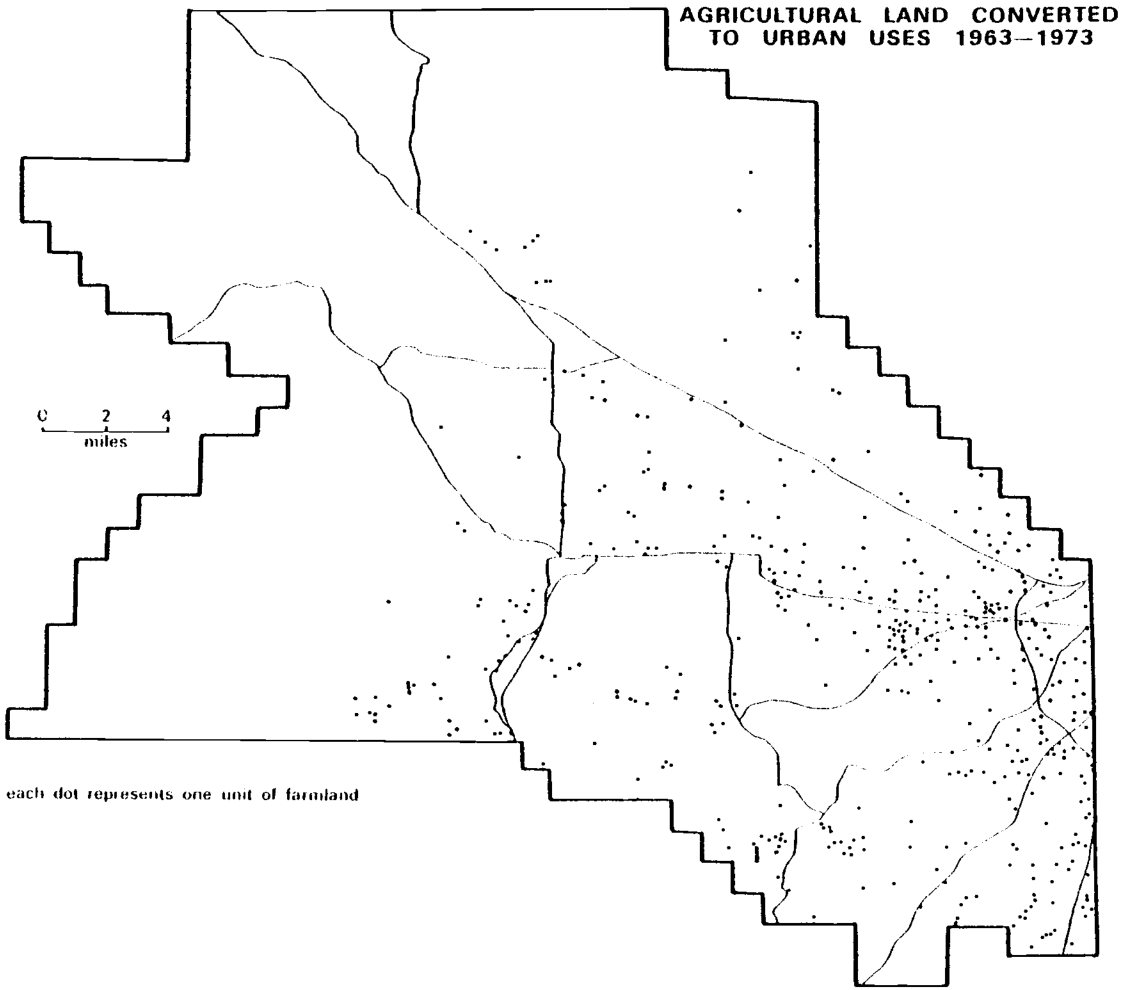
	Frequency (Observational Units)	Percent
Residential	355	.779
Commercial	87	.191
Public	14	.031
Total	456	1.00

The overwhelming degree to which converted agricultural lands have been transformed to residential uses concurs with land use trends for Washington County. The Washington County Comprehensive Framework Plan notes that urban development in the County, during the study period, can be characterized as suburban sprawl, "low density spotted developments" (Washington County Planning Department, 1973, p. 35). Large scale commercial or industrial development was not widespread. Public facilities and land use expanded in response to the need resulting from residential development. Thus, it appears the character of converted agricultural land identified in this investigation is in agreement with the findings of the county planning agency.

The Location of Converted Farmland

Spatially, agricultural lands converted to urban uses were distributed throughout the county. However, an examination of Figure 7 shows that the pattern of land transformation was not random. Viewed from a geographical perspective, concentrations of converted farmland are apparent in the eastern area and along the southern boundary of the County. The large number of observations in the southeastern quadrant, which includes the Tigard, Tualatin, Sherwood, and Kings City areas, is correlated with the rapid suburbanization and population increase which occurred in the area during the 1960's and early 1970's. Many of the observational units in this area are subdivisions. Conversely, the large number of observations in the southern area is primarily associated with a more dispersed type of land conversion in the foothills of the Chehalem Mountains. Generally

Figure 7.



AGRICULTURAL LAND CONVERTED
TO URBAN USES 1963–1973
0 2 4
miles
each dot represents one unit of farmland

in the latter case the converted acreage involved individual observations and is much smaller than in the southeastern section.

Another concentration of converted farmland, which may be less apparent from visual examination, is a broad linear corridor in the central portion of the county. This pattern forms an axis extending from Beaverton through Hillsboro, Cornelius, and Forest Grove. This aggregation of converted agricultural land is strongly associated with the rapid low density, suburban development which occurred during the 1960's. During the period from 1960-1970, the census tracts in this area grew by 11,600 new residents, a 44 percent increase in population. Thus, the concentration of conversion in this area is not unexpected.

Among those areas of the county which did not experience extensive farmland conversion were the north, northwest, and northeastern sections. Generally speaking those areas with an absence of farmland conversion were either situated in isolated, physically rough terrain or were located in already urbanized sections of the county. In the previously urbanized areas, the absolute quantity of agricultural acreage available for land development was significantly lower than in other sections of the county. Northwest Washington County represents the former case, whereas, northeast Washington County is an example of the latter.

With regards to the situational location of converted land, observational units were identified in urban, urban-rural fringe and rural sections of Washington County. But the distribution of units was not uniform. As one might expect, farmland transition was most extensive in rural and urban-rural fringe areas (see Table 7). The greatest number of observational units are found in areas identified by the study as rural, comprising 43 percent of the total observational units. Forty percent of the conversion units are situated in urban-rural fringe areas. The remaining 17 percent of the observations are in portions of Washington County identified as urban. Factors contributing to the greater numbers of observational units in rural areas are varied. Two important considerations, however, are the extensive amounts of farmland available for development in rural areas, and the lower market values of land in isolated rural areas.

Table 7. Geographical Location of Converted Farmland.

	Frequency (Observational Units)	Percent	Acreage Converted	Percent
Urban	78	17	1867.20	18
Urban-Rural	182	40	7273.75	70
Rural	196	43	1292.55	12
Total	456	100	10,433.50	100

One apparent locational characteristic of the transformed farmland which is visually discernable in Figure 7 is a correlation between observational units and the highway network. Converted farmland tends to be situated near major transportation lines, including State Road 8, State Road 208, State Road 210, State Road 47, State Road 217, and U.S. Highway 26. This visual evaluation is tested statisti ally later in this chapter.

Data Transformation

Logarithmic data transformation is frequently used in both the social and natural sciences in order that data approximate more closely to a linear series (Hammond and McCullagh, 1975, p. 87). The initial data analysis in this investigation was performed without data transformation. However, to increase the explanatory power of the model and better linearize the regression function, the data were transformed to logarithmic form. The natural logarithms were used for all variables, excepting planning protection (X_8). In undertaking the transformation, scatter plots suggested by Neter and Wasserman (1974, p. 123-130) were employed to insure appropriate application of the technique.

Site Characteristic Models

Washington County: Accessibility Model

The variables included in the accessibility model are those site characteristics that deal specifically with accessibility to urban centers. As noted earlier, the general hypothesis for this set of variables states that as accessibility increases with regard to employment opportunities and amenities associated with urban centers, the probability that land will remain in agricultural uses decreases. This is to say, farmland adjacent to an urban place would be much less likely to remain in agriculture than land located further away. Symbolically, the model is stated

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + E$$

where:

Y = the acres of agricultural land converted to urban use by observation unit (logarithmically transformed).

X_1 = the distance to the Portland city center (logarithmically transformed).

X_2 = the distance to the nearest urban place (logarithmically transformed).

X_3 = the distance to the nearest freeway access point (logarithmically transformed).

and B_0, B_1 . . . B_3 are empirically determined parameters, and E is the random error term.

The forward selection model building procedure used in this analysis and throughout the investigation is illustrated in Table 8. In step one, distance to Portland (X_1) is included in the model as it exhibited the highest partial correlation coefficient (.496) of the three variables. The partial correlation coefficient indicates that 49 percent of the variation in the agricultural land conversion is "explained" by distance from Portland.

Table 8. Washington County Forward Selection Procedural Model Accessibility Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_1	.021	.496	--	448.1*
2	X_2	.096	.604	.108	123.9*
3	X_3	.077	.604	.001	.03

$$Y = 3.71 - 2.05\,X_1 - 1.06\,X_2$$

*Statistically significant beyond the 1% level of probability.

In the second step, distance to the nearest urban place (X_2) is included in the model as the next most important variable. The coefficient of determination, commonly identified as R^2, is increased to .604. The coefficient of determination is a measure of the proportionate reduction of the total variation in farmland conversion (Y) associated with the use of independent variables (X_1 and X_2) (Neter and Wasserman, 1974, p. 89). The measure .604 indicates that 60.4 percent of the variation in agricultural land development is accounted for by X_1 and X_2. The degree of precision added by the inclusion of X_2 to the model is .108 or 10.8 percent. In the final step, distance to the nearest freeway access point (X_3) had very little impact on R^2, and was not statistically significant in the model. Owing to the lack of statistical significance, X_3 was deleted from the final accessibility model for the County. The decision to drop X_3 was reaffirmed by a Cp analysis developed for the model.[1] As expected, Cp criterion indicated the two variable model (X_1 and X_2) was the most effective accessibility model.

The failure of distance to the nearest freeway access point (X_3) to generate a high level of explanation or to even prove statistically significant was quite unexpected. As previously noted, earlier researchers had found that the construction and location of freeway access facilities was a major stimulus for land development (Council on Environmental Quality, 1976, p. 35). In retrospect, it would

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[1] For a discussion of Cp criterion, the reader is directed to Appendix C.

appear that the inclusion of a freeway access variable may have poor judgement. During the course of the investigation, it became apparent that an extensive network of arterial highways connected much of Washington County, while freeways were limited to two roadways. Moreover, it also became evident that the arterial road system was a vital component of the commuter trip pattern for Washington County residents. In light of this information, it can be suggested that accessibility to arterials is a factor which could play a more critical role than freeway accessibility. Future investigators may wish to consider the Washington County situation prior to development of their study designs.

The final Washington County accessibility model, with variables X_1 and X_2, produced a level of explanation around 60 percent. As hypothesized, the variables operated in a negative direction. This is to say, that as the scale of agricultural land conversion increased by an average of one acre, the distance to Portland decreased by an average of 2.05 miles and the distance to the nearest urban place declined by an average of 1.06 miles. While the final model provided only a partial explanation of farmland conversion, the high degree of association ($R^2 = .604$) between accessibility and land conversion is significant is significant from both a theoretical and applied perspective.

Washington County: Infrastructural-Policy Model

The second major research hypothesis explored in this investigation is that governmental policy and infrastructural decision-making have significant implications on the land conversion process. The impact of institutional decisions on agricultural land results in establishment of unique locational site characteristics. These institutionally generated characteristics may affect decisions on the type and location of land conversion since they change the relative desirability and cost of land development. The hypothesis assumed by this investigation is that institutional decisions resulting in increased availability to public services and facilities stimulate agricultural land conversion.

In line with the research hypothesis, a model for infrastructural policy factors is postulated. The equation is as follows:

$$Y = B_0 + B_1X_4 + B_2X_5 + B_3X_6 + B_4X_7 + B_5X_8 + E$$

where:

Y = the acres of agricultural land converted to urban use per observation unit (logarithmically transformed)

X_4 = the aerial distance to the nearest sewerage trunk line (logarithmically transformed)

X_5 = the aerial distance to the nearest water line (logarithmically transformed)

X_6 = the aerial distance to the nearest developed area (logarithmically transformed)

X_7 = distance to the nearest elementary school (logarithmically transformed)

X_8 = planning and zoning designation

and B_0, B_1 . . . B_5 are empirically determined parameters and E is the random error term.

The regression analysis finds that the five infrastructural-policy factors account for .708 percent of the variation in spatial distribution of farmland conversion (see Table 9). All of the predictor variables, with the exception of planning designation (X_8), are significant beyond the one percent level of probability. Among the predictor variables, distance to the nearest developed area (X_6) is exceptionally strong with a partial correlation of .63; while distance to the nearest water line (X_5) and distance to the nearest sewerage trunk line (X_4) add to the R^2 by 5.9 percent and 1.4 percent, respectively.

Using the Cp criterion, the best infrastructural-policy model is determined to be the four variable model, with X_4, X_5, X_6, X_7. The dropping of X_8 reduced the R^2 by only .001 percent, and reduced the Cp (total squared error) significantly. The coefficient of correlation for the final model was .707.

Table 9. Washington County Forward Selection Procedural Model Infrastructural-Policy Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_6	.065	.631	--	778.1*
2	X_5	.055	.690	.059	86.2*
3	X_4	.053	.704	.014	20.7*
4	X_7	.079	.707	.003	5.7*
5	X_8	.023	.708	.001	1.5

$$Y = .439 - .49\,X_6 - .29\,X_5 - .20\,X_4 - .18\,X_7$$

*Statistically significant beyond the 1% level of probability.

The strength of association between infrastructural-policy factors and agricultural land conversion throughout the county was very high. As noted in the previous section, it was a premise of this investigation that governmental policy and infrastructure were significant forces influencing patterns of farmland conversion. That is, areas with governmental services will have larger amounts of agricultural land transition than will those agricultural lands situated at greater distances from public facilities. The analyses showed that as the scale of farmland conversion increased aerial distance to water and sewerage lines declined, developed areas were found to be in closer proximity, and the travel distance to elementary schools dropped. A possible explanation for the failure of the planning and zoning variable to play a significant role in the model may lie in the research design of this investigation rather than with the variable. This point will be explored later in this chapter.

Washington County: Social Model

Beyond the accessibility and infrastructural factors which earlier proved significant forces in the development of farmland, it is also the hypothesis of this investigation that certain social factors of location are major considerations in land use decision-making. In this regard, it was a supposition that socioeconomic factors endow an area with an image and character, which impacts the future spatial pattern of development. The social prestige level of neighborhoods can dictate the form and rate of growth. For example, areas with high family incomes or scenic vistas, may be important factors spurring rapid farmland transition. Conversely, neighborhoods or areas blighted by deteriorating housing or experiencing static growth may serve to discourage future urban development nearby. Thus it was an investigation hypothesis that farmland conversion would be greatest in neighborhoods (i. e. census tracts) that were most affluent and desirable with lesser conversion in the least attractive sections of the county. The equation depicting this hypothesis is:

$$Y = B_0 + B_1X_9 + B_2X_{10} + B_3X_{11} + B_4X_{12} + B_5X_{13} + B_6X_{14} + E$$

where:

Y = the acres of agricultural land converted to urban use per observation unit (logarithmically transformed)

X_9 = median family income by census tract

X_{10} = median value of housing stock by census tract

X_{11} = percentage of substandard housing by census tract

X_{12} = median level of education attained by persons over 21 by census tract

X_{13} = percentage of population change from 1960 to 1970 by census tract

X_{14} = site elevation, calculated to the nearest foot

and B_0, B_1, . . . B_5 are empirically determined parameters and E is the random error term.

The examination of the impact of the six social factors on farm-land conversion throughout the county found a moderate degree of association. The level of explanation, with five significant variables was .528 (see Table 10). The deletion of the non-significant variable, median level of education (X_{12}), did not affect the degree of explained variation.

Table 10. Washington County Forward Selection Procedural Model Social Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_9	1.054	.427	--	338.4*
2	X_{14}	.147	.495	.066	61.7*
3	X_{13}	.104	.515	.020	18.7*
4	X_{11}	.162	.522	.007	6.7*
5	X_{10}	.782	.528	.006	4.8*
6	X_{12}	1.453	.528	.008	.76

$$Y = 1.76 + 7.49\,X_9 - 1.19\,X_{14} + .55\,X_{13} + .41\,X_{11} - 1.62\,X_{10}$$

*Statistically significant beyond the 1% level of probability.

The analysis indicated that the scale of agricultural land conversion increased in those areas with higher median family income (X_9), lower site elevations (X_{14}), and increased population change (X_{13}). However, the analyses also showed increasing magnitudes of agricultural transition in areas with declining housing values (X_{10}) and increasing amounts of substandard housing (X_{11}). One contributing factor which may account for this paradox is the high value housing stock in eastern Washington County. Many of the older residential districts in this section of the county are upper income neighborhoods, with the highest housing values in Washington County. In these areas, all farmland had been developed prior to the study period. Thus, agricultural transition taking place primarily in central and southern Washington County was occurring in census tracts with lower housing values and higher rates of substandard housing. Under these circumstances, the negative value of X_{10} and the positive value of X_{11} were not unexpected. This explanation was given qualified support during discussions with Washington planning personnel (Stout, 1977).

Among the predictor variables, median family income (X_9) was exceptionally powerful with a partial regression coefficient of .42. One could infer from this finding, that development activity is spurred in areas situated in proximity to high income neighborhoods, with social prestige translating into increased pressure on farmlands. The site elevation (X_{14}) and population change (X_{13}) were variables of secondary importance increasing the R^2 by six percent and two percent, respectively. The other three social variables added little explanation power, although two were statistically significant.

Washington County: Environmental Model

The final submodel was developed to examine the effect of environmental characteristics on farmland transition. As noted earlier, few investigators have explored empirically the impact of an environmental matrix on the patterns of land development. It was hypothesized that urban development and agricultural land uses are competing for the same land resources.

Arithmetically, the postulated model is stated:

$$Y = B_0 + B_1X_{15} + B_2X_{16} + B_3X_{17} + B_4X_{18} + B_5X_{19} + B_6X_{20} + B_7X_{21} + B_8X_{22} + B_9X_{23}$$

where:

Y = the acres of agricultural land converted to urban use per observation unit (logarithmatically transformed)

X_{15} = soil capability class (logarithmatically transformed)

X_{16} = slope (logarithmatically transformed)

X_{17} = irrigation suitability (logarithmatically transformed)

X_{18} = drainage class (logarithmatically transformed)

X_{19} = effective root zone (logarithmatically transformed)

X_{20} = available water holding capacity (logarithmatically transformed)

X_{21} = erosion hazard class (logarithmatically transformed)

X_{22} = septic tank drain field limitation class (logarithmatically transformed)

X_{23} = shrink-swell potential rating (logarithmatically transformed)

and B_0, B_1, . . . B_9 are empirically determined parameters, and E is the random error term.

The impact of the selected environmental variables on the magnitude of farmland conversion throughout Washington County proved moderately significant. The coefficient of determination with all nine variables was .496 (see Table 11). Using Cp criterion, the best model was identified as the five variable model, including drainage (X_{18}), erosion hazard (X_{21}), irrigation suitability (X_{17}), effective root zone (X_{19}), and slope (X_{16}). The R^2 of this model is .492. All five variables are statistically significant at the 1 percent level of probability.

Despite the moderately strong R^2 values, however, an examination of the regression coefficients and their signs raises a number of perplexing questions. Several variables, including the most powerful predictor, were found to operate in a direction contradictory to the research hypothesis. Soils with lower drainage capabilities (X_{18}) and shallower root zones (X_{19}) were subject to large scale land conversion. Conversely, other variables in the model operated as expected, with increased farmland conversion associated with soils possessing low erosion hazard (X_{21}), high irrigation suitability (X_{17}) and decreasing slope (X_{16}).

In an attempt to explain these "illogical" signs, the simple regression coefficients and the correlation among independent variables were examined. A review of the simple regression models found that all variables operated identically in both the simple and

Table 11. Washington County Forward Selection Procedural Model Environmental Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_{18}	.031	.318	--	211.8*
2	X_{21}	.336	.457	.139	116.6*
3	X_{17}	.486	.480	.023	19.7*
4	X_{19}	.324	.487	.007	5.6*
5	X_{16}	.152	.492	.005	5.1*
6	X_{20}	.323	.494	.002	1.3
7	X_{23}	.250	.495	.001	1.3
8	X_{15}	.446	.496	.001	.58
9	X_{22}	.276	.496	.0001	.10

$$Y = 2.57 + .35\,X_{18} - .26\,X_{21} - 2.07\,X_{17} - .74\,X_{19} - .33\,X_{16}$$

*Statistically significant beyond the 1% level of probability.

multiple regressions. Moreover, multicollinearity among predictor variables was also not a significant problem. The apparent lack of error in methodology indicates that the unexplained signs, as well as, lack of significance among other predictor variables, is attributable to factors or conditions outside the scope of the model. A discussion of the problems associated with the operation of the environmental submodel is presented in Chapter VI.

The moderate level of explanation and unanticipated signs associated with the environmental submodel for Washington County cast strong suspicion as to the practical applicability of this model. The problems with illogical signs continued to plague the environmental submodel in all geographical sections of the county. Owing to these factors, the reader is cautioned to interpret the submodel findings with prudence. With regards to the research hypothesis, although the five variable model proved statistically significant, reliance on the model's results is not advised.

Urban Washington County: Accessibility Model

In the second phase of the regression analyses, separate multiple regression models were fitted for each set of site characteristics within the geographical subareas of the county. The structure and symbols employed in the previous regression equations are used in these subarea models. Additionally, the hypotheses postulated for the entire county are tested for each geographical subarea. In the interest of facilitating the discussion, the readers' attention is directed to the earlier sections of Chapter V for review of the individual research hypotheses and model structure.

With respect to accessibility factors, the analyses indicated a significant difference in variable behavior between urban areas and the entire county. In contrast to the strong correlation of the accessibility model for the entire county, accessibility in urban areas does not account for a significant amount of variation in farmland conversion. As illustrated in Table 12, the regression equation with three variables produces a coefficient of determination of .112. Only one variable, distance to the nearest urban place (X_2), is statistically significant beyond the one percent level. When those variables that are not statistically significant are dropped from the model, the remaining simple regression model explains 10 percent of the variation in agricultural land conversion in urban Washington County.

Table 12. Urban Washington County Forward Selection Procedural Model Accessibility Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_2	.280	.102	--	9.16*
2	X_1	.848	.110	.008	.69
3	X_3	.155	.112	.002	.19
	$Y = 1.53 - .794 X_2$				

*Statistically significant beyond the 1% level of probability.

The lack of relationship between accessibility and land conversion probably results from the fact that most of the transformed farmland is part of a noncontiguous "fill in" process, in an area with highly developed transportation and political organizations. The site advantage of location near a transportation line or activity node is negated when these conditions occur throughout the area. Under these circumstances, distances from freeways or urban areas would be insignificant in land use decision making.

Although the accessibility model for urbanized areas was extremely ineffective, the lack of a significant correlation was not totally unexpected. Only 82 units of farmland were identified in the 13 census tracts comprising urbanized Washington County. Agricultural land in the area is typically scattered and restricted to small parcels. The transportation network, including freeways, primary roads, and arterials, was with few exceptions, totally operational prior to the study period. Similarly, the organization of municipal governmental structure was already well developed.

Urban Washington County: Infrastructural-Policy Model

In contrast to the lack of significance associated with accessibility factors, the infrastructural-policy model generated a strong measure of precision. As illustrated in Table 13, the infrastructural-policy factors produce a 54.9 percent level of explanation in urbanized Washington County. However, the strong association achieved results primarily from the effect of only two independent variables, distance to the nearest developed area (X_6) and distance to the nearest sewerage trunk line (X_4). Predictor variables X_5 and X_7 were dropped from the equation as they lacked statistical significance. Variable X_8 was not included in the original analysis as all areas in the urbanized portion of the county had planning and zoning regulation prior to the study period.

Table 13. Urban Washington County Forward Selection Procedural Model Infrastructural-Policy Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_6	.112	.480	--	74.0*
2	X_4	.075	.546	.066	11.4*
3	X_5	.096	.549	.003	.51
4	X_7	.144	.549	.0004	.07
	$Y = .36 - .23 X_6 - .78 X_4$				

*Statistically significant beyond the 1% level of probability.

The final infrastructural-policy model, confirmed by Cp criterion, includes only X_6 and X_4. This model is significant beyond the 1 percent level of probability, and the coefficient of determination is .546. The results of the urban model provide only a partial explanation of the land transition. However, the strength of association (54.6 percent) of the model, as well as the high degree of statistical significance suggests that these variables may prove valuable in subsequent composite analyses.

Urban Washington County: Social Model

In sharp divergence with the previous regression analysis, the social model for urban Washington County demonstrated little descriptive power. With all six independent variables included in the model, the R^2 was only .067 (see Table 14). The percentage of population change (X_{13}) was the only significant variable, and could only account for three percent of the variation in land conversion. The lack of statistical significance necessitated the rejection of the hypothesis that social factors play an influential role in farmland conversion in urban Washington County.

Urban Washington County: Environmental Model

The environmental model for urban Washington County demonstrated only slightly greater precision than the social model. This ineffectiveness was a marked contrast from the relatively successful application of the environmental model for the entire county. For urbanization sections of the county, the full model, with nine variables, generated an R^2 of .108 (see Table 15). Only one predictor variable,

Table 14. Urban Washington County Forward Selection Procedural Model Social Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_{13}	.455	.031	--	2.6*
2	X_{12}	15.314	.049	.018	1.4
3	X_{14}	.737	.053	.004	.30
4	X_{10}	2.653	.064	.011	.87
5	X_{11}	.273	.067	.003	.24
6	X_9	3.617	.067	.0007	.05
	$Y + 1.37 + .43\ X_{13}$				

*Statistically significant beyond the 10% level of probability.

Table 15. Urban Washington County Forward Selection Procedural Model Environmental Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_{22}	.284	.046	--	3.8*
2	X_{16}	.310	.061	.015	1.2
3	X_{18}	.072	.079	.018	1.4
4	X_{17}	1.626	.094	.015	1.2
5	X_{23}	.912	.104	.01	.92
6	X_{21}	.820	.106	.002	.16
7	X_{15}	1.955	.108	.002	.12
8	X_{20}	1.779	.108	.0002	.01
9	X_{19}	1.668	.108	.0001	.005
	$Y = -1.06 + 5.11\ X_{22}$				

*Statistically significant beyond the 5% level of probability.

septic tank drainage field limitation (X_{22}), was statistically significant at the 5 percent level of probability. Again the environmental model did not operate as expected with the soils having the most extensive septic drainage limitations explaining the greatest land conversion. Based on the lack of significance, the author concluded that environmental factors have little impact on farmland transition in urban Washington County.

Urban-Rural Fringe: Accessibility Model

The accessibility model for the urban-rural fringe produced results similar to the earlier accessibility model for urban Washington County. The coefficient of determination, with three predictor variables is .128. Nevertheless, the variables distance to the nearest urban place (X_2) and distance to Portland (X_1) are statistically significant above the one percent probability level and are retained in the final model. Both variables performed as anticipated with distance to Portland and to the nearest urban place decreasing with increased scale of farmland conversion (see Table 16). The R^2 of the final model is 12 percent.

The low explanatory power of the accessibility model for the rural-urban fringe was an unexpected result. Although two of the predictor variables were statistically significant, it was hypothesized that the strength of association between accessibility and farmland conversion would be greater. This lack of strong relationship may in part be a result of conditions similar to urban Washington County. The existence of an extensive transportation network and well developed hierarchy in the older developed sections of the urban-rural fringe may have reduced the importance of accessibility factors.

Table 16. Urban-Rural Fringe Forward Selection Procedural Model Accessibility Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_2	.149	.067	--	14.1*
2	X_1	.413	.127	.06	13.2*
3	X_3	.130	.128	.001	.12
	$Y = 2.67 - 1.13\ X_2 - .622\ X_1$				

*Statistically significant beyond the 1% level of probability.

The lack of correlation may also indicate that in the most dynamic land conversion areas (i.e. the urban-rural fringe), accessibility factors are not singularly important enough to affect farmland transition. Distance to urban areas or distance to Portland are significant considerations, but their relative impact is not great.

Urban-Rural Fringe: Infrastructural-Policy Model

The examination of infrastructural-policy variables for the urban-rural fringe revealed a moderately strong degree of association, with four statistically significant variables. As pointed out in Table 17, the coefficient of determination for the four variable model is .483. As expected, Cp analysis suggested that the best model for "explaining" conversion behavior is the four variable form.

Table 17. Urban-Rural Fringe Forward Selection Procedural Model Infrastructural-Policy Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_6	.084	.408	--	133.7*
2	X_5	.065	.465	.065	20.8*
3	X_4	.068	.476	.011	4.17**
4	X_7	.110	.483	.013	2.54**
5	X_8	.073	.484	.001	.34

$$Y = .59 - .53\,X_6 - .21\,X_5 - .16\,X_4 + .17\,X_7$$

* Statistically significant beyond the 1% level of probability.

** Statistically significant beyond the 5% level of probability.

Among the variables, distance to the nearest developed area (X_6) and distance to the nearest water line (X_5) were most effective contributing 46.5 percent to the R^2. A comparison of the infrastructural-policy model for the urban-rural fringe with urban Washington County shows strong parallels. With the exception of X_5, those factors which were important on the urban-rural fringe were equally important in the urban portion of Washington County. This would seem to suggest a similarity in forces impacting conversion patterns. In both areas the initial three variables entering the model included X_6, X_5, and X_4. Although distance to the nearest water line (X_5) was not significant in urban Washington County, the analyses would seem to indicate that proximity to existing development and economically available sewage and water service are the primary policy characteristics increasing the attractiveness of agricultural conversion in the most densely developed areas.

Urban-Rural Fringe: Social Model

As indicated on Table 18, the social model for the urban-rural fringe was rather ineffective. The power of the full model accounted for only 9.7 percent of the variation in farmland conversion. Three variables, median family income (X_9), site elevation (X_{14}), and percentage of substandard housing (X_{11}) were statistically significant, with X_9 and X_{11} operating as expected. The explained variation, however, was only 8.7 percent.

Although producing a slightly higher R^2, the modeling results for the urban-rural fringe replicate the overall effectiveness attained by the social model for the urbanized portion of the county. In both cases, the models did not perform as well as expected. This lack of performance suggests that in a suburban land market, with relatively homogeneous demographic and economic characteristics, social factors, at least those chosen for analysis, do not play a significant role in land conversion decision-making. If this presumption is true, then those portions of suburban areas in which social factors would be of least importance would be in areas of least diversity. In the case of Washington County, the census tracts grouped as urban Washington County and the urban-rural fringe (i.e. census tracts 1-19, 24, 25, 26, 29, 31, and 32) exhibit little variation with regard to median income, social composition, educational achievement, and substandard housing (U.S. Bureau of the Census, 1970). Thus the low R^2 values for urban and urban-rural fringe areas may reflect the impact of homogenity.

Table 18. Urban-Rural Fringe Forward Selection Procedural Model Social Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_9	2.473	.030	--	6.0*
2	X_{14}	.317	.056	.02	5.4*
3	X_{11}	.234	.087	.031	6.4*
4	X_{13}	.195	.095	.008	1.7
5	X_{10}	1.761	.097	.002	.28
6	X_{12}	2.675	.097	.0002	.04

$$Y = 17.3 + 5.54\,X_9 - .89\,X_{14} + .55\,X_{11}$$

*Statistically significant beyond the 1% level of probability.

Urban-Rural Fringe: Environmental Model

The analysis of the environmental model for the rural-urban fringe produced results somewhat similar to the earlier model for the urban area. In both geographical subareas, the explained variation was low. In the fringe, the R^2 with nine variables was only .148 (see Table 19). Using Cp criterion, the best model was determined to be a model with two variables--drainage class (X_{18}) and erosion hazard (X_{21}). Both of these variables were statistically significant. The coefficient of determination for this final model is .127.

Table 19. Urban-Rural Fringe Forward Selection Procedural Model Environmental Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_{18}	.048	.106	--	23.2*
2	X_{21}	.554	.127	.021	4.5*
3	X_{15}	.903	.135	.008	11.7
4	X_{23}	.455	.140	.005	1.0
5	X_{19}	.810	.143	.003	.79
6	X_{17}	.949	.147	.004	.85
7	X_{16}	.200	.148	.0006	.11
8	X_{22}	.438	.148	.0003	.05
9	X_{20}	.844	.148	.0001	.02

$$Y = .88 + .21\,X_{18} - .78\,X_{21}$$

*Statistically significant beyond the 1% level of probability.

The lack of effectiveness, as portrayed by the low coefficient of determination, would seem to suggest that environmental factors play a minimal role in land conversion decision-making in the urban-rural fringe area of Washington County. The general absence of impact in both the urban and urban-rural fringe sections of the county indicates a lack of significance attached to environmental characteristics. There appears to be little discernable correlation between variation in farmland development and physical factors.

Rural Washington County: Accessibility Model

In sharp contrast to other geographical subareas in the county, the three factor accessibility model was moderately effective in the rural portions of Washington County. All three accessibility variables were statistically significant, although distance to the nearest freeway access point (X_3) was significant only beyond the 5 percent confidence level. The total coefficient of determination with all variables was .450. This is to say, 45 percent of the variation of rural farmland conversion was responsive to the accessibility model. Additionally, all three variables functioned as expected, with increasing magnitudes of converted farmland marked by declines in the distance to Portland and urban places, and increasing accessibility to freeways.

As noted on Table 20, the set of "best" independent variables for the rural model would be a judgemental decision. The precision added to the model by X_3 is minimal; however, it is strongly significant. Fortunately, the use of Cp criterion facilitates the identification of the best set of independent variables. The calculated Cp values plotted against p indicated that the equation with X_1, X_2, X_3 had less bias than the two variable model. Consequently, the accessibility model with all three variables is selected.

Table 20. Rural Washington County Forward Selection Procedural Model Accessibility Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_1	.387	.208	--	91.1*
2	X_2	.183	.441	.133	48.2*
3	X_3	.108	.450	.009	3.3**

$$Y = 3.76 - 1.92\,X_1 - 1.28\,X_2 - .19\,X_3$$

* Statistically significant beyond the 1% level of probability.

** Statistically significant beyond the 5% level of probability.

A strong correlation between accessibility and land conversion in rural areas was hypothesized, and confirmed by the regression analysis. It was a supposition that in rural areas where the road network is less developed and the distances between urban settlements is greater, accessibility forces would be important considerations in agricultural land conversion. Of special note is the statistical significance of freeway access (X_3). Nowhere in the earlier analyses was this variable a significant factor for explaining conversion patterns. Apparently, the less intensive primary and secondary road network, with fewer multilaned highways, makes location near access to freeways a more significant factor.

Rural Washington County: Infrastructural-Policy Model

A comparison with earlier infrastructural-policy models showed the level of explanation in rural areas to be lowest of any geographical subarea. However, even in this weakest performance, the model, with with five variables, generates a coefficient of determination of .446. The final rural model includes distance to the nearest water line (X_5), distance to the nearest elementary school (X_7) and distance to the nearest developed area (X_6). The signs for all variables were in agreement with the research hypothesis. Increasing farmland conversion was correlated with decreasing aerial distance to water lines and nearby developed areas, and declines in travel distance to elementary schools. The R^2 for this Cp derived model is .442 (see Table 21).

Table 21. Rural Washington County Forward Selection Procedural Model Infrastructural-Policy Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_5	.109	.356	--	112.9*
2	X_7	.126	.424	.068	23.8*
3	X_6	.117	.442	.018	6.7*
4	X_4	.161	.446	.004	1.3
5	X_8	.150	.446	.0009	.92
	$Y = .44 - .43\ X_5 - .53\ X_7 - .30\ X_6$				

*Statistically significant beyond the 1% level of probability.

This model would seem to indicate that while there appears to be a significant relationship between institutional factors and farmland conversion in rural areas, the measure of association is weakest in the rural areas. The decrease in explanation power, however, was not totally unexpected, as urban development in rural areas is in many cases low density, large lot subdivision. Under these circumstances, individuals or developers often meet infrastructural requirements at a small scale. Septic tanks or "package" sewage treatment plants replace the need for community treatment systems. Individual or community wells meet water needs. Thus, because of actions by the private sector the importance of institutional investments may be decreased.

Rural Washington County: Social Model

The analyses of the social model in the rural section of the county produced a threefold increase in R^2 from the earlier social analyses for urbanized and urban-rural fringe areas. However, the degree of precision was still below most other site characteristics models. Five predictor variables were statistically significant with a coefficient of determination of .299. The only non-significant variable was percentage of substandard housing (X_{11}) (see Table 22).

Table 22. Rural Washington County Forward Selection Procedural Model Social Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_{14}	.199	.207	--	53.5*
2	X_9	1.845	.240	.033	8.9*
3	X_{12}	2.266	.277	.037	10.4*
4	X_{10}	1.259	.293	.016	4.6*
5	X_{13}	.257	.299	.006	2.2**
6	X_{11}	.583	.305	.006	1.5

$$Y = 1.83 - 1.03\ X_{14} + 5.5\ X_9 - 8.96\ X_{12} + 2.70\ X_{10} + .69\ X_{13}$$

* Statistically significant beyond the 1% level of probability.

** Statistically significant beyond the 5% level of probability.

Although the number of significant variables and the R^2 value was higher in rural Washington County than any other subsection of the County, the social model's general tendency of low descriptive power continued. The R^2 of .299 indicates that slightly less than one-third of the variation in rural farmland conversion can be accounted for by social variables.

With the exception of site elevation (X_{14}), all the significant variables operated as expected. Increasing farmland conversions occurred in neighborhoods (i.e. census tracts) with increasing median income and education, characterized by higher value homes, and experiencing the largest rates of population increase. In the case of site elevation, however, greatest conversion occurred in lower areas where scenic vistas and aesthetic amenity values are lower.

Despite the statistical significance, the low R^2 suggests that the application of social data for managing farmland conversion would be of minimal value. Overall, the social model proved to be the least effective of the submodels analyzed.

Rural Washington County: Environmental Model

In sharp divergence with the urban and urban-rural fringe subareas, the model for rural areas proved moderately effective.

The model including nine variables produced an R^2 of .456 (see Table 23). Seven of the variables were statistically significant. Cp criterion, however, identified the six variable model as being most efficient and effective. The final environmental model includes drainage (X_{18}), irrigation suitability (X_{17}), erosion hazard (X_{21}), septic tank drainfield limitation (X_{22}), shrink-swell potential (X_{23}), and slope (X_{16}). The coefficient of determination is .459.

Table 23. Rural Washington County Forward Selection Procedural Model Environmental Factors.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_{18}	.038	.230	--	60.9*
2	X_{17}	.464	.384	.154	50.7*
3	X_{21}	.402	.419	.035	12.6*
4	X_{22}	.280	.439	.020	6.7*
5	X_{23}	.283	.452	.013	4.7*
6	X_{16}	.204	.459	.007	2.4**
7	X_{20}	.310	.465	.006	2.5**
8	X_{19}	.298	.465	.00002	.007
9	X_{15}	.440	.465	.00001	.003

$$Y = 1.14 + .29\,X_{18} - 1.76\,X_{17} + 1.40\,X_{21} - .74\,X_{22} + .56\,X_{23} - .71\,X_{16}$$

* Statistically significant beyond the 1% level of probability.

** Statistically significant beyond the 5% level of probability.

Despite the large number of significant variables, however, the problem of illogical signs continued to fault the effectiveness of the environmental submodel. Among the variables operating in line with the hypothesis were irrigation suitability, septic tank drainfield limitations, shrink-swell potential, and slope. However, increased farmland conversion was also associated with soils having poorer drainage and higher erosion hazards.

As in earlier analyses, simple regression coefficients and intercorrelation among predictor variables were examined as potential causes for the unexplained signs. Neither explanation was effective. The lack of explanation for variable behavior suggests that caution is advised in interpreting the findings of the model.

The marked contrast between the explanatory power of the environmental model in rural areas and other subsections of Washington County suggests that a different set of development factors may be operating in rural areas. There is an increase of R^2 values as one moves across the spectrum from urban to rural subareas. This increase in the explanation variation of converted farmland indicates that environmental factors assume greater importance in conversion decision-making in rural areas.

Washington County Agricultural Land Conversion Model

The individual submodels presented in the previous sections demonstrate that the variation in farmland conversion can only be partially explained on the basis of component models alone. Thus, it is incumbent to combine the individual site characteristic models into a composite model in an effort to increase the amount of descriptive power.

The hypothesis tested in the composite models is that the scope of farmland conversion throughout Washington County is significantly influenced by site characteristics associated with individual units of agricultural acreage. This is to say, that the combined impact of the twenty-three accessibility, infrastructural-policy, social, and environmental predictor variables are a primary input into agricultural land conversion decisions. Thus, those units of farmland with convenient access, public infrastructure in close proximity, located in socially desirable areas of the county, and situated on higher quality agricultural land will be transformed to urban uses in greater quantities than farmland not exhibiting these conditions.

In order to test the research hypothesis, the F-test statistic is used for hypothesis testing. The null hypothesis (H_o) is that there is no relationship between farmland conversion rates and locational characteristics. If the null hypothesis is accepted the B coefficients for each predictor variable would equal zero (B = 0). If a relationship exists (H_A), the B coefficients are not equal to zero ($B \neq 0$), and the calculated F-values will be greater than the table F-value, with appropriate degrees of freedom. The significant level used in this investigation is .95.

In the interest of expediting the discussion, a formal statement of the composite model is excluded. The readers attention, however, is directed to Table 24 which presents a complete listing of the predictor variables, and to previous sections of this chapter which present the assumptions included in the multiple regression modeling techniques.

The results of the forward selection regression for the model are illustrated in Table 25. The inclusion of all 23 predictor variables produces a coefficient of determination of .784. The first 16 variables entering the model are all statistically significant beyond the 5 percent level of probability.

Applying the C_p criterion, the most effective and efficient model is determined. The model selected includes 14 independent variables. Two statistically significant variables are dropped from the final model selected using C_p criterion.

The coefficient of determination for the Washington County model is .780. Variables included in the model are distance to the

Table 24. Independent Variables for Washington County Agricultural Land Conversion Model.

	Site Characteristics
	<u>Accessibility Factors</u>
X_1	distance to the Portland city center
X_2	distance to the nearest urban place
X_3	distance to the nearest freeway access point
	<u>Infrastructural-Policy Factors</u>
X_4	distance to the nearest sewerage trunk line
X_5	distance to the nearest water line
X_6	distance to the nearest developed area
X_7	distance to the nearest elementary school
X_8	planning and zoning designation
	<u>Social Factors</u>
X_9	median family income
X_{10}	median value of housing stock
X_{11}	amount of substandard housing
X_{12}	median education
X_{13}	population change
X_{14}	elevation
	<u>Environmental Factors</u>
X_{15}	soil capability class
X_{16}	slope
X_{17}	irrigation suitability
X_{18}	drainage
X_{19}	effective root zone
X_{20}	available water holding capacity
X_{21}	erosion hazard
X_{22}	septic tank drain field limitation
X_{23}	shrink-swell potential

Table 25. Washington County Forward Selection Procedural Model Agricultural Land Conversion Model.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_6	.003	.631	--	778.1*
2	X_1	.144	.698	.067	100.5*
3	X_{18}	.024	.720	.022	36.1*
4	X_5	.047	.737	.017	29.1*
5	X_{17}	.172	.749	.012	21.7*
6	X_4	.048	.755	.006	10.1*
7	X_{11}	.094	.761	.006	12.2*
8	X_{13}	.069	.768	.007	12.6*
9	X_{22}	.163	.771	.003	6.3*
10	X_{23}	.172	.775	.004	7.0*
11	X_{19}	.231	.777	.002	3.8*
12	X_3	.065	.778	.001	3.2*
13	X_{12}	1.070	.779	.001	1.7**
14	X_{10}	.597	.780	.001	2.2*
15	X_9	.944	.781	.001	1.7**
16	X_2	.103	.782	.001	1.4
17	X_{14}	.146	.782	.0004	.72
18	X_{16}	.110	.783	.0004	.74
19	X_{21}	.233	.784	.0003	.54
20	X_{15}	.303	.784	.0002	.43
21	X_7	.704	.784	.0002	.28

Table 25. Continued.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
22	X_8	.023	.784	.0001	.19
23	X_{20}	.229	.784	.00001	.01

$$Y = 1.99 - .47 X_6 - .67 X_1 + .13 X_{18} - .10 X_5 - .97 X_{17}$$

$$- .23 X_4 + .43 X_{11} + .31 X_{13} - .38 X_{22} + .42 X_{23}$$

$$- .30 X_{19} - .08 X_3 - 2.07 X_{12} + .69 X_{10}$$

* Statistically significant beyond the 1% level of probability.

**Statistically significant beyond the 5% level of probability.

the nearest developed area (X_6), distance to Portland (X_1), drainage (X_{18}), distance to the nearest water line (X_5), irrigation suitability (X_{17}), distance to the nearest sewerage line (X_4), amount of substandard housing (X_{11}), population change (X_{13}), septic tank drainage field limitation (X_{22}), shrink-swell potential (X_{23}), effective root zone (X_{19}), distance to nearest freeway access point (X_3), median education (X_{12}), and median value of housing stock (X_{10}). Among the variables in the model, X_6 is the mosteffectual with a partial regression coefficient of .631. Other variables increasing the R^2 by at least 2 percent are X_1 and X_{18}, which add 6.7 and 2.2 percent respectively (see Table 26).

A review of variable operation in the composite model shows that as the scale of farmland conversion increased the distance to the nearest developed area (X_6) and the aerial distance to sewerage and water lines (X_4 and X_5) decreased. Similarly, the travel distance to Portland (X_1) and the distance to freeway access (X_3) dropped as conversion increased. With regards to social variables, the percentage of substandard housing (X_{11}) increased, median educational attainment (X_{12}) declined, the median value of housing (X_{10}) rose, and the percentage of population change (X_{13}) grew in areas experiencing larger amounts of farmland conversion. Among the environmental variables, increased land conversion was accompanied by poorer drainage (X_{18}), irrigation potential (X_{17}), shallow root zones

Table 26. Washington County Agricultural Land Conversion Model Significant Variables.

Variables	Percent of Variation Explained
*Distance to the nearest developed area (X_6)	63.1
*Distance to the Portland city center (X_1)	6.7
Soil drainage (X_{18})	2.2
*Distance to the nearest water line (X_5)	1.7
*Irrigation suitability (X_{17})	1.2
*Distance to the nearest sewerage trunk line (X_4)	0.6
Percentage of substandard housing (X_{11})	0.6
*Percentage of population change (X_{13})	0.7
*Septic tank drain field limitation (X_{22})	0.3
*Soil shrink-swell potential (X_{23})	0.4
Soil effective root zone (X_{19})	0.2
*Distance to the nearest freeway access point (X_3)	0.1
Median educational attainment (X_{12})	0.1
*Median value of housing stock (X_{10})	0.1
	78.0

*Variable operating in agreement with the general research hypothesis.

(X_{19}), increased shrink-swell potential (X_{23}), and reduced septic tank limitations (X_{22}).

An examination of the coefficient signs shows that most variables operated as expected. All of the accessibility and policy-infrastructural variables in the model were in agreement with the research hypothesis. However, two social variables appeared to contradict the model's assumptions, percentage of substandard housing (X_{11}) and median educational attainment (X_{12}). A possible explanation for this discrepancy, as noted earlier, may lie in the spatial housing structure of the County. Much of eastern urbanized Washington County is established middle class neighborhoods. These areas, which are suburban Portland, are comprised of well maintained, moderately priced, single family housing. Social diversity, as measured by a mix of incomes and social levels, is low. Similarly, the quantity and individual size of agricultural units available for conversion in eastern parts of the County are far below the county side mean. Given these circumstances, the conversion of small scattered agricultural parcels in the eastern areas of the County may have skewed the direction in which several social variables operate.

As in the earlier environmental submodels, directional problems continue to plague the soil related variables. Predictor variables erosion hazard, irrigation potential, septic tank limitations, and shrink-swell potential operated in concert with the hypothesis.

However, the drainage and effective root zone variables were again contrary to the research assumptions. As multicollinearity was not a problem, the continued unexplained behavior of these variables suggests that factors outside the scope of the model were acting on the variables.

Viewed from the perspective of the submodels, five of the environmental variables, four social variables, three accessibility variables, and two infrastructural-policy variables are aggregated in the final county model. If, however, the precision added to the model by individual variables is tallied by submodel, the relative importance of component site characteristics is changed significantly. A summation of partial regression coefficients shows that the two infrastructural-policy variables contribute .654 to the final R^2, accessibility factors add .068, while the unpredictable environmental components and social variables contribute .043 and .015 respectively.

The entering F-value for the Washington County model is 1.76. The calculated F-value is statistically significant beyond the 5 percent level of probability. The F table value for $\alpha = .05$, $F(.95; 13, \infty) = 1.75$. Reference to the F distribution in the statistical table indicates that the probability of obtaining an F ratio equal to or greater than 1.76 is less than .05. Therefore it can be concluded that it is unlikely that this data was drawn from a population in which R = 0. This permits the rejection of the null hypothesis (H_0) that $B_1 = B_2 \ldots B_{14} = 0$. Thus, it is assumed that the B coefficients assume values other than zero, and that there is a relationship between agricultural land conversion and the 14 independent variables.

Urban Washington County Agricultural Land Conversion Model

The regression modeling techniques used in the preceeding section was replicated for each of the component subareas in the county. The hypothesis tested earlier for the entire county is similarly applied to each subunit. Thus, for urban Washington County, the hypothesis tested is that the degree of agricultural land conversion in urban areas of the county is significantly influenced by composite site characteristics.

Table 27 presents a summary of the forward selection regression modeling process. With all 22 variables included in the model, the R^2 is .711. Using C_p criterion, however, the "best" model is shown to be a reduced model with seven variables. All the variables included in this final urban composite model are statistically significant beyond the 5 percent level of probability.

The coefficient of determination in the urban Washington County model is .663. Among the variables included in the model are distance to the nearest developed area (X_6), distance to the nearest

Table 27. Urban Washington County Forward Selection Procedural Model Agricultural Land Conversion Model.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_6	.118	.480	--	74.0*
2	X_2	.285	.556	.076	13.4*
3	X_{13}	.381	.608	.052	10.2*
4	X_4	.087	.625	.017	3.6*
5	X_1	.934	.637	.012	2.3**
6	X_{15}	1.766	.650	.013	3.7*
7	X_{20}	1.180	.663	.013	2.7*
8	X_{11}	.199	.676	.013	3.1*
9	X_3	.132	.682	.006	1.5
10	X_{14}	.791	.687	.005	.97
11	X_{17}	1.163	.691	.004	.97
12	X_{18}	.048	.695	.004	.73
13	X_{12}	1.445	.699	.004	.88
14	X_{19}	1.424	.705	.006	1.3
15	X_9	2.874	.707	.002	.46
16	X_7	.160	.707	.003	.58
17	X_{21}	.545	.710	.001	.16
18	X_{10}	1.892	.771	.0003	.14

Table 27. Continued.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
19	X_{22}	2.633	.711	.00004	.008
20	X_{23}	.667	.711	.00001	.002
21	X_5	.099	.711	.000005	.001
22	X_{16}	.273	.711	.000001	.0003

$$Y = -2.11 - .88\,X_6 - .65\,X_2 + .51\,X_{13} - .12\,X_4$$

$$+ 1.4\,X_1 + 1.46\,X_{15} + .89\,X_{20}$$

* Statistically significant beyond the 1% level of probability.

** Statistically significant beyond the 5% level of probability.

urban place (X_2), distance to Portland (X_1), soil capability class (X_{15}), and available water holding capacity of the soil (X_{20}) (see Table 28).

Table 28. Urban Washington County Agricultural Land Conversion Model Significant Variables.

Variables	Percent of Variation Explained
* Distance to the nearest developed area (X_6)	48.0
* Distance to the nearest urban place (X_2)	7.6
* Percentage of population change (X_{13})	5.2
* Distance to the nearest sewerage trunk line (X_4)	1.7
Distance to the Portland city center (X_1)	1.2
Soil capability class (X_{15})	1.3
Available water holding capacity of the soil (X_{20})	1.3
	66.3

*Variable operating in agreement with the general research hypothesis.

All the predictor variables added at least one percent to the overall precision of the model, with three variables, X_6; X_2; and X_{13}, accounting for 60 percent of the explained variation. The important role of these variables in urban land conversion may suggest a contiguous development pattern in this area. However, the effectiveness of these factors may also reflect a "filling in" process in which the remaining bypassed agricultural acreage was being developed. Aerial photo data indicates that the latter explanation is more plausible.

An examination of the seven variable model shows that as farmland conversion increases distance to the nearest developed area (X_6), distance to the nearest urban place (X_2), and distance to the nearest sewerage trunk line (X_4) decline. Moreover, the percentage of population change (X_{13}) and distance to Portland (X_1) increase with larger scale farmland development. Finally, increasing agricultural conversion is associated with declining soil quality (X_{15}) and soils with reduced water holding capacity (X_{20}).

A review of variable signs shows that four variables operated as hypothesized, while three variables did not perform according to the hypothesis. Two of the three deviant variables were environmental factors which proved poor predictors in other portions of the County. The third variable, however, was distance to Portland, a predictor which operated in accordance with the research hypothesis in most other analyses.

While the performance of the environmental variables was not totally unexpected, in light of earlier analyses, the performance of distance to Portland was entirely unexpected. The failure of this variable to operate as anticipated points up the fact that the research findings must be interpreted in the context of specific geographical subareas of the County. Viewed from the perspective of urban Washington County, the sign attached to distance to Portland can be viewed reasonable. Those agricultural lands found in urbanized areas were located on the periphery of the subarea. Land closest to Portland was developed prior to the study period. Hence, the farmland conversion analyzed reflects a pattern of conversion which is greatest in areas most distant from Portland. Complementing the increased distance from Portland, the composite model found that distance to other urban places (X_2) and to nearby developed areas (X_6) declined with increased conversion activity. All of these findings reflect the unique spatial characteristics operating in the 13 urbanized census tracts of Washington County.

Among the four submodels comprising site characteristics, two variables are included from each group, with the exception of the social factors. Infrastructural-policy variables contribute .497 to the R^2. Next most powerful is the accessibility factors adding .088. Of least importance are the social and environmental categories contributing .052 and .026, respectively.

The research hypothesis is tested with an F-test statistic using the procedure outlined previously. The calculated F-value for the composite urban model is 2.77. The result of the test was a rejection of the null hypothesis and acceptance of the research hypothesis at the .99 level.

Urban-Rural Fringe Agricultural Land Conversion Model

The coefficient of determination for the full 23 variable model is .637 (see Table 29). The final model selected, however, includes only 14 variables and generated an R^2 of .627. All of the variables included in the final urban-rural fringe model are statistically significant beyond the 5 percent level of probability.

As in the earlier composite models, distance to the nearest developed area (X_6) was the most powerful predictor contributing 40.8 percent to the final R^2. Other variables included in the model are distance to the nearest water line (X_5), drainage (X_{18}), distance to Portland (X_5), population change (X_{13}), distance to the nearest sewerage line (X_4), amount of substandard housing (X_{11}), median family income (X_9), median education (X_{12}), distance to the nearest elementary school (X_7), distance to the nearest urban place (X_2), elevation (X_{14}), slope (X_{16}), and soil capability class (X_{15}) (see Table 30).

The modeling results show that increased agricultural land conversion was accompanied by declines in the aerial distance to the nearest urban development (X_6), decreased distances to the closest

Table 29. Urban-Rural Fringe Forward Selection Procedural Model Agricultural Land Conversion Model.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_6	.080	.408	--	133.7*
2	X_5	.069	.465	.057	20.8*
3	X_{18}	.036	.489	.024	8.8*
4	X_1	.555	.511	.022	9.8*
5	X_{13}	.156	.530	.019	7.3*
6	X_4	.070	.550	.020	8.2*
7	X_{11}	.168	.562	.012	4.6*
8	X_9	2.476	.581	.019	8.3*
9	X_{12}	1.883	.593	.012	5.4*
10	X_7	.107	.603	.010	4.4*
11	X_2	.133	.607	.004	1.7**
12	X_{14}	.321	.614	.007	3.3*
13	X_{16}	.163	.622	.008	4.0*
14	X_{15}	.649	.627	.005	2.4*
15	X_3	.115	.630	.003	1.4
16	X_{19}	.620	.632	.002	.68
17	X_{21}	.392	.633	.001	.79
18	X_{17}	.665	.634	.0009	.41
19	X_{23}	.330	.635	.007	.35

Table 29. Continued.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
20	X_{20}	.597	.597	.0014	.69
21	X_{22}	.355	.637	.0004	.17
22	X_8	.069	.637	.0003	.15
23	X_{10}	1.369	.637	.0003	.15

$$Y = -3.10 - 62\, X_6 - .15\, X_5 + .14\, X_{18} + 2.09\, X_1 + .29\, X_{13} - .26\, X_4 + .72\, X_{11} + 8.42\, X_9 - 3.69\, X_{12} + .24\, X_7 + .12\, X_2 - .81\, X_{14} - .18\, X_{16} - .46\, X_{15}$$

* Statistically significant beyond the 1% level of probability.

**Statistically significant beyond the 5% level of probability.

water and sewerage lines (X_5 and X_4), and increasing travel distance to the nearest elementary school (X_7). With respect to accessibility, the distance to Portland (X_1) and the distance to the nearest urban place (X_2) increased as agricultural land conversion increased in magnitude. Larger amounts of farmland conversion were also correlated with areas having higher median family income (X_9), lower median education (X_{12}), increased substandard housing (X_{11}), and increased population growth (X_{13}). Moreover, increased rates of farmland transition were associated with well drained acreage (X_{18}), low slopes (X_{16}), lower elevations (X_{14}), and high quality agricultural land (X_{15}).

Structurally, the urban-rural fringe model includes predictor variables from all four component submodels. The social submodel contributed the largest number of variables with five variables in the model, but the resolution added to the model by these factors was only .069. The next largest contributing category, infrastructural factors, with four variables, proves to be the most powerful as the partial correlation coefficients of these variables total .495. The precision added by the remaining components is .037 by 3 environmental variables, and .026 for 2 accessibility factors.

The operation of variables in the urban-rural fringe model proved to have the greatest uncertainty when viewed against other geographical subareas. A number of variables which were

Table 30. Urban-Rural Fringe Agricultural Land Conversion Model Significant Variables.

Variables	Percent of Variation Explained
*Distance to the nearest developed area (X_6)	40.8
*Distance to the nearest water line (X_5)	5.7
Soil drainage (X_{18})	2.4
Distance to the Portland city center (X_1)	2.2
*Percentage of population change (X_{13})	1.9
*Distance to the nearest sewerage trunk line (X_4)	2.0
Percentage of substandard housing (X_{11})	1.2
*Median family income (X_9)	1.9
Median educational attainment (X_{12})	1.2
Distance to the nearest elementary school (X_7)	1.0
Distance to the nearest urban place (X_2)	0.4
*Site elevation (X_{14})	0.7
*Slope (X_{16})	0.8
*Soil Capability Class (X_{15})	0.5
	62.7

*Variable operating in agreement with the general research hypothesis.

statistically significant in other sections of the county operated differently in this model. Among the infrastructural-policy variables, greater distances to elementary schools (X_7) was found to correlate with increasing farmland conversion. In all other areas of the county, where this variables was significant, the results were reversed. A possible explanation for this contradictory operation may be found in the dynamic character of the urban-rural fringe and factors operating in this area that were not included in the model. As noted previously, the research findings must be interpreted in the geographical context in which they operate.

The negative direction of the accessibility to education variable indicates that farmland conversion was greatest away from existing elementary schools. It may be suggested that larger amounts of "available" farmland existed at locations which are more isolated, thus facilitating conversion in these areas. This is not to say, however, that other distance related factors are also not significant in the urban-rural fringe. Distance to the nearest developed area (X_6), and aerial distance to the nearest water and sewerage lines (X_5 and X_4) emerged as valuable predictors, with the variables operating as expected. Nevertheless, what is suggested is that permanent public facilities, such as schools, may be less significant for explaining land conversion in a dynamic market such as the urban-rural fringe.

Another predictor variable which did not perform as anticipated was median educational attainment (X_{12}). The behavior of the median education variable suggests that areas with lower educational attainment are a positive factor associated with greater amounts of farmland conversion. However, a set of background data which should be considered prior to interpreting the importance of the variables behavior, is the educational homogeneity of the urban-rural fringe. The range of educational attainment in this area is from 11.3 years to 12.7 years. These data suggest that the area lacks a strong measure to heterogeneity, which is requisite requirement for this variable to operate effectively. Hence, a strong reliance on this variable for explaining conversion patterns in the urban-rural fringe for Washington County is not suggested.

Certainly the most unsettling component of the urban-rural fringe composite model is the directional operation of the distance to Portland (X_1) and distance to the nearest urban place (X_2) variables in the model. In the earlier accessibility submodel developed for the urban-rural fringe, these variables proved to be an important predictor which operated in concert with the research hypothesis. Their performance in the composite model, however, indicates a paradoxical reversal in operation.

In an attempt to explain the erratic performance of both variables, multicollinearity was explored. An analysis of intercorrelation among independent variables, however, found little evidence to support this idea. The highest level of correlation among the predictor variables was only -.304, between distance to Portland and median family income (X_9). The failure of standard explanations to explain the circumstances surrounding distance to urban areas suggests that a hidden or masked relationship exists between the erratic variables and one or more predictor variables added in the composite model. Unfortunately, detection and correction of this disruptive intercorrelation is beyond the control of the investigator.

In light of this difficulty, several comments regarding the distance to Portland and distance to the nearest urban place variables are appropriate. First, both distance to Portland and distance to the nearest urban place are statistically significant descriptors for examining farmland conversion in Washington County. Secondly, under more controlled conditions there is a negative relationship between the pattern of agricultural land conversion and the two variables. Finally, there may be a significant intercorrelation between variables included in the composite site characteristic model which causes the operation of the two accessibility variables to vascilate. Given these conditions, the investigator suggests that the operational direction of the two variables in the composite site characteristic model be viewed with suspicion.

In accordance with hypothesis testing procedures, the full model was statistically tested using the F-value statistic. The calulated F-value for the full model is 2.46. A comparison of the calculated F and the table F-values shows that the full model is statistically significant beyond the one percent level of probability. Based on the tests, the null hypothesis is rejected. Thus, one can assume, within the probability limits established, that agricultural land conversion in the urban-rural fringe is influenced by the 14 site characteristics in the model.

Rural Washington County Land Conversion Model

The final composite conversion model is restricted in focus to rural Washington County. The model with all 23 variables generates an R^2 of .677 (see Table 31). However, using Cp criterion, the final model selected includes only 12 variables. The coefficient of determination for this model is .666. As in the previous composite models, all the variables entering the rural model are statistically significant beyond the 5 percent level of probability.

Predictor variables which provide the greatest degree of explanation to rural farmland conversion are distance to nearest water line (X_5), and distance to Portland (X_1) with partial correlation coefficients of .356 and .129, respectively. Other factors included in

Table 31. Rural Washington County Forward Selection Procedural Model Agricultural Land Conversion Model.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
1	X_5	.120	.356	--	112.9*
2	X_1	.557	.485	.129	50.8*
3	X_{18}	.034	.530	.045	19.3*
4	X_6	.103	.564	.034	15.7*
5	X_9	1.821	.588	.024	11.4*
6	X_2	.260	.616	.028	14.8*
7	X_{23}	.261	.629	.013	6.8*
8	X_{22}	.237	.641	.012	6.4*
9	X_{21}	.339	.652	.011	6.3*
10	X_8	.032	.658	.006	3.5*
11	X_{16}	.180	.662	.004	2.2*
12	X_{17}	.420	.666	.004	2.3*
13	X_{19}	.266	.668	.002	1.0*
14	X_7	.124	.669	.001	.62
15	X_{11}	.488	.670	.001	.49
16	X_3	.119	.671	.001	.59
17	X_{12}	2.392	.674	.002	1.9*
18	X_{13}	.233	.676	.002	.92
19	X_{10}	1.280	.676	.0003	.21

Table 31. Continued.

Step	Variable	Standard Error	R^2	Increase in R^2	F Value
20	X_{14}	.201	.677	.0003	.16
21	X_{20}	.274	.677	.0003	.17
22	X_4	.237	.677	.0001	.03
23	X_{15}	.376	.677	.0001	.02

$$Y = 16.01 - .29\,X_5 - 1.90\,X_1 + .18\,X_{18} - .37\,X_6 - 3.5\,X_9 - .70\,X_2 + .64\,X_{23} - .57\,X_{22} + .93\,X_{21} - .05\,X_8 - .44\,X_{16} - .51\,X_{17}$$

* Statistically significant beyond the 1% level of probability.

**Statistically significant beyond the 5% level of probability.

the rural model are drainage (X_{18}), distance to the nearest developed area (X_6), median family income (X_9), distance to the nearest urban place (X_2), shrink-swell potential (X_{23}), septic tank drainage limitations (X_{22}), erosion hazard (X_{21}), planning (X_8), slope (X_{16}), and irrigation suitability (X_{17}) (see Table 32).

An examination of the relationship expressed by the final composite model shows that increasing agricultural land conversion is marked by decreasing distances to water lines (X_5), shorter travel distances to Portland (X_1) and other urban areas (X_2), and reduced distance to the nearest developed area (X_6). Moreover, the propensity for farmland conversion increases with acreage having poorer drainage (X_{18}), lower shrink-swell potential (X_{23}), fewer septic tank limitations (X_{22}), increased erosion hazard (X_{21}), slight slope (X_{16}), and low potential for irrigation (X_{17}). Finally, farmland development is increased in areas with lower median income (X_9) and in sections with planning and zoning (X_8).

The operation of predictor variables in the rural composite model were generally in agreement with the research hypotheses. However, the directional operation of median family income (X_9) and soil shrink-swell potential (X_{23}) displayed a shift from earlier social and environmental submodels. An examination for multicollinearity suggests that this may be a possible explanation for this erratic operation. The simple regression coefficient for the dependent

Table 32. Rural Washington County Agricultural Land Conversion Model Significant Variables.

Variables	Percent of Variation Explained
*Distance to the nearest water line (X_5)	35.6
*Distance to the Portland city center (X_1)	12.9
Soil drainage (X_{18})	4.5
*Distance to the nearest developed area (X_6)	3.4
Median family income (X_9)	2.4
*Distance to the nearest urban place (X_2)	2.8
*Soil shrink-swell potential (X_{23})	1.3
*Septic tank drain field limitation (X_{22})	1.2
Soil erosion hazard (X_{21})	1.1
*Planning designation (X_8)	0.6
*Slope (X_{16})	0.4
*Irrigation suitability (X_{17})	0.4
	66.6

*Variable operating in agreement with the general research hypothesis.

variable and median family income is .564. Further, an examination of the correlation matrix found a moderate degree of intercorrelation between the distance to the nearest water line (X_5) and income levels (-.570) and distance to Portland and income levels (-.550). The intercorrelation between these factors, viewed in concert with the simple regression coefficient, suggests that multicollinearity is a possible cause of the directional shift in the composite model.

Similar circumstances surround the shrink-swell variable. The simple regression coefficient for this variable and farmland conversion is -.057. However, there is a moderate degree of intercorrelation between shrink-swell potential and distance to Portland (.401) and a partial correlation coefficient of .415 for shrink-swell potential measured against percentage of substandard housing. These conditions surrounding the operation of shrink-swell potential suggest a strong probability of multicollinearity affecting this variable in the composite model.

If the rural model is examined from the perspective of the component submodels, six environmental variables, three infrastructural-policy variables, two accessibility variables, and two social variables are included. The most effective category of variables are the infrastructural-policy contributing .085, and social variables totaling .028.

The calculated F-value for the rural model is 2.30. This value exceeds the table F at the 1 percent level of probability. Accordingly, the null hypothesis is rejected. The alternative hypothesis that locational characteristics influence agricultural conversion rates in rural Washington County is thus accepted.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In the preceeding chapter, regression models for agricultural land conversion in Washington County were developed and hypotheses tested. In this final section, the data presented in the earlier four chapters and the modeling results are integrated and discussed in the context of the overall study purpose and design. In a sense, this section will serve as a qualitative examination of the research hypotheses with respect to farmland transition in Washington County. Those variables and groups of factors which contribute most the the explanation of farmland conversion throughout the study are are noted. Geographical variations in variable effectiveness are recorded. Finally, an interpretation of these findings with respect to the overall study model is developed.

A special emphasis in this final chapter will be to place the results of this investigation in the context of the overall agricultural land conversion problem. Accordingly, the chapter examines the applicability of the study findings to land use planning strategies to protect agricultural land resources.

The Impact of Site Characteristics

As noted earlier, individual models were generated for each set of site characteristic variables and for the composite model. As expected, the effectiveness of individual site factors and groups varied extensively with respect to explaining agricultural land conversion. Several of the hypothesized variables were consistently strong performers accounting for much of the variation in farmland transition. Conversely, numerous variables proved of only peripheral value during the modeling.

Infrastructural-Policy Factors

The results of the regression models showed the most powerful set of variables to be the infrastructural-policy factors. The infrastructural submodel, which includes four significant variables, is able to "explain" 70.7 percent of the variation in farmland conversion in Washington County. In the final composite model, three infrastructural-policy variables are included, and account for 65.4 percent of the explained variation.

Throughout the analyses, the most important individual variable is distance to the nearest developed area (X_6). This variable was developed to examine the importance of previous policy decisions which permit farmland conversion to occur, thereby setting a precedent for continued development activity in adjacent farmland. Previous investigators have found these decisions to have an effect on future development patterns. Sinclair, for example, documented a number of studies which pointed out the impact of new suburban growth on nearby agricultural operations. He concluded that "bulldozing often awaits the harvesting of the current crop" (Sinclair, 1967, p. 86).

The data developed for Washington County indicate that the pattern of farmland conversion is strongly related to this variable. In almost every modeling experience, distance to the nearest developed area was the first variable included in the model. The partial regression coefficients for this variable, in all but one case ranged from .631 to .408. Only in rural portions of Washington County was this factor not ranked as most effective. Other infrastructural variables which also exhibited strong explanatory powers were distance to the nearest sewerage trunk line (X_4) and distance to the nearest water line (X_5). In almost every case these variables proved to be consistently important factors. In the final composite model, X_5 accounted for 1.7 percent and X_4 for .6 of the R^2.

The most unexpected performance among the infrastructural-policy factors was exhibited by planning and zoning designation (X_8). Previous research by Chapin and Weiss (1962) found that "zoning protection" was a significant factor for explaining land development patterns in Greensboro, Lexington, and Winston-Salem, North Carolina. This research indicated that land with zoning regulations was more desirable for urban use and thus had a propensity to be converted to urbanization. In the current study, however, the planning variable was defined simply as whether the observation was located in an area included in the county's partially completed zoning and planning program. As a consequence of adopting simpler approach, a number of important policy considerations associated with the county's land regulations were not included in the operation of the variable. Specifically, the Washington County zoning ordinance during the period from 1963 to 1973 included several rural districts and residential zoning districts which permitted the conversion of farmland to urban development either outright or by exception. Moreover, subarea land use plans developed for portions of Washington County during the study period contained no prohibition against farmland development. Finally, the planning and zoning variable, as used in this investigation, did not differentiate between zoning districts or planned areas which permitted or prohibited farmland conversion. Given these circumstances, the measurement of agricultural land conversion against land which simply possessed or lacked planning and zoning regulations was flawed.

The lack of data and late stage of analysis did not permit revision of this variable at the point at which the difficulties were realized. However, the results attached to this variable provide future investigators with insight as to development of a similiar variable so as to avoid similiar problems. Future investigators should exercise caution in generating zoning and planning variables. Special attention should be taken to include all land use options available in any land regulation. The research findings of this investigation suggest that the use of a simple or too narrow classification scheme may generate data of little value for analysis purposes.

The basic conclusions of most previous researchers examing infrastructure has been that these decisions have an important impact on the location, type and magnitude of development. Increased provision for public services stimulate urban growth. For example, studies have quantified the causal relationship between expanding public services and urban development for the Boston, Denver, Minneapolis-St. Paul, and Washington, D. C. metropolitan areas (Environmental Impact Center Inc., 1975b). The findings produced in other areas are reaffirmed in Washington County. It is apparent from the study data that the decision to convert farmland to urban uses in Washington County was strongly influenced (county-wide infrastructural-policy model $R^2 = .707$) by the available public facilities and by previous policies permitting development activities. Inherent in these findings is the notion that control of farmland conversion may be found in the staging and programming of utility service and land development policies. The application of the concepts will be discussed later.

Accessibility Factors

A second set of variables which were found to contribute significantly to the explanation of variation in farmland conversion were the accessibility factors. Two of the three accessibility factors, distance to Portland (X_1) and distance to the nearest urban place (X_2), were statistically significant in all but one model. Conversely, the effect of distance to the nearest freeway access point (X_3) proved significant only in rural areas.

The significance of distance to Portland (X_1) and distance to the nearest urban place (X_2) in the analyses is found in the level of explanation attached to these factors. Countywide, the R^2 achieved by the distance to Portland and distance to the nearest urban place is .604. That is, 60.4 percent of the pattern of agricultural land conversion is accounted for by these two factors. Neither variable proved dominant in a majority of regression models; rather both were significant factors in almost all equations. This suggests that accessibility to urban areas, both inside and outside of the county, is of more importance than locational relationships to any specific urban area. This is to say, that the critical element in the land conversion decision was not the travel distance to Beaverton, Forest Grove, or Portland, but rather the ease of movement to any urban place.

The lack of statistical significance associated with X_3 indicates that freeway access has not been a primary concern in the decision to convert agricultural land, except in rural areas. This finding would seem to diverge from earlier empirical studies. Previous researchers have found that freeway access has a positive impact on land development, especially single family housing construction (Environmental Impact Center, Inc., 1975b, p. 6). A possible explanation for this inconsistent finding may be found in the adequacy of the existing road network which makes reliance on freeways unnecessary in Washington County. The extensive system of four laned primary roads connecting Washington County with other sections of the Portland metropolitan area means that those areas situated near State Road 217 and U. S. Route 26 enjoy no special accessibility benefits. Under these circumstances, X_3 would not emerge as a critical factor in the development of farmland.

The primary difficulty surrounding the accessibility variables was concern with the changing direction of coefficients in the urban-rural fringe subarea. In the accessibility submodel, the distance to Portland (X_1) and distance to the nearest urban place (X_2) variables behaved in a manner consistent with other submodels for the remainder of the County. In the composite model, however, coefficients changed direction. This reversal in signs is believed to be a result of masked intercorrelation between variables in the composite model, rather than a real change in variable operation. The problem of hidden intercorrelation causing irrational variable operation is a serious handicap for researchers in social and behavioral sciences. Neter and Wasserman (1974) note that many data do not permit experimental controls to mitigate the difficulty and in these circumstances the data must be accepted irrespective of their problems. Fortunately, X_1 and X_2 were included in the earlier submodel, where intercorrelation was not a problem. This analysis permits a more accurate appraisal of the value of these accessibility factors for describing the farmland conversion pattern.

The high R^2 values associated with X_1 and X_2 reinforce the conclusions of earlier investigations. Previous research has noted that the greater the accessibility to urban areas, the greater the amounts of land development activity. Moreover, the findings of this investigation go one step further in providing specific insight into the impact of accessibility on agricultural land use. The data generated in Washington County demonstrate a significant relationship between the scope of agricultural land conversion activity and accessibility to urban places.

Social Factors

In contrast to the strong measure of precision found in earlier sets of factors, only a moderate degree of variation was explained by the group of social variables. In the final regression analyses, five of the six social variables were statistically significant, with an R^2 of .528. The only non-significant variable was median education of persons over the age of 21 (X_{21}).

The most effective social factors in a majority of models were median family income (X_9) and site elevation (X_{14}). The correlation coefficients for these two variables totaled .495 in the social variable submodel. These data indicate that in making the determination to convert farmland, proximity to higher income areas and location in the Tualatin Valley floor (i.e. lower elevations) were the most critical social elements impacting the decision-making process. It would appear that these factors emerged as more important considerations than either the value of adjacent housing, amounts of substandard housing, or recent population changes in an area.

It should be noted, however, that site elevation performed in a manner contrary to the original hypothesis. One can infer from the direction in which it operated that the importance attached to elevation was more physical than social. The tendency for larger amounts of conversion to occur at lower elevations suggests that the fewer construction constraints found in lower areas were more important than the aesthetics of higher locations. Given these findings, site elevation takes on an environmental orientation.

The prominence attached to median family income (X_9) and site elevation (X_{14}) was an unexpected result. It had been hypothesized that the entire set of social variables would impact on farmland development. Hence, the limited success of these two divergent variables from the group of six is unexplained.

Overall, the social factors showed only moderate success at explaining agricultural land conversion. Earlier researchers have indicated the social environment of an area influences land development patterns (Chapin and Weiss, 1962; Brown, 1966). For example, Chapin and Weiss found that proximity to racially mixed neighborhoods and blighted neighborhoods were deterrents to land development activities in Greensboro and Winston-Salem. Similarly, Brown observed that in Tulsa, Oklahoma nonwhite neighborhoods and blighted areas were strongly correlated with the pattern of idle land (Brown, 1967, p. 77). A strong relationship along these lines does not apparently exist with respect to the urbanization of farmland in Washington County.

A possible explanation for this situation may be found in the character of urban development in the area. Washington County has been and remains middle and upper middle class suburbia for the Portland metropolitan area. Fewer poor people and minorities are found in the county than in any other political unit in the region (U. S. Bureau of the Census, 1970). Given the circumstances of a relatively homogeneous suburban environment, social differences are negligible, and the importance of social factors is secondary. One might expect more importance attached to social factors if greater diversity existed in the area. Consequently, the 50 percent of variation in conversion patterns explained by social factors may not be unexpected.

Environmental Factors

The final set of site characteristics examined was a group of environmental variables. As in the case of social factors, the environmental variables proved only moderately successful in explaining conversion activity. The countywide coefficient of determination for the environmental submodel was .492. Moreover, only five of the nine environmental factors were statistically significant.

The moderate degree of correlation ($R^2 = .492$) between farmland conversion and environmental elements was not a totally unexpected finding. Earlier researchers examining a different set of physical factors found that environmental constraints had only minimal impact on land development actions (Chapin and Weiss, 1962). The current investigation had hypothesized that physical land characteristics, especially those physical properties desirable for agricultural land use, would be of primary importance in the decision to transform farmland. The research findings, however, indicate that, although a number of environmental factors were significant, the direction and impact of these variables were in many occasions confusing.

Although unanimity with respect to the most powerful environmental factor was not observed in the analyses, soil drainage class (X_{18}) proved to be overall the most important variable in this group. Only in urban sections, where farmland preservation was of minor importance was drainage not a significant factor in interpreting farmland conversion. The partial correlation coefficient for X_{18} is .318 for the county. The relationship established was that the scale of individual observational units of land conversion increased as soil wetness problems become more acute. However, several extenuating circumstances surround the operation of this variable which cast suspicion as to these conclusions. A discussion of these circumstances for this variable, as well as, soil capability class (X_{15}) are found in the following section.

Other environmental factors which were of secondary importance in explaining conversion activity were soil erosion hazard (X_{21}), slope (X_{16}), and irrigation class (X_{17}). In the case of these variables, the data analysis noted that the scope of agricultural land conversion increased significantly for soils with increased irrigation suitability, lower amounts of slope, and decreased susceptibility to soil erosion. The correlation with respect to these variables (with the exception of rural areas) suggests that farmers and land developers in Washington County were competing for land with positive agricultural attributes. The data, however, indicate that winners of the competition were usually the development interests.

Variables which added little to the explanation of the data and proved non-significant in all parts of the County included soil capability class (X_{15}) and available water-holding capacity of the soil (X_{20}). Additionally, septic tank drainage field limitations (X_{22}) and soil shrink-swell potential (X_{23}), were non-significant factors in all sections of the County, except in rural areas.

A summary assessment of the environmental variables and sub-model must note their general weakness. Throughout the analyses, the strength of association and significance attached to the soil related characteristics proved marginal. Among the significant variables, the direction of operation was often contradictory to the research assumptions. With the exception of soil drainage, the precision added to the analyses by environmental factors was uniformly low. The sum of these difficulties suggests that future investigators exploring the question of farmland conversion may be served by using environmental variables sparingly or conducting pretests to examine the applicability of selected environmental factors prior to their inclusion in the general study design.

Farmland Conversion and Environmental Factors

The results of the regression analyses for the environmental variables may prompt the suggestion that agricultural land conversion is occurring on marginal farmland in greater amounts than on prime agricultural acreage. This conclusion, based on the direction and magnitude of significant variables, is not, however, warranted. The regression analyses carried out in this investigation examined the magnitude of farmland conversion, using acres of transformed land in an observational unit as the dependent variable. Thus R^2 value and regression coefficients provide inference regarding the operation of individual observational units measured against a given level of X.

Contrary to the conclusion that one may reach by simply looking at directional signs, the descriptive data generated by this investigation show a marked propensity for conversion activity to affect prime agricultural acreage. The aggregate data presented on Table 33 shows that 94.7 percent of the converted agricultural acreage between 1963-1973 was considered "prime" (Soil Capability Classes I, II, III), with 99.4 percent classified as agricultural lands (Soil Capabilities Classes I, II, III, and IV) by the Oregon Land Conservation and Development Commission definition.

Table 33. Tabulation for Soil Capability Class.

	Soil Capability Class		Acreage Converted	
	Number of Observations	Frequency	Number of Acres	Percentage
I	10	2.2%	356.60	3.4%
II	251	55.0%	8005.00	76.7%
III	119	26.1%	1522.65	14.6%
IV	47	10.3%	491.55	4.7%
VI	29	6.1%	57.70	0.6%
Total	456	100.0%	10433.50	100.0%

Additional study of these aggregate data show that observational units containing higher quality soil resources provided larger amounts of converted land per observational unit than lower capability class. Consequently, individual units of converted prime agricultural land were of a greater magnitude than transition among lower quality soils. These data suggest that during the study period demand and pressure for higher quality agricultural land was greater than the strain of conversion placed on lower quality farmland.

Complementary findings are observed in Table 34. The portrayed data shows that on an overall basis, far greater amounts of well drained acreage were converted to urban use than were poorly drained agricultural land during the study period. Nearly 92 percent of the transformed farmland was grouped in drainage class 1 and 2. Not surprisingly, the scale of conversion which took place on the most well drained lands far exceeded a normal distribution. Comprising 81.6 percent of the acreage in Washington County, drainage classes 1 and 2 absorbed 92 percent of the land conversion during the study period.

It may seem that the tabular data are divergent from the findings of the regression analyses; however, a discrepancy does not really exist. A visual analysis of Table 34 reveals that the scale of individual units of converted farmland was greater among the more poorly drained drainage classes, despite the larger quantities of conversion among better drained soils. The regression analyses that were carried out were sensitive only to the scale of individual conversion operations. Hence, the model correctly recognized the larger scale conversion associated with poorly drained soils, while the tabular aggregate data show that greater amounts of well drained soils were converted during the study period.

The data presented on Tables 33 and 34 provide another perspective on the questions surrounding the agricultural land conversion problem in Washington County. The regression model of environmental factors analyzed the impact of the selected variables on the pattern of conversion behavior. The conclusions reached should not be given wider interpretation. The aggregate data provides an overview of the total scope of the problem through descriptive information. These data point out the magnitude of the agricultural land conversion process as it existed in Washington County during the study period. Both sets of information serve to complement the other providing a more complete picture of the process.

Table 34. Tabulation for Soil Drainage Characteristics.

	Soil Drainage Class		Acreage Converted	
	Number of Observations	Frequency	Number of Acres	Percentage
I	255	55.9%	3430.95	32.8%
II	154	33.8%	6116.91	58.6%
III	11	2.4%	107.78	1.0%
IV	5	1.1%	117.04	1.1%
V	24	5.3%	483.35	4.6%
VI	7	1.5%	117.50	1.7%
Total	456	100.0%	10433.50	99.8%

Composite Factors

In the final composite model for farmland conversion, 14 of the 23 site characteristic variables were statistically significant. This model was found to contribute significantly to the explanation of variation in the urbanization of agricultural land. The level of explanation achieved by the model was .780; that is, slightly greater than three quarters of the variation in land conversion was related to the included factors.

Variables from all four sets of site characteristics were included in the composite model. However, three infrastructural-policy variables, distance to the nearest developed area (X_6), distance to the nearest water line (X_5), and distance to the nearest sewerage trunk line (X_4) added more precision to the model than all other variables combined. The effectiveness of the infrastructural policy factors in the composite model affirm the findings of the earlier individual submodels. Among the individual regression models, the infrastructural-policy factors were significantly stronger than other variables for describing farmland conversion. If examined independently, the infrastructural-policy variables accounted for 70 percent ($R^2 = .707$) of farmland development activity.

No other set of site characteristics exhibited the explanatory power of infrastructural policy factors; however, several individual variables demonstrated a strong measure of effectiveness. Distance to Portland (X_1) although it is the only statistically significant accessibility variable, is the second most powerful factor in the model. Increased accessibility to Portland accounts for 6.7 percent of the explained variation. Another individual factor of importance is soil drainage class (X_{18}). This variable is the most powerful environmental factor included in the composite model.

Approximately three percent of the variation in land conversion is accounted for by this variable. It should be noted that both variables were the most powerful factors in their individual submodels. Distance to Portland (X_1) accounted for 49.6 percent of the variation in the accessibility submodel, while soil drainage class (X_{18}) explained 31.8 percent of the variation in the environmental submodel. Thus, their strength in the composite model was not unexpected.

Despite the inclusion of four social variables in the composite model, none of these factors added much precision to the model. The summed partial correlation coefficients for all social factors was only .015. This lack of effectiveness suggests that social factors exhibit only secondary importance when considered in conjunction with other site characteristics. Social factors are included in the set of variables included in the land conversion decision process; however, their importance would appear to be subordinate to other considerations.

In the final analysis, the composite model proved to be an extremely significant tool for explaining the variation in agricultural land conversion. The precision of the model compares favorably with earlier models examining land development behavior (Alonso, 1965; Chapin and Weiss, 1962; Brown, 1967; Yates, 1965). The strong descriptive powers exhibited by the model suggest that the investigation's findings may be applicable in land planning efforts to control farmland conversion.

Locational Aspects of Farmland Conversion

One of the assumptions of this investigation was that farmland conversion behavior would differ significantly in divergent areas of Washington County. It was presumed that the variables influencing land development patterns in more urbanized sections would operate differently in less developed areas. Moreover, the investigation postulated that unique combinations of variables could be employed to explain the pattern of land development decisions in sections of the county, which possess differing levels of urban activity.

The results of the data analyses confirmed these earlier suppositions. The research findings show a number of differences in variable performance related to locational criteria. Moreover, the combination of site characteristic variables which achieved the highest total level of explanation also varied in different sections of the county.

In examining farmland development in the most urbanized sections of Washington County, it was found that the set of infrastructural-policy factors proved most effective. A two variable infrastructural-policy model, including distance to the nearest developed area (X_6) and distance to the nearest sewerage line (X_4), explained 54.6 percent of farmland development behavior. In sharp contrast to the success of this group of variables, accessibility, environmental, and social variables were extremely ineffective in examining urban farmland conversion. Among these factors, the most powerful set of variables, accessibility factors, could only achieve 10.2 percent explanation. These data indicate that in urban Washington County the impact of infrastructural and policy decisions has a greater propensity to influence farmland development than does accessibility, social, and environmental factors.

In those sections of the county that are least urbanized, the operation of variables in urban areas is reversed. Accessibility, environmental, and social factors exhibited their highest levels of explanation in rural portions of Washington County. The seven variable environmental model accounted for 46.5 percent of the variation in farmland conversion. The coefficient of determination for a three factor accessibility model is .450. The level of explanation for the five variable social model is 29.9 percent. Although the level of explanation in all three models was not exceedingly high their percision was greater in these rural areas than in other more developed sections of the county. Conversely, the infrastructural policy factors proved weakest in these rural sections. However, even at this lowest level of explanation the coefficient of determination was .442.

The analyses for rural areas suggest that the importance of accessibility, environmental, and social factors in the decision-making process are most critical in rural areas. In no other section of the county did these factors contribute as much to explaining farmland development. In contrast, the importance of infrastructural-policy factors remained high; however, their impact was greater in urbanized areas. Finally the data indicate that accessibility and environmental considerations play a more influential role in rural areas than does infrastructural and policy factors. The least important set of variables appears to be social factors.

The one section of Washington County which was consistently most difficult to successfully analyze was the area with the most unstable land market, the urban-rural fringe. No set of individual site characteristics showed exceptional strength in explaining farmland conversion in this area. The infrastructural-policy model acheived only a moderate level of explanation with 48.3 percent of the variation interpreted. However, no other individual set of factors accounted for more than 13 percent of the conversion. The accessibility and environmental submodels resolved only 12.7 percent of the variation, while the social submodel could explain 8.7 percent of the farmland conversion.

The conclusions reached from these models suggest that in the dynamic land market of the urban-rural fringe, individual submodels lack effective descriptive power. Only infrastructural-policy factors appear to have any success in explaining fringe conversion behavior. In contrast, the composite site characteristic model performed rather effectively ($R^2 = .627$) in these areas. With respect to these findings, the data may indicate that individual site characteristics lack impact on land conversion, but selectively aggregated they can effectively analyze land conversion behavior.

The one major exception to geographical variation in variable performance was observed in the composite model. The level of explanation achieved by this aggregate model was nearly uniform in all portions of Washington County. The composite model was most successful in urban Washington County accounting for 67.6 percent of the variation in conversion; however, the differential with its lowest level of explanation was less than five percent ($R^2 = .627$) in urban-rural fringe areas. This uniformity and level of precision suggests broad applicability of the composite model. The data indicated that the composite model can be used effectively in areas with varying stages of urban development.

The primary difficulties attached to the composite models were associated with unexplained signs. Apparent intercorrelation caused illogical sign changes for several variables, especially in the urban-rural fringe and rural areas. Regrettably, problems of intercorrelation are inherent in regression models with large numbers of related variables. An additional complication emerged with a number of statistically significant variables operating divergently from the general research hypotheses. As noted earlier, however, individual data must be viewed in the geographical matrices in which they operate. While certain assumptions are made for the broader region, the subarea context may provide a situation where variables function in a different manner. These unique circumstances do not, however, detract from the general significance attached to the predictor. Rather, they add to the overall understanding of the local factors related to farmland conversion patterns.

In the final examination, it would appear that the individual site characteristics models proved most effective in explaining farmland development in rural areas of Washington County. Conversely, these models demonstrated the lowest measure of precision in urban areas. In interpreting these results, one consideration which should be remembered is the character and availability of farmland. Those units of converted agricultural acreage in urban Washington County are smaller and scattered. Their conversion reflects a "filling in" process. Conversely, agricultural parcels available for conversion in rural areas tend to be larger in size. Given these circumstances, the strengths and weaknesses of the submodels in rural and urban areas may be inherent in the operational methodology of the site characteristic model; that is, inference as to the likelihood of conversion and its distribution is made from the correlation of the variable to scale of conversion within an observational unit. These background conditions suggest that in using the regression results, the findings for rural Washington County and countywide may be more readily replicated and applicable than the modeling results for urban Washington County.

In contrast to the individual submodels, the composite which includes the most powerful variables from all four sets of factors, was slightly more powerful in urban areas than in other parts of the county. This lack of consistency in the behavior of variables suggests that individual site characteristics achieve their most effective performance in areas with the least complex land conversion characteristics (i. e. rural areas). Conversely, composite models which incorporate diverse site characteristics can more accurately account for conversion behavior in more dynamic and diverse areas, such as in urbanized areas.

The Application of Research Findings

The research results of the investigation found that the site characteristics model provided a consistently powerful tool for understanding farmland transition in all sections of Washington County, Oregon. Application of the model to the entire county explained 78 percent of the variation of the pattern of agricultural conversion.

When the model was restricted to urbanized portions of the county the explained variation was 67.6 percent. In the urban-rural fringe and in rural areas the model accounted for 62.7 percent and 66.6 percent of the conversion behavior, respectively. Most importantly, the composite site characteristic models were all statistically significant, providing strong correlation and systematic results.

The strong measure of reliability associated with the site characteristic methodology, viewed within the framework of concern for farmland conversion, suggests that the conclusions of this investigation may have broad policy implications. The linkage between the conversion of farmland to urban land uses and site characteristics provide insight regarding the operation of agricultural land conversion process. Drawing on the relationships pointed out in the investigation, Washington County and other governmental units may find that the study study findings can assist in improving mechanisms for controlling land conversion.

Traditionally, communities seeking to control land use patterns have relied almost exclusively on "police power" mechanisms, such as zoning, subdivision regulation, and code enforcement. Many times, however, these techniques fail to substantially control or coordinate land use. The source of this failure is not explained easily but rather reflects a complex interaction of variables and market mechanisms. Two of the most critical flaws in this traditional strategy are the absence of coordination between police power regulations and public investment policy, and the total reliance on police power mechanisms for controlling land development.

In many cases, community decision-makers establish a set of land use regulations to operate independently of public policy decisions related to community investments. Typically, these regulatory mechanisms become static and outdated ordinances which are expected to function efficiently, while uncoordinated public investment decisions are made which are contradictory to regulatory policies. In the resulting controversy over haphazard, ill-planned subdivisions, and shopping centers, there is widespread indignation and dismay over the failure of regulatory techniques to control the rapid increase in farmland conversion. Because of situations such as this, the record of independent regulatory techniques for coping with farmland transition lacks credibility.

The lack of success and inherent problems associated with earlier farmland conservation policies measured against the results of the site characteristic model points out the practical value of the Washington County study. The information and data analyses of this study may provide insight in dealing with this problem. The site characteristic model noted a strong linkage between patterns of farmland development and a number of diverse site characteristic variables. Several of those factors which accounted for much of the variation in development were characteristics created or dependent on societal action. This is to say, public policy decisions and public investments may create a locational advantage or disadvantage for land development in an area. These decisions may bring about a change in site characteristics and impact on the land conversion decision-making process.

Throughout the analyses, the most consistently important site factor proved to be distance to the nearest developed area (X_6). The operation of this variable is, of course, dependent on previous land planning policy with respect to subdivision control. Public policy which permits or encourages noncontiguous or low density development patterns is in effect stimulating additional farmland conversion. Conversely, land use controls which constrict the location of new development, reducing the areal extent of urban expansion, reduce pressures for the development of farmland.

Two other closely related factors which played a major role in explaining farmland transition were distance to the nearest water line (X_5) and distance to the nearest sewerage line (X_4). The location and timing of water and sewerage facilities are among the most critical and costly public policy decisions made by the local community. Both site characteristics are dependent on large scale public investment. In rural Washington County, access to a public water line was the most important predictor variable, and in the urban-rural fringe it was the second most important factor. The overall analyses for Washington County indicate a significant link between public investment in water and sewerage lines and the conversion of agricultural land. Easy access to these infrastructural investments is strongly correlated with large amounts of farmland conversion. It would appear that water and sewerage facilities have a powerful impact on the location, pattern, and timing of farmland transition in Washington County.

In contrast to the effectiveness of previous variables, the site characteristic model also identified several public policy related factors that proved of little value in explaining conversion behavior. One factor which was expected to produce high levels of explanation was planning designation (X_8). This variable, which is a direct regulatory policy instrument, was hypothesized to strongly influence the transition of agricultural acreage. The study findings, however, showed that planning and zoning designation was of little significance in retarding farmland development. The burden for failure to operate significantly is not inherent in the variable. Rather, as previously noted, the research context and development of the variable created circumstances which flawed variable operation. Owing to this, the reasons for lack of significance attached to planning and zoning can not be considered within the scope of the research findings.

An additional policy related site factor which was thought to impact land conversion was access to freeways (X_3). Due to the adequate alternative road network, this variable proved of little value. The data suggest that in Washington County the location of freeway access points does not significantly affect agricultural land conversion behavior. These results are contradictory with most previously empirical investigations (Council on Environmental Quality, 1976, p. 5).

The data analyses for Washington County show that proximity to previously developed areas and water and sewerage lines introduces increased pressure for farmland conversion, with the result being substantially greater amounts of farmland development in the areas exhibiting these characteristics. Conversely, the findings note that most agricultural lands covered by zoning and planning regulations were converted to urbanized uses at rates equivalent to areas without zoning and planning protection.

The rapid rate of agricultural land conversion, both nationally and in Oregon, suggest that the traditional police power approaches to control land transition are not entirely effective. The data and analyses generated by this investigation corroborate other studies that new strategies incorporating the impact of newly developed areas and availability of water and sewerage facilities may prove effective for reducing agricultural land conversion.

Previous commitment to scattered urbanization through zoning approval or construction of non-contiguous suburban development increases demand for farmland conversion. In order to mitigate these pressures, special policy considerations could be formulated for agricultural acreage situated near existing urban development (X_6) or land scheduled for development. Special consideration might include the creation of a new category of zoning district (e.g. threatened agricultural zone) or the identification of "areas of critical concern" (i.e. resource lands subject to urbanizing pressures). For these districts or zones specific ad hoc regulatory measures and land use policies could be formulated and implemented. These measures would be designed to protect the integrity of farm operations inside the special areas while protecting the agriculturalist from encroachment.

An additional complementary policy element for protecting farmland would be a strong capital investment plan. This plan would guide new development through the provision of public facilities, especially water and sewerage. Large, comprehensive water and sewerage facilities planning would continue to be encouraged; however, the projects would be phased. With this approach, facilities are added as needed, and the locational decisions would be used to induce urbanization in selected areas, while effectively reducing development potential in other areas. Moreover, the staging stimulates the infilling of areas bypassed by previous urban development, avoiding further sprawl. The staging of water and sewerage by a capital investment plan would certainly direct the transition of agricultural land. The net impact on agricultural lands from this type of policy is that land transition would be less disorderly and less scattered. The amount of agricultural areas impacted by close proximity to water and sewerage lines would be reduced significantly. The increased pressures for land conversion generated by water and sewerage facilities could be controlled.

Both land management policies, the agricultural special district and the staged capital investment plan, would be strong measures for helping control agricultural land conversion. The findings of the site conversion model indicate that inclusion of site related factors can significantly improve the performance of land use controls. The effectiveness of these measures, however, would be strengthened if employed in concert with other control mechanisms. These policies are not designed to replace the tranditional planning tools (i. e. comprehensive planning, zoning, subdivision regulation), but rather serve as complementary elements to increase the overall effectiveness of the land management process. As noted earlier, an effective land management system requires a range of regulatory, financial, and policy components to achieve any measure of success.

Finally, the study findings and ideas with respect to policy implications do not represent a solution for farmland conversion. The research objectives of this investigation were to examine agricultural land conversion in one area at one point in time. The vehicle for this research was a land conversion model based on site characteristics. The study data show that a strong linkage exists between a number of site characteristics and the pattern of farmland development. The empirical nature of the investigation means there are, of course, inherent restrictions in the applicability of the study conclusions. Nevertheless, the study area--Washington County, Oregon--is not unlike numerous suburban counties situated in metropolitan regions which have experienced rapid urban growth in the past twenty-five years. Thus the linkage between site characteristics and land development demonstrated in this study may well provide insight for planners and decision makers in other communities facing extensive agricultural land conversion.

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APPENDICES

APPENDIX A

PHOTO INTERPRETATION METHODOLOGY

The use of aerial photos to examine land use changes has been widely employed by a variety of investigators and research organizations. For example, the Economic Research Service, U. S. Department of Agriculture has, during the past 23 years, employed analysis of sequential aerial photography to measure changes in land use. In developing photo interpretation procedures and interpretative keys for use in the Washington County study, the earlier strategies employed by the Economic Research Service and individual researchers were relied upon extensively (Dill, 1959; Avery, 1965; Dill and Otte, 1970; Frey and Dill, 1971; and Weins, unpublished).

Aerial photo coverage of Washington County is available for different years at varying scales from a number of governmental sources. For study purposes the time period from 1963-1973 was selected to measure agricultural land conversion. U. S. Agricultural Stabilization and Conservation Service aerial photography at a scale of 1:20,000 was employed for the 1963 data and National Aeronautical and Space Administration color infrared photography with a scale of 1:30,000 was used for 1973 data. The photographic scale for both sets of photography permitted the required interpretation.

Following the selection of the aerial photos, the next requirement was to determine the categories of land use change that could be identified and measured by interpretation. Four categories of agricultural land use and three categories of urban use were identified and selected. The seven definitive classifications selected covered most possible urban and rural land uses:

Cropland. Even tone and texture. In some cases, distinct row patterns are visible. Lack of natural vegetation, and sharply defined boundaries.

Pasture. Up to 30 percent tree crown cover showing unmistakable signs of animal use, such as stock ponds, animal trails, and salt block. Lacked appearance of recent tillage. Frequently a regular shape with distinct boundaries.

Orchard. Includes areas used for fruit and berry production. Also included are ornamental and tree nurseries. Distinguishable by regular spacing and pattern to plants. In some cases, irrigation works are visible.

Forestland. Over 10 percent tree crown cover and no other visible uses. Areas of less than 10 percent tree corwn cover with evidence of logging.

Residential. Houses and yards associated with them, apartment complexes, mobile home sites, and urban residential streets.

<u>Commercial.</u> Business and industrial activities and land obviously associated with them that are found in the urban core and other business areas.

<u>Institutional.</u> Public facilities and land areas associated with them, such as churches, schools, hospitals, cemeteries, recreational facilities and transportation improvement.

The photo analysis was basically a systematic comparison of individual areas for the two points in time to identify changes. Photo interpretation was aided by using a pocket stereoscope and a scanning stereoscope for stereo coverage. In the initial step in the analysis, those areas urbanized prior to 1963 were identified and noted on transparent acetate with a rapidograph pen. Following the elimination of those areas from consideration farmland acreage in 1963 was located and noted. Subsequently land use changes from agricultural to urban use were identified and outlined on acetate. The type of agricultural land use in 1963 and the new 1973 urban use were recorded on work sheets at the same time. Concurrently, each observational unit of converted land was assigned a record number to ease later data storage and manipulation.

Observational units were identified in a two stage process. Initially, visual characteristics of the converted agricultural land uses were made. Units of contiguous urban development, with integrated road networks, utility connections, and urban activity patterns were classified as preliminary observational units. Finally, the locational and size data for the preliminary units were checked with the records in the Washington County Tax Assessors Office and the county Planning Department. Discrepancies were corrected.

In order to calculate the individual shifts in farmland, a dot grid was employed. Each of the individual observational units were measured using a transparent dot grid prepared by the Oregon State University School of Forestry, (Template No. F220), with 256 dots per square inch. Each dot is equivalent to .249 acres on the aerial photography with a scale of 1:20,000. The use of a grid to measure land use from aerial photography is an extensively applied technique used in planning, geography, geology, and forestry. The measurement accuracy of dot grid, especially at the scale at which it was applied, provides a degree of precision which is unavailable in other data sources (Dill and Otte, 1970, p. 3).

Following the identification of observational units, acetate overlay sheets were developed. Information included on the sheets included units of converted farmland, location of elementary schools, water and sewage lines, and freeway access points. These sheets were employed in later locational analyses.

APPENDIX B

DATA SOURCES

A diverse set of information sources were utilized to develop the data for the Washington County farmland conversion study. Owing to the variety of variables analyzed in the land conversion model, socio-economic, transportation, infrastructural, policy, and soils data were required. Included in the following table is a list of the predictor variables modeled and the source and type of information for each variable:

X_1 (distance to the Portland city center)	field data, calculated from aerial photography and the Washington County map
X_2 (distance to the nearest urban place)	field data, calculated from aerial photography and the Washington County map
X_3 (distance to the nearest freeway access point)	field data, calculated from aerial photography and the Washington County map
X_4 (distance to the nearest sewerage trunk line)	field data, calculated using Stevens, Thompson, and Rungun, Inc. Tualatin Basin Water and Sewerage Master Plan
X_5 (distance to the nearest water line)	field data, calculated using Stevens, Thompson, and Rungun, Inc. Tualatin Basin Water and Sewerage Master Plan
X_6 (distance to the nearest developed area)	field data, calculated from aerial photography
X_7 (distance to the nearest elementary school)	field data, calculated using Washington County Intermediate Education District, Washington County District Schools Directory, 1976-1977
X_8 (planning designation)	published data, City-County Joint Planning Department (Washington County), Patterns of Development

X_9 (median family income)	published data, U. S. Bureau of the Census, Census of Population and Housing: 1960 Census Tracts Portland SMSA
X_{10} (median value of housing stock)	published data, U. S. Bureau of the Census, Census of Population and Housing: 1960 Census Tracts Portland SMSA
X_{11} (amount of substandard housing)	published data, U. S. Bureau of the Census, Census of Population and Housing: 1960 Census Tracts Portland SMSA
X_{12} (median education)	published data, U. S. Bureau of the Census, Census of Population and Housing: 1960 Census Tracts Portland SMSA
X_{13} (population change)	published data, U. S. Bureau of the Census, Census of Population and Housing: 1960 Census Tracts Portland SMSA and U. S. Bureau of the Census, Census of Population and Housing: 1970 Census Tracts Portland SMSA
X_{14} (elevation)	published data, U. S. Geological Survey, Topographic maps 7.5 and 15 minute series for Washington County, Oregon
X_{15} (soil capability class)	published data, U. S. Department of Agriculture, Soil Conservation Service, Soil Survey of Washington County, Oregon (Preliminary draft)
X_{16} (slope)	published data, U. S. Geological Survey, Topographic maps 7.5 and 15 minute series for Washington County, Oregon
X_{17} (irrigation suitability)	published data, U. S. Department of Agriculture, Soil Conservation Service, Soil Survey of Washington County, Oregon (Preliminary draft)
X_{18} (drainage)	published data, U. S. Department of Agriculture, Soil Conservation Service, Soil Survey of Washington County, Oregon (Preliminary draft)
X_{19} (effective root zone)	published data, U. S. Department of Agriculture, Soil Conservation Service, Soil Survey of Washington County, Oregon (Preliminary draft)

X_{20} (available water-holding capacity)	published data, U. S. Department of Agriculture, Soil Conservation Service, <u>Soil Survey of Washington County, Oregon</u> (Preliminary draft)
X_{21} (erosion hazard)	published data, U. S. Department of Agriculture, Soil Conservation Service, <u>Soil Survey of Washington County, Oregon</u> (Preliminary draft)
X_{22} (septic tank drain field limitation)	published data, U. S. Department of Agriculture, Soil Conservation Service, <u>Soil Survey of Washington County, Oregon</u> (Preliminary draft)
X_{23} (shrink-swell potential)	published data, U. S. Department of Agriculture, Soil Conservation Service, <u>Soil Survey of Washington County, Oregon</u> (Preliminary draft)

APPENDIX C

THE Cp STATISTIC

Cp criterion is a tool employed by scientists using regression analysis to choose the most effective regression model. The Cp statistic provides the investigator with the total squared error for each set of independent variables included in the model. The total squared error of any regression model has two components, the bias component and the random error component. When there is no bias in a regression model (with p-1 independent variables) Cp has an expected value of p, where p equals the number of parameters in the model. Since the researcher is searching for the model with little bias, the Cp values provide an excellent measure for selecting the best model.

Application of the Cp criterion to testing model effectiveness is easily accomplished. Following the calculation of Cp values for each model, all values are plotted against p. As noted in Figure 8, the plotted variables are an effective visual display which is easily interpreted. Those regressions with little bias will tend to fall near the line Cp = p. Those regressions with substantial bias will fall above the line. By examining the location of the Cp values with respect to the Cp = p line, the investigator can select the preferred

Cp Values For Composite Models

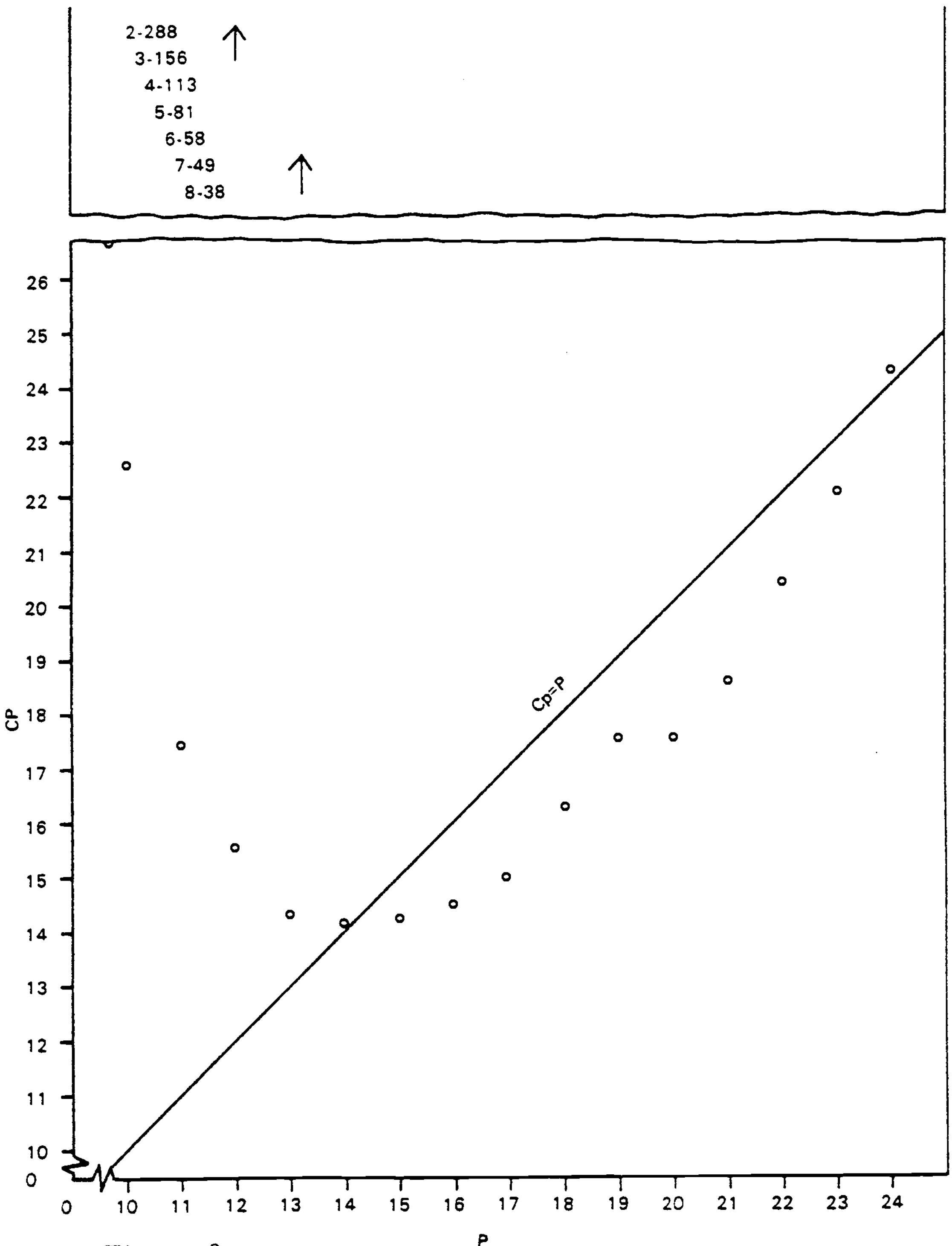

Figure 8.

combination of independent variables with the least amount of bias. Owing to this fact, the Cp criterion allows for the selection of the most powerful model, and provides a major advantage over other techniques for selecting the best model.

The Cp values displayed in Figure 8 reflect the use of the technique in the Washington County study. The data points represent the inclusion of all 23 variables in the composite model for Washington County. All the regressions up to step 1 in the forward selection procedure were found to be statistically significant. The use of R^2 or mean square error (MSE) criteria did not, however, provide the best guidance as to selecting the most effective final model. But by using plotted Cp values, the most efficient and effective model was selected. The calculation and plotting of Cp values was the procedure that was followed for determining all the models developed in this study.