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THE CENTER FOR
AGRICULTURE AND RURAL DEVELOPMENT
IOWA STATE UNIVERSITY, AMES, IOWA 50011

LAND USE INVENTORY AND PROJECTION MODEL WITH APPLICATIONS TO IOWA AND ITS SUBREGIONS

by
James A. Gibson, and
John F. Timmons

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Iowa State University

Ames, Iowa

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LAND USE INVENTORY AND PROJECTION MODEL WITH APPLICATIONS TO IOWA AND ITS SUBREGIONS*

James A. Gibson and John F. Timmons**

I. INTRODUCTION

Any land use planning activity requires an information support system. Land use legislation enacted in Iowa in 1977 requires capability in inventorying, analyzing and projecting land uses (87). This legislation provides for the development of a state land use policy from recommendations generated by county and state land preservation commissions. These recommendations involve consideration of current land uses and projections of land needed for the various land uses in the future. Proposed federal land use legislation requires states to develop their future U.S. land use needs. Both H.R. 10294 and S. 984 introduced in the U.S. Congress in 1974 and 1975, respectively, included provisions for states to develop a land use planning process with federal assistance.[1] This planning process

[1] Previous bills introduced in National Congress in 1971 (S. 632), 1972 (S. 992), and 1973 (S. 268), contained similar provisions. Although federal land use legislation has not yet been enacted, these proposals are indicative of Federal action.

*Project 2045 Iowa Agricultural and Home Economics Experiment Station. For more detailed information on additional data, data collection, methods and analysis regarding this study, see "Supplemental Appendices: Land Use Inventory and Projection Model with Application to Iowa and Its Subregions." CARD Miscellaneous Report, Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa.

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included inventories of land resources and projections of land needed and suitable for various types of uses to meet future national, state, and local needs.

Thus, both state and federal initiatives provide important incentives for development and application of land use inventories, analyses and projections. This study is an effort to respond to these state and federal land use planning needs through developing and applying a land use inventory and projection model to Iowa and its subregions.

Current Land Use Concerns

Citizen concerns regarding the uses of Iowa's land resources have increased in recent years. These concerns emulate from changing population distributions and lifestyles, increases in world demands for farm products, environmental pressures, prospective energy shortages, change in technology, and the realization that land resources are becoming relatively scarce and expensive.

According to the U.S. Deparment of Agriculture (99), the Corn Belt states which include Iowa, are more likely to be affected by a tight supply of cropland in the next 10 years or so than any other region of the nation. This conclusion is based on projected demands, including high export assumptions, for farm products, particularly feed grains and soybeans. A recent study by the National Academy of Sciences finds that increases in U.S. farm efficiency (output per unit of land) may be tapering off (73, p. 1). In 1974, Iowa farmers plowed

farmland that had not been planted to corn or soybeans for over a decade. This has caused concern among soil conservationists who fear excessive soil loss may result from intensive farming of the state's more erosive soils (22, p. 3).

An emerging energy shortage and the resulting increase in the cost of irrigated water in Western states may tend to shift agricultural production to regions including the Corn Belt which are less limited by water supplies (67). In addition, substantial amounts of water in the Western States currently devoted to agriculture may in the future have to compete with mining, coal gasification, manufacturing and other energy related demands, further enhancing the demand for farm land in Iowa and other less arid states.

The 1975 Midwest Governors Conference emphasized the following land use concerns (57, p. 1): Lands productive for agricultural purposes are being constantly diminished by the conversion of arable lands to purposes other than agriculture. Both energy and fertilizer supplies and prices may be expected to exercise constraining influences on future agricultural production. The nation cannot rely on the continuing never-ending series of technological improvements that have substantially increased agricultural productivity in recent years. Environmental constraints and regulations established in the interests of better long-term productivity may be expected to set limits on some types of short-term agricultural productivity. As stated by Harl, "Virtually all major concerns of national importance involve some dimension of land use" (29, p. 1).

Land Use Planning in Retrospective Prospect

During the depression years of the early 1930's, land was farmed intensively to increase income in order to avoid farm mortgage foreclosure and tax delinquency. Urban unemployment and the migration of people back to the land further aggravated the accumulation of surpluses of farm products. During this period there was a widespread interest in land use planning. Much attention was devoted to the gradual removal of settlements from areas of marginal soil productivity. Land use activity during this period concentrated on the development and application of land classification techniques. As stated by Kelso, "The intent was to map geographically the patterns of physical and biological characteristics of the environment. Often the problem-solving relevance of these classifications was vague, and in most cases their economic interpretation was more vague" (49, p. 3). Interest in land use planning during the 1930's was substantiated by the establishment of the National Planning Board in 1934 and the subsequent establishment of State Planning Boards in most states, including Iowa. Within Iowa, land use planning committees were formed in each of Iowa's 99 counties. The National Planning Board was given the responsibility of planning the use of land resources throughout the nation (60). State Planning Boards dealt with more detailed land use planning within states (48). Iowa's county land use planning committees concentrated on detailed land use planning within counties.

Consequently, land use planning is not a new activity. It was detailed and widespread throughout Iowa during the 1930's. With renewed interest in land use planning in the 1970's, it seems appropriate to examine briefly the abortive land use planning efforts of the 1930's.

Three possible explanations are offered for the shortcomings and failures of these earlier land use planning efforts. One possible explanation is that land use planning activities within counties and states were conducted largely by technicians with insufficient citizen input or participation in the process. Consequently, the planning process was little understood or appreciated by local citizens, who, with their elected officials, were not inclined to implement recommendations developed by planners acting largely in response to state and federal initiatives and directions.

A second possible explanation is that land use planning activities with few exceptions were largely descriptive and superficial, without relevant data and analysis as foundations for land use policies and programs.

A third possible explanation is that World War II diverted attention and resources from land use planning to pressing problems associated more directly with the war effort.

Review of land use planning experiences of the 1930's suggests that current and future land use planning involve more widespread citizen involvement in the process. Such review also suggests greater emphasis be placed upon data and its analysis. These considerations

were recognized in the legislative intent of Iowa's 1977 legislation as follows, "It is the intent of the General Assembly of the State of Iowa to provide for the development of land preservation policy recommendations for the consideration of the General Assembly through a process that emphasizes the participation and recommendations of citizens and local governments" (87, p. 1).

Land Use Research Needs

Throughout the U.S., land use data have evolved gradually and piecemeal to meet specific needs. No comprehensive system of collection, analysis, and publication of land use data has ever been put into operation. There has been no consistent data set developed to show amounts and changes of land in various uses within counties, regions, and states. There is little agreement and consistency concerning land use definitions and projection dates.

Data from a survey of Iowa incorporated places in 1975 revealed that only 9 percent of them use a land use classification system, and only 20 percent had a land use planning activity (26, p. 460). Of the 61 percent of the incorporated places responding to the question on the type of land use classification, 43 percent reported using their own land use classification system. Of the estimated 11 percent of Iowa incorporated places that make land use projections, only 28 percent projected uses as far as 1980.

Of the 16 multi-county planning regions in Iowa, only four regions used a land use classification system and each region used a different

system (26, p. 485). Four of the 16 regions reported land use projections and each of these regions used different projection dates.

Serious problems are encountered in obtaining land use data.[2] Federal, state, regional, county, and local governments are largely unaware of the data being collected by each other. There is little uniformity or coordination in organizing and disseminating basic data. However, methodological approaches exist for the development of techniques to obtain, organize, and analyze land use data. The challenge is to obtain and present needed data in a quantitative analysis format which will be useful to concerned citizens, land use planners, and decision makers at state, regional and local levels who are involved in making and implementing land use policy.

Objectives of Study

Specific objectives of this study are: First, develop a model for projecting future nonagricultural and agricultural land uses under varying assumptions; Second, apply the model to Iowa and its subregions; Third, identify major economic determinants affecting past and present demands for Iowa agricultural and nonagricultural land resources; and Fourth, appraise alternative policies and assumptions affecting land use changes with assistance of the model.

In meeting these objectives, the model should possess the capability of appraising the interactions between agricultural and

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[2] For an excellent review of land use information systems in the U.S., see (16).

nonagricultural land use demands under alternative policies. The model should also provide uniformity of estimation procedures, base and projection target dates, and land use classes. It should be useful to planning entities within Iowa including incorporated places, multi-county regions, counties and state agencies. Furthermore the model should be applicable to planning applications in other states with appropriate adjustments to their needs.

Methods and Procedures

Reorientation of land use planning suggests that research emphasis be placed on positive studies of "what is" as well as normative studies of "what ought to be." This orientation of land use planning involves the concept of a land use process which implies changes in land uses over time. The land use process concept implicitly hypothesizes the existence of identifiable determinants affecting the use of land. Study of land use processes is complex, but effective land use planning requires understanding of past and present land uses, causal factors associated with land use changes and relationships of one land use to another.

In order to deal with the problem of land use within the above orientation, baseline projections of land use are undertaken in this study. Baseline projections are defined as estimates of what land uses are expected to materialize if there are no demand, supply and institutional changes of an unusual and unforeseen nature or magnitude in the causal factors which have been changing over time and which are

expected to continue on course into the future. Baseline projections include the following three purposes. First, they provide one assessment of future land resource needs based upon recent trends. Second, they can be used as an indicator of potential land use problematic situations in terms of a divergence between future desired land uses and baseline projected land uses. Third, they provide a framework for analyzing alternative projections reflecting induced normative changes. Thus, comparisons of land use projections under baseline and various policy alternatives provide a preview of possible effects of policy changes.

This study focuses on two general categories of land use, agriculture and nonagriculture, with their respective subsets of uses. Levels of spatial aggregation are the incorporated place, county, multi-county regions, and the state. Major emphasis is devoted to projecting the impact of nonagricultural expansion on the agricultural land base and the ability of the agricultural land base to meet future farm product requirements under alternative assumptions.

This study quantifies and analyzes current land uses and projects future land use changes for the state of Iowa and its subregions. Though this study focuses primarily on Iowa, the methods and model developed would appear applicable to other states and their subregions.

This study does not seek to advocate or influence the direction of land use in Iowa. Rather, it seeks to provide useful facts with interpretations for those who desire a better understanding of Iowa land use as well as those who would like to consider changes in land use which differ from baseline projections.

Relevant land use data were obtained from Iowa and federal government agencies to provide past and present nonagricultural land uses as a data base for making projections. In addition, mail surveys and telephone follow-up procedures were used in obtaining land use data and information from a sample of 122 Iowa incorporated places, the 99 county extension agents, and the 16 multi-county planning entities (26). Data were also obtained from published secondary data sources. To determine past and present agricultural land uses and to provide a data base for projections, published and unpublished data were obtained from the U.S. Department of Agriculture and the Iowa State Department of Agriculture.[3]

[3]Readers interested in more detailed 1) data collection and analysis procedures, 2) data sources, and 3) detailed data by counties and regions, may obtain a copy of "Supplementary Appendix, A Land Use Inventory and Projection Model with Applications to Iowa and Its Subregions," CARD, 1978.

II. LAND USE INVENTORY AND PROJECTION MODEL

Land Use Modeling

A model translates theories from a theoretical framework to a concrete case (54, p. 7). Thus, a model is explicit in terms of objectives and data needs whereas theories and conceptual frameworks can be vague (31, p. 181). According to Lowry (54, p. 7), "The model builder, even if he has high appreciation of theory, usually is forced to build a model likely to reflect its theoretical origins only in oblique and approximate ways. Mechanisms that work, however, mysteriously come to be substituted for those whose virtue lies in theoretical elegance." Strategic model simplifications also derive not from the conviction that the theory is wrong, but from the more reasonable premise that its literal translation into a tool for analysis requires data which may not be readily obtainable.[4] However, an important function of the model is to specify data needs which can be satisfied from secondary and primary sources.

The land use model developed in this study has two major purposes: projection and planning. The projection purpose seeks to identify values or ranges of values for specific Iowa land uses depending on

[4]Economist Robert Gordon, in his presidential address to the 88th American Economic Association meetings, states (27, p. 12),"The road to salvation will not be an easy one for those who have been seduced by the siren of mathematical elegance or those who too often seek to test unrealistic models without much regard for the quality or relevance of the data they feed into their models. But let us all continue to worship at the alter of science. I ask only that our credo be: 'relevance with as much rigor as possible,' and not 'rigor regardless of relevance.' And let us not be afraid to ask -- and try to answer -- the really big questions."

assumptions regarding the causal variables. The distinction between projection and prediction is important. Results of projection are in effect the numerical consequences of the assumptions chosen. Assumptions are statements of belief that have not been proven. Prediction on the other hand seeks to articulate a real and concrete state of a system at some explicit time in the future (14, p. 200). Any interpretation of projections must interpret the underlying assumptions, which in themselves may contain major elements of uncertainty and subjective probability. The essence of importance for the land use projection model is not the exact quantities of land uses projected, but the projected direction of changes in land uses, relative magnitudes, relative speed of changes, and sequences in time. Errors in projections cannot be eliminated, but their effects can be reduced through the use of sensitivity analysis, and by the maintenance of flexibility to accommodate revised projections at future dates.

Evaluation of a modeling strategy cannot be disassociated from the purpose for which the model is built. The merits of the land use projection model in this study are not its value for prediction, but its value for experimenting with policies and planning whose consequences cannot be readily visualized outside a data and modeling context. Thus, the main purpose of projections of land use is to serve as a basis for making public land use policy and planning decisions. Projection of future conditions is necessarily an implicit part of the decision making process. Legislators and administrators necessarily make decisions on the basis of future expectations. The land use projection

model makes explicit projections of land use. Projections become a primary function of researchers whose aim is to aid legislators and administrators make better decisions.

The planning purpose of this model is to help choose between alternative future land use outcomes and alternative land use policies and programs associated with those outcomes. The planning purpose of the model incorporates the above projection objectives, but, in addition, provides for the evaluation of alternative land use policies. The projections in the model are intended as a planning tool. They are not goals, and they do not necessarily express what is desirable or undesirable.

Figure 1 provides a schematic overview of the land use projection model. There are two general parts of this land use projection model: projected cropland uses and projected noncropland uses. With regard to the cropland segment of the land use projection model, a shift and share technique is used to disaggregate ranges of national U.S. projections of food and fiber requirements to the state of Iowa and then to multi-county regions within the state (Figures 1 and 2). Given ranges of projections of future yields by land qualities within Iowa regions, including an allowance for crop failure, projections of the acreage required for crop production in Iowa regions are made. Projections of future yields which are crucial in developing projections for cropland requirements, are based upon several qualifying assumptions which are stated in Section IV of this report.

The noncropland segment of the land use projection model is built around a system of land use accounting for the Iowa regions. For each region, future nonagricultural land uses (includes urban, highways, airports, public recreation, private recreation, and extraction land uses) and noncropland agricultural land uses (includes pasture, forest, and other land in farms) by quantities and qualities are projected in individual land use subcategories. Urban land use quantity projections are made by regression analysis, and other nonagricultural land use quantity projections are made by trend extrapolations. Projections of qualities of nonagricultural land uses and noncropland agricultural land uses are made by extrapolations from the initial inventory according to rules specific to the subcategory of land use under consideration. The projections assume that nonagricultural demand for land resources is perfectly price-inelastic at the price levels at which land would be sold for agricultural purposes, or that nonagricultural land uses pre-empt agricultural land uses.

The regional projections of cropland requirements (which are highly dependent upon projected yields as emphasized above) are compared to projections of the supply of land services for cropland purposes (given projections of nonagricultural and noncropland agricultural land uses) to project a surplus or deficit of regional cropland acres. Various ranges of assumptions of nonagricultural land use absorption and noncropland agricultural land use conversion to cropland uses are considered.

Policy shocks are also introduced into the model. These include environmental constraints in the form of cropland resource restrictions and agricultural land use constraints in the form of restrictions on nonagricultural qualities of land use.

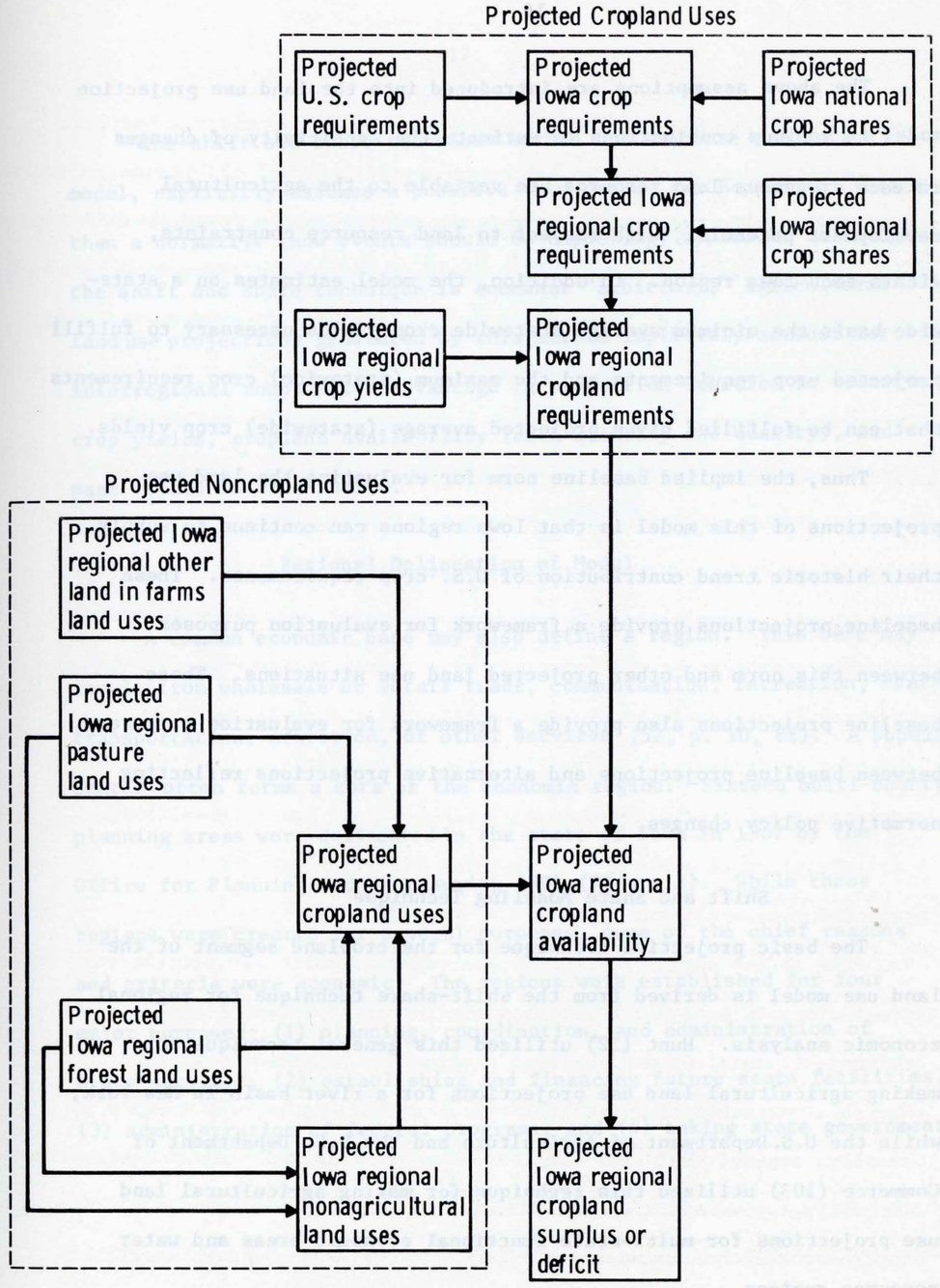

Figure 1: Schematic overview of land use projection model.

The above assumptions are introduced into the land use projection model in various combinations to estimate the sensitivity of changes in each exogenous land resource use variable to the agricultural development potential, with respect to land resource constraints, within each Iowa region. In addition, the model estimates on a statewide basis the minimum average statewide crop yields necessary to fulfill projected crop requirements and the maximum (statewide) crop requirements that can be fulfilled given projected average (statewide) crop yields.

Thus, the implied baseline norm for evaluating the land use projections of this model is that Iowa regions can continue to supply their historic trend contribution of U.S. crop requirements. These baseline projections provide a framework for evaluation purposes between this norm and other projected land use situations. These baseline projections also provide a framework for evaluation purposes between baseline projections and alternative projections reflecting normative policy changes.

Shift and Share Modeling Technique

The basic projection technique for the cropland segment of the land use model is derived from the shift-share technique for regional economic analysis. Hunt (32) utilized this general technique for making agricultural land use projections for a river basin in New York, while the U.S. Department of Agriculture and the U.S. Department of Commerce (103) utilized this technique for making agricultural land use projections for multi-state functional economic areas and water resource regions.

The shift and share technique within the land use projection model, explicitly assumes a positive (how events are happening) rather than a normative (how events should be happening) approach. Although the shift and share technique is somewhat "arbitrary," agricultural land use projections generated by this method implicitly account for interregional comparative advantage in production embodied in relative crop yields, cropland availability (both quantity and quality), and past trends in crop shares.

Regional Delineation of Model

A common economic base may also define a region. This base may result from wholesale or retail trade, communication, recreation, health, transportation, education, or other services (52, p. 10, 82). A population center often forms a core of the economic region. Sixteen multi-county planning areas were delineated in the state of Iowa in 1967 by the Office for Planning and Programming (39) (Figure 2). While these regions were created for several purposes, some of the chief reasons and criteria were economic. The regions were established for four major purposes; (1) planning, coordination, and administration of state services, (2) establishing and financing future state facilities, (3) administration of federal programs, and (4) taking state government

closer to the people. Four major criteria were used by the Iowa office of Planning and Programming to delineate the 16 regions; (1) region boundaries would follow existing county boundaries, (2) the region would share a common focal point or central place, (3) a limit of one hour driving time to reach the central place, and (4) an adequate economic base to support existing and future services or facilities (39).

For purposes of this study, land uses are regionalized on the basis of the 16 multi-county planning areas. There are several reasons for this choice. First, there is no one ultimately correct regional delineation for all purposes. Where problems are physical, the river basin or soil area delineation may be appropriate, but where research has policy implications that include both social and economic problems, the physical criterion is not appropriate. For example, agricultural land uses are affected by urban land use externalities, and similarly, urban land uses are affected by agricultural land use externalities. A delineation based solely on a physical criterion ignores these important interactions.

The second reason for the chosen regionalization is because the preparation of land use policies is one of the important planning tasks assigned the multi-county regional governments. Currently, these regional entities manage a substantial share of the Federal Housing Urban Development (HUD) 701 comprehensive planning funds which would otherwise go into state or other local planning activities (106). HUD 701 grants will not be approved after August 1977, unless an applicant has complied with the land use requirement. This new land use element,

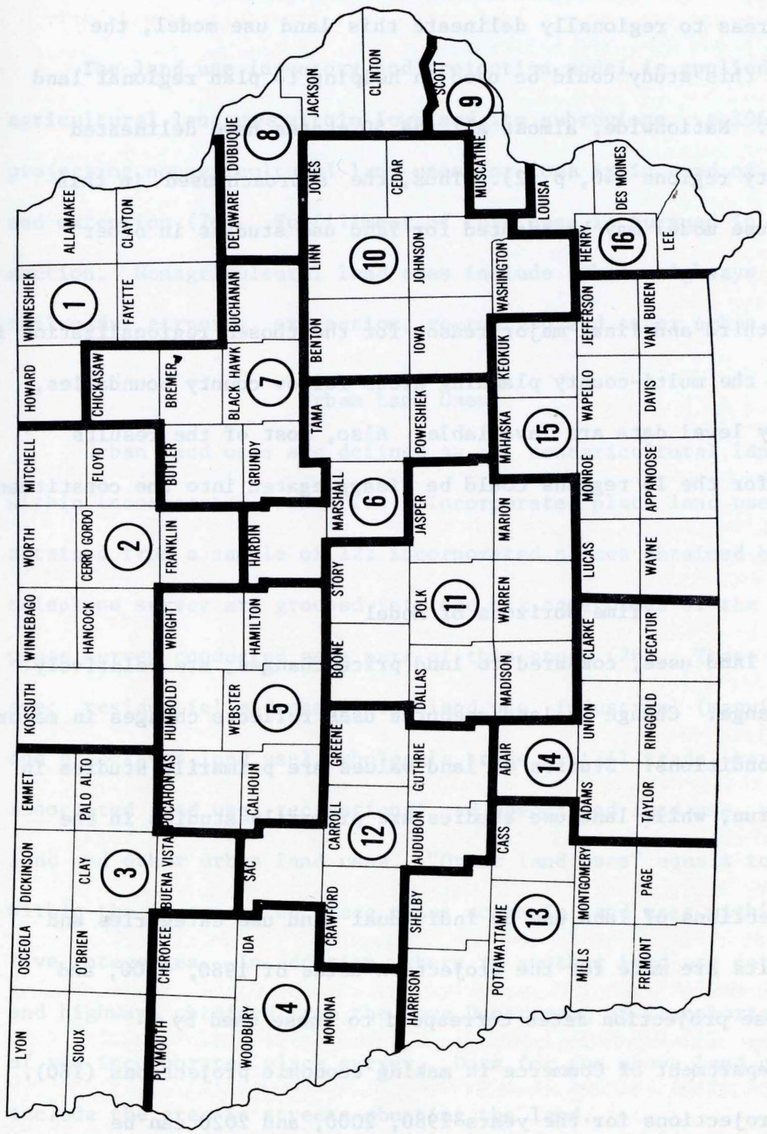

Figure 2: Iowa 16 multi-county planning areas.

mandated by Congress, could make HUD a leading federal agency in administering land use matters. It is expected that by using the 16 economic areas to regionally delineate this land use model, the results of this study could be used in helping to plan regional land use policy. Nationwide, almost all the 50 states have delineated multi-county regions (40, p. 2). Thus, the approach used in this Iowa land use model may be adapted for land use studies in other states.

The third and final major reason for the chosen regionalization is that since the multi-county planning areas follow county boundaries, much county level data are available. Also, most of the results presented for the 16 regions could be disaggregated into the constituents' counties.

Time Horizons of Model

Most land uses, compared to land price changes, are relatively slow to change. Change in land resource uses reflects changes in major economic conditions. Studies of land values are primarily studies in the short-run, while land use studies are primarily studies in the long-run.

Projections of land use by individual land use categories and spatial units are made for the projection dates of 1980, 2000, and 2020. These projection dates correspond to those used by the U.S. Department of Commerce in making economic projections (180). Land use projections for the years 1980, 2000, and 2020 can be considered near-term, medium-term, and long-term projections, respectively.

III. APPLICATION OF MODEL TO IOWA'S NONAGRICULTURAL LAND USES BY STATE AND SUBREGIONS

The land use inventory and projection model is applied to nonagricultural land uses within Iowa and its subregions. A 1964 study projecting nonagricultural land uses for Iowa is in need of updating and extension (78). Fulfillment of this need is pursued in this section. Nonagricultural land uses include urban, highways and roads, railroads, airports, extraction, recreation and other urban uses.

Urban Land Uses

Urban land uses are defined as all nonagricultural land uses within incorporated boundaries. Incorporated place land use data obtained from a sample of 122 incorporated places obtained by mail and telephone survey are grouped into the six categories of the incorporated place survey conducted as a part of this study (26). These categories are: residential and associated land use, industrial (manufacturing and associated land use), wholesale trade, retail trade, services and associated land use, recreational and associated land use, undeveloped land and other urban land uses. "Other land uses" equals total acres within the incorporated place minus acres in land uses within the other five categories. In addition, there is another land use category, roads and highways, obtained from the Iowa Department of Transportation instead of the incorporated place survey. Data for the above land use categories include the area in streets abutting the land.

This section identifies major factors affecting net land conversions to and among urban uses. Land uses prior to 1970 are inventoried, and between 1970 and 2020 are projected.

Incorporated place land use proportions

Residential and associated land uses in 1973 accounted for an average of 23 percent of the total area of incorporated places (including agricultural land within incorporated place boundaries) which represented 42 percent of the nonagricultural use area of incorporated places. The proportion of the total incorporated place area in residential land use has remained stable over the past 43 years from 1930 to 1973. (See Tables 1 to 4 inclusive, "Supplemental Appendices: Land Use Inventory and Projection Model with Application to Iowa and Its Subregions," CARD Miscellaneous Report). It was found that Iowa residential urban land use on a per capita basis increased on the average only .03 acres from 1930 to 1973.

The industrial (manufacturing) land use proportion of the total incorporated place area increased from 2 percent in 1930 to 3.3 percent in 1973. Wholesale trade, retail trade, and services and associated land use increased from 2 percent to 4.6 percent of the total incorporated place area over the same 43 year period. Both of these trends reflect the transition from agricultural to urban uses reflecting population shifts.

Niedercorn and Hearle (63, p. 6) estimate residential land use proportions of 31 percent of the total incorporated place area for 22 large American cities. They also estimate residential land use proportions of 39 percent of the developed incorporated place area. In comparison, corresponding proportions estimated for Iowa incorporated

places of 50,000 or more population are 26 percent and 38 percent, respectively. The Niedercorn and Hearle study estimated industrial proportions of .08 of the total incorporated place area and .10 of the developed incorporated place area. Corresponding coefficients estimated for Iowa incorporated places of 50,000 or more population are .03 and .04. Similarly, Niedercorn and Hearle estimated commercial proportions of .04 and .05, respectively. Corresponding proportions estimated for Iowa incorporated places of 50,000 or more population are .04 and .06, respectively. Finally, Niedercorn and Hearle estimated road proportions of .19 and .25, and the corresponding proportions estimated for Iowa are .08 and .12, respectively. In general, the Iowa proportions of total incorporated place land are lower than those from the Niedercorn and Hearle study. Perhaps this is explained by the high proportion of agricultural land in Iowa incorporated place boundaries which is discussed in the following section "Incorporated Place Agricultural Land Use."

Incorporated place agricultural land use

Land included in Iowa's incorporated places was divided into agricultural and nonagricultural land uses. Agricultural land within incorporated places is defined as land of 10 acres or more that has not been platted and is given preferential taxation millage rates as agricultural land. This section discussed the phenomenon of agricultural land within incorporated places.

Between 1960 and 1970 the proportion of agricultural land within Iowa's incorporated places remained approximately constant -- around 43 percent. Within population size classes of incorporated places, the largersize classes generally had a smaller percentage of their total area in agricultural land. This tendency may be a reflection of the competition for land and the lower market value placed on a given parcel of land in a smaller population size incorporated place. But this effect seems to be diminishing over time in that between 1960 and 1970 the percentage of incorporated area devoted to agricultural land increased consistently for all size classes of incorporated places greater than 5,000 in population and decreased consistently for those incorporated places less than 5,000 in population. In spite of the relatively constant average statewide proportion of agricultural incorporated place land to total incorporated place land between 1960 and 1970, the absolute amount of agricultural land within incorporated places increased 63,065 acres (from 367,120 acres to 430,185 acres) or 17 percent between 1960 and 1970.

Incorporated place agricultural land per person in 1970 averaged .21 acres for all population size classes of incorporated places. The 1970 incorporated place per capita agricultural land coefficient was .10 for those greater than 50,000 population, .12 for those of 10,000 to 50,000, .12 for those of 5,000 to 10,000 population, .20 for those of 2,500 to 5,000 population, .25 for those of 1,500 to 2,500 population, and .60 for those less than 1,500 in population. Just as the smaller population size class incorporated places generally have a larger proportion of their total area in agricultural land,

the smaller incorporated places consistently have a larger per capita agricultural land coefficient. Again, this may be the direct result of economic pressure. A large concentration of population has the effect of forcing land values up within and around the incorporated place resulting in more intensive use of land.

Niedercorn and Hearle (63, p. 6) found that, on the average, 24 percent of the area within American cities consists of vacant land. This statistic was based on a sample of 22 American cities with populations greater than 100,000 people. Their definition of vacant land included agricultural land, parking lots, and water area. Contrary to Niedercorn's and Hearle's conclusion (63, p. 17) that vacant land in the larger American cities is disappearing, Iowa's incorporated places greater than 50,000 population showed agricultural land had increased from 28 percent in 1960 to 34 percent in 1970.

An earlier study by Bartholomew (7, p. 123) disclosed that 44 percent of land area in cities of 5,000 to 50,000 population, 44 percent of land area in cities of 50,000 to 100,000 population, 36 percent of land area in cities of 100,000 to 250,000 population, and 22 percent of land area in cities of 250,000 to 300,000 population was vacant. Vacant land was defined by Bartholomew as residual land use after all other developed nonagricultural land uses were considered. A later study by Bartholomew (6, p. 73) of 28 American cities of 50,000 or less population using his same definition of vacant land use, found

that 47 percent of the total city area was vacant.

When the average 7.5 percent devoted to undeveloped lots in this study is added to the 43 percent of agricultural land, the total 50.5 percent average proportion is obtained for Iowa incorporated place land devoted to agriculture and vacant lots. If incorporated places of less than 50,000 population are considered, the corresponding proportion is 53 percent. From these comparisons, Iowa seems to have a greater than U.S. average proportion of its incorporated place land area absorbed by agriculture and vacant lots.

The proportion of Iowa vacant land is greater in less populous cities. This result is consistent with a recent study by Northam (64) p. 349) which derived an inverse regression relationship between "vacant" land per capita and city size. As the city size becomes greater, the proportion of vacant land per capita become less.

The general conclusion reached with respect to Iowa agricultural land within incorporated places is that there are relatively large amounts of agricultural land within Iowa's incorporated places and these stocks comprise a potential land supply of considerable value in terms of accommodating additional urban land use needs. Projections of future urban land use needs are compared with the amount of agricultural land within incorporated places existing in 1970 by counties and regions for 1980, 2000, and 2020. Given projections of future urban land use needs, there is enough existing agricultural land within Iowa incorporated places to meet these incorporated place land use needs on a regional basis for all but two regions, regions 11 and 13, to the year 2000

without having to annex or absorb any additional acreage.[5] Regions 11 and 13 can meet their urban land use needs on a regional basis by utilizing their agricultural land within incorporated places to the year 1990. On a county basis, 78 of the 99 counties can meet their future urban land use needs to the year 1990 by utilizing the amount of agricultural land presently existing within their incorporated places.[6] If a public land use policy includes as one of its objectives the desire to eliminate land use pressures and conflicts on the rural-urban fringe, then seeking a means whereby conversion of these relatively large urban agricultural and vacant land stocks to urban uses, should be considered.

The large stocks of agricultural land within Iowa incorporated places add credence to Gaffney's (25) argument that urban land prices are uneconomically high and that the scarcity of urban land is an artificial one, maintained by the holdout of underestimated supplies in anticipation of overestimated future demands. The increasing amount of agricultural land within incorporated places might then be explained by relatively high urban land prices. These high urban land prices

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[5] These projections ignore any land quality restraints, such as slope and drainage, on the use of these lands for urban uses. However, given projections of future urban land use needs, 12 of the 16 regions are expected to have more than 1,000 remaining acres of agricultural land within incorporated places in the year 2000.

[6] There is substantial variation among individual incorporated places with respect to the proportion of total land area in agricultural land uses. These projections are on a county level of aggregation and ignore possible individual incorporated place deviations between urban land needs and agricultural land availability within the incorporated place.

discourage building on lands within incorporated places and divert construction to lands further out for the urban centers.

Incorporated place per capital land uses

Between 1960 and 1970, urban population density declined, or incorporated places urban area per capita increased, for every population size group of incorporated places in Iowa and for every region except region 9, which is a relatively high nonagriculturally oriented region. On a statewide average basis, urban land (incorporated place) per capita increased from .26 to .28 acres per capita from 1960 to 1970.

From 1930 to 1973 residential land use per capita increased from .08 acres to .11 acres, commercial land use per capita increased from .006 to .02 acres, and manufacturing land use per capita increased from .006 to .014 acres. Niedercorn and Hearle (63, p. 9) calculated coefficients of .01, .01, and .04 for residential, commercial, and manufacturing land use per capita, respectively, from a sample of 22 large American cities.

Coefficients of .08, .01, and .01 were calculated for residential, commercial, and manufacturing land use per capita, respectively, for Iowa incorporated places of 50,000 or more population. Commercial land use per capita varies little from the above U.S. wide coefficients, and it might be expected that large Iowa incorporated places would have much less urban acres per capita devoted to manufacturing land use compared to a cross-section of large American cities. What is surprising is the large Iowa urban residential land use per capita coefficient. But this is consistent with the general observation that Iowa has very

few high density residential structures, such as high rise apartment buildings. This is also consistent with the finding that the average price of Iowa agricultural real estate has in the past had little influence on Iowa urban land absorption per capita.

Manufacturing and associated land uses utilized on the average of .096 acres per employee in 1967, and commercial land uses utilized on the average of .154 acres per employee in 1967. For incorporated places of 50,000 or more population, the corresponding coefficients are .06 and .09, respectively. These compare with coefficients of .034 and .047, respectively, derived from a sample of 22 large American cities (163, p. 15). Thus, large Iowa incorporated places use more than double the urban land per employee compared to the national average. This may reflect a surplus of land as a factor of production relative to other factors of production in Iowa compared to the national average.

Incorporated place annexation frequencies and percentage changes in incorporated place land area from 1960 to 1970

Between 1960 and 1970, an estimated 24.9 percent of Iowa's total incorporated places reported a net increase in land area, while 25.3 percent reported annexation of land area. In this same time period, it is estimated that only 1.6 percent of Iowa's total incorporated places had a net decline in land area, while 2.0 percent had de-annexation of land area. The percentage of incorporated places that had a net increase in total incorporated place area consistently declined on the average from the large to small incorporated place population size classes. The above relationship generally corresponds to the estimated

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percentage of Iowa incorporated places that had experienced changes in population from 1960 to 1970.

The percentage of Iowa incorporated places that reported annexation between 1960 and 1970 generally corresponds to similar calculations for the rest of the U.S. Fuguitt and Beale (24, p. 14) found that between 1960 and 1970, 60 percent of U.S, incorporated places of 2,500 to 4,999 initial population had annexation, 70 percent of U.S. incorporated places of 5,000 to 9,999 population had annexation, 75 percent of U.S. incorporated places of 10,000 to 24,999 population had annexation, and 82 percent of U.S. incorporated places of 25,000 to 50,000 population had annexation. The corresponding figures found for Iowa are 54.8 percent and 78.8 percent respectively, and 88.9 percent for incorporated places of 10,000 to 50,000, and 100 percent for incorporated places of 50,000 plus population.

Of the incorporated places of 50,000 or more population, 71.4 percent had an increase in population, and 100 percent of the incorporated places in this size class had an increase in net land area between 1960 and 1970. Of the incorporated places of 1,500 or less population, 40.5 percent had an increase in population; however, only 15.8 percent of the incorporated places in this population size class had a net increase in land area in the same period. Zero percent of those incorporated places greater than 50,000 in population that had increased in population between 1960 and 1970 had no annexation of land, while 77.7 percent of those incorporated places less than 1,500

in population that had increased in population had no annexation of land. Thus, the larger the population size class of the incorporated place, the more likely it had experienced annexation corresponding with an increase in its population.

There is no evidence for the converse, that the larger the population size class of the incorporated place, the more likely it had de-annexation corresponding with a decrease in its population. Zero percent of those incorporated places greater than 50,000 in population that decreased in population had de-annexation, while .3 percent of those incorporated places less than 1,500 in population that decreased in population had de-annexation. The fact that only 2.0 percent of all Iowa's incorporated places had any de-annexation of land and that only 1.6 percent had an actual net decline in land area indicates the irreversible nature of the urban land use process, even though there is much land within Iowa incorporated places not physically urbanized.

Between 1960 and 1970, Iowa's total incorporated place land area increased 16.8 percent through net land annexation. The percentage of the incorporated places total 1960 land area that had net annexation consistently declined on the average from the large to small incorporated place population size classes. While over 37 percent of the incorporated places total 1960 land area with populations greater than 50,000 had net annexation, only 7.6 percent of the total 1960 land area of incorporated places with populations between 1,500 and 2,500 had a net annexation of land.

Higher percentage changes in the 1960 total incorporated place land area occurred in the larger population size class towns, and a majority of the absolute change in total incorporated place land area occurred in the larger populated incorporated places. Over 78 percent of the change in total incorporated place nonagricultural land area between 1960 and 1970 occurred in incorporated places greater than 2,500 in population.

Urban land use trends in Iowa incorporated places

Between 1960 and 1970, there was an estimated increase of 92,015 total acres of Iowa nonagricultural incorporated place land. This is a 19.3 percent increase over the estimated 1960 nonagricultural incorporated place base area data. Total incorporated place area increased an estimated 155,083 acres, but when the estimated 63,068 acre increase of agricultural land within incorporated places is subtracted, an estimated 92,015 acres remains. The average acres of nonagricultural incorporated place land area per person (average land absorption coefficient) increased from .26 to .28 acres per capita between 1960 and 1970, supporting the general notion of increased urban sprawl.[7]

Change in incorporated place nonagricultural land area between 1960 and 1970 divided by change in urban population between 1960 and 1970 (marginal land absorption coefficient) was calculated for all

[7]This is consistent with general urban sprawl trends in the rest of the U.S. For example, Otte (33) found that acres of land area per person in urban parts of Standard Metropolitan Statistical Areas increased on the average for the U.S. from .179 to .204 acres per person between 1960 and 1970.

regions that had both a positive change in nonagricultural incorporated place land area and a positive change in urban population. On a statewide basis, the marginal land absorption coefficient between 1960 and 1970 was estimated at .4 acre of nonagricultural incorporated place land per capita increase in incorporated place population.

Of the 92,015 total acres of nonagricultural incorporated place land increase, 29.8 percent (27,470) came from incorporated places of 50,000 or more population, 25.2 percent (23,235) came from incorporated places of 10,000 to 50,000 population, 15.1 percent (13,960) came from incorporated places of 5,000 to 10,000 population, 8.5 percent (7,909) came from incorporated places of 2,500 to 5,000 population, 4.8 percent (4,437) came from incorporated places of 1,500 to 2,500 population, and 16.3 percent (15,001) came from incorporated places of less than 1,500 in population.

The average land absorption coefficient increased consistently from 1960 to 1970 for all size classes of incorporated places. Also, the average land absorption coefficient generally increased, moving from the large population size class incorporated places to the smaller size class incorporated places.[8] The marginal land absorption coefficient did not show this same relationship between different size classes of incorporated places.

[8]This is consistent with Clawson et. al.'s (17, p. 84) finding that there is a direct relationship between size of population and average density.

A constant average urban incorporated place land absorption coefficient of .27 acres per capita was calculated for the period of 1960 to 1970 for all population size classes of incorporated places. If only incorporated places greater than 2,500 in population are considered, this coefficient drops to .21 acres per capita. During this same period, a constant average incorporated place land absorption of .31 acres per capita was calculated for incorporated places greater than 2,500 population. (See Tables 12 to 13c, inclusive for the derivation of these coefficients in "Supplementary Appendices: Land Use Inventory and Projection Model with Applications to Iowa and Its Subregions," CARD Miscellaneous Report).

In a study by Otte (65, p. 5), constant marginal land absorption coefficients for urban parts of Standard Metropolitan Statistical Areas hereafter called SMSA's, were calculated for the period 1960 to 1970 for different regions within the U.S.[9] For the Corn Belt region, Otte calculated a constant marginal land absorption coefficient of .46 acres per capita, and for the 48 states a constant marginal land absorption coefficient of .32 acres per capita. Using the exact same definitions that Otte used and the same census data, a constant marginal land absorption coefficient of .7 acres per capita for the

[9]A SMSA (Standard Metropolitan Statistical Area) is a group of counties defined by the U.S. Census Bureau as an entire area in and around a city of at least 50,000 people in which activities form an integrated economic and social system. Urban parts of SMSA's are comprised of "urbanized area" within an SMSA as delineated by the census, plus additional urban places of over 2,500 population. The Census Bureau's major objective in delineating urbanized areas is to enable separation of urban and rural populations near the larger cities.

state of Iowa was calculated.[10] Again, regardless of the criteria used, it is apparent that Iowa's incorporated place land absorption per capita is higher than the Corn Belt average and considerably higher than the national average.

The large number of cities included in the analysis of urban land use trends suggested that an analysis according to city population size and regionalization might be meaningful. Though little analysis was made on regional comparisons of coefficients because of research time constraints, the data are available for future investigations. In some cases, the grouping of coefficients by incorporated place population size classes pointed out significant correlations, and in other cases there is an obvious lack of correlation.

The above data set provides raw material for future analysis. The primary purpose of this subsection was to compare the derived Iowa incorporated place land use coefficients with land use coefficients derived for other American incorporated places. Future analysis could well pursue further Iowa land use interrelationships among the different population size classes of incorporated places and spatial regions. For example, a study of urban hierarchies, such as central cities and their satellite cities and the corresponding land use patterns, would be a logical extension of this study. Urban land use patterns may be strikingly different if incorporated place hierarchies

[10]This Iowa coefficient was calculated with the assistance of Robert Otte, Agricultural Economist, U.S. Department of Agriculture, in a private communication, March 1975.

are considered rather than individual incorporated places in that certain land uses in the central city are utilized by people living in satellite cities and vice versa. Bartholomew (6, p. 120) initiated this type of investigation more than 20 year ago, but little land use research has followed up on this. Related to this type of investigation is the hypothesis that local peculiarities will often cause significant variations in the amount of land used for a particular purpose in a given incorporated place. For example, a summer resort incorporated place may have a high proportion of residential land use. Examination of individual incorporated place high and low range land use proportions and per capita land use coefficients in this study reveal wide ranges from calculated averages. Further examination of those individual incorporated places that deviate widely from the norm is needed.

Estimating changes in urban land uses

In this subsection, a modified application of an econometric model suggested by Muth (59), and tested by Rao (69) in California, is made for urban growth in Iowa. The results of this investigation are then compared with other studies.

Muth's classic 1961 article is one of the few theoretical studies of the specific conversion of rural land to urban land. The general framework of Muth's paper is a Von Thunen-like model of land use determination which postulates a market for commodities at some fixed point in space, around which land of homogenous physical characteristics

extends to an infinite distance. Firms of two competitive industries locate on this land. The two firms could be assumed to be urban services and agricultural production. Muth's model is concerned with long-run locational equilibrium conditions.

Muth's model conceives of a regression analysis of changes in the land area used for urban purposes as being a function of the relative changes in demand for the products of the two industries. His model implies that the form of the equation will be linear. Muth's model also suggests that change in urban land area is a function of technology, price gradients (reflecting changes in transportation costs), and nonland costs. The regression equation for empirical testing here will only test demand variables because of limitations of data.

One of the principal reasons for the noticeable absence of regression studies involving changes in urban land area is the lack of data on the number of acres of urban land that are annually converted from rural to urban uses. Annual time series data on the conversion of rural to urban land uses were not available. Data that were available were the change in urban land use from 1960 to 1970 for 81 counties in Iowa.

Urban land uses for this regression study includes a conglomeration of all nonagricultural land uses within incorporated places greater than or equal to 2,500 in population in 1970. There were 18 counties out of Iowa's 99 counties in 1970 that did not have any incorporated places of 2,500 population or greater. Thus, urban land area, as defined by this study, is the total number of acres inside incorporated

places' boundaries greater than 2,500 population minus acres assessed for agricultural uses. Urban land includes the total number of acres devoted to residential, commercial, and industrial land uses and land uses that are auxiliary to urban uses, such as land under roads, schools, and undeveloped nonagricultural land uses.

Since equilibrium in the commodity market is assumed, a deflated average value of farmland and buildings per acre is used to reflect quantity demanded of agricultural commodities through derived demand. Quantity demanded of urban services is reflected by urban population and deflated aggregate family income.

It is assumed that urban growth starts when population increases. When a county gains urban population the immediate effect is the absorption of more land necessitated by the increase in population. Even though there is no increase in urban population, change in residential habits induced by changes in personal income and preference for lower density residential quarters may also tend to increase total urban land area. Thus, population and income are expected to have coefficients with positive signs and explain most of the change in urban land area.

Considering that urban services and agricultural production compete for land use, an increase in the price of agricultural land (reflecting an increased demand for agricultural land) may be expected to have an adverse effect on urban land growth, in that private urban land uses must outbid the going price per acre that agriculture is able to pay.

Using ordinary least squares regression, change in county urban land from 1960 to 1970 was regressed on change in county urban population from 1960 to 1970,[11] on change in county deflated average value of farmland[12] and buildings per acre from 1960 to 1970, and on change in deflated aggregate county income from 1960 to 1970. (See equation 2, Table 1). All hypothesized signs were found to exist.

There is significant collinearity, or a fixed relationship, between X_1 (change in urban county population) and X_3 (change in deflated aggregate county income), as indicated by the degree of closeness of the linear relationship between X_1 and X_3. A similar correlation coefficient of .88 was calculated. (See Tables 9 to 11 inclusive, "Supplementary Appendices: Land Use Inventory and Projection Model with Applications to Iowa and Its Subregions" for data on which this calculation is based). This multi-collinearity makes it difficult to obtain precise estimates of the relative effects of X_1 and X_3.

Heteroscedasticity, nonconstant variance of the error terms, appeared to be within acceptable bounds for this model. A plot of the

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[11] Urban land is here defined as all nonagricultural land within each county within the boundaries of incorporated places greater than 2,500 in population in 1970. Urban population is defined as all population within each county residing within incorporated places greater than 2,500 in population in 1970. Incorporated places greater than 2,500 in population were used because of the availability of census land data for this population size class. Also, of the net Iowa population growth between 1960 and 1970, all of it occurred within incorporated places. The population living in unincorporated places declined. Of the total population growth in incorporated places between 1960 and 1970, 95 percent of it occurred in incorporated places greater than 2,500 in population.

[12] The choice of this average land price variable as a surrogate for price at the urban perimeter appears reasonable, since there is a gradient of land prices decreasing away from the urban area, and since factors affecting the average price affect prices all along this gradient.

Table 1. County urban land use regression[a]

Regression results										
Equation number	Independent variable[b]	Number of counties	Constant	X_1	X_2	X_3	D.F.	D.W.	$\bar{R}^2$	F
1	Y	79	275.44	.28 (18.18)***			77	1.97	.80	
2	Y	81	263.58	.21 (4.41)***	-3.27 (-.53)	.00002 (2.61)***	77	1.91	.72	70.91**
3	Y	81	100.03	.21 (4.40)***		.00002 (2.62)***	78	1.91	.72	107.20**
4	Y	81	495.84	.32 (13.64)***	-3.22 (-.51)		78	1.97	.70	95.82**
5	Y	81	334.58	.32 (13.89)***			79	1.97	.70	
6	Y	81	-136.49		-.71 (-.10)	.00005 (12.30)***	78	2.06	.65	78.08**
7	Y	81	-171.56			.00005 (12.57)***	79	2.05	.66	
8	Y	81	130.37		14.52 (1.28)*		79	2.10	.008	

[a]The top numbers are O.L.S. regression coefficients, and the numbers in parentheses are t statistics for each coefficient.

[b]Y = change in county urban land use acres, 1960 to 1970; X_1 = change in county urban population, 1960 to 1970; X_2 = change in deflated average county value of farm land and buildings per acre, 1959 to 1969; and X_3 = change in deflated aggregate county income, 1959 to 1969.

***Indicates significance under .005 for one tail t test.

**Indicates significance under .01 for one tail t test.

*Indicates significance under .15 for one tail t test.

residuals revealed no systematic expansion or contraction with respect to the arrangement of the residuals providing no suspicion of nonconstant variance of the residuals (20, p. 117).

Autocorrelation, serial correlation in the error terms of each observation, is hypothesized to be of no problem in this model. The hypothesis of nonserial correlation (independent distribution of the dependent variables) implies that if the change in urban land use in one incorporated place were "disturbed" -- for example, by an abnormally large public urban land use acquisition -- that this would not affect the change in urban land use for any other incorporated place. In general, this assumption appears realistic for this model. A widely used test for autocorrelation is the Durbin-Watson test (70, p. 122). The Durbin-Watson D for equation one was 1.97, which at the 5 percent significance level accepts the null hypothesis that the error terms are serially independent. The Durbin-Watson D for equation two was 1.91, again accepting the null hypothesis at the 5 percent level.

Both change in population and change in income coefficients were found to be significantly different from zero. The coefficient of change in deflated average county value of farmland and buildings per acre was found to be insignificant. Change in urban population is by far the most significant variable, explaining 70 percent of the variation in change in urban land use. Though the change in income coefficient is significantly different from zero, it does not greatly add in explaining variation in urban land use because of its collinearity with change in urban population.

Projection of urban land uses

Projections of urban land use are made by using equation 1 in Table 1. This equation is based on only 79 of the original 81 counties that contained incorporated places of 2,500 or greater population in 1970. Equation 5 contained all 81 counties. In equation 1, Pottawattamie and Black Hawk counties were omitted from the regression as outliers. The city of Council Bluffs in Pottawattamie County and the city of Waterloo in Black Hawk County had unusually large changes in urban land for their respective changes in urban populations. The city planners at both of these incorporated places were contacted to determine the source of the deviation. In 1965 approximately 16,000 acres of nonagricultural flood plain land was annexed into the city of Council Bluffs. This land has been slowly subdivided for residential purposes. Also, in 1968 another 3,000 acres of land was annexed for further subdivision purposes but was not used for agricultural purposes and sat idle for an interlude. In 1967 approximately 6,000 acres of nonagricultural land was annexed into the city of Waterloo for airport control land. It is felt that the above extraneous factors help to make the two county observations aberrant. While there is little evidence to conclude that similar extraneous factors are not involved with the 79 included observations, equation 1 was still preferred over equation 5, since both the intercept and slope terms in equation 1 result in more conservative projections.

Equation 1 is used to project future county urban land use by utilizing total county population projections (26) for 10 year increments

from 1970 to 2020. Projected population declines, as well as projected population increases, are utilized in the projection equation, but there are no projected population declines large enough to result in a negative change in urban land use.

Urban land use for Pottawattamie and Black Hawk counties, the two outliers, were projected differently than the other 97 counties. They were treated as follows:

$$\text{If } UL_{1960} + (275.4 + .282\Delta UP_{\substack{1960 \text{ to } 1970 \\ \text{(actual)}}}) + (275.4 + .282\Delta TP_{1970 \text{ to } 1980}) < \text{actual urban land in 1970}$$

then no change in urban land is projected for 1970 to 1980. If actual urban land in 1970 is less than the above sum, then the difference between this sum and the actual is assumed to equal the change in urban land from 1970 to 1980. Similarly, if

$$UL_{1960} + (275.4 + .282\Delta UP_{\substack{1960 \text{ to } 1970 \\ \text{(actual)}}}) + (275.4 + .282\Delta TP_{1970 \text{ to } 1980}) + (275.4 + .282\Delta TP_{1980 \text{ to } 1990}) < \text{actual urban land in 1970}$$

then no change in urban land is projected for 1980 to 1990. If actual urban land in 1970 is less than the above sum, then again, the difference between this sum and the actual is assumed to equal the change in urban land from 1980 to 1990. This procedure is repeated for these two counties until actual urban land in each county is less than projected. Thereafter, equation 1 in Table 1 is used to make the remaining projections for these two counties.

County urban land use projections are summed to derive regional urban land use projections. From 1970 to 1980, it is projected, using the above method, that urban land uses for the entire state will absorb 98,644 acres. Following a modified form of Snedecor and Cochran's equation 6.12.1 (85, p. 155), the following 95 percent confidence interval for the 1970 to 1980 change in urban land use eatimate for the state was calculated.[13] The results are as follows:

$$P(\hat{Y}-S\hat{y}\ t.05 \leq \hat{Y} \leq \hat{Y} + S\hat{y}\ t.05) = .95$$

where

$\hat{Y} = 98,644$

$S\hat{y} = 17,254$

$t.05 = 1.989$
77 d.f.

Therefore, we are 95 percent confident that $\hat{Y}$ lies between 64,326 and 132,962 acres, in that the procedure itself will, 95 percent of the

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[13] With the assistance of Wayne A. Fuller, Professor of Statistics, Iowa State University, the following modified Snedecor and Cochran equation was derived:

$$S^2\hat{y} = (99^2)\left\{\frac{\sum_{i=1}^{81}(Y_i-\hat{Y}_i)^2}{79}\right\}\left\{\frac{1}{99} + \frac{1}{81} + \frac{(X_0-\bar{X})^2}{\sum_{i=1}^{81}(X_i-\bar{X})^2}\right\}$$

where

Y_i = Δ urban land, 1960 to 1970, for i-th county

$\hat{Y}_i$ = predicted urban land, 1960 to 1970, for i-th county, computed using UL = 275.44 + .282 UP

X_i = Δ urban population, 1960 to 1970, for i-th county

$\bar{X}$ = mean Δ urban population, 1960 to 1970, for 81 counties

X_0 = mean Δ urban population, 1970 to 1980, for 99 counties

time, give limits that enclosed $\hat{Y}$. This confidence interval assumes the population projection from 1970 to 1980 to be known with certainty.

The following assumptions are implicit in the urban land use projection procedure. Per capita land requirements for urban use are not assumed to remain constant over the period considered. Population increases in incorporated places less than 2,500 in population and population increases outside of incorporated places are assumed to result in changes in urban land as if it occurred in incorporated places of 2,500 or greater population. Though this assumption is not realistic as a larger urban land use per capita occurs in smaller incorporated places, this assumption will have little effect on the accuracy of the projections if it is assumed that the vast majority of future population growth will occur in incorporated places greater than 2,500 in population. The projections resulting from the above model are conservative if it is assumed that urban population will increase and rural population will decrease. (These population shifts result in a smaller change in total population than change in urban population.) This is because the projection equation was built on changes in urban population, but the projections are made on changes in total population. These projections are conditional in that they assume that agricultural land prices are not a particularly strong constraint on urbanization, as had been true in the past. However, in the future, if world food shortages continue or government policies are enacted (such as preservation of prime agricultural lands), land prices may come to influence

urbanization. Finally, these projections implicitly assume little deviation from the Iowa average 1960 to 1970 population profile. It could be hypothesized that land absorption is a function of the population profile. For example, a change in the population profile could result in a fewer people per household, but more households per capita, yielding higher land absorption per capita, ceteris paribus.[14]

Summary of estimating changes in urban land uses

Though urban economists have developed a number of general theories (2) for explaining the process of urban expansion, there has been little serious empiricalization of the process of urban expansion onto nonagricultural land. Results from the few studies (76, p. 17; 69, p. 21) that have been done, along with results from this study, agree that the primary variable determining total new urban land required is population growth. The alternative value of land for agriculture appears in this study and in Rao's (69) study, at least over ranges observed in the past, to be insufficient to significantly affect which land is developed for urban use. This implicit price-inelastic demand for total new urban land, at least over the ranges observed, may be a reflection of the subsistence aspect of urban land use, in that approximately 42 percent of Iowa urban land use is in residential and associated land uses.

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[14]This hypothesis may warrant further research. Iowa's relatively high land absorption coefficient per capita may be partially related to its relatively old age population profile.

Of the several studies (69, 1, 20, 3, 19, 63, 76, 12, 17) which have analyzed urban land conversion, most of them have conducted only gross analyses of the area of concern. None are exactly comparable because of differences in data time periods, geographic territories covered, definitions of urbanization, and data sources. However, a very general comparison can be made to highlight basic differences and similarities to the estimates in this study.

This study is based upon a larger empirical sample and more exacting measurement techniques than most of those reported in the studies cited. This Iowa study accounts for the effect of population growth on areas already considered urban, in that it accounts for changes in agricultural land within incorporated place's boundaries, as well as the effect of population growth on land shifting to urban use outside of incorporated places. In addition, this study estimates a functional marginal or incremental rate of change of urban land use, while the other studies largely confined their empirical estimates to average land use per capita or in a few cases to constant marginal land absorption per capita. A marginal rate of change of urban land use is calculated in this Iowa study which is not constant per capita, but varies per capita with respect to the change in population.

For a 10-year change in county urban population of 1,681 people, the mean value of the estimated function, equation 1 (Table 1) estimates a functional marginal urban land absorption coefficient of .44 acres per capita increase. This functional coefficient is far higher than

any of the constant average or constant marginal land absorption coefficients found in the cited studies. This function coefficient is even significantly higher than the constant average and constant marginal land absorption coefficients found in this study for Iowa. The constant average and constant marginal urban land absorption coefficients found for Iowa are, respectively, .27 and .40 acres per capita. These coefficients are on the high side of the general order of magnitude of findings in the nine cited studies.

The only other derived nonconstant marginal land absorption coefficient found in the literature is the base equation of Ruth and Krushkhov (76, p. 18). Solving $dL = d^{-4.51}dP^{.8}$, where dP = 1,681, and dividing the result by 1,681 and then multiplying by 100 (because dL is in 100 acres), gives a functional marginal land absorption coefficient of .25, larger than any of the above cited coefficients but still significantly smaller than that found for Iowa.

There is strong evidence to conclude that the marginal land absorption coefficient is considerably larger than the average land absorption coefficient. This study also demonstrates that constant average or constant marginal land absorption coefficients are misleading. Depending on the rate of population growth, the rate of urban land absorption varies systematically less than proportionally. As population growth proceeds, perhaps, it initially shifts to land outside of old incorporated place boundaries, and subsequent population growth absorbs areas already considered urban. These areas are agricultural land inside of incorporated boundaries and underdeveloped present urban land. This

would help explain why the marginal urban land absorption coefficient is larger than the typically derived average urban land absorption coefficient (or the inverse of the average density coefficient). The average urban land absorption coefficient is based on a long-term average for the entire urban area, whereas the marginal urban land absorption coefficient considers recent changes in urban land use outside of old incorporated place boundaries that have recently been annexed.

Besides the equation developed in this study, Ruth and Krushkhov are the only other researchers (to these authors' knowledge) to derive a nonconstant marginal land absorption function showing that the greater the annual growth in a county, the less land is needed per added person. Their (76, p. 18) hypothesis for this is that the faster the growth in a county, the more rapid the increase in the price of land is likely to be. However, no data were available on land prices in the Ruth and Krushkhov study to prove this assertion.

Results of this study indicate that the degree of closeness of the linear relationship between X_1, change in urban county population, and X_2, change in deflated average county value of farmland and buildings per acre, is very low (.205). This supports literature (74, p. 12) that concludes that prices of agricultural land for agricultural uses are

determined primarily outside of the urban sector.[15] Thus, the Ruth and Krushkhov statement (76, p. 18) that the faster the population growth in a county, the more rapid the increase in the price of land is likely to be, is not exactly correct. The more rapid the increase in population growth, perhaps the more likely the increase in the price of "urban land," but not necessarily of agricultural land.[16] The above explanation helps to account for the highly insignificant average value of farmland coefficient in Table 1.

Contrary to this study's conclusion that the average value of land for agriculture, over the range observed, is insufficient to affect how much land is developed for urban use, Watt (110) finds a significant inverse relationship between the rate at which farmland has been urbanized and the value of farm property at the urban perimeter. A summary of research work completed by Watt postulates the following scenario. Farmland in the future will become more valuable primarily

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[15] Using O.L.S, regression, the change in deflated average county value of farmland and buildings per acre from 1959 to 1969 was regressed on change in county urban population between 1960 and 1970 for 81 counties with incorporated places greater than 2,500 in population in 1970. Though the change in the urban population coefficient was found to be positively significantly different from zero at the .05 level, it explained less than 4 percent of the variation in change in deflated average county price of farmland and buildings.

[16] Two early studies (77 and 79) that used cross-sectional models to measure the impact of local population pressure on farm real estate values found that variations in farm real estate values were positively associated with variations in population pressure as measured by total county population. Ruttan (79, p. 129) found that the impact of population pressure on farm real estate values tended to diminish between 1939 and 1954. Scharlach et, al, (79) used in 1959 data. It could be hypothesized that changes in urban population have had a diminishing impact on changes in farm real estate values over time.

because of the influence of events occurring at the international level. The U.S. balance of trade probably will depend increasingly on the ability of U.S. farmers to increase food exports at a rate comparable to increases in imports of petroleum and other products. As farm product prices increase in response to accelerating farm exports, the price of farmland will tend to rise. Consequently, higher priced farm land adjacent to U.S. urban areas will less likely be converted to urban uses. Therefore, urban areas would tend to increase their density of land use on relatively fewer acres.

An inverse relationship between the average value of farm property at the urban perimeter and the rate at which land is converted from agricultural use to urban use per person added to the population in Watt's study is derived, based on pooled data, from large urban areas across the United States. Since Watt's model (110) is based on pooled city data, average conditions for a particular area may not be applicable to his model without fine tuning it to account for peculiarities of that area. Because of the strong evidence that several types of farmland markets exist, studying land use on a type-of-area basis gives promise for improving forecasts and analysis (14, p. 13). Future land use studies should delineate the overall land market into smaller land markets involving more homogeneous types of land and more homogeneous demands for those types of land (81, p. 1500).

In summary, over the empirical range of various types of land supplies and urban demands, average value of agricultural land and buildings appears limited in explaining variations associated with conversions of agricultural land to urban uses. This observation is consistent with Barlowe's reasoning (5, p. 22) that demand for

land is definitely inelastic. This situation exists because most people have somewhat limited and routine demands and needs for most land resources. The range of needs for living area are limited even though more and better (emphasis here) living accommodations may be demanded when incomes are high than when they are low. Schultz (80, p. 1,000), on the other hand, states, "...urban people are demanding more land for industry, residences, recreation, and for a more satisfying environment in large part because of increases in their income that make their demand effective and the modernization of agriculture that contributes to the supply of land." Available evidence on the income elasticity of demand for housing services is inconclusive (31, p. 70).

Highways and Road Land Use

In land area and population, Iowa finds itself about average in the United States. For example, in 1970, it ranked 25th in population and 25th in area among the 50 states. In 1966, however, it ranked third in total secondary or county road mileage. In addition, the state had the largest farm-to-market or federal aid secondary road system in the nation, which amounted to 34,000 miles. This was an average of .48 miles of secondary roads in the state for each farm unit in 1966 (13, p. 80).

The Statistics Section of the Iowa State Highway Commission furnished unpublished data for this study on the number of miles and corresponding right-of-way widths for various classes of roads in Iowa for 1960 and 1970. In 1970 there were 1,103,393 total acres (3.1

percent of the state's surface area) of road right-of-ways in the state, of which 996,906 acres were outside incorporated places. Between 1960 and 1970, there was an estimated increase of 38,167 acres in total road right-of-way acres outside incorporated places. This is a 4.0 percent increase over the 1960 total road right-of-way acres.

The 1,103,393 total acres in 1970 correspond to approximately 112,000 total miles of roads. It is interesting to note that in 1904 Iowa had 102,448 miles of total roads (13, p. 76), though this 1904 mileage in terms of total acreage absorbed was proportionally less than present day mileage because of smaller right-of-way widths.

Over 76 percent of the total acreage in road right-of-ways in the state in 1970 was in the secondary rural road system with only 2 percent in the interstate system. Of the total right-of-way road acreage in the state, 88 percent is nonsurfaced and 66 percent (735,169 acres) is shoulders and remaining right-of-way. Thus, not even considering the 239,746 acres in primarily nonsurfaced, rural secondary roads, there is considerable acreage (2 percent of the state's surface area) in nonsurfaced road right-of-way land use.

There is little information on how much of the 695,510 acres of remaining right-of-way in the state could be cultivated under an all-out food production situation. Much of this land may not be productive because of drainage problems and inaccessibility for machinery, but

undoubtedly some of it could be cultivated.[17] In past dry years, the state has given permission to farmers to harvest hay in the road right-of-way.

Because of continuing expansion in farm sizes and reduced traffic volume on secondary rural roads with resulting declining road revenues, there has been considerable deactivation of these nonsurfaced roads by cities and counties in recent years. The Iowa State Highway Commission estimates that approximately 120 miles (or 960 acres using an average of 8 acres per mile) of secondary rural roads per year have actually been deactivated in recent years.[18] Results from the 1975 Iowa extension survey estimate that 5,491 acres of roads were converted to agricultural land between 1968 and 1973, or approximately 1,000 acres per year on the average. (This estimate corrects for a 5.1 percent county nonresponse.)

Projections of additional land needed for new highways and roads are based upon an unpublished mimeo, "Lands Need Estimate" (46), provided by the Iowa Department of Transportation. These projections are based upon completion of the 1968 approved Iowa Expressway System Plan prepared by the Iowa Highway Commission and the U.S. Department of Transportation (45). These plans are required by Iowa law. The projections

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[17] However, this may conflict with the use of this land as a wildlife sanctuary. See (30) for a study assigning monetary values to the conservation of habitats and species within the context of land use planning.

[18] This estimate was obtained from Jack Klein, Head of Iowa Highway Statistics, Iowa Department of Transportation, June, 1975.

are made on a statewide basis for the period 1970 to 1990. It is anticipated that proposed construction to be completed by 1990 will require an additional 103,201 total acres of road right-of-way over the present system. This will be an increase of 9.3 percent over the 1970 total road right-of-way acres in the Iowa road system.

Proposed statewide interstate, freeway, expressway, and rural primary right-of-way road acres are regionalized for the 16 regions according to the existing 1970 respective proportions of each category in each region to its total state acreage. Estimates of future additional acres in road right-of-way include acres both inside and outside incorporated boundaries. To avoid double counting of future road right-of-way acres because road right-of-way acres inside incorporated places are implicitly included in the urban projections, this study assumed that for future road right-of-way acre additions, 83 percent of the interstate, 82 percent of the expressway, and 90 percent of the freeway acres are outside incorporated places. These percentages are based on the existing 1970 spatial distribution of the present road system.

The Iowa Highway, Road and Street Needs Report for 1971 to 1990 (47, p. II-1) indicates that the tentative completion year for the Interstate System is fiscal 1977. The estimated 10,399 total acres of road right-of-way needed between 1970 and 1980 to finish Iowa's share of the presently conceived interstate system is assumed to be acquired and completed by 1980. One-half of the 43,181 total acres of proposed additional freeway road right-of-way is assumed to be completed by

1980, and the other half is assumed to be completed by 1990. Similarly, of the 37,864 total acres of expressway and 7,272 total acres of rural primary right-of-way acres to be completed by 1990, one-half of each respective total is assumed to be completed by 1980, and the other half by 1990. The 4,485 acres of municipal primary and city streets proposed to be completed by 1990 are implicitly included in the urban projections.

The above road right-of-way acre projections only go to the year 1990. They also only include projections of acres needed for new additions and do not include any increase in acres needed for widening and improving present roads. It is difficult to project the acres needed for future widening, because in some cases the state may already own the needed right-of-way, and in other cases the state would have to acquire it. Thus, it is assumed that acres deactivated of secondary rural roads between 1970 and 1990 will offset acres acquired for widening and upgrading the present road system. Since there is no basis for projections of additional acres absorbed by roads beyond 1990, this study assumed that increased deactivation of secondary rural roads from 1990 to 2020 will offset any additional acres needed for new roads and improvements of the existing road system. For this reason, total acres in road right-of-way are held constant beyond 1990.

It should be noted that the old assumptions on which road planning were based are presently being challenged. The projections used here are probably slightly on the high side, in that previous five-year plans have failed to complete projects within time limits (62). Some of the projections made in this study will probably be delayed in time

because of rising costs and dwindling funds. For example, the cost of building a mile of highway has risen 100 percent between 1967 and 1974. Also, federal aid to Iowa road funding fell $15 million from 1973 to 1974, and fuel tax collections have fallen since the energy crisis (58).

Railroad Land Use

The railroad land use data of this subsection is based upon unpublished Iowa Department of Revenue data and Iowa State Commerce Commission Annual Reports (41 and 42). In 1920 there were 119,285 acres of Iowa railroad right-of-way, while in 1970 there were 94,484 acres (.3 percent of the state's total land area). These acreage figures are for open country railroad lines and do not include the acreage in railroad yards inside incorporated places. This railroad acreage is implicitly included in the urban place acreage data. Between 1915 and 1920, the state had its peak railroad mileage and it has declined consistently every year since. At the peak time of this well-developed railroad network, no farm was more than seven miles from a railroad (13, p. 76).

Projecting the annual rate of railroad abandonment into the future is difficult because what should be done economically and what is done politically are two different things. Much of the rail track in Iowa was laid around the beginning of the century. Most grain in Iowa is presently hauled on unit trains (trains carrying a single commodity) consisting of jumbo hopper cars which weigh much more than the track originally laid down at the turn of the century was meant to accommodate.

Upgrading light lines is very expensive. Grain cooperatives pay shipping rates to railroads for use of their tracks, and shipping rates vary depending on the number of cars shipped per train. A single car may cost 35.8 cents per bushel, while a 50-car train may cost 29.9 cents per bushel (4, p. 20). Thus, unit trains with corresponding rate reductions tend to render branch lines with single car terminals uneconomical. Railroads have adapted to declining use of rural rail trackage by applying to the Interstate Commerce Commission for permission to abandon specific lines or spurs. There has been much recent public concern about the economic effect on rural areas of rail abandonments (93, p. 76). A study by the USDA's Economic Research Service found that, overall, farmers and consumers are not likely to suffer from such abandonments, although some farmers may face increased transportation costs for both their products and their inputs (100, p. 6).

From 1930 to 1970, there was an average annual statewide rate of Class I railroad abandonment of 573 acres per year. From 1970 to 1974, there was an average annual statewide rate of Class I railroad abandonment of 1,442 acres per year. Because of the above conditions, future railroad acreage abandonment is not seen as tapering off. It is projected that 100 miles of track (1,212 acres) each year will be abandoned to the year 2020.[19] The projected statewide figure was proportioned to the 16 regions according to regional shares of total

[19]This projection may be conservative in light of the Chicago, Rock Island, and Pacific Railroad failure in March 1975 (90, p. 17). The Rock Island is the second largest line in Iowa with over 23 percent of the state's total rail mileage.

state railroad acreage.

There is little information on how much of the railroad abandonment acreage is converted to agricultural uses. Dr. Phillip Baumel, Iowa State University Extension Economist, who has done research on the Iowa rail grain transportation system, estimated that less than one-half of the present railroad abandonments could be easily returned to agricultural uses.[20]

At the time of this writing, a bill had been introduced into the Iowa House which would require the Iowa Department of Transportation to give priority (the power of eminent domain) to those seeking the land for recreation trails, conservation, or some other public purpose. The Citizens Advisory Committee on Environmental Quality has urged the conservation of the nation's unused miles of railroad lines into hiking, biking, and skiing trails (109). Thus, it is assumed that over one-half of the abandonment acreage will be used for some form of public recreation land use and that any small railroad acreage that is converted to agricultural uses will be offset by any new additional railroad right-of-way expansions on agricultural lands.

Airport Land Use

The Iowa Aeronautics Commission furnished unpublished data on acreage in municipal and private airports in 1974. There were 124 municipal airports in the state, absorbing the 22,640 acres, and 120

[20]Private communication, January 1975.

private airports in the state, absorbing 730 acres, in 1974.

The 1972 Iowa State Airport System Plan's goal, which considers airport developments necessary to meet the needs of civil aviation, is to have at least one municipal airport in each county by 1990. The number of municipal airports has been fairly constant up to approximately 1960. From 1960 to 1974, the number of municipal airports in the state has almost doubled. In 1974, there were only six remaining counties that did not have a municipal airport. These counties were Iowa, Warren, Mills, Keokuk, Wayne, and Louisa.

To derive the 1960 and 1970 regional airport land use base figures, the average regional acres per municipal airport for 1974 were multiplied times the number of municipal airports per region for 1960 and 1970. Private airport acreage was ignored because of the small acreage involved and their temporary nature. For example, many Iowa private airports are nothing more than a cleared farm field. It is thus estimated that 8,697 acres were absorbed by municipal airports between 1960 and 1970. This is a 65.8 percent increase over the 1960 airport land use base figure.

To project future airport acreage, this study assumed that the six counties without a municipal airport will have one by 1990. The 1974 statewide average of 182 acres per municipal airport is assumed, with one-half of the acreage being absorbed between 1970 and 1980 and the other half being absorbed between 1980 and 1990. To project municipal airport acreage for the other 93 counties, the 1970 statewide average of .0078 acres municipal airport per capita is assumed to hold

constant and is multiplied times projected regional population. The above .0078 coefficient compares with a 1970 U.S. wide average of .008 acres of airport per capita. For the six counties without a municipal airport, 1990 to 2020 projections were also made by using the above per capita method.

The above projections may be conservative in that a recent testimony before the U.S. House Aviation Subcommittee urged that national transportation planning include at least one airport for every incorporated community in the county (68). It is also assumed that all the above projected airport acreage will fall outside incorporated places. Though this may not actually happen, it is assumed, because the incorporated place projections do not include airports. In 1974, less than 14 percent of the state's total airport acreage fell within incorporated places.

Extraction Land Use

In 1972, Iowa ranked 31st in the U.S. in the value of its mineral production. Iowa utilized 55,300 acres between 1930 and 1971 for its mining industry according to a U.S. Bureau of Mines survey (66, p. 36). Of these 55,300 acres, 18,300 acres have been reclaimed.[21]

The county extension survey results of this study (26, p. 461) estimated that in 1970, 30,398 acres were absorbed by extraction land uses, including extraction land that is idle and is used for no other

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[21] Reclaimed in this survey means that reconditioning or restoration work has been completed on mined areas and waste disposal areas in compliance with federal, state, or local laws (66, p. 8).

purpose, but had been mined in the past. This estimate corrects for an 11.1 percent county nonresponse rate. The extraction land use estimates were corrected for county nonrespondents by assuming that the extraction acreage for each of those counties that did not respond is equal to the mean county extraction acreage in the appropriate region for the given year.

There is very little information on how much of these 30,398 acres are permanently idle. According to a state mine inspection report (88, p. 18), only 958 acres were actively disturbed by mineral production in Iowa in 1970. This is less than 4 percent of the owned extraction land use acreage. Apparently, there is significant mineral production potential on presently owned extraction acreage. There is also little information on how much extraction land is actually returned to nonextraction land uses. The same report indicates that 850 acres were "rehabilitated" in 1970 (88, p. 18). (See reference (88, p. 51) for a definition of rehabilitation.) Neither this definition of rehabilitation nor the 18,300 acres estimated to have been "reclaimed" by the U.S. Bureau of Mines (66, p. 8) gives any indication of how much past extraction land use acreage is actually converted to other land uses.

Between 1960 and 1970, the county extension survey results estimated that 4,683 acres were absorbed by the extraction industry. This is an 18.2 percent increase over the 1960 base figure. It is estimated that over 53.3 percent of this increase was for sand and gravel, and

45 percent was for limestone extraction.[22] Gypsum, clay, and coal accounted for an estimated 1.1 percent, .2 percent, and .4 percent, respectively, of this 4,683 acre increase. Sand and gravel accounted for over 53 percent of the 1970 extraction land use acreage.

To project extraction land use, the average of the 1960 to 1970 state mean extraction acreage change per county and the 1963 to 1973 state mean extraction acreage change per county was multiplied times 99 counties to give an estimated 4,305 acres assumed to be absorbed by extraction land use each 10 years from 1970 to 2020. These 4,305 acres were proportioned to the 16 regions by multiplying them times the average of the 1960 to 1970 regional mean acreage change per county and 1963 to 1973 regional mean acreage change per county for each region. This was then multiplied times the number of counties in each region divided by the sum of the 16 regional average 10-year changes per region. The proportions were assumed to remain constant over time.

It is difficult to project future extraction land use acreage as the state and nation strive for energy self-sufficiency.[23] In 1974, three million dollars was approved by the Iowa State Legislature for a three-year research project on the feasibility of expansion of the coal mining industry in the state (Senate File 1362). Iowa's peak

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[22] Iowa is the nation's leading limestone using state according to the Iowa Limestone Producers Association. Most of the limestone is used in agriculture to reduce soil acidity.

[23] See the Iowa Energy Policy Council (125, p. i) statement of land use acreage needed for energy self-sufficiency.

year for coal production was 1917, and it has declined ever since (88, p. 28). Nearly 100 percent of Iowa's coal production is used in the state, though Iowa's coal production only supplies 12 percent of the state's coal consumption (107, p. 13). There is little accurate determination of the present extent of Iowa's coal reserves (71, p. 16). Iowa coal has a high sulfur content, thus economic technological methods must be developed to wash the coal and reduce its sulfur content. Acidity and erosion are primary problems which damage farmland. Acidity becomes a major problem when spoil containing sulphur is left on the surface. These problems are caused by faulty strip mining and reclamation. Thus, if a relatively inexpensive way is not found to reduce the sulfur content in Iowa coal and to provide land reclamation, Iowa may be a long way from having a booming coal industry. The above extraction land use projections may be conservative if (1) it is found that there is sufficient recoverable coal of suitable quality in Iowa to support a mining industry and (2) that economic conditions change so that mining Iowa coal will be profitable.

Recreation Land Use

Recreation land use is divided into public recreation and private recreation land use. Both the public and private recreation land uses discussed here are outside incorporated areas. Recreation land use inside incorporated areas is covered under urban land uses.

Public recreation land use data were tabulated from published inventories of public recreation land by the Iowa Conservative Commission and unpublished U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service data (36, 35, 38, 34, 33, 43, 9, 44).

Many errors and inconsistencies were found in the above public recreation land use data. One recurring problem was that land classified as owned by one governmental agency, for example, the state, in one year was listed as owned by another agency (county) in other years, creating a double counting problem in comparing time series data. Some public recreation land was listed as owned by both the state and federal government with no breakdown for each. Also, much federal land in Iowa is under many different federal jurisdictions, such as the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service. This land is under many different management arrangements, such as leases and fee simple ownership, creating much data confusion. Thus, the public land use acreage figures presented here are as accurate as can be, given that they are decoded from the confusing original secondary data.

In 1970, both public and private recreation land uses outside incorporated areas occupied 387,719 acres of land and water, or .17 acres per capita compared with a U.S. wide average of .39 acres of recreation land and water per capita. Iowa has one of the smallest percentages of its lands in state and federal ownership of all the 50 states. It also has one of the smallest amounts of state and federal lands per capita of all the 50 states.

In 1974, 42 percent of the nation's land (not surface) was held by federal, state, or local government for a variety of uses. Approximately 33 percent of the nation's land is just federally owned (9, p. 9). This study estimates that in 1970, 454,924 acres of Iowa recreation lands

and waters (1.2 percent of the state's land) were held by federal, state, and local government. Of the 454,924 acres of public recreation lands and waters, approximately 57 percent is under federal ownership (of which 49 percent is in reservoir and associated land use), 31 percent is in wildlife areas, 17 percent in Mississippi River navigation channel projects, 2 percent in river access and undeveloped lands, and 1 percent in fish hatcheries and national monuments.[24] Approximately 65 percent of the federal and state recreation land and waters is land area, while approximately 95 percent of the county recreation land and waters is land area.

Between 1960 and 1970, it is estimated that 203,240 acres were absorbed by public recreation land and water uses. This is an 80.8 percent increase over the 1960 public recreation land and water use base figure. Of the 203,240 acre increase, approximately 50 percent is accounted for by three federal reservoirs, Red Rock Reservoir and Saylorville Reservoir in region 11, and Rathbun Reservoir in region 15. Much of the relatively large increase in public recreation land in region 1 is attributed to the Upper Mississippi River National Wildlife Refuge. Only 27.4 percent of the 203,240 acre increase is attributed to state and county recreation land acquisitions, with 12.7 percent and 14.7 percent, respectively, for state and county recreation lands

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[24] In addition to the 1.2 percent of the state's land in public recreation uses, very little other land is owned publicly. For example, in 1969, 807 acres were owned by the federal government in Iowa for use by the USDA, U.S. Commodity Credit Corporation, U.S. General Services Administration, U.S. Post Office, and the U.S. Veterans Administration (108).

and waters.

The county extension survey results (26, p. 462) estimated that in 1970, 32,794 acres were absorbed by private recreation land uses outside incorporated areas. Private recreation land uses include golf courses, drive-in theaters, fairgrounds and sports assembly complexes, private parks and campgrounds, and privately planned recreation (second home) subdivisions. These estimates were corrected for county nonrespondents by assuming that the subcategory of private recreation land use acreage for those counties that did not respond was equal to the mean county subcategory private recreation acreage in the appropriate region for the given year.

Between 1960 and 1970, the county extension survey results estimated that 15,271 acres were absorbed by private recreation land uses. This is an 87.1 percent increase over the 1960 private recreation land use base figure and is the highest percentage increase of all the major nonagricultural land use categories. Of the 15,271 acre increase, approximately 35 percent is accounted for by golf courses, 1 percent by drive-in theaters, 2 percent by fairgrounds and sports assembly complexes, 40 percent by private parks and private campgrounds, and 21 percent by recreation (second home) subdivisions. (See subsection on other urban land use for a discussion of undeveloped acres in private recreation subdivisions.)

Projecting future public recreation land absorption is difficult. Public financing for land and water projects is almost completely

unpredictable, since monies come from legislative appropriations which vary considerably from year to year.[25]

It is doubtful the federal government will exert much additional impact on recreation land use in the foreseeable future in Iowa. Most of the land for the Mississippi River Navigation Project was purchased in fee in the 1930's and none was purchased after 1950. There are no federal reservoirs being planned in Iowa that are likely to receive federal funding in the near future.[26] Projections from Outdoor Recreation (36), the official outdoor recreation plan for the state of Iowa, estimate 12,864 acres of fee simple land under the long-range acquisition program for the Upper Mississippi River National Recreation Area in region 16 (36, Vol. 9, p. 48). One-half of this acreage is assumed to be acquired from 1970 to 1980, and one-half is assumed to be acquired from 1980 to 1990. In addition, 2,031 acres of land were absorbed by the Saylorville Reservoir in region 11 from 1970 to 1974.

The State Conservation Commission is the only state agency which is directly concerned with providing outdoor recreation in Iowa. It is empowered to develop a system of state parks which should be of statewide or at least regional significance regarding recreation potential. Attention is given to the geographical distribution of these areas (34, p. 19). To project state recreation land use, the

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[25] Public ownership of land has been described as the ultimate in determining control over land (9, p. 9).

[26] Private communication with the Kansas City District and St. Paul District, U.S. Army Corps of Engineers, January 1975.

42-year average annual state recreation land use requirement from 1933 to 1974 totaling 4,459 acres per year was assumed to continue to the year 2020. This projection is proportioned to the 16 regions on the basis of the proportion of total land area in each region to the statewide total land area.

Legislation enacted by the Iowa General Assembly in 1955 enables counties to acquire parks and other recreation areas. As of 1974, 95 of Iowa's counties have established conservation boards. The method of financing the boards is through the local county mill levy. In general, county conservation boards will undoubtedly continue to develop rural areas of local significance. To project county recreation land use, the 17-year average annual state recreation land use requirement from 1960 to 1977 of 2,487 acres per year was assumed to continue to the year 2020. Data for the years 1975 to 1977 were based on projected acquisition data in reference (36). This projection is proportioned to the 16 regions in the same manner as the above state recreation land use projections.

To project private recreation land use, the average of the 1960 to 1970 state mean acreage change per county and the 1963 to 1973 state mean acreage change per county was multiplied times 99 counties to give an estimated 17,571 acres assumed to be absorbed by private recreation land uses each 10 years from 1970 to 2020. This 17,571 acres was proportioned to the 16 regions by multiplying it times the average of the 1960 to 1970 regional mean acreage change per county and the 1963 to 1973 regional mean acreage change per county for each region. This was

then multiplied times the number of counties in each region and divided by the sum of the 16 average 10-year changes per region. The proportions were assumed to remain constant over time. It should also be remembered that the discussed railroad projected abandonments provide an additional source of potential recreation lands.

Private recreation land use projections are regionally proportioned on the basis of past trends, whereas public recreation land use projections are proportioned on the basis of area. This is because public recreation land use changes are assumed to be largely independent of the private market, whereas private recreation land use changes are more highly related to private market changes.

The above public recreation land use projections may be conservative in light of the 1973 open space legislation (S.F. 577) that appropriated 2 million dollars from the general fund of the state of Iowa to the State Conservation Commission for the biennium beginning July 1, 1973, and ending June 20, 1975, to be used for the acquisition of land available from willing sellers, but not including abandoned railroad right-of-way (33). The continuation of the above program is uncertain, for it was undertaken as a one-shot experiment and does not have permanent annual appropriations.

There is a wide diversity of professional opinion with respect to open space standards. Clawson is among the economists who have attempted to develop open space standards. Clawson, quoted in Little's Challenge of the Land (51, p. 20), arrived at a requirement of 78 acres of open space, of all kinds, per 1,000 population. The National Recreation and

Park Association has advocated a permanent allocation of open space of 10 acres per 1,000 population (51, p. 20). For purposes of comparison, the recreation (both public and private) land use projections of this study based on trend extrapolation provide for 34 acres per 1,000 projected population from 1970 to 1980.

Although agriculture is not explicitly mentioned in the above standards, it should be considered as contributing to open space requirements. That agriculture does make these contributions is a fact which often appears to pass unnoticed, and may explain Iowa's relatively low amount of recreation land per capita. Private farmland provides outdoor recreation, especially fishing and hunting, which may or may not interfere with agricultural productivity. But as land in farms falls and farms become more commercialized, the public may have less access to private farmland open space. Iowa's abundance of rich farmland in private ownership has rendered more difficult the task of securing private outdoor recreation areas. Many times it becomes necessary to acquire land for recreation uses which is well suited to agriculture, resulting in relatively high prices for recreation land.

Another factor besides population growth affecting future recreation land use, especially private recreation land use, is growth in real per capita income. With regards to public recreation land use, increasing per capita real income and leisure time may just result largely in increased use of present public parks, assuming the increased leisure time comes during the week and not on the weekend.

Other Urban Land Use

Other urban land uses include salvage yards and waste disposal dumps land use, cemetery land use, manufacturing and associated land use, wholesale, retail, and services and associated land use, housing (first home) subdivisions land use, mobile home park land use, and nonfarm residential land use. All of the above land uses are outside incorporated boundaries, including land use in unincorporated areas.

The county extension survey results estimated that in 1970, 102,781 acres were absorbed by other urban land uses. This estimate corrects for a 10.1 percent county nonresponse rate.

Between 1960 and 1970, it is estimated that 9,574 acres were absorbed in total by other urban land uses. This is a 10.2 percent increase over the 1960 other urban land use base figures and is one of the lowest percentage increases of all the nonagricultural land use categories. Within this other urban land use category, though, privately planned housing (first home) subdivisions increased 23.5 percent over its 1960 base figure. Though the above other urban land uses are included in 1970 nonagricultural land use base figures, future other urban land uses are not projected directly, but are implicitly included in the urban projections.

There is much national concern with rural land being subdivided for both first and second home subdivisions (72, p. 263). One of the basic concerns has to do with the extent and duration of subdivision underdevelopment. Information with regards to the duration of present

Iowa rural subdivision underdevelopment was unobtainable, but some information on the present extent of Iowa rural subdivision underdevelopment was obtained.

Results of the extension survey estimated that, as of December 31, 1974, there were 955 privately planned housing (first home) subdivisions outside incorporated areas within the state of Iowa that occupied 29,302 acres. Of these 29,302 acres, as much as 14,042 acres (48 percent of the total were undeveloped.[27]

As of December 31, 1974, there are 59 privately planned recreation (second home) subdivisions outside incorporated areas within the state of Iowa that occupied 10,331 acres. Of this 10,331 acres, as much as 8.492 acres (82 percent of the total) were undeveloped.[28] Though it may seem that Iowa has an unusually high percentage of recreation subdivision land undeveloped, it should be noted that for the nation as a whole in 1971, at least six recreational lots were sold for each second home constructed (72, p. 264).

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[27]Undeveloped acres were calculated from the ratio of lots subdivided to homes actually constructed. Thus, it is assumed in calculating undeveloped acres that roads and other nonhousing subdivision land uses are undeveloped or underused in the same proportion that lots are undeveloped to total lots subdivided. It is also implicitly assumed that in each subdivision the lots are of average equal size and that a house on a subdivided lot of three acres is not any more undeveloped than a house on a subdivided lot of .3 acres.

[28]Undeveloped acres here were calculated by the same method given in the preceding footnote. In addition, lake acreage was subtraced from the total number of acres in the recreation subdivisions.

Summary of Nonagricultural Land Uses

Between 1960 and 1970, it was estimated that Iowa nonagricultural land uses increased 371, 649 acres, or a 19.7 percent increase over the 1960 base figure. Over 80 percent of this increase is accounted for by public recreation, urban, and rural road and highway land use. Of the 371,649 acre nonagricultural land use increase, 54.6 percent is attributed to public recreation land use, 24.7 percent to nonagricultural incorporated place land use (including urban roads), and 10.7 percent to outside incorporated place road and highway land use. Table 2 summarizes Iowa nonagricultural land use changes from 1960 to 1970 by land uses and by regions.

Table 3 summarizes 1970 Iowa land use. In 1970 there was an estimated 2.3 million acres of total nonagricultural land use in Iowa. Of this total, .9 million acres are total highways and roads right-of-way (outside of incorporated places), .5 million acres are nonagricultural incorporated place land, and .4 million acres are public recreation land use. Of the .5 million acres of nonagricultural incorporated place land, .2 million acres are residential and associated land use and .1 million acres are highways and roads.

In 1970 total nonagricultural land within incorporated places greater than 1,500 in population absorbed 1.77 percent of Iowa's total land area. This is roughly comparable to a national (50 state) land area average of 1.52 percent. The above comparison corresponds to .22 urban acres per capita in Iowa and .16 urban acres per capita nation-

Table 2. Summary of nonagricultural land use acreage change estimates for regions and state, 1960 to 1970

Region	Nonagricultural less than 2,500 total population incorporated place land acres	Nonagricultural greater than 2,500 population incorporated place land acres	Rural highway and road acres	Airport acres	Extraction acres
1	945	834	929	279	105
2	2,764	1,259	98	830	784
3	4,461	3,248	72	725	234
4	1,250	817	2,055	978	360
5	3,289	2,381	1,049	549	384
6	2,751	2,538	2,259	349	420
7	11,892	10,275	1,191	718	102
8	6,426	5,373	3,434	626	130
9	3,883	3,026	799	0	174
10	15,571	15,494	4,125	744	588
11	21,001	11,924	8,710	890	208
12	1,800	1,422	166	118	186
13	9,764	8,976	8,102	452	408
14	272	150	3,150	173	210
15	3,109	2,234	1,320	992	310
16	2,835	2,575	708	274	80
Total	92,015	72,574	38,167	8,697	4,683
Percent increase over 1960 base	19.3	25.2	4.0	65.8	18.2

Table 2. (continued)

Region	Public recreation acres	Golf course acres	Drive-in theater acres	Fairground and sports complex acres	Private park and campground acres	Private recreation subdivision acres	Salvage yard and waste disposal dump acres (outside)
1	35,858	394	0	0	360	0	0
2	5,011	611	3	0	8	0	7
3	3,285	380	0	1	67	52	34
4	1,338	250	0	34	30	0	52
5	2,934	356	0	-42	2,136	2	27
6	5,446	150	0	0	155	0	13
7	3,969	775	-18	184	0	0	55
8	3,846	487	20	60	416	850	-1
9	5,161	166	0	0	456	27	39
10	3,115	367	0	29	603	0	41
11	78,815	800	17	9	1,641	514	25
12	2,655	183	0	0	0	1,420	26
13	6,128	263	-2	7	83	0	5
14	3,749	0	1	0	204	40	22
15	39,713	43	1	4	0	0	6
16	2,217	211	6	100	334	23	21
Total	203,240	5,436	28	386	6,493	2,928	372
Percent increase over 1960 base	80.8	72.6	6.8	20.3	120.7	124.9	7.6

Table 2. (continued)

Region	Cemetery acres (outside)	Manufacturing and associated use acres (outside)	Wholesale, retail, and services and associated use acres (outside)	Housing subdivision acres (outside)	Mobile home park acres (outside)	Nonfarm residential acres (outside)	Total acres
1	0	27	82	4	0	94	39,081
2	1	19	34	178	3	106	10,457
3	2	4	64	6	1	69	9,457
4	28	74	106	269	24	91	6,939
5	9	99	464	230	10	122	11,618
6	0	15	39	547	7	74	12,225
7	10	42	65	294	14	227	19,520
8	5	63	3	282	17	35	16,699
9	0	298	204	569	116	160	12,052
10	29	150	101	481	24	286	26,254
11	12	79	134	911	31	148	113,945
12	2	9	15	8	2	133	6,723
13	77	31	17	35	1	174	25,545
14	9	81	106	137	11	60	8,225
15	0	12	18	138	9	78	45,753
16	1	130	1	56	49	110	7,156
Total	185	1,133	1,453	4,145	319	1,967	371,649
Percent increase over 1960 base	1.9	4.2	11.3	23.5	21.8	10.0	19.7

Table 3. Estimated 1970 Iowa Land Use

Land Use	Acres
1. Airports	21,922
2. Urban (nonagricultural incorporated place land use)	569,584
3. Rural highways and roads[a]	996,906
4. Urban highways and roads	106,487
5. Total highways and roads	1,103,393
6. Railroads[a]	95,426
7. Public recreation[a]	454,924
8. Private recreation[a]	32,795
9. Extraction[a]	30,398
10. Other urban[a]	102,781
Total nonagricultural land uses (= 1+2+3+6+7+8+9+10)	2,304,736
Residential and associated land use	239,225
Manufacturing and associated land use	33,605
Wholesale trade, retail trade, services and associated land uses	47,275
Recreational and associated land use	43,288
Undeveloped land use	79,172
Highways and roads	106,487
Other	20,532
Nonagriculture	569,584
Agriculture	430,185
Total incorporated place land uses	999,769

[a]Land use outside of incorporated places

wide. Tables 4, 5, and 6 provide similar comparisons of Iowa and U.S. land uses for highway and road, railroad, airport, recreation, and extraction land uses. For highway and road and railroad land uses, Iowa has both a greater percent of total area and acres per capita than the nation-wide average. For airport and recreation land uses, Iowa has both a smaller percent of total area and acres per capita than the nation-wide average. For extraction land use, Iowa has a greater percent of total land area but smaller acres per capita than the nation-wide average. The percent of total land area in both highway and road and extraction land uses is significantly greater than the national average, while the percent in recreation land use is significantly less than the national average.

Table 7 summarizes Iowa nonagricultural land use area estimates for the years 1970, 1980, 2000, and 2020, for the 16 Iowa regions and seven nonagricultural land use categories. This table also provides the percent of each individual land use to the total Iowa surface area and individual land use acres per capita. U.S. Department of Commerce area measurement definitions of land and water area were used. Stated briefly, ponds, lakes or similar areas are counted as inland water if their areas are 40 acres or more; streams or canals must be 1/8 mile or more in width to be counted. All other areas are tabulated as land (104). The sum of land and water equals total Iowa surface acres. For 1970, the sum of airport, urban (incorporated place nonagricultural land use), rural highway and road, railroad, public recreation, private

Table 4. Estimated Iowa nonagricultural land use, 1970

Land Use	Acres	Percent of total land acres	Acres per capita[a]
Total land acres	35,804,800	100.0	12.67
Nonagricultural Urban acres[b]	569,584	1.60	.20
Total urban acres[c]	636,220	1.77	.22
Highway and road acres[d]	1,103,393	3.08	.39
Railroad acres	95,426	.26	.03
Airport acres	21,922	.06	.007
Recreation acres	487,719	1.36	.17
Extraction acres	30,398	.08	.01

[a]Based on a 1970 Iowa population of 2,825,041.

[b]Urban acres equals nonagricultural land acres within all population size class incorporated places.

[c]Urban acres equals total land acres within all incorporated places greater than 1,500 in population.

[d]Includes urban highway and road acres.

Table 5. United States nonagricultural land use, 1969[a]

Land use	Acres[b]	Percent of total land acres	Acres per capita[c]
1. Total land acres[d]	2,264,000,000	100.0	11.09
2. Urban acres[e]	34,590,000	1.52	.16
3. Highway and road acres	20,977,000	.92	.01
4. Railroad acres	3,221,000	.14	.01
5. Airport acres	1,755,000	.07	.008
6. Recreation acres[f]	81,337,000	3.59	.39
7. Public installation and facilities acres[g]	27,505,000	1.21	.13
8. Extraction acres[h]	3,700,000	.01	.01

[a]Land use data relating to land uses 2 to 7 above are taken from (23) and are estimates based primarily on reports and records of federal and state land management and conservation agencies.

[b]Includes Alaska and Hawaii.

[c]Assumes a U.S. fifty state population of 204,000,000.

[d]As reported by U.S. Census of Population (105). The land area includes all dry land; land temporarily or partly covered by water, such as marshland, swamps, and flood plains; linear water areas less than one-eighth mile wide; and other water bodies with less than 40 acres of surface area.

[e]Includes towns of 1,000 or more population.

[f]Includes national parks, state parks, wilderness and primitive areas, federal wildlife refuges, and state wildlife refuges.

[g]Includes federal land administered by the Department of Defense and the Atomic Energy Commission, and state land in institutional and miscellaneous special uses.

[h]Extraction land acres utilized 1930 to 1971, taken from (66).

Table 6. Comparison of 1969 U.S. nonagricultural land use area with 1970 Iowa nonagricultural land use area

Land use	Percent of total land acres		Acres per capita	
	U.S.	Iowa	U.S.	Iowa
Total land acres			11.09	12.67
Urban acres	1.52	1.77[a]	.16	.22
Highway and road acres	.92	3.08	.01	.39
Railroad acres	.14	.26	.01	.03
Airport acres	.07	.06	.008	.007
Recreation acres	3.59	1.36	.39	.17
Extraction acres	.01	.08	.01	.01

[a]Urban acres equals total land acres within incorporated places greater than 1,500 in population.

Table 7a. 1970 Iowa nonagricultural land use area estimates

Land use	Total acres	Land	Water	Air-port	Urban	Rural highway
Region 1						
Acres	2,140,928	2,113,280	27,648	447	12,331	53,024
Acres/total acres				0.000	0.006	0.025
Acres/population				0.005	0.129	0.554
Region 2						
Acres	2,873,984	2,867,840	6,144	1,522	33,380	82,087
Acres/total acres				0.001	0.012	0.029
Acres/population				0.010	0.217	0.534
Region 3						
Acres	3,105,024	3,074,560	30,464	1,811	28,574	89,046
Acres/total acres				0.001	0.009	0.029
Acres/population				0.012	0.195	0.608
Region 4						
Acres	2,203,264	2,199,680	3,584	2,934	33,304	61,736
Acres/total acres				0.001	0.015	0.028
Acres/population				0.018	0.201	0.372
Region 5						
Acres	2,217,728	2,213,760	3,968	1,373	25,635	62,666
Acres/total acres				0.001	0.012	0.028
Acres/population				0.011	0.207	0.507
Region 6						
Acres	1,572,672	1,572,480	192	488	14,246	45,014
Acres/total acres				0.000	0.009	0.029
Acres/population				0.005	0.139	0.440
Region 7						
Acres	2,025,280	2,024,320	960	1,793	42,689	54,791
Acres/total acres				0.001	0.021	0.027
Acres/population				0.008	0.191	0.245
Region 8						
Acres	2,012,160	1,987,840	24,320	1,564	36,508	50,499
Acres/total acres				0.001	0.018	0.025
Acres/population				0.008	0.178	0.247
Region 9						
Acres	584,896	574,080	10,816	926	36,941	14,900
Acres/total acres				0.002	0.063	0.025
Acres/population				0.005	0.205	0.083

Table 7a. (continued)

Urban highway	Total highway	Rail-road	Public rec-reation	Private rec-reation	Extrac-tion	Other urban	Total nonagri-culture
3,270	56,294	3,779	64,618	1,520	810	4,971	141,500
0.002	0.026	0.002	0.030	0.001	0.000	0.002	0.066
0.034	0.588	0.039	0.675	0.016	0.008	0.052	1.479
5,734	87,821	9,448	19,672	1,568	4,096	6,461	158,234
0.002	0.031	0.003	0.007	0.001	0.001	0.002	0.055
0.037	0.571	0.061	0.128	0.010	0.027	0.042	1.029
5,730	94,776	9,448	40,921	1,283	4,041	2,194	177,318
0.002	0.031	0.003	0.013	0.000	0.001	0.001	0.057
0.039	0.647	0.065	0.279	0.009	0.028	0.015	1.211
7,005	68,741	3,779	4,961	752	560	3,194	111,220
0.003	0.031	0.002	0.002	0.000	0.000	0.001	0.050
0.042	0.414	0.023	0.030	0.005	0.003	0.019	0.670
5,345	68,011	8,503	8,945	3,138	1,980	5,034	117,274
0.002	0.031	0.004	0.004	0.001	0.001	0.002	0.053
0.043	0.550	0.069	0.072	0.025	0.016	0.041	0.949
4,104	49,118	5,669	6,730	746	1,348	4,891	79,132
0.003	0.031	0.004	0.004	0.000	0.001	0.003	0.050
0.040	0.480	0.055	0.066	0.007	0.013	0.048	0.774
8,070	62,861	6,614	11,320	1,521	1,260	5,594	125,582
0.004	0.031	0.003	0.006	0.001	0.001	0.003	0.062
0.036	0.281	0.030	0.051	0.007	0.006	0.025	0.562
6,041	56,540	4,724	39,543	4,080	1,720	6,729	145,367
0.003	0.028	0.002	0.020	0.002	0.001	0.003	0.072
0.030	0.276	0.023	0.193	0.020	0.008	0.033	0.710
6,913	21,813	1,890	12,123	991	1,114	2,866	71,751
0.012	0.037	0.003	0.021	0.002	0.002	0.005	0.123
0.038	0.121	0.011	0.067	0.006	0.006	0.016	0.399

Table 7a. (continued)

	Total acres	Land	Water	Air-port	Urban	Rural highway
Region 10						
Acres	2,427,264	2,426,240	1,024	1,736	52,234	68,972
Acres/total acres				0.001	0.022	0.028
Acres/population				0.006	0.167	0.221
Region 11						
Acres	3,055,360	2,986,880	68,480	2,002	99,953	91,557
Acres/total acres				0.001	0.033	0.030
Acres/population				0.004	0.199	0.182
Region 12						
Acres	2,228,544	2,227,840	704	944	49,232	62,203
Acres/total acres				0.000	0.022	0.028
Acres/population				0.010	0.534	0.674
Region 13						
Acres	3,037,248	3,029,120	8,128	1,354	37,058	88,528
Acres/total acres				0.000	0.012	0.029
Acres/population				0.007	0.197	0.470
Region 14						
Acres	2,205,952	2,204,800	1,152	346	16,199	61,499
Acres/total acres				0.000	0.007	0.028
Acres/population				0.006	0.262	0.994
Region 15						
Acres	3,168,704	3,164,160	4,544	1,587	29,705	81,428
Acres/total acres				0.001	0.009	0.026
Acres/population				0.010	0.193	0.529
Region 16						
Acres	1,168,192	1,137,920	30,272	1,095	21,595	28,956
Acres/total acres				0.001	0.018	0.025
Acres/population				0.009	0.182	0.244
State total						
Acres	36,027,200	35,804,800	222,400	21,922	569,584	996,906
Acres/total acres				0.001	0.016	0.028
Acres/population				0.008	0.202	0.353

Table 7a. (continued)

Urban highway	Total highway	Rail-road	Public rec-reation	Private rec-reation	Extrac-tion	Other urban	Total nonagri-culture
9,081	78,053	6,614	34,835	1,806	1,944	9,232	177,373
0.004	0.032	0.003	0.014	0.001	0.001	0.004	0.073
0.029	0.250	0.021	0.111	0.006	0.006	0.030	0.568
18,441	109,998	9,448	85,503	8,850	2,672	14,675	314,660
0.006	0.036	0.003	0.028	0.003	0.001	0.005	0.103
0.037	0.219	0.019	0.170	0.018	0.005	0.029	0.627
4,095	66,298	5,669	7,558	2,650	2,298	3,311	133,865
0.002	0.030	0.003	0.003	0.001	0.001	0.001	0.060
0.044	0.719	0.061	0.082	0.029	0.025	0.036	1.451
8,372	96,900	7,559	16,187	887	1,472	5,180	158,225
0.003	0.032	0.002	0.005	0.000	0.000	0.002	0.052
0.044	0.515	0.040	0.086	0.005	0.008	0.028	0.841
3,358	64,857	2,834	7,579	924	1,057	2,355	92,793
0.002	0.029	0.001	0.003	0.000	0.000	0.001	0.042
0.054	1.049	0.046	0.123	0.015	0.017	0.038	1.500
6,815	88,243	6,614	51,208	939	3,630	3,701	178,812
0.002	0.028	0.002	0.016	0.000	0.001	0.001	0.056
0.044	0.574	0.043	0.333	0.006	0.024	0.024	1.162
4,113	33,069	2,834	43,221	1,140	396	22,393	121,630
0.004	0.028	0.002	0.037	0.001	0.000	0.019	0.104
0.035	0.278	0.024	0.364	0.010	0.003	0.189	1.024
106,487	1,103,393	95,426	454,924	32,795	30,398	102,781	2,304,736
0.003	0.031	0.003	0.013	0.001	0.001	0.003	0.064
0.038	0.391	0.034	0.161	0.012	0.011	0.036	0.816

Table 7b. 1980 Iowa nonagricultural land use area estimates

	Airport	Urban	Rural highway	Urban highway
Region 1				
Change 1970 to 1980	78	4,158	1,608	366
Acres	525	16,489	54,632	3,636
Acres/total acres	0.000	0.008	0.026	0.002
Acres/population	0.005	0.156	0.518	0.034
Region 2				
Change 1970 to 1980	84	5,534	3,028	577
Acres	1,606	38,914	85,115	6,311
Acres/total acres	0.001	0.014	0.030	0.002
Acres/population	0.010	0.235	0.514	0.038
Region 3				
Change 1970 to 1980	104	6,432	1,895	459
Acres	1,915	35,006	90,941	6,189
Acres/total acres	0.001	0.011	0.029	0.002
Acres/population	0.012	0.218	0.567	0.039
Region 4				
Change 1970 to 1980	111	5,595	2,641	517
Acres	3,045	38,899	64,377	7,522
Acres/total acres	0.001	0.018	0.029	0.003
Acres/population	0.017	0.215	0.356	0.042
Region 5				
Change 1970 to 1980	33	2,750	2,133	332
Acres	1,406	28,385	64,799	5,677
Acres/total acres	0.001	0.013	0.029	0.003
Acres/population	0.011	0.223	0.508	0.045
Region 6				
Change 1970 to 1980	154	3,487	1,502	364
Acres	642	17,733	46,516	4,468
Acres/total acres	0.000	0.011	0.030	0.003
Acres/population	0.006	0.160	0.420	0.040
Region 7				
Change 1970 to 1980	69	3,545	4,458	678
Acres	1,862	46,234	59,249	8,748
Acres/total acres	0.001	0.023	0.029	0.004
Acres/population	0.008	0.190	0.244	0.036

Table 7b. (continued)

Total highway	Railroad	Public rec-reation	Private rec-reation	Extrac-tion	Total nonagri-culture
1,974	-485	4,170	780	208	11,002
58,268	3,294	68,788	2,300	1,018	152,502
0.027	0.002	0.032	0.001	0.000	0.071
0.552	0.031	0.652	0.022	0.010	1.446
3,605	-1,122	5,560	513	662	15,381
91,426	8,326	25,232	2,081	4,758	173,615
0.032	0.003	0.009	0.001	0.002	0.060
0.552	0.050	0.152	0.013	0.029	1.048
2,354	-1,122	6,250	638	241	15,560
97,130	8,326	47,171	1,921	4,282	192,878
0.031	0.003	0.015	0.001	0.001	0.062
0.606	0.052	0.294	0.012	0.027	1.202
3,156	-485	4,170	2,666	311	15,494
71,899	3,294	9,131	3,418	871	126,714
0.033	0.001	0.004	0.002	0.000	0.058
0.397	0.018	0.050	0.019	0.005	0.700
2,465	-1,091	4,170	1,459	429	10,974
70,476	7,412	13,115	4,597	2,409	128,248
0.032	0.003	0.006	0.002	0.001	0.058
0.553	0.058	0.103	0.036	0.019	1.006
1,866	-727	2,770	334	382	8,629
50,984	4,942	9,500	1,080	1,730	87,761
0.032	0.003	0.006	0.001	0.001	0.056
0.461	0.045	0.086	0.010	0.016	0.793
5,136	-848	4,170	931	83	13,256
67,997	5,766	15,490	2,452	1,343	138,838
0.034	0.003	0.008	0.001	0.001	0.069
0.280	0.024	0.064	0.010	0.006	0.571

Table 7b. (continued)

	Airport	Urban	Rural highway	Urban highway
Region 8				
Change 1970 to 1980	248	9,352	4,161	676
Acres	1,812	45,860	54,660	6,717
Acres/total acres	0.001	0.023	0.027	0.003
Acres/population	0.008	0.197	0.235	0.029
Region 9				
Change 1970 to 1980	151	6,672	795	255
Acres	1,077	43,613	15,695	7,168
Acres/total acres	0.002	0.075	0.027	0.012
Acres/population	0.005	0.216	0.078	0.036
Region 10				
Change 1970 to 1980	324	10,348	3,399	678
Acres	2,060	62,582	72,371	9,759
Acres/total acres	0.001	0.026	0.030	0.004
Acres/population	0.006	0.182	0.211	0.028
Region 11				
Change 1970 to 1980	567	21,444	5,435	1,227
Acres	2,569	121,397	96,992	19,668
Acres/total acres	0.001	0.040	0.032	0.006
Acres/population	0.005	0.213	0.170	0.034
Region 12				
Change 1970 to 1980	51	3,085	2,678	603
Acres	995	52,317	64,881	4,698
Acres/total acres	0.000	0.023	0.029	0.002
Acres/population	0.010	0.538	0.667	0.048
Region 13				
Change 1970 to 1980	273	5,718	4,601	915
Acres	1,627	42,776	93,129	9,287
Acres/total acres	0.001	0.014	0.031	0.003
Acres/population	0.008	0.201	0.437	0.044
Region 14				
Change 1970 to 1980	33	2,622	1,823	407
Acres	379	18,821	63,322	3,765
Acres/total acres	0.000	0.009	0.029	0.002
Acres/population	0.006	0.293	0.985	0.059

Table 7b. (continued)

Total highway	Railroad	Public rec-reation	Private rec-reation	Extrac-tion	Total nonagri-culture
4,837	-606	4,170	1,764	116	19,811
61,377	4,118	43,713	5,844	1,836	165,178
0.031	0.002	0.022	0.003	0.001	0.082
0.264	0.018	0.188	0.025	0.008	0.710
1,050	-242	1,390	620	164	9,792
22,863	1,648	13,513	1,611	1,278	81,543
0.039	0.003	0.023	0.003	0.002	0.139
0.113	0.008	0.067	0.008	0.006	0.405
4,077	-848	4,860	1,235	402	20,568
82,130	5,766	39,695	3,041	2,346	197,941
0.034	0.002	0.016	0.001	0.001	0.082
0.239	0.017	0.116	0.009	0.007	0.577
6,662	-1,122	7,591	3,033	233	38,303
116,660	8,326	93,094	11,883	2,905	352,963
0.038	0.003	0.030	0.004	0.001	0.116
0.205	0.015	0.163	0.021	0.005	0.619
3,281	-727	4,170	1,511	180	11,675
69,579	4,942	11,728	4,161	2,478	145,540
0.031	0.002	0.005	0.002	0.001	0.065
0.715	0.051	0.121	0.043	0.025	1.496
5,516	-970	5,560	1,045	340	17,537
102,416	6,589	21,747	1,932	1,812	175,762
0.034	0.002	0.007	0.001	0.001	0.058
0.481	0.031	0.102	0.009	0.009	0.826
2,230	-364	4,170	290	163	9,101
67,087	2,470	11,749	1,214	1,220	101,894
0.030	0.001	0.005	0.001	0.001	0.046
1.043	0.038	0.183	0.019	0.019	1.585

Table 7b. (continued)

	Airport	Urban	Rural highway	Urban highway
Region 15				
Change 1970 to 1980	250	5,463	4,526	795
Acres	1,837	35,168	85,954	7,610
Acres/total acres	0.001	0.011	0.027	0.002
Acres/population	0.011	0.215	0.526	0.047
Region 16				
Change 1970 to 1980	118	2,439	2,945	381
Acres	1,213	24,034	31,901	4,494
Acres/total acres	0.001	0.021	0.027	0.004
Acres/population	0.010	0.195	0.258	0.036
State total				
Change 1970 to 1980	2,648	98,644	47,628	9,230
Acres	24,570	668,228	1,044,534	115,717
Acres/total acres	0.001	0.019	0.029	0.003
Acres/population	0.008	0.215	0.337	0.037

Table 7b. (continued)

Total highway	Railroad	Public rec-reation	Private rec-reation	Extrac-tion	Total nonagri-culture
5,321	-848	6,250	179	299	16,967
93,564	5,766	57,458	1,118	3,929	195,779
0.030	0.002	0.018	0.000	0.001	0.062
0.573	0.035	0.352	0.007	0.024	1.198
3,326	-364	8,522	573	95	14,692
36,395	2,470	51,743	1,713	491	136,322
0.031	0.002	0.044	0.001	0.000	0.117
0.295	0.020	0.419	0.014	0.004	1.104
56,858	-11,971	77,943	17,571	4,308	248,742
1,160,251	83,455	532,867	50,366	34,706	2,553,478
0.032	0.002	0.015	0.001	0.001	0.071
0.374	0.027	0.172	0.016	0.011	0.823

Table 7c. 2000 Iowa nonagricultural land use area estimates

	Airport	Urban	Rural highway	Urban highway
Region 1				
Change 1990 to 2000	71	3,895	0	0
Acres	698	25,242	56,240	4,002
Acres/total acres	0.000	0.012	0.026	0.002
Acres/population	0.006	0.199	0.444	0.032
Region 2				
Change 1990 to 2000	68	5,061	0	0
Acres	1,795	50,876	87,330	6,721
Acres/total acres	0.001	0.018	0.030	0.002
Acres/population	0.009	0.265	0.454	0.035
Region 3				
Change 1990 to 2000	93	5,620	0	0
Acres	2,141	48,085	92,836	6,648
Acres/total acres	0.001	0.015	0.030	0.002
Acres/population	0.011	0.254	0.491	0.035
Region 4				
Change 1990 to 2000	113	5,678	0	0
Acres	3,292	50,991	66,392	7,911
Acres/total acres	0.001	0.023	0.030	0.004
Acres/population	0.015	0.238	0.310	0.037
Region 5				
Change 1990 to 2000	44	3,294	0	0
Acres	1,512	35,397	66,557	5,932
Acres/total acres	0.001	0.016	0.030	0.003
Acres/population	0.011	0.252	0.473	0.042
Region 6				
Change 1990 to 2000	130	3,140	0	0
Acres	940	24,917	47,768	4,781
Acres/total acres	0.001	0.016	0.030	0.003
Acres/population	0.007	0.194	0.372	0.037
Region 7				
Change 1990 to 2000	66	6,690	0	0
Acres	2,008	58,631	63,707	9,426
Acres/total acres	0.001	0.029	0.031	0.005
Acres/population	0.007	0.207	0.225	0.033

Table 7c. (continued)

Total highway	Railroad	Public recreation	Private recreation	Extraction	Total nonagriculture
0	-485	4,170	780	208	9,124
60,242	2,324	77,128	3,860	1,434	173,352
0.028	0.001	0.036	0.002	0.001	0.081
0.475	0.018	0.609	0.030	0.011	1.368
0	-1,212	5,560	513	662	11,864
94,051	5,902	36,352	3,107	6,082	201,451
0.033	0.002	0.013	0.001	0.002	0.070
0.489	0.031	0.189	0.016	0.032	1.048
0	-1,212	6,250	638	241	12,842
99,484	5,902	59,671	3,197	4,764	222,336
0.032	0.002	0.019	0.001	0.002	0.072
0.526	0.031	0.316	0.017	0.025	1.176
0	-485	4,170	2,666	311	12,938
74,303	2,324	17,471	8,750	1,493	155,362
0.034	0.001	0.008	0.004	0.001	0.071
0.347	0.011	0.082	0.041	0.007	0.726
0	-1,091	4,170	1,459	429	9,396
72,489	5,230	21,455	7,515	3,267	149,240
0.033	0.002	0.010	0.003	0.001	0.067
0.516	0.037	0.153	0.053	0.023	1.061
0	-727	2,770	334	382	6,756
52,549	3,488	15,040	1,748	2,494	103,467
0.033	0.002	0.010	0.001	0.002	0.066
0.410	0.027	0.117	0.014	0.019	0.806
0	-848	4,170	931	83	11,940
73,133	4,070	23,830	4,314	1,509	166,207
0.036	0.002	0.012	0.002	0.001	0.082
0.259	0.014	0.084	0.015	0.005	0.588

Table 7c. (continued)

	Airport	Urban	Rural highway	Urban highway
Region 8				
Change 1990 to 2000	250	9,357	0	0
Acres	2,361	66,017	58,696	7,367
Acres/total acres	0.001	0.033	0.029	0.004
Acres/population	0.008	0.224	0.199	0.025
Region 9				
Change 1990 to 2000	160	7,314	0	0
Acres	1,412	58,920	15,989	7,320
Acres/total acres	0.002	0.101	0.027	0.013
Acres/population	0.006	0.234	0.064	0.029
Region 10				
Change 1990 to 2000	245	10,566	0	0
Acres	2,650	84,450	75,395	10,360
Acres/total acres	0.001	0.035	0.031	0.004
Acres/population	0.006	0.207	0.184	0.025
Region 11				
Change 1990 to 2000	374	15,985	0	0
Acres	3,488	158,121	99,801	20,357
Acres/total acres	0.001	0.052	0.033	0.007
Acres/population	0.005	0.231	0.146	0.030
Region 12				
Change 1990 to 2000	61	3,832	0	0
Acres	1,133	60,405	67,559	5,301
Acres/total acres	0.001	0.027	0.030	0.002
Acres/population	0.010	0.529	0.592	0.046
Region 13				
Change 1990 to 2000	154	7,780	0	0
Acres	2,077	57,755	95,416	9,728
Acres/total acres	0.001	0.019	0.031	0.003
Acres/population	0.008	0.222	0.367	0.037
Region 14				
Change 1990 to 2000	25	2,721	0	0
Acres	438	24,206	64,519	4,044
Acres/total acres	0.000	0.011	0.029	0.002
Acres/population	0.006	0.347	0.926	0.058

Table 7c. (continued)

Total highway	Railroad	Public rec-reation	Private rec-reation	Extrac-tion	Total nonagri-culture
0	-606	4,170	1,764	116	15,657
66,063	2,906	52,053	9,372	2,068	202,020
0.033	0.001	0.026	0.005	0.001	0.100
0.224	0.010	0.177	0.032	0.007	0.686
0	-242	1,390	620	164	9,648
23,309	1,164	16,293	2,851	1,606	101,827
0.040	0.002	0.028	0.005	0.003	0.174
0.093	0.005	0.065	0.011	0.006	0.405
0	-848	4,860	1,235	402	17,308
85,755	4,070	49,415	5,511	3,150	236,417
0.035	0.002	0.020	0.002	0.001	0.097
0.210	0.010	0.121	0.013	0.008	0.578
0	-1,212	5,560	3,033	233	25,185
120,158	5,902	104,214	17,949	3,371	411,067
0.039	0.002	0.034	0.006	0.001	0.135
0.176	0.009	0.152	0.026	0.005	0.601
0	-727	4,170	1,511	180	9,754
72,860	3,488	20,068	7,183	2,838	168,166
0.033	0.002	0.009	0.003	0.001	0.075
0.638	0.031	0.176	0.063	0.025	1.473
0	-970	5,560	1,045	340	14,879
105,144	4,649	32,867	4,022	2,492	207,368
0.035	0.002	0.011	0.001	0.001	0.068
0.404	0.018	0.126	0.015	0.010	0.797
0	-364	4,170	290	163	7,369
68,563	1,742	20,089	1,794	1,546	117,781
0.031	0.001	0.009	0.001	0.001	0.053
0.984	0.025	0.288	0.026	0.022	1.690

Table 7c. (continued)

	Airport	Urban	Rural highway	Urban highway
Region 15				
Change 1990 to 2000	58	4,622	0	0
Acres	2,150	45,431	90,480	8,405
Acres/total acres	0.001	0.014	0.029	0.003
Acres/population	0.012	0.252	0.502	0.047
Region 16				
Change 1990 to 2000	30	2,686	0	0
Acres	1,380	29,945	34,846	4,875
Acres/total acres	0.001	0.026	0.030	0.004
Acres/population	0.010	0.219	0.255	0.036
State total				
Change 1990 to 2000	1,942	98,241	0	0
Acres	29,475	879,389	1,083,531	123,178
Acres/total acres	0.001	0.024	0.030	0.003
Acres/population	0.008	0.239	0.295	0.034

Table 7c. (continued)

Total highway	Railroad	Public rec-reation	Private rec-reation	Extrac-tion	Total nonagri-culture
0	-848	6,250	179	299	11,408
98,885	4,070	69,958	1,476	4,527	224,337
0.031	0.001	0.022	0.000	0.001	0.071
0.549	0.023	0.388	0.008	0.025	1.245
0	-364	2,090	573	95	5,474
39,721	1,742	62,355	2,859	681	157,293
0.034	0.001	0.053	0.002	0.001	0.135
0.291	0.013	0.456	0.021	0.005	1.151
0	-12,241	69,480	17,571	4,308	191,542
1,206,709	58,973	678,259	85,508	43,322	2,997,691
0.033	0.002	0.019	0.002	0.001	0.083
0.328	0.016	0.185	0.023	0.012	0.816

Table 7d. 2020 Iowa nonagricultural land use area estimates

	Airport	Urban	Rural highway	Urban highway
Region 1				
Change 2010 to 2020	83	4,716	0	0
Acres	866	34,420	56,240	4,002
Acres/total acres	0.000	0.016	0.026	0.002
Acres/population	0.006	0.230	0.376	0.027
Region 2				
Change 2010 to 2020	94	5,769	0	0
Acres	1,987	62,810	87,330	6,721
Acres/total acres	0.001	0.022	0.030	0.002
Acres/population	0.009	0.287	0.399	0.031
Region 3				
Change 2010 to 2020	122	6,723	0	0
Acres	2,375	61,136	92,836	6,648
Acres/total acres	0.001	0.020	0.030	0.002
Acres/population	0.011	0.281	0.426	0.031
Region 4				
Change 2010 to 2020	134	6,528	0	0
Acres	3,545	63,509	66,392	7,911
Acres/total acres	0.002	0.029	0.030	0.004
Acres/population	0.014	0.256	0.267	0.032
Region 5				
Change 2010 to 2020	54	3,464	0	0
Acres	1,615	42,240	66,557	5,932
Acres/total acres	0.001	0.019	0.030	0.003
Acres/population	0.011	0.276	0.435	0.039
Region 6				
Change 2010 to 2020	120	3,422	0	0
Acres	1,181	31,308	47,768	4,781
Acres/total acres	0.001	0.020	0.030	0.003
Acres/population	0.008	0.219	0.334	0.033
Region 7				
Change 2010 to 2020	80	6,833	0	0
Acres	2,156	72,152	63,707	9,426
Acres/total acres	0.001	0.036	0.031	0.005
Acres/population	0.007	0.226	0.200	0.030

Table 7d. (continued)

Total highway	Railroad	Public rec-reation	Private rec-reation	Extrac-tion	Total nonagri-culture
0	-485	4,170	780	208	9,957
60,242	1,354	85,468	5,420	1,850	193,014
0.028	0.001	0.040	0.003	0.001	0.090
0.403	0.009	0.572	0.036	0.012	1.292
0	-1,212	5,560	513	662	12,598
94,051	3,478	47,472	4,133	7,406	227,047
0.033	0.001	0.017	0.001	0.003	0.079
0.430	0.016	0.217	0.019	0.034	1.037
0	-1,212	6,250	638	241	13,974
99,484	3,478	72,171	4,473	5,246	249,879
0.032	0.001	0.023	0.001	0.002	0.080
0.457	0.016	0.332	0.021	0.024	1.148
0	-485	4,170	2,666	311	13,809
74,303	1,354	25,811	14,082	2,115	182,427
0.034	0.001	0.012	0.006	0.001	0.083
0.299	0.005	0.104	0.057	0.009	0.734
0	-1,091	4,170	1,459	429	9,576
72,489	3,048	29,795	10,433	4,125	168,302
0.033	0.001	0.013	0.005	0.002	0.076
0.473	0.020	0.195	0.068	0.027	1.099
0	-727	2,770	334	382	7,028
52,549	2,034	20,580	2,416	3,258	117,071
0.033	0.001	0.013	0.002	0.002	0.074
0.367	0.014	0.144	0.017	0.023	0.818
0	-848	4,170	931	83	12,097
73,133	2,374	32,170	6,176	1,675	190,244
0.036	0.001	0.016	0.003	0.001	0.094
0.229	0.007	0.101	0.019	0.005	0.596

Table 7d. (continued)

	Airport	Urban	Rural highway	Urban highway
Region 8				
Change 2010 to 2020	275	10,150	0	0
Acres	2,904	86,091	58,696	7,367
Acres/total acres	0.001	0.043	0.029	0.004
Acres/population	0.008	0.242	0.165	0.021
Region 9				
Change 2010 to 2020	154	7,144	0	0
Acres	1,728	73,265	15,989	7,320
Acres/total acres	0.003	0.125	0.027	0.013
Acres/population	0.006	0:245	0.054	0.025
Region 10				
Change 2010 to 2020	227	9,972	0	0
Acres	3,125	105,357	75,395	10,360
Acres/total acres	0.001	0.043	0.031	0.004
Acres/population	0.007	0.224	0.160	0.022
Region 11				
Change 2010 to 2020	311	13,466	0	0
Acres	4,161	187,005	99,801	20,357
Acres/total acres	0.001	0.061	0.033	0.007
Acres/population	0.005	0.243	0.129	0.026
Region 12				
Change 2010 to 2020	94	4,992	0	0
Acres	1,308	69,879	67,559	5,301
Acres/total acres	0.001	0.031	0.030	0.002
Acres/population	0.010	0.514	0.497	0.039
Region 13				
Change 2010 to 2020	164	8,230	0	0
Acres	2,402	74,215	95,416	9,728
Acres/total acres	0.001	0.024	0.031	0.003
Acres/population	0.008	0.245	0.315	0.032
Region 14				
Change 2010 to 2020	19	2,551	0	0
Acres	480	29,279	64,519	4,044
Acres/total acres	0.000	0.013	0.029	0.002
Acres/population	0.006	0.396	0.872	0.055

Table 7d. (continued)

Total highway	Railroad	Public rec-reation	Private rec-reation	Extrac-tion	Total nonagri-culture
0	-606	4,170	1,764	116	16,475
66,063	1,694	60,393	12,900	2,300	234,737
0.033	0.001	0.030	0.006	0.001	0.117
0.186	0.005	0.170	0.036	0.006	0.660
0	-242	1,390	620	164	9,472
23,309	680	19,073	4,091	1,934	120,836
0.040	0.001	0.033	0.007	0.003	0.207
0.078	0.002	0.064	0.014	0.006	0.405
0	-848	4,860	1,235	402	16,696
85,755	2,374	59,135	7,981	3,954	270,793
0.035	0.001	0.024	0.003	0.002	0.112
0.182	0.005	0.126	0.017	0.008	0.575
0	-1,212	5,560	3,033	233	22,603
120,158	3,478	115,334	24,015	3,837	458,276
0.039	0.001	0.038	0.008	0.001	0.150
0.156	0.005	0.150	0.031	0.005	0.594
0	-727	4,170	1,511	180	10,947
72,860	2,034	28,408	10,205	3,198	189,537
0.033	0.001	0.013	0.005	0.001	0.085
0.536	0.015	0.209	0.075	0.024	1.394
0	-970	5,560	1,045	340	15,339
105,144	2,709	43,987	6,112	3,172	238,043
0.035	0.001	0.014	0.002	0.001	0.078
0.347	0.009	0.145	0.020	0.010	0.786
0	-364	4,170	290	163	7,193
68,563	1,014	28,429	2,374	1,872	132,142
0.031	0.000	0.013	0.001	0.001	0.060
0.927	0.014	0.384	0.032	0.025	1.786

Table 7d. (continued)

	Airport	Urban	Rural highway	Urban highway
Region 15				
Change 2010 to 2020	65	4,990	0	0
Acres	2,284	55,552	90,480	8,405
Acres/total acres	0.001	0.018	0.029	0.003
Acres/population	0.012	0.283	0.460	0.043
Region 16				
Change 2010 to 2020	35	2,800	0	0
Acres	1,452	35,714	34,846	4,875
Acres/total acres	0.001	0.031	0.030	0.004
Acres/population	0.010	0.239	0.234	0.033
State total				
Change 2010 to 2020	2,031	101,750	0	0
Acres	33,569	1,083,932	1,083,531	123,178
Acres/total acres	0.001	0.030	0.030	0.003
Acres/population	0.008	0.258	0.258	0.029

Table 7d. (continued)

Total highway	Railroad	Public recreation	Private recreation	Extraction	Total nonagriculture
0	-848	6,250	179	299	11,783
98,885	2,374	82,458	1,834	5,125	248,048
0.031	0.001	0.026	0.001	0.002	0.078
0.503	0.012	0.420	0.009	0.026	1.262
0	-364	2,090	573	95	5,593
39,721	1,014	66,535	4,005	871	168,650
0.034	0.001	0.057	0.003	0.001	0.144
0.266	0.007	0.446	0.027	0.006	1.130
0	-12,241	69,480	17,571	4,308	195,140
1,206,709	34,491	817,219	120,650	51,938	3,389,046
0.033	0.001	0.023	0.003	0.001	0.094
0.287	0.008	0.194	0.029	0.012	0.806

recreation, extraction, and other urban land use acres equals nonagricultural land use acres. Urban highway land use acres are assumed to be included with urban land use acres. Change in nonagricultural land use acres equals the sum of airport, urban, rural highway and road, public recreation, private recreation, and extraction land use acres. Though railroad land use acres decline over time, they are assumed not to shift out of nonagricultural land use into agricultural land use. Change in other urban land use acres after 1970 is assumed to be included with the projected urban land acres. Projected acres in nonagricultural land use for each of the projected base years is equal to the previous total nonagricultural land use base figures plus the change in nonagricultural land use from the previous base figure to the new base figure.

Total nonagricultural land uses are projected to increase 1,084,310 acres between 1970 and 2020 or from 6.4 percent of Iowa's surface area to 9.4 percent. Total nonagricultural land use is projected to stay constant at approximately .8 acre per capita for both 1970 and 2020. With respect to individual land uses within the nonagricultural land use category, the percentage of urban, public recreation, and private recreation land use acres to total Iowa surface acres increases, while the corresponding percentage for railroad land use acres decreases. The percentage of airport, rural highway and road, urban highway, total highway, and extraction land use acres to total Iowa surface acres remains approximately constant. Urban land use is projected to increase from 1.6 percent of the Iowa surface area in 1970 to 3.0 percent in 2020, public recreation from 1.3 percent to 2.3 percent, and private recreation from .1 percent to .3 percent.

IV. APPLICATION OF MODEL TO IOWA'S AGRICULTURAL LAND USES BY STATE AND SUBREGIONS

Agricultural Qualities of Land and Prior Uses of Land Absorbed by Nonagricultural Land Uses

In the absence of detailed information on the qualities of Iowa's agricultural land absorbed by nonagricultural land uses presently available for Iowa, some generalizations are drawn from an elementary[29] analysis of the proportionate share of the better agricultural land in the more urbanized counties. Otte (65, p. 13) found that for the 48 contiguous states, Standard Metropolitan Statistical Areas (SMSAs) have slightly more than their proportionate share of the better agricultural land, that is, land in Conservation Needs Inventory (CNI) Land Capability Classes (LCC) I, II, and III. He found that 15 percent of this land is in the 13 percent of the total land area comprising the SMSAs. For the Corn Belt states, Otte found that only 19.1 percent of this land is in the 18 percent of the total land area comprising the SMSAs.

The seven SMSA counties in Iowa[30] contain only 8.06 percent of the state's agricultural land in LCC I, II, and III as determined from the 1967 CNI, whereas these counties contain 8.52 percent of the total surface land area of the state. If only the percent of Land Capability Classes I

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[29]This analysis says nothing about the actual absorption of different qualities of agricultural land by nonagricultural land uses, nor does it say anything about the relation of population distribution and agricultural land quality distribution within the counties of interest.

[30]These seven SMSA counties are Linn, Scott, Polk, Dubuque, Pottawattamie, Woodbury, and Black Hawk counties.

and II in these Iowa SMSA counties is considered, these seven counties contain only 6.82 percent of the state's agricultural land in LCC I and II compared to the 8.52 percent of the total surface area of the state that they contain (Table 8).

If the notion of urbanized counties is expanded from the seven SMSA counties to the 19 counties that had a greater than average population change from 1950 to 1970, similar results are found. For example, it is found that the 19 counties with greater than average population change from 1950 to 1970 contain 19.54 percent of the state's I, II, and III LCC agricultural land and 19.49 percent of the state's total surface area. While these 19 counties contain 20.01 percent of the state's cropland, they contain only 19.76 percent of the state's cropland in LCC I, II, and III.

Similar data were inspected for those 19 counties that are projected to have greater than average population change from 1970 to 1990. It is found that these counties are also expected to have slightly less than their proportionate share of the better agricultural lands (Table 8).

All the above results for Iowa diverge from those found by Otte in the rest of the U.S. on the average. The urbanized counties in Iowa do not have more than their proportionate share of the better agricultural land. This is not generally expected in Iowa given the hypothesis that many Iowa cities originated as trade centers serving agricultural communities. This hypothesis assumes that the better the soil in an area, the more prosperous the local farmers, the faster the market grows, and hence, the greater the conversion of prime quality agricultural land to

Table 8. Quality of land resources within urbanized counties of Iowa[a]

Land percentage	Urbanized counties: 7 SMSA counties	19 counties with greater than average population change, 1950 to 1970	19 counties with projected greater than average population change, 1970 to 1990	17 counties with projected greater than average population change, 1950 to 1990
	(percent)			
Cropland				
Iowa total cropland	8.38	20.01	20.65	19.13
Agricultural land				
Iowa total agricultural land	8.11	19.86	21.16	18.86
Surface area				
Iowa total surface area	8.52	19.49	20.74	18.46
LCC I to III cropland				
Iowa LCC I to III cropland	8.18	19.76	19.72	18.70
LCC I to III agricultural land				
Iowa I to III agricultural land	8.06	19.54	19.87	18.54
LCC IV to VII cropland				
Iowa LCC IV to VII cropland	18.28	22.56	29.65	23.30

[a]Source of data is the Iowa Conservation Needs Inventory (CNI) (96). Cropland is CNI cropland in 1967. Agricultural land is total CNI inventory acreage in 1967. (LCC refers to CNI Land Capability Classes.)

Table 8. (continued)

Land percentage	Urbanized counties: 7 SMSA counties	19 counties with greater than average population change, 1950 to 1970	19 counties with projected greater than average population change, 1970 to 1990	17 counties with projected greater than average population change, 1950 to 1990
	(percent)			
LCC IV to VII agricultural land				
Iowa IV to VII agricultural land	8.35	21.31	27.07	20.34
LCC I to II cropland				
Iowa LCC I to II cropland	6.80	19.95	16.97	17.48
LCC I to II agricultural land				
Iowa LCC I to II agricultural land	6.82	19.82	17.23	17.46
LCC III to VII cropland				
Iowa LCC III to VII cropland	10.81	14.70	26.33	21.68
LCC III to VII agricultural land				
Iowa LCC III to VII agricultural land	9.61	19.90	25.75	20.50

urban sites. But this hypothesis ignores the equally plausible hypothesis that many cities are founded and flourish as transportation centers. For example, with respect to Iowa, four of the seven SMSA counties and seven of the 19 counties with greater than average population changes from 1950 to 1970 border either the Missouri or Mississippi Rivers.

There is little evidence that Iowa urban land consumes better LCC land at a greater rate than poorer LCC land. Even so, it can be argued that because Iowa has such a large amount of productive LCC cropland compared to other states, that the absolute amount of good LCC cropland lost to total nonagricultural uses is important relative to the rest of the United States. Iowa contains 12 percent of the total LCC I, II, and III nonirrigated row cropland in the 48 contiguous states (Table 9). Krause and Hair (50, p. 9) argue that urban expansion in Corn Belt states with such a high proportion of good U.S. land would take much prime agricultural land, except that this region accounts for such a small percentage of U.S. urban area expansion. For Iowa, though, if it is assumed that approximately 55 percent[31] of the estimated 371,649 acres absorbed by nonagricultural land uses in the state between 1960 and 1970 actually came out of cropland, this 203,581 acres is 7.8 percent of the 2.6 million acres (97, p. 9) of estimated total U.S. cropland urbanized between 1960 and 1970. This 7.8 percent could be considered important with respect to the rest of the U.S. if it is considered that this 7.8 percent of cropland acres lost is of higher than average LCC cropland within the

[31]This 55 percent is derived from the assumptions used in the Iowa land use model.

Table 9. Amount of land in Iowa and the United States in selected land capability classes[a]

Land capability class	Acres in U.S.	Acres in Iowa	Percent of U.S. total in Iowa
	(x1,000)	(x1,000)	
Total inventory acres			
I	83,144.0	4,063.4	4.8
II	474,425.0	14,285.6	3.0
III	438,445.0	9,637.2	2.1
I to III	996,014.0	27,986.2	2.8
Irrigated and non-irrigated cropland			
I	36,276.0	3,634.0	10.0
II	223,534.0	16,058.4	7.1
III	365,243.0	23,959.7	6.5
I to III	625,053.0	43,652.1	6.9
Non-irrigated cropland			
I to III	327,200.0	23,943.2	7.3
Irrigated and non-irrigated row cropland			
I to III	145,417.0	15,428.9	10.6
Non-irrigated row cropland			
I to III	127,574.0	15,428.9	12.0

[a]Source of data, U.S. Department of Agriculture Conservation Needs Inventory, 1967 (96, 101).

United States.

Given the present absence of precise estimates of the sources of land and qualities of land absorbed by nonagricultural land uses in Iowa, the following assumptions are made for the 1970 and 2020 baseline land use projections. Urban land uses and airport land uses are assumed to come out of Conservation Needs Inventory Land Capability Classes (LCC) I, II, and III cropland, proportional to the amounts of cropland existing in each respective LCC.

Rural highway and extraction land uses are assumed to come out of cropland and pasture proportional to the amount of land existing in each respective land use. Rural highway and extraction land uses are assumed to come out of LCC I, II, III, IV, V, VI, and VII, within cropland and pasture uses proportional to the amount of land existing in each respective LCC within each land use.[32] The above assumption is generally consistent with Dill's (19, p. 7) conclusion that highways are built on land with nearly all terrain and soil conditions existing in his study area.

Public recreation and private recreation land uses are assumed to come 30 percent from cropland, 30 percent from pasture, and 40 percent from commercial forest.[33] Public recreation and private recreation land

[32]These land use classifications correspond with those used in the 1967 Conservation Needs Inventory.

[33]For those regions without commercial forest, 20 percent from cropland and 20 percent from pasture is substituted for the 40 percent from commercial forest.

uses are assumed to come out of LCC I, II, III, IV, V, VI, and VII within cropland, pasture, and commercial forest proportional to the amount of land existing in each respective LCC within each land use. An examination of recreation lands purchased under the Iowa Conservation Commission Open Space Program (33, p. 4) revealed that 15 percent came from cropland, 26 percent came from pasture, 57 percent came from timber, and 2 percent came from other lands. Since this program is concerned only with the acquisition of unique natural and historic area recreation sites, it is assumed a slightly higher percentage of recreation lands in general come from cropland and a slightly lower percentage come from forest lands.

Given all the baseline assumptions with respect to quantities, qualities, and prior uses of land absorbed by nonagricultural land uses, it is projected that Iowa will lose .7 percent of its 1970 LCC I, II, and III cropland between 1970 and 1980, 1.4 percent of its 1970 LCC I, II, and III cropland between 1970 and 1990, and finally 3.0 percent of its 1970 LCC I, II, and III cropland between 1970 and 2020. These estimates correspond to baseline projected statewide losses of .6 percent of the 1970 total cropland base between 1970 and 1980, 1.3 percent of the 1970 total cropland base between 1970 and 1990, and 2.9 percent of the 1970 total cropland base between 1970 and 2020.

Projected Iowa Crop Requirements

The shift and share agricultural projection procedure begins with national projections of future crop requirements. Allocation of U.S. crop requirements to Iowa by using the state's historic contribution record as the basis for disaggregation adheres to the principle that the

larger the area, the more adequate and reliable the statistical measures. "Allocation" here is a procedure; it does not necessarily imply optimality or constraints. Due to limitations in projecting complex agricultural production relationships far into the future, it is unrealistic to assume an ability to distribute projected agricultural output to the last unit. It is arbitrarily chosen to consider only those Iowa commodities that presently contribute at least 1 percent of the U.S. physical output. These crops for Iowa are: corn for grain, corn for silage, soybeans for beans, oats for grain, and hay crops.[34]

Projected U.S. crop requirements

Projected U.S. food and fiber requirements are either directly adopted or adopted in modified form from U.S. Department of Commerce and U.S. Department of Agriculture, OBERS Projections of Economic Activity in the U.S. (102, 103), hereafter called OBERS. (Table 26) These projections are updated and revised at periodic intervals, making them useful as a source of dynamic variable inputs into the land use projection model as as new revisions are made.

For purposes of testing the sensitivity of the land use projection model to U.S. crop requirement assumptions, a high export demand alternative is considered for corn, soybeans, and oats. Export projections for 1980 for corn, soybeans, and oats are adapted from Rojko's (95) study of a high U.S. export demand alternative. This alternative projects that

[34] In 1970 there were less than 70,000 Iowa acres planted to all other crops not considered in this study.

Table 10. OBERS projected U.S. commodity requirements: 1980, 2000, and 2020[a]

Commodity	Unit	Assumption	Domestic		Net exports	Total U.S.
			Food	Feed		
	(millions)					
Corn, 1980	bu.	E	230.9	4,477.7	1,159.0	6,036.0
		C	242.3	4,724.2	1,159.0	6,302.2
Corn, 2000		E	272.4	5,031.3	1,275.0	6,761.1
		C	317.0	5,913.5	1,275.0	7,717.9
		E	306.7	5,395.0	1,402.5	7,294.9
		C	410.7	7,334.8	1,402.5	9,403.3
Soybeans, 1980	bu.	E	0.0	732.8	570.0	1,457.2
		C	0.0	773.0	570.0	1,505.0
Soybeans, 2000		E	0.0	833.3	684.0	1,684.8
		C	0.0	973.3	684.0	1,858.3
Soybeans, 2020		E	0.0	898.3	752.0	1,811.3
		C	0.0	1,221.0	752.0	2,188.0
Silage[b], 1980 (corn and sorghum)	tons	E	0.0	130.2	0.0	130.2
		C	0.0	136.7	0.0	136.7
Silage, 2000		E	0.0	142.3	0.0	142.3
		C	0.0	166.1	0.0	166.1
Silage, 2020		E	0.0	150.0	0.0	150.0
		C	0.0	202.5	0.0	202.5
Oats, 1980	bu.	E	58.1	659.6	86.1	4.9	808.7
		C	61.0	696.2	90.4	4.9	852.5
Oats, 2000		E	71.1	586.5	89.2	4.0	750.8
		C	82.7	690.0	103.8	4.0	880.5

[a] Source of data: (15, Vol. 1, p. C-2), (14, Vol. 1, p. C-2).

[b] Source of data: Unpublished OBERS back-up data, U.S. Department of Agriculture, Economic Research Service.

Table 10. (continued)

Commodity	Unit	Assumption	Domestic			Net exports	Total U.S.
			Food	Feed	Other		
	(millions)						
Oats, 2020	bu.	E	81.9	500.6	89.0	4.0	675.5
		C	109.6	680.0	119.2	4.0	912.8
Hay[b], 1980	tons	E	0.0	124.1	0.0	0.0	124.1
		C	0.0	130.4	0.0	0.0	130.4
Hay, 2000		E	0.0	137.3	0.0	0.0	137.3
		C	0.0	160.8	0.0	0.0	160.8
Hay, 2020		E	0.0	142.7	0.0	0.0	142.7
		C	0.0	197.7	0.0	0.0	197.7

feed-grain exports by 1985 might be nearly three times that of the 1969 to 1972 base. Given Rojko's 1980 high feed-grain export projections, and assuming the 1970 feed-grain export commodity mix, 1980 exports of corn, soybeans, and oats are estimated to be 1,244.9, 838.0, and 43.8 million bushels, respectively. The same annual rates of change from 1980 to 2000 and from 2000 to 2020 in export demand that OBERS assumed for corn and soybean exports are used to project 2000 and 2020 corn and soybean exports from the estimated 1980 Rojko base figures. Projections of oat exports for 2000 and 2020 are assumed to be the same as the 1980 estimate from Rojko's study.

For purposes of applying the land use projection model, OBERS series E total U.S. commodity requirements are assumed as trend requirements and OBERS series C domestic requirements and the above derived export requirements are assumed as high trend requirements. (See Table 11 for a specification of two ranges, trend and high trend, of U.S. commodity requirements used in the projection model).

Projected Iowa national crop shares

Agricultural production among the various states of the United States is closely associated with precipitation, growing season, soils, and other characteristics of the land base. Historically, agricultural production has tended to concentrate in regions of comparative economic advantage. Economic resources in crop and pasture production for a given area are functions of projected national markets, the productive characteristics of the region's agricultural resources (as modified by changing technology), the availability of other economic resources, and various institutional forces.

Projected Iowa crop shares of national output are directly adapted

Table 11. Projected U.S. commodity requirements

Commodity	Assumption	Year 1980	1990[a]	2000	2010[a]	2020
		(millions)				
Corn (bu.)	Trend	6,036.0	6,388.2	6,761.1	7,022.9	7,294.9
	High trend	6,388.1	7,063.4	7,810.1	8,614.7	9,502.4
Soybeans (bu.)	Trend	1,457.2	1,566.8	1,684.8	1,746.9	1,811.3
	High trend	1,773.0	1,965.4	2,178.7	2,352.0	2,539.1
Oats (bu.)	Trend	808.7	779.2	750.8	712.1	675.5
	High trend	891.4	905.7	920.3	936.3	952.6
Silage (tons)	Trend	130.2	136.1	142.3	146.0	150.0
	High trend	136.7	150.6	166.1	183.3	202.5
Hay (tons)	Trend	124.1	130.5	137.3	139.9	142.7
	High trend	130.4	144.8	160.8	178.2	197.7

[a]For projected U.S. commodity requirements in the years 1990 and 2010, the following formula was used: $B(1 + \Delta)^n = V_n$; where B is the value in the base year, Δ is the annual rate of change, n is the number of years involved, and V_n is the value in the n-th year. For example, letting the appropriate 1980 projection = B and the 2000 projection = V_n, then Δ can be solved. This Δ is then used to solve for the 1990 projection using the above formula. The 2010 projections are solved for in a similar manner.

from OBERS projections. The OBERS projections are baseline, denoting an initial statistical framework for use in planning land uses. These projections are estimates of what can be expected to materialize if there are no policy or program changes of an unusual or unforeseen nature or magnitude in the factors which have been changing over time and which are expected to continue on course in the future. Thus, the projected Iowa crop shares used in this Iowa land use model are consistent with projections made for the rest of the United States.

The projected Iowa crop shares are multiplied times the projected U.S. commodity requirements to obtain quantitative estimates of projected Iowa crop requirements for the years 1980, 2000, and 2020.

Projected Iowa Regional Crop Requirements

Transformation of projected Iowa crop requirements to the 16 multi-county planning regions is accomplished by multiplying projected Iowa crop requirements for each projected year times projected state regional crop shares for each projected year.

Projected Iowa regional crop shares

To proportion projected state crop requirements to the 16 multi-county planning regions, the historical percentage distribution of state production among its 16 regions was examined for the past six to eight federal agricultural census years, depending upon data availability for the crop of interest. The time span considered, limited by the available data, varied from 25 to 35 years. Because of the absence of sufficient time series state regional crop share data (eight discrete points at most)

and because of the additional difficulties involved in projecting for the relatively small geographical areas considered, projected state regional crop shares were assumed to equal the mean of the 1959, 1964, and 1969 estimated shares. In most cases, the mean regional crop shares for 1959, 1964, and 1969 varied relatively little from the mean calculated over the more extended period initially examined. In addition, the standard deviations calculated for the mean regional shares in most cases do not appear excessively large, indicating relative stability in the regional crop shares over time. The mean regional crop shares for the most recent three federal agricultural census years are assumed to implicitly capture the most recent regional crop comparative advantage trends.

In projecting state regional crop shares, it is assumed that these projections are related to national production requirements and are independent of the region's production requirements. This is reasonable, because for the crops considered, each region's production is dominated by the national market. All of the major crops presently grown in Iowa are related to animal feed. Corn, oats, silage, and hay are basic livestock feeds. The soybean is a source of meal concentrate. Iowa is in a strong surplus position in meat products, thus, projections of Iowa crop production can be reasonably tied to growth in national and international demand.

Projected Iowa Regional Cropland Requirements

To derive projections of Iowa regional cropland requirements, regional crop requirements must be related to regional land productivity. Projected Iowa regional cropland requirements are equal to projected

Iowa regional crop requirements divided by projected Iowa regional crop yields.

The method of yield extrapolation is weak in trying to explain adaptations of new technologies or long runs of exceptional weather conditions for crop yields. In addition, factors that act to reduce future yield increases include possible future periodic droughts (91), possibly heavier than average crop losses from insect and disease conditions (83, p. 1), long-term deterioration of cropland now in production (83, p. 3), de-emphasis on future technological change (18, p. 990), uncertainties involving environmental restrictions on land input usage, uncertainties of land input prices, and the availability of less productive land that can be brought into production (10, p. 2). There is much debate regarding the significance of the above factors. For example, with respect to the hypothesis de-emphasizing future technological change, Iowa State University has recently announced the preliminary results of a new foliar fertilization process that boosts soybean yields experimentally by an impressive 10 to 20 bushels per acre on the average, possibly making this discovery comparable with the advent of hybrid seed corn (56).

Projecting yields into the future is obviously hazardous. Yield projections reflect the judgment that there are many potential yield increasing technologies which are yet developed but which will be developed over time.

The derivation of prospective Iowa regional commodity yields by land quality involves (1) estimates of Iowa average crop yields; (2) measures of the relation of average regional crop yields to average state

crop yields; and (3) measures of the relation of average regional crop yields to regional crop yields by specific land qualities. The necessary measures are developed from historical state and regional yields for each commodity.

Projected average state crop yields

Ordinary least squares regression is used to regress historical state yield data against time for the 27-year period from 1947 to 1973 for the five crops of interest (Table 12). These least squares trends are then used to project trend state commodity yields along with a standard error of each project state yield. (See Table 13 for a summary of yield and standard deviation projections).

Results of trend yield extrapolations are highly dependent upon the selection of the time period for which the trend is fitted. By using trend yield data from 1947 on, credit for increasing yields during the 1950's cannot be attributed to the simple shift from common varieties to hybrids. For example, Thompson et al. (92) note that adoption of hybrid corn seed in the Corn Belt states essentially was at 100 percent by 1945. Thus, the base time period used in this regression generally considers the modern technological agricultural era.

For purposes of testing the sensitivity of the land use projection model to different state crop yield assumptions, two ranges of projected state crop yields are used, trend and low trend. The low trend assumption assumes that the rapid rate of increase in research and resource development in agriculture that occurred in the 1947 to 1973 period will continue at a slower rate of increase in the 1970 to 2020 period. Low trend projected state commodity yields are equal to the trend projected

Table 13. Projected trend average state Iowa crop yields, 1980 to 2020

Year	Corn		Soybeans	
	Yield	Standard deviation[a]	Yield	Standard deviation
	(bu./acre)		(bu./acre)	
1980	122.648	7.982	37.765	2.586
1990	148.222	8.882	43.333	2.878
2000	173.795	10.007	48.900	3.242
2010	199.369	11.290	54.468	3.658
2020	224.943	12.683	60.036	4.109

[a]From Snedecor and Cochran's equation 6.12.1 (85, p. 155), the variance of an individual projection is composed of the error of individual estimates around the regression line plus that of points along that line. The variance of an individual projection $S^2_{\hat{Y}_i}$ is:

$$S^2_{\hat{Y}_i} = \left(\frac{\sum_{i=1}^{27} (Y_i - \hat{Y}_i)^2}{25} \right) \left(1 + \frac{1}{27} + \frac{(X' - \bar{X})^2}{\sum_{i=1}^{27} (X_i - \bar{X})^2} \right)$$

where X' is the value of the independent variable for the year of projection, and $\bar{X}$ is the mean of the independent variable in the regression analysis. The above terms represent the variance estimates of individual observations about the regression line, of the intercept of the regression line, and the slope coefficient associated with the independent variable X', respectively. The above calculated standard deviations are the square root of this variance formula.

Table 13. (continued)

Oats		Silage (corn)		Hay	
Yield	Standard deviation	Yield	Standard deviation	Yield	Standard deviation
(bu./acre)		(tons/acre)		(tons/acre)	
62.734	5.984	17.288	1.252	3.415	.140
71.775	6.659	19.927	1.407	4.012	.156
80.816	7.503	22.566	1.598	4.608	.176
89.857	8.465	25.205	1.813	5.205	.198
98.898	9.509	27.845	2.046	5.801	.223

state commodity yields minus two corresponding estimated standard deviations. Given the regression procedure, the low trend projected state crop yields delimit those minimum crop yields which there is at least a nine out of 10 chance of being less than or equal to actual state yields, assuming normal yield distributions.

All the above yield projections assume nonirrigated agriculture. Target years of projection assume a normal year with no unusual weather conditions, disease problems, and other unusual circumstances.[35] The projected yields assume continued technological progress, availability of inputs, and prices and costs favorable to using additional inputs to achieve increased production.

The yield data and projections are representative of harvested acreage. In projecting Iowa cropland requirements, it is necessary to account for acreage that on a year-to-year basis is lost from crop failure or ownership inflexibilities (such as estate transfer or operator illness). Thus, to account for crop failures and ownership inflexibilities, an additional .0176 of projected crop requirements is assumed in the land use projection model application. This is equivalent, for model application purposes, to assuming an additional .0176 of the harvested crop acreage requirements.[36]

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[35]These projections also implicitly assume no crop rotation constraints. The projected average yield per harvested acre for the projected year may not be possible year after year under continuous cropping on the same land.

[36]This .0176 is a five-year (1969 to 1973) national average of crop failure acres divided by harvested crop acres. Source of data is reference (98, p. 4).

Projected average regional crop yields

The mean deviation of each region's commodity yield from that of the state average for the past six to eight federal agricultural census years, depending upon data availability for the crop of interest, is utilized to project the relation of regional crop yields to state average crop yields. This mean regional crop yield deviation noted over the 25 or 35 years considered is assumed to persist in the year of projection.

Projected regional yields are derived by combining the projected state yields and projected relations of regional to state yields. Thus, the projected trend regional yield for the i-th crop in the j-th region is expressed as

$$\hat{\bar{Y}}_{ij} = \hat{\bar{Y}}_{i} + \hat{d}_{ij}$$

where $\hat{\bar{Y}}_{i}$ is the estimated average state yield of the i-th crop for the year of projection, and $\hat{d}_{ij}$ is the estimated mean deviation yield for region j in the production of the i-th commodity. (Numerical estimates of $\hat{d}_{ij}$'s are summarized in Table 14).

The variability of regional yield estimates is obtained by combining estimates of extrapolated state crop yield variability with estimates of regional mean yield deviation variability, assuming independence of state and regional variability. The variance of a projected regional yield estimate for the i-th crop in the j-th region may thus be estimated as

$$\hat{S}^2Y_{ij} = \hat{S}^2Y_{i} + \hat{S}^2d_{ij}$$

where $\hat{S}^2Y_{i}$ is the variance of the extrapolated state yield estimate of the i-th crop, and S^2d_{ij} the j-th region's variance of past yields

Table 14. Mean regional commodity yield deviations from state average yields[a]

Region	Corn (grain)	Soybeans (for beans)	Oats (for grain)	Silage (corn)	Hay (all)
	(bu./acre)	(bu./acre)	(bu./acre)	(tons/ acre)	(tons/ acre)
1	-0.302	-5.939	.738	-0.119	0.049
2	1.769	-1.163	4.241	0.373	0.083
3	2.156	0.229	4.377	-0.004	0.302
4	-4.605	-0.161	-1.420	-0.741	0.199
5	3.461	0.915	4.630	0.596	0.175
6	4.573	2.563	0.013	0.990	0.082
7	1.521	-1.066	0.277	0.246	0.002
8	9.459	1.937	3.274	1.544	0.173
9	9.795	2.366	5.232	2.024	0.453
10	5.064	2.147	-0.832	1.330	-0.021
11	-1.119	0.733	-1.761	-0.238	-0.021
12	-1.319	0.284	-2.291	-0.254	-0.033
13	-7.251	0.051	-6.497	-1.307	0.089
14	-14.111	-2.371	-9.962	-2.581	-0.427
15	-9.669	-1.555	-7.636	-1.567	-0.381
16	1.525	1.623	-3.293	0.375	-0.053

[a]Mean regional commodity yield deviations are equal to:

$$\hat{d}_{ij} = \frac{\left(\sum_{i=1}^{n} Y_{ij}\right) - \left(\sum_{i=1}^{n} \bar{Y}_i\right)}{n}$$

where $\hat{d}_{ij}$ is the mean deviation yield for region j in the production of the i-th commodity, Y_{ij} is the regional yield for crop i, $\bar{Y}_i$ is the average state yield for crop i, and n is the number of years considered.

Source of data is the 1969, 1964, 1959, 1954, 1949, 1944, 1939, and 1934 Federal Agricultural Census (18, 19, 20, 21, 22, 23, 24, 25). There was no complete federal agriculture census data available for silage for 1934 and 1944; for soybeans for 1934 and 1939; and for hay for 1934 and 1939. Y_{ij} is equal to the sum of all the county production in the j-th region for the i-th crop divided by the sum of all county harvested acres in the j-th region for the i-th crop. $\bar{Y}_i$ is equal to the sum of all the county production in the state for the i-th crop divided by the sum of all county harvested acres in the state for the i-th crop.

about that region's mean yield deviation from average state yields. In order to test the sensitivity of the land use projection model to different regional yield assumptions, two ranges of projected regional yields were assumed, trend and low trend. A low trend projected regional yield for the i-th crop in the j-th region is expressed as

$$\hat{\bar{Y}}_{ij} = \hat{\bar{Y}}_{ij} - 2\hat{SY}_{ij}$$

where the terms are defined above. Given the regression procedure, the low trend projected regional crop yields delimit those minimum crop yields which there is at least a nine out of 10 chance of being less than or equal to actual regional yields, assuming normal yield distributions. Numerical estimates of $\hat{SY}_i$ and $\hat{Sd}_{ij}$ are found in Tables 13 and 15, respectively.

Projected regional crop yields by land qualities

Projections of regional crop yields by land qualities have to be based upon regional data on different soil resources classified into reasonably homogenous groups. The only data on groupings of soils regionalized on county boundaries that can be reaggregated to multi-county planning regions that are consistent throughout Iowa are the Land Use Capability Classes and subclasses of the U.S. Department of Agriculture Iowa Conservation Needs Inventory (CNI) (97). This scheme of classification was originally designed to indicate the susceptibility of land to erosion or other hazards and to guide intensiveness of use. A study by Shrader and Landgren (84) on the feasibility of using Land Use Capability Classes (LCC) as a base for estimating yield production potential concluded that there is enough similarity between production

Table 15. Standard deviations of mean regional commodity yield deviations from state average yields[a]

Region	Corn (grain)	Soybeans (for beans)	Oats (for grain)	Silage (corn)	Hay (all)
	(bu./acre)	(bu./acre)	(bu./acre)	(tons/acre)	(tons/acre)
1	8.967	1.393	1.945	2.406	0.104
2	4.046	1.039	3.093	2.529	0.084
3	6.207	0.893	3.578	2.437	0.197
4	3.308	1.770	3.160	2.885	0.146
5	4.532	1.443	5.069	2.756	0.110
6	3.973	0.975	2.771	2.883	0.063
7	4.696	1.437	3.151	2.110	0.096
8	3.564	1.928	2.507	2.495	0.116
9	2.747	1.996	2.991	2.927	0.120
10	4.079	0.831	4.637	2.123	0.086
11	4.759	0.944	2.676	2.965	0.064
12	3.913	1.296	2.485	3.036	0.115
13	7.823	1.872	4.117	3.898	0.117
14	6.434	2.099	3.910	2.573	0.079
15	5.352	1.839	4.595	2.722	0.098
16	4.997	1.502	4.407	2.891	0.081

[a]Standard deviations of mean regional commodity yield deviations from state average yields are equal to:

$$\hat{S}d_{ij} = \sqrt{\frac{\sum_{i=1}^{n}\left[(Y_{ij} - \bar{Y}_i) - (\hat{d}_{ij})\right]^2}{n-1}}$$

where Y_{ij} is the regional yield for crop i, $\bar{Y}_i$ is the average state yield for crop i, $\hat{d}_{ij}$ is the mean regional commodity yield deviation for the i-th crop, and n is the number of years considered. Source of data is the 1969, 1964, 1959, 1954, 1949, 1945, 1939, and 1934 Federal Agriculture Census (18, 19, 20, 21, 22, 23, 24, 25). There was no complete federal agriculture census data available for silage for 1934 and 1944; for soybeans for 1934 and 1939; and for hay for 1934 and 1939.

potentials and land capability classes to justify the preparation of summaries of production potentials by land use capability subclasses for the North Central States.

With regional crop production permitted on all qualities of land, the average yield of the i-th crop in the j-th region can be written as

$$\hat{\bar{Y}}_{ij} = \sum_{k=1}^{n} A_{jk} \hat{Y}_{ijk}$$

where $\hat{\bar{Y}}_{ij}$ is the projected average regional crop yield per acre for the i-th crop in the j-th region. A_{jk} is a weighting factor that measures the importance of land quality (LCC) k in the j-th region or $A_{jk} = a_{jk}/C_j$, where a_{jk} is the cropland acres in the k-th land quality class in the j-th region, and C_j is the total cropland acres in the j-th region. $\hat{Y}_{ijk}$ is the projected regional yield per acre for the i-th crop in the j-th region on the k-th land quality class.

The weighting factors, A_{jk}, are determined by reaggregating the 1967 CNI data to the 16 multi-county regions and solving for the ratio a_{jk}/C_j that then existed. These weights are assumed constant for all years of projection. There are 16 different weights[37] for each of the 16 multi-county planning regions.

Given the projected average regional crop yield for the i-th crop in the j-th region, $\hat{\bar{Y}}_{ij}$, the projected regional yield per acre (for the i-th crop in the j-th region on the k-th land quality class (Land Capability Class), $\hat{\bar{Y}}_{ijk}$) can be solved given the assumed relationships

[37]The 16 different weights correspond to the following CNI land capability subclasses: 1, 2E, 2S, 2W, 3E, 3S, 3W, 4E, 4S, 4W, 5W, 6E, 6S, 7E, 7S, and 7W.

between crop yields on different land capability classes (Table 16). These yield relationships are assumed for all years of projection.[38] Given the 16 planning regions, the five crops considered, the 16 land capability subclasses in each region, and the two ranges of projected regional yields assumed, there were 2,560 (16x5x16x2) different projected regional crop yields by land capability classes solved for on the computer.

Agricultural Land Use Data Base

The only available data on both groupings of soils and agricultural land uses regionalized on county boundaries is the Iowa Conservation Needs Inventory (CNI) (97). The first inventory was taken in 1958 and was updated for the year 1967. Different sampling techniques and land capability class definitions were used for the 1958 and the 1967 CNI inventories. Consequently, it is impossible to infer with any degree of accuracy the shifts between the two inventory periods in qualities and quantities of land uses both within the CNI inventory acreage land use classes and from the inventory agricultural land uses to noninventory, nonagricultural land uses. The United States is in need of an accurate nationally consistent inventory of its land resources that can detect these actual changes over time. Future national inventories of land resources should include nonagricultural land uses in addition to the

[38] These relationships between crop yields are assumed to remain constant over time, though future technology could possibly narrow the yield potential relationship between different land capability classes by improving the moisture holding capacity of the present high numbered land capability classes.

Table 16. Iowa maximum relative crop yield potential by land capability classes[a]

Crop	Land capability class[b]	Maximum relative yield potential relationships
Corn (for grain)	I	1.00
	IIE,IIW,IIIE	0.90
	IIIW	0.70
	IIS,IVE,IVW	0.60
	VI all	
	IIIS,V all, VII all	0.50
	IVS	0.40
Soybeans (for beans)	I	1.00
	II	0.95
	IIIE	0.87
	IIIS,IIIW	0.80
	IVE	0.75
	IVS,IVW	0.62
	V,VII,VII all	0.40
Oats (for grain)	I,II,III IV,V, VI,VI all	1.00
Silage (corn)	I	1.00
	IIE,IIW,IIIE	0.90
	IIIW	0.70
	IIS,IVE,IVW	0.60
	VI all	
	IIIS,V all VII all	0.50
	IVS	0.40
Hay (all)	I,II,IIIE	1.00
	IIIW	0.83
	IIIS,IV,V all	0.75
	VI,VII all	0.40

[a] These relationships were determined after private communication with Dr. William D. Shrader, Professor of Agronomy, Iowa State University, May, 1975.

[b] It is assumed that no crops are grown on the less than 400 acres of class VIIIE land in the state.

agricultural land uses.[39]

The CNI inventory data include total surface area in the state after federal land, urban and built-up areas, and water areas have been deducted from the total land area. Water areas include areas of more than 40 acres and rivers wider than 1/8 mile; federal land includes all federally owned land except cropland operated under lease or permit; urban and built-up areas include cities, villages, and built-up areas of more than 10 acres, industrial sites (except strip mines, borrow and gravel pits), railroad yards, cemeteries, airports, golf courses, etc.[40]

There are six land use categories of concern to this model in the CNI inventory data. Cropland, pasture and range, commercial forest, noncommercial forest, other land in farms, and other land not in farms. The sum of cropland, pasture and range, total forest, other land in farms, and other land not in farms is equal to the total land in the

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[39]For the 1967 CNI, a soil survey was made on each sample area by the Soil Conservation Service before the field inspection. The Iowa State University Statistical Laboratory processed and expanded the basic 2 percent area sampling. These expanded data were then analyzed by County Conservation Needs Inventory Committees and were adjusted. These adjusted data have been published (97). On the advice of Dr. Roy Hickman of the Iowa State University Statistical Laboratory, it was decided to use the unpublished CNI data that were expanded for sampling but were not adjusted by individual county committees. These unpublished data were felt to be more statistically reliable. The main difference between the two data sets is that the unpublished nonadjusted CNI data estimates approximately one-half million acres less of forest lands and a corresponding one-half million acres more of pasture and range lands at the state level than the adjusted published CNI data.

[40]For further information on definitions of land uses used in the CNI, see Soil Conservation Service unpublished mimeo 378, U.S. Soil Conservation Service, Des Moines, Iowa.

CNI inventory.

Cropland includes both irrigated and nonirrigated land used primarily for the production of field crops, close grown crops, summer fallow, rotation hay and pasture, and idle cropland.[41] Pasture and range includes lands producing forage plants, principally introduced species, for animal consumption. Commercial forest includes land at least 10 percent stocked by forest trees of any size producing or capable of producing crops of industrial wood. Noncommercial forest includes forest land which is incapable of yielding crops of industrial wood.[42] Other land in farms includes land considered a part of the farm: farmsteads, farm roads, feed lots, ditch banks, fence and hedge rows, and the like. Other land not in farms includes rural nonfarm residences and investment tracts.

Procedure Used to Estimate Future Baseline Iowa Agricultural Land

To adjust the 1967 CNI data to the 1970 base data needed for this land use projection model for each of the 16 regions, three-tenths of the estimated nonagricultural land use change estimates in Table 2 are

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[41]Irrigated cropland in Iowa in 1967 was only 23,098 acres, or .087 percent of the state's cropland (50).

[42]Noncommercial forest also includes an undetermined amount of public and private recreation lands with forest cover. For this reason, it was assumed that future public recreation and private recreation land uses come out of commercial forest instead of noncommercial forest. This information was obtained in a private communication with Mr. Black of the U.S. Department of Agriculture Soil Conservation Service, Des Moines, Iowa, November 6, 1975.

subtracted from the 1967 CNI data according to the assumptions used with respect to agricultural qualities of land and prior uses of land absorbed by nonagricultural land uses. This 1970 regionalized baseline agricultural land use acreage is then adjusted downward for each of the projection years (1980, 2000, and 2020) according to the projected quantities of nonagricultural land absorption in Table 7 and the assumptions with respect to agricultural qualities of land and prior uses of land absorbed by nonagricultural land uses.

The proportion assumptions used with respect to agricultural qualities of land and prior uses of land absorbed by nonagricultural land uses are for the proportions that existed in the year prior to the projection. For example, to calculate the 1970 regionalized agricultural land use acreage data base, the regional proportions existing in 1967 were used. To calculate the 1980 agricultural data base, the regional proportions existing in 1970 were used, and similarly for the projection years 2000 and 2020. Tables 17a, b, c and d respectively, summarize the 1970, 1980, 2000, and 2020 estimated Iowa baseline land use acreage by land capability classes on a statewide level.

Iowa Cropland Requirement Clearing Procedure

To compare projected Iowa regional cropland requirements with the projected regional agricultural land resource base for each year of projection, cropland acres needed (given assumptions of regional crop yields by LCC and regional crop requirements) are compared with cropland acres available.

To summarize total cropland acres available compared with total

Table 17a. 1970 baseline Iowa land use acreage by land capability classes

LCC	Cropland	Pasture-range	Commercial forest	Noncommercial forest	Total forest	Other land in farms	Other land not in farms	Total land
1	3,633,228	187,104	53,041	47,274	100,315	119,265	21,507	4,061,419
2E	6,064,305	365,406	52,594	30,717	83,311	289,199	23,916	6,826,137
2S	271,675	28,568	5,545	1,828	7,373	10,112	3,460	321,188
2W	6,083,134	864,001	65,100	57,134	122,234	106,909	21,621	7,197,899
3E	6,917,116	1,099,966	154,634	83,823	238,457	241,909	30,059	8,527,507
3S	89,886	6,545	1,636	409	2,045	2,662	1,659	102,797
3W	876,835	104,411	65,045	38,386	103,431	18,153	10,992	1,113,822
4E	1,274,628	662,732	108,840	62,011	170,851	37,036	4,519	2,149,766
4S	195,138	33,947	18,627	13,572	32,199	7,766	6,757	275,807
4W	71,659	21,824	427	402	829	1,503	871	96,686
5W	118,764	246,446	101,688	72,080	173,768	22,414	3,914	565,306
6E	525,499	477,267	133,755	91,176	224,931	19,291	7,765	1,254,753
6S	33,033	18,782	8,266	2,892	11,158	1,409	0	64,442
7E	162,623	410,875	216,124	140,350	356,474	27,088	3,301	960,361
7S	23,038	94,352	233,264	56,242	289,506	5,504	3,566	415,966
7W	6,705	4,145	195	796	991	792	11,425	24,058
8L	0	0	0	0	0	0	391	391
Total	26,347,326	4,626,371	1,218,781	699,092	1,917,873	911,012	155,723	33,958,305

Table 17b. 1980 baseline Iowa land use acreage by land capability classes

LCC	Cropland	Pasture-range	Commercial forest	Noncommercial forest	Total forest	Other land in farms	Other land not in farms	Total land
1	3,612,345	185,189	51,560	47,274	98,834	119,265	21,507	4,037,140
2E	6,027,797	361,330	50,566	30,717	81,283	289,199	23,916	6,783,525
2S	270,393	28,194	5,369	1,828	7,197	10,112	3,460	319,356
2W	6,049,440	855,682	63,072	57,134	120,206	106,909	21,621	7,153,858
3E	6,851,424	1,090,621	151,158	83,823	234,981	241,909	30,059	8,448,994
3S	88,789	6,448	1,595	409	2,004	2,662	1,659	101,562
3W	868,127	103,239	63,149	38,386	101,535	18,153	10,992	1,102,046
4E	1,269,021	657,802	106,653	62,011	168,664	37,036	4,519	2,137,042
4S	193,955	33,585	18,258	13,572	31,830	7,766	6,757	273,893
4W	71,403	21,730	423	402	825	1,503	871	96,332
5W	118,121	243,816	99,483	72,080	171,563	22,414	3,914	559,828
6E	523,180	473,549	130,749	91,176	221,925	19,291	7,765	1,245,710
6S	32,930	18,591	8,089	2,892	10,981	1,409	0	63,911
7E	161,873	407,472	209,891	140,350	350,241	27,088	3,301	949,975
7S	22,934	93,412	230,382	56,242	286,624	5,504	3,566	412,040
7W	6,659	4,094	191	796	987	792	11,425	23,957
8E	0	0	0	0	0	0	391	391
Total	26,168,391	4,584,754	1,190,588	699,092	1,889,680	911,012	155,723	33,709,560

Table 17c. 2000 baseline Iowa land use acreage by land capability classes

LCC	Cropland	Pasture-range	Commercial forest	Noncommercial forest	Total forest	Other land in farms	Other land not in farms	Total land
1	3,574,756	181,757	48,646	47,274	95,920	119,265	21,507	3,993,205
2E	5,961,784	354,171	46,812	30,717	77,529	289,199	23,916	6,706,599
2S	268,015	27,503	5,025	1,828	6,853	10,112	3,460	315,943
2W	5,989,173	840,904	59,170	57,134	116,304	106,909	21,621	7,074,911
3E	6,731,889	1,074,979	144,732	83,823	228,555	241,909	30,059	8,307,391
3S	86,713	6,272	1,539	409	1,948	2,662	1,659	99,254
3W	852,222	101,112	59,383	38,386	97,769	18,153	10,992	1,080,248
4E	1,260,528	649,649	102,546	62,011	164,557	37,036	4,519	2,116,289
4S	192,089	32,974	17,552	13,572	31,124	7,766	6,757	270,710
4W	71,022	21,583	415	402	817	1,503	871	95,796
5W	117,087	239,164	95,654	72,080	167,734	22,414	3,914	550,313
6E	519,681	467,374	125,164	91,176	216,340	19,291	7,765	1,230,451
6S	32,668	18,257	7,737	2,892	10,629	1,409	0	62,963
7E	160,784	401,936	198,969	140,350	339,319	27,088	3,301	932,428
7S	22,770	91,725	224,878	56,242	281,120	5,504	3,566	404,685
7W	6,582	3,997	183	796	979	792	11,425	23,775
8E	0	0	0	0	0	0	391	391
Total	25,847,763	4,513,357	1,138,405	699,092	1,837,497	911,012	155,723	33,265,352

Table 17d. 2020 baseline Iowa land use acreage by land capability classes

LCC	Cropland	Pasture-range	Commercial forest	Noncommercial forest	Total forest	Other land in farms	Other land not in farms	Total land
1	3,542,723	178,601	45,747	47,274	93,021	119,265	21,507	3,955,117
2E	5,905,209	347,654	43,234	30,717	73,951	289,199	23,916	6,639,929
2S	265,970	26,853	4,681	1,828	6,509	10,112	3,460	312,904
2W	5,938,387	827,274	55,347	57,134	112,481	106,909	21,621	7,006,672
3E	6,624,681	1,061,430	138,660	83,823	222,483	241,909	30,059	8,180,562
3S	84,854	6,112	1,507	409	1,916	2,662	1,659	97,203
3W	837,774	99,160	55,617	38,386	94,003	18,153	10,992	1,060,082
4E	1,253,744	642,613	98,600	62,011	160,611	37,036	4,519	2,098,523
4S	190,651	32,455	16,878	13,572	30,450	7,766	6,757	268,079
4W	70,741	21,467	407	402	809	1,503	871	95,391
5W	116,206	234,952	92,164	72,080	164,244	22,414	3,914	541,730
6E	516,913	462,021	119,893	91,176	211,069	19,291	7,765	1,217,059
6S	32,458	17,965	7,384	2,892	10,276	1,409	0	62,108
7E	159,952	397,296	188,925	140,350	329,275	27,088	3,301	916,912
7S	22,641	90,217	219,572	56,242	275,814	5,504	3,566	397,742
7W	6,516	3,905	175	796	971	792	11,425	23,609
8E	0	0	0	0	0	0	391	391
Total	25,569,420	4,449,975	1,088,791	699,092	1,787,883	911,012	155,723	32,874,013

cropland acres required on a regional and statewide basis, the total cropland acres required for each region were calculated on the computer by determining the individual cropland requirements for the five crops in the following sequential order: first, corn for grain; second, soybeans for beans; third, corn for silage; fourth, oats for grain; and fifth, hay. When the acres required for each of the five individual crops were calculated in the above order for each region and for each year of projection, it was assumed that each crop uses first the remaining cropland acreage available by that land capability classification that corresponds to the individual crop's highest productivity. When the remaining acreage in this LCC was used up, the next remaining most productive LCC acreage for the individual crop is used. This procedure was implemented until the individual crop requirement was met. The procedure is reiterated with the next crop in sequence.

The sum of the regional cropland acreage required for each of the five crops equals the total regional cropland acreage required. The difference between total regional cropland acres available and total regional cropland acres required is equal to regional cropland acres remaining. According to the above procedure, when the total regional cropland acres remaining becomes negative before all the regional crop demands are met, the deficient crop demands are divided by the corresponding projected average regional crop yields to determine the average regional cropland acre deficiency (Table 18).

Table 18. Example of cropland requirement clearing procedure (Region: 5; Year: 1980; Model: Baseline (1), trend crop requirements and trend yields)

LCC	Total cropland acres	Projected yields				
		Corn	Soybeans	Corn silage	Oats	Hay
1	430,252	140.216	40.987	19.885	67.364	3.647
2E	320,555	126.194	38.937	17.896	67.364	3.647
2S	29,003	84.129	38.937	11.931	67.364	3.647
2W	917,030	126.194	38.937	17.896	67.364	3.647
3E	86,241	126.194	35.659	17.896	67.364	3.647
3S	9,689	70.108	32.789	9.942	67.364	2.735
3W	127,174	98.151	32.789	13.919	67.364	3.027
4E	6,470	84.129	30.740	11.931	67.364	2.735
4S	3,276	56.086	25.412	7.954	67.364	2.735
4W	0	84.129	25.412	11.931	67.364	2.735
5W	1,615	70.108	16.395	9.942	67.364	2.735
6E	3,635	84.129	16.395	11.931	67.364	1.459
6S	0	84.129	16.395	11.931	67.364	1.459
7E	613	70.108	16.395	9.942	67.364	1.459
7S	0	70.108	16.395	9.942	67.364	1.459
7W	400	70.108	16.395	9.942	67.364	1.459
Total	1,935,951					

Crop	Total cropland acres available	Crop requirements[a]	Acres needed	Acres remaining	LCC used
Corn	1,935,951	108,610,000	827,999	1,107,951	1,2E,2W
Soybeans	1,107,951	36,460,000	961,059	146,892	2S,2W,3E,3S
Corn silage	146,892	380,000	27,780	119,111	3W
Oats	119,111	4,530,000	68,430	50,681	3W
Hay	50,681	310,000	99,078	-48,397[b]	3W,3S,4E,4S, 5W,6E,7E,7W

[a]Crop requirements are corrected for crop failure requirements.

[b]$-48{,}397 = \frac{173{,}745 \text{ tons deficient of hay}}{3.59 \text{ ton per acre}}$.

3.59 = average Region 5 1980 trend yield of hay per acre across all LCC.

V. PROJECTED NONAGRICULTURAL AND AGRICULTURAL LAND USES UNDER BASELINE AND ALTERNATIVE PROJECTIONS

The baseline projections are best estimates of what is expected to materialize if there are no changes of an unusual nature or magnitude in the factors which have been changing over time. There are two basic sets of assumptions used in the baseline projections: (1) trend yields or low trend yields and (2) trend crop requirements or high trend crop requirements. Thus, there are four different combinations of baseline projections: (1) trend yields and trend crop requirements, (2) trend yields and high trend crop requirements, (3) low trend yields and trend crop requirements, and (4) low trend yields and high trend crop requirements.

Statewide Baseline Projections

The Iowa land use projection model is applied on (1) an aggregate statewide basis using average state crop yields and (2) on a regionalized basis utilizing regionalized crop yields by LCC.

On a statewide basis using average state crop yields, in only one year of projection, 1980, and for only one of the four combinations of baseline projections (high trend crop requirements and low trend yields) is there a deficit of cropland acres after projected baseline state crop requirements are fulfilled. Given this exception, for 1980, 2000, and 2020, there is a surplus of cropland acres for each of the four combinations of baseline projections.

The cropland acres remaining for each projected year exceed the cropland acres remaining for the proceeding year of projection under

each of the four combinations of baseline projections. This resulting pattern of solutions indicates that projected yields consistently outpace, over time, projected crop requirements for each of the four combinations of baseline projections. The deficit cropland acres under high trend crop requirements and low trend yields in 1980 indicate that projected crop yields have not caught up with projected crop requirements under this most demanding cropland absorption combination of assumptions. But after 1980, projected crop yields consistently outpace crop requirements for each combination of baseline projections. Surplus cropland acres for each year of projection range from highest to lowest, respectively, for the following four combinations of baseline projections:

1. trend crop requirements and trend yields,
2. trend crop requirements and low trend yields,
3. high trend crop requirements and trend yields, and
4. high trend crop requirements and low trend yields.

Regionalized Baseline Projections

This subsection summarizes the regionalized Iowa land use projection model solutions utilizing regional crop yields by LCC. For the trend crop requirements and trend yields combination of baseline projections, every region has a surplus of cropland acres for every year of projection except region 5, which has a projected deficit of 48,397 acres in 1980 (Table 19.a.). Region 5 has one of the highest historical regional crop shares for corn and soybeans of any region in the state. For 1980, projected crop yields have not caught up with the

Table 19a. Regional surplus or deficit cropland acres remaining after projected baseline crop requirements are fulfilled (Model: Baseline (1), trend crop requirements and trend yields)

Region	Year				
	1980	1990	2000	2010	2020
	(acres)				
1	589,264	673,833	729,666	783,537	821,870
2	339,782	518,655	631,522	761,940	854,752
3	302,181	488,942	608,045	743,956	840,399
4	405,839	530,177	608,331	689,978	745,189
5	-48,397	116,831	210,910	320,143	401,848
6	243,410	334,081	393,319	453,622	494,972
7	368,948	480,346	549,807	626,889	680,148
8	444,462	530,436	582,361	638,069	674,514
9	31,247	60,115	72,880	86,299	94,203
10	513,201	619,098	686,554	756,848	805,258
11	348,874	489,358	572,400	666,530	731,990
12	361,295	497,398	579,076	666,465	727,274
13	682,238	843,578	945,445	1,049,377	1,116,770
14	527,115	608,899	658,779	709,690	744,494
15	402,733	521,690	594,769	672,879	728,704
16	146,438	192,013	221,430	253,629	276,319
State total	5,658,630	7,505,450	8,645,294	9,879,851	10,738,704

large projected crop requirements for this region, indicating the region is presently producing agricultural commodities at near land resource use capacity.

For the trend crop requirements and low trend yields combination of baseline projections, regions 2, 3, 4, 5, 6, 9, 11, 12, 13, 15, and 16 have deficit cropland acres for 1980; regions 5 and 9 have deficit cropland acres for 2000 (Table 20.b.). For 2020 under this combination of baseline projections, all regions have a surplus of cropland acres. Region 9 is a relatively high nonagriculturally oriented region with 12.3 percent of its total surface area in nonagricultural land uses in 1970 and a projected 20.7 percent of its total surface area in non-agricultural land uses by 2020. For both 1970 and 2020, this is the highest percentage in nonagricultural land uses for any region.

For the high trend crop requirements and trend yields combination of baseline projections, regions 3, 5, and 9 have deficit cropland acres for 1980, and regions 5 and 9 have deficit cropland acres for 2000 and 2020 (Table 20.c.). All the other regions, for all the projected years, have a surplus of cropland acres. Region 3 is similar to region 5 in that it has one of the highest historical regional crop shares for corn and soybeans of any region in the state. But, under baseline assumptions, region 3 had a half million more acres of available cropland than region 5 in 1970.

For the high trend crop requirements and the low trend yields combination of baseline projections, regions 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15, and 16 have deficit cropland acres for 1980; regions 2,

Table 20a. Regional surplus or deficit cropland acres remaining after projected baseline crop requirements are fulfilled (Model: Baseline (2), trend crop requirements and low trend yields)

Region	Year				
	1980	1990	2000	2010	2020
	(acres)				
1	308,097	459,283	552,106	633,338	689,941
2	-259,919	45,115	233,367	409,776	532,423
3	-438,584	-86,768	143,088	335,831	469,470
4	-32,673	202,393	344,376	460,399	537,907
5	-592,932	-353,299	-212,965	-58,751	67,193
6	-61,993	131,952	217,558	302,169	359,716
7	14,882	207,982	316,156	423,424	496,419
8	200,200	343,283	425,126	504,630	554,366
9	-64,581	-27,353	-6,534	22,323	40,089
10	171,512	369,478	478,750	577,429	643,086
11	-190,203	28,185	235,609	376,990	473,395
12	-90,630	176,056	306,264	434,407	522,327
13	-22,447	368,004	550,563	716,269	828,354
14	220,080	401,052	490,211	570,469	623,501
15	-116,314	137,365	300,497	438,690	518,259
16	-45,835	43,185	102,839	152,061	185,599
State total	-1,001,340	2,445,913	4,477,011	6,299,454	7,542,045

Table 20b. Regional surplus or deficit cropland acres remaining after projected baseline crop requirements are fulfilled (Model: Baseline (3), high trend crop requirements and trend yields)

Region	Year 1980	1990	2000	2010	2020
			(acres)		
1	521,056	578,549	604,289	622,829	623,867
2	70,639	193,502	237,033	276,814	283,278
3	-3,621	138,926	180,910	221,077	222,536
4	252,990	343,024	378,418	403,640	405,574
5	-327,394	-250,575	-225,945	-195,408	-193,303
6	135,683	188,199	212,013	228,699	228,793
7	242,382	312,474	341,126	363,333	364,777
8	370,163	418,628	442,482	453,523	447,050
9	-15,318	-7,374	-7,772	-9,208	-17,043
10	393,446	458,664	484,981	502,216	497,406
11	95,033	195,950	226,673	250,205	243,408
12	201,766	287,778	324,029	352,928	356,862
13	518,624	622,397	668,808	703,234	707,753
14	442,748	498,981	525,043	544,777	549,310
15	211,077	307,827	342,736	373,847	376,932
16	70,496	100,509	109,282	118,027	116,555
State total	3,179,770	4,387,459	4,844,106	5,210,533	5,213,755

3, 4, 5, 6, 9, 11, 12, 15, and 16 have deficit cropland acres for 2000; and regions 2, 3, 5, 6, 9, 11, 15, and 16 have deficit cropland acres for 2020 (Table 12.d.).

These results demonstrate that the baseline high trend crop requirements and low trend yields projections are by far the most demanding in terms of regional cropland acreage absorption of the four baseline combinations of projections. Under this combination of baseline assumptions, the sum of the individual excess or deficit regional cropland acres for the 16 regions is negative for 1980 and 2000, and is positive for 2020.

The sum of individual excess or deficit regional cropland acres for the 16 regions does not equal the solved-for statewide excess or deficit cropland acres under the nonregionalized model (using average statewide crop yields, not by individual LCC). This is due to different crop yield assumptions used in the statewide model and the regionalized model. Trend yields under the regionalized model result in greater total surplus acres than under the statewide model. This is because each region has greater than average statewide crop yields (due to using high productivity land first). This is evident: since there is less of a discrepancy between the statewide and regional model with respect to the statewide surplus or deficit cropland acres under the high trend crop requirements and trend yields projections than between the statewide and regional model with respect to trend crop requirements and trend yields projections. Under the high trend crop requirements, the model has to use the lower productivity land in addition to the higher

Table 20c. Regional surplus or deficit cropland acres remaining after projected baseline crop requirements are fulfilled (Model: Baseline (4), high trend crop requirements and low trend yields)

Region	Year 1980	1990	2000	2010	2020
			(acres)		
1	216,008	335,928	393,642	433,368	446,431
2	-595,810	-390,693	-305,004	-236,024	-204,477
3	-779,896	-549,148	-443,178	-370,228	-348,394
4	-207,532	-66,015	-5,379	65,844	83,302
5	-935,588	-773,910	-707,757	-649,016	-633,030
6	-158,904	-92,177	-53,613	-22,433	-15,539
7	-152,584	-17,299	59,916	103,613	116,456
8	79,226	197,001	253,169	277,263	278,092
9	-115,712	-92,610	-85,835	-81,988	-87,260
10	-58,672	140,482	217,626	259,030	263,980
11	-492,115	-331,231	-238,682	-192,086	-191,988
12	-285,317	-121,556	-59,623	-4,666	30,734
13	-213,846	-2,480	160,678	265,117	301,898
14	49,472	230,830	309,306	356,454	373,046
15	-285,089	-162,438	-95,259	-46,212	-29,390
16	-136,077	-76,472	-58,292	-40,937	-38,146
State total	-4,072,436	-1,771,788	-658,285	117,099	345,715

productivity land. Low trend yields under the regionalized model result in less surplus acres than under the statewide model, because low trend yields under the regionalized model are lowered an additional two standard regional deviations.

For the near-term 1980 projections, the baseline regionalized model is more sensitive (with respect to changing a regional outcome in terms of surplus or deficit acres) to the ranges of projected yield combinations than to the ranges of projected crop requirements (Table 21). For the medium-term 2000 projections, the model is equally sensitive to the ranges of projected yield combinations and to the ranges of projected crop requirements. Finally, for the long-term 2020 projections, the model is slightly more sensitive to the ranges of projected crop requirements than to the ranges of projected yield combinations.

In summary, the baseline projections indicate that Iowa cropland resource use capacity can fulfill baseline cropland requirements for trend yields, but not for low trend yields, in the near term. In the medium term, the baseline projections indicate that Iowa cropland resource use capacity can fulfill baseline crop requirements for three of the four combinations of baseline projections, but not for the high trend crop requirements and low trend yields combination of alternative baseline projections. For the long term, the baseline projections indicate that Iowa cropland resource capacity can fulfill baseline cropland requirements for all four combinations of baseline projections.

Table 21. Number of regions with baseline projections of deficit cropland acres

Baseline assumption[a]	Year				
	1980	1990	2000	2010	2020
	(number of regions)				
1. TD/TY	1	0	0	0	0
2. HD/TY	3	2	2	2	2
3. TD/LY	11	3	2	1	0
4. HD/LY	13	12	10	9	8
Change in number of regions with deficit cropland acres as a result of changing crop requirement assumption	4	11	10	10	10
1. TD/TY	1	0	0	0	0
2. TD/LY	11	3	2	1	0
3. HD/TY	3	2	2	2	2
4. HD/LY	13	12	10	9	8
Change in number of regions with deficit cropland acres as a result of changing yield assumptions	20	13	10	8	6

[a]TD = trend crop requirements; HD = high trend crop requirements; TY = trend yields; and LY = low trend yields.

Formulation of Alternative Projections and Regionalized Empirical Results

Alternative projections to the baseline projections are developed for projecting Iowa's agricultural land resource use capacity to meet the projected ranges of food and fiber needs under differing assumptions. These alternative projections include differing assumptions of (1) agricultural quantity and quality land resource use, (2) nonagricultural quantity and quality needs, and (3) restraints on agricultural land resource qualities that might be imposed to protect the environment.

This subsection formulates nine alternative sets of projections to the baseline projections. Each of the nine alternative sets of projections has four combinations of projected yields and crop requirements. These combinations correspond to the four combinations of baseline projections for each year of projection. The four combinations of alternative projections for each of the nine alternative sets of projections are compared to the corresponding four combinations of baseline projections on a regional basis.

Commercial forest and pasture conversion to cropland alternative projections a

Future additions to Iowa cropland resources will result from flood control and drainage of present and potential cropland and from agricultural land use conversion to cropland.[43] Additions to cropland

[43]Iowa cropland presently being used may not be adequately drained. It is estimated that 1.2 million acres of the 7.8 million acres in 23 north central Iowa counties are inadequately drained of surplus moisture (15). Adequate drainage of this land may require public formation of drainage districts that stretch across county lines and follow watersheds.

resulting from the development of irrigation are assumed to be minor in Iowa.

Currently available data give little information about the potential for additional Iowa agricultural land being developed and used as cropland. An expansion of the cropland base would most likely come from present agricultural noncropland LCC I and II. In general, LCC I and II lands are considered very good for crops. Class III land is considered fair, and LCC IV acceptable if under special management (94, p. 8). Soils in LCC III have limitations for cultivation. When the land is tilled, conservation practices are more difficult to apply and maintain than with LCC II land. Limitations affect (1) the amount of clear cultivation practicable, (2) timing of planting, tillage, and harvesting, and (3) choice of crops. Class IV land has severe limitations for both choice of crops and for latitude of management. Its yields may be low, relative to inputs, and be fit only for intermittent cultivation.

The CNI data on acres of land in LCC I and II, commercial forest and pasture and range, may overstate the land actually available for future crop production. The CNI data on this land do not indicate the extent to which they may have limitations due to ownership patterns, plot size, sunk costs for other high value uses, and legal constraints.

An undetermined amount of land is held in relatively small ownership units, reflecting historical settlement and farm organization patterns. Some LCC I and II noncropland is in small tracts surrounded by poorer quality land.

Potential cropland requires some type of development before it

can be converted to cropland. For example, wet soils may need small-scale private investment drainage works such as tiling or surface drains; some may require major public works to improve outflow of water from a large area.

An important factor in land conversion to cropland is individual expectation of future cost-price relationships. Landowners must expect crop production to be profitable for a number of years before landowners make investments in drainage or clearing. Conversion of land to cropland will likely be phased over extended periods of time, even with continuing favorable cost-price relationships. Lack of capital may slow development plans. Large-scale drainage projects mean planning and evaluation and usually legislative action for public financing. This process requires changes in public policy and also often involves many years.

Shifts of pasture and range land uses to cropland uses may be both economically and ecologically unwise. Yields on such lands may not equal the average long-term yields on presently cropped area. Increased soil erosion may also occur on such lands. With respect to the possible increase of cropland at the expense of pasture and range, Long (53, p. 253) views the decision between the cultivation of crops for intensive feeding, or investing in better yields from our grasslands to increase carrying capacity as a major factor in increasing the world's meat supply.

It is also economically and ecologically questionable whether present forest land should be sacrificed to future crop production.

Increased soil erosion may occur once forest cover is removed from fragile soils. A 1974 U.S. Department of Agriculture Forest Service survey of Iowa's woodlands shows that Iowa's commercial forest[44] land base has declined 44 percent since the previous survey in 1954 (95, p. 1). Although area statistics from this 1974 survey cannot be compared directly to the 1954 survey because of changes in definitions and survey techniques, it is apparent that Iowa's commercial forest land base has declined. Most of the loss in forest land can be attributed to clearing for pasture and crops (61). This decline in commercial forest land is a significant problem in a state where total forest land constitutes approximately 5 percent of the total land area.

While the national 50-state average is about 2.26 acres of total forest land per capita, Iowa total forest land per capita amounts to only .67 acres.[45] And in terms of publicly owned forest land that is readily available for public recreation land use, Iowans have only .01 acres per person compared with a national average of about .67 acres of public forest land per person.[46] Thus, if Iowans are to enjoy the

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[44] Commercial forest land for the 1974 survey is defined as forest land producing or capable of producing crops of industrial wood and at least 16.7 percent stocked by forest trees of any size (95, p. 3).

[45]
$$2.26 = \frac{462 \times 10^6 \text{ acres of CNI U.S. total forest land (178, p. 5)}}{204 \times 10^6 \text{ 1970 U.S. 50-state population}}$$

$$.67 = \frac{1.9 \times 10^6 \text{ acres of CNI Iowa total forest land}}{2.8 \times 10^6 \text{ 1970 Iowa population}}$$

[46] This assumes an average U.S. public ownership of 30 percent of total forest land and a 2 percent average Iowa public ownership of total forest land (38, p. 24).

benefits of forest recreation that are normally available to other Americans, a major Iowa public forest acquisition program will be needed.

All the above factors make projections of land use conversion to cropland and cropland drainage difficult. For this reason, cropland conversion is considered as an alternative projection and not a baseline projection. No projections are made for increases in productivity due to drainage of present cropland.

Alternative projections *a* assumes that portions of LCC I, IIe, and IIw pasture and range, and LCC I and IIe commercial forest will be converted to cropland over the projection period. It is assumed that one-half the acreage in these designated soil classes will be available for conversion to cropland between 1970 and 2020, and that 10 percent of the 1970 base will be converted to cropland for each of the five 10-year periods from 1970 to 2020.[47] This assumption adds 152,148 acres to statewide LCC I and II cropland each 10-year period from 1970 to 2020. Under alternative projections *a*, the loss of cropland to nonagricultural land uses is approximately offset by the conversion of commercial forest and pasture to cropland on a statewide basis. Alternative projections *a* estimate that 760,740 acres of agricultural land could be converted to cropland between 1970 and 2020 in Iowa. This is compared with a projected

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[47] Even after projected nonagricultural land uses for each projected period are taken from LCC I, IIe, and IIw pasture and range, and LCC I and IIe commercial forest in each region, there is still at least 50 percent of the 1970 base land in these land use categories existing in 2020 in each region.

777,906 acres of cropland lost to nonagricultural land uses between 1970 and 2020 in Iowa under baseline projections.

For the trend crop requirements and trend yields combination of alternative projections a, there is no change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the trend crop requirements and low trend yields combination of alternative projections a, the only change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections is that region 9 has a surplus of 1,297 acres in 2000. For the high trend crop requirements and trend yields combination of alternative projections a, there is no change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the high trend crop requirements and low trend yields combination of alternative projections a, the following regional changes occur: region 6 has a surplus of 61,604 acres in 2020 and region 15 has a surplus of 116,399 acres in 2020.

Other land in farms conversion to cropland alternative projections b

Future additions to Iowa cropland resources may result from conversion of agricultural land that is presently used for farm roads, farm living space, farm family gardens, farm buildings, corrals, fence rows, etc., to cropland. Currently available data again give little information about this potential for additional Iowa cropland.

As the farm population decreases, as farm families shift residences off the farm, and as the average size of Iowa farms increases, the space requirements for "other land in farms" will decline.

Between 1958 and 1968, there was a decline of 40,000 Iowa farms, with the average size of farms increasing 47 acres, from 184 to 231 acres. Between 1966 and 1976, there was a decline of 20,000 Iowa farms, with the average size of farms increasing 30 acres, from 223 to 253 acres (86).

Alternative projections b assumes a decline of 20,000 Iowa farms for each of the five 10-year projection periods (1970 to 1980, 1980 to 1990, 1990 to 2000, 2000 to 2010, and 2010 to 2020). Thus, it is projected that the number of Iowa farms will fall from 145,000 farms in 1970 to 45,000 farms in 2020. It is assumed that, on the average, a maximum of four additional acres of cropland will be available from the loss of each average farm. This assumption adds 80,000 acres of statewide cropland each 10-year period from 1970 to 2020, or 400,000 acres of cropland between 1970 and 2020. This projected 80,000 acres each 10-year period is allocated to the 16 regions according to the proportion of the region's "other land in farms" LCC I, IIe, and IIw land to the total statewide "other land in farms" LCC I, IIe, and IIw land for 1970.

For the trend crop requirements and trend yields combination of alternative projections b, there is no change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the trend crop requirements and low trend yields combination of alternative projections b, there is also no change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the high trend crop requirements

and trend yields combination of alternative projections b, the only change in the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections is that region 3 has a surplus of 16,732 acres in 1980. For the high trend crop requirements and low trend yields combination of alternative projections b, the following regional changes occur: region 4 has a surplus of 20,381 acres in 2000 and region 6 has a surplus of 6,901 acres in 2020.

Commercial forest, pasture, and other land in farms conversion to cropland alternative projections c

Alternative projections c combines simultaneously the assumptions of alternative projections a and alternative projections b. Alternative projections c allows the maximum amount of land conversion to cropland under any of the alternative projections. This set of projections allows for a maximum available cropland resource base. The only change in any of the 16 regions having a net surplus or deficit of cropland acres from individual comparable alternative projections a and alternative projections b is that region 9 has a surplus of 8,560 acres in 2000 and region 9 has a surplus of 10,104 acres in 2020 for the high trend crop requirements and low trend yields combination of alternative projections c.

Fragile cropland restraints alternative projections d

Alternative projections d measures the impact on Iowa cropland resource use capacity of fragile cropland removed from production. Alternative projections d reflects a public policy alternative to improve the quality of the environment by removing cropland from production that has detrimental effects on the quality of water, air, vegetative

cover, and wildlife when subjected to agricultural uses.[48]

Fragile lands for alternative projections d are defined as LCC IV, V, VI, and VII cropland. Alternative projections d assumes that all fragile croplands are permanently removed from crop production between 1970 and 1980.

For the trend crop requirements and trend yields combination of alternative projections d, the only change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections is that region 9 has a deficit of 10,264 acres in 1980. For the trend crop requirements and low trend yields combination of alternative projections d, the following regional changes occur: region 7 has a deficit of 22,962 acres in 1980, region 8 has a deficit of 25,797 acres in 1980, region 10 has a deficit of 42,158 acres in 1980, region 14 has a deficit of 71,618 acres in 1980, region 15 has a deficit of 9,164 acres in 2000, and region 9 has a deficit of 2,482 acres in 2020. For the high trend crop requirements and trend yields combination of alternative projections d, the following regional changes occur: region 11 has a deficit of 86,105 acres in 1980 and region 15 has a deficit of 84,091 acres in 1980. For the high trend crop requirements and low trend yields combination of alternative projections d, the following regional changes occur: region 8 has a deficit of 121,646

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[48] Future land use shifts from cropland to pasture and woodland will undoubtedly occur. This will most likely occur primarily in LCC V, VI, and VII. Though this scenario is not incorporated in the baseline projections, some of its impact on Iowa's cropland resource use capacity is implicitly included in alternative projections d.

acres in 1980, region 14 has a deficit of 197,031 acres in 1980, region 10 has a deficit of 4,079 acres in 2000, region 13 has a deficit of 78,466 acres in 2000, region 4 has a deficit of 63,011 acres in 2020, and region 12 has a deficit of 79,253 acres in 2020.

Prime cropland preservation alternative projections e

Alternative projections e measures the impact on Iowa cropland resource use capacity of the public policy alternative of preserving highly productive cropland from nonagricultural land use conversion. Alternative projections e analyzes the effect of a general statewide prime agricultural cropland preservation policy on Iowa cropland resource use capacity.

Prime cropland for alternative projections e is defined as LCC I, II, and III cropland. Alternative projections e assumes that nonagricultural land uses do not absorb any LCC I, II, and III cropland from 1980 to 2020. Alternative projections e assumes urban land uses and airport land uses come out of LCC IV, V, VI, and VII cropland proportional to the amounts of cropland existing in each respective LCC. Rural highway and extraction land uses are assumed to come out of cropland and pasture proportional to the amount of land existing in each respective land use, and out of LCC IV, V, VI, and VII proportional to the amount of land existing in each respective LCC within each land use. Public recreation and private recreation land uses come out of LCC IV, V, VI, and VII cropland, pasture, and commercial forest proportional to the

amount of land existing in each respective LCC within each land use.[49]

For the trend crop requirements and trend yields combination of alternative projections e, there is no change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the trend crop requirements and low trend yields combination of alternative projections e, and for the high trend crop requirements and trend yields combination of alternative projections e, again, there is no change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the high trend crop requirements and low trend yields combination of alternative projections e, region 4 has a surplus of 5,411 acres in 2000.

Accelerated nonagricultural land absorption alternative projections f

Alternative projections f measures the impact on Iowa cropland resource use capacity of accelerated nonagricultural land absorption over baseline projections. Alternative projections f analyzes the sensitivity of nonagricultural land absorption projections on Iowa cropland resource use capacity.

Baseline projections of nonagricultural land absorption may understate the impact on Iowa cropland resource use capacity. For example, between 1970 and 1980, this study projects that urban land uses absorb 98,644 acres. The upper bound on the 95 percent confidence interval for

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[49] Region 5 does not have enough LCC IV, V, VI, and VII cropland to meet the above assumptions in 2010 and 2020. In 2010 and 2020, some region 5 LCC IIIw cropland is absorbed by nonagricultural land uses. For all 16 regions, there is sufficient LCC IV, V, VI, and VII pasture to meet the above assumptions.

this projection is 132,962 acres. This is 35 percent greater acreage absorption than the baseline projections. Changes in Iowa's future population profile may lead to increases in urban land absorption per capita with actual urban land absorption per capita exceeding projected baseline absorption. Baseline projections of urban land absorption may be conservative if there are significant changes in population distribution from metropolitan to nonmetropolitan Iowa. Also, the projected baseline quantities of nonagricultural land absorption do not include any direct estimates for land that is removed from agriculture and left idle in anticipation of future nonagricultural use, nor do the baseline projections include any estimates of underused agricultural land as the result of anticipated future urban land use. Baseline projections of public recreation land absorption are conservative if there are substantial increases in public funds appropriated for the acquisition of public recreation land. Also, Iowa extraction land use baseline projections may be conservative if it is found that there is sufficient recoverable coal of suitable quality in Iowa to support a mining industry and that economic conditions change to allow mining Iowa coal to be profitable.

All the above future possibilities would make the baseline nonagricultural land absorption projections conservative. Accelerated nonagricultural land absorption alternative projections f are defined as two times the projected baseline quantities of nonagricultural land absorption. Alternative projections f are implemented for the projection periods 1980 to 2000 and 2000 to 2020.

For the trend crop requirements and trend yields combination of

alternative projections f, there are no changes in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the trend crop requirements and low trend yields combination of alternative projections f, the only change in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections is that region 9 has a deficit of 9,784 acres in 2020. For the high trend crop requirements and trend yields combination of alternative projections f, there are no changes in any of the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections. For the high trend crop requirements and low trend yields combination of alternative projections f, the only change in the 16 regions having a net surplus or deficit of cropland acres from comparable baseline projections is that region 12 has a deficit of 21,118 acres in 2020.

Fragile cropland restraints and accelerated nonagricultural land absorption alternative projections g

Alternative projections g combines simultaneously the assumptions of alternative projections d and alternative projections f. Alternative projections g assumes the most demanding set of alternative projections in terms of Iowa cropland resource use capacity. This set of alternative projections assumes fragile cropland is removed from production, accelerated baseline nonagricultural land absorption, and no allowance for land conversion to cropland.

For the trend crop requirements and trend yields combination of alternative projections g, there are no changes in any of the 16 regions

having a net surplus or deficit of cropland acres from individual comparable alternative projections d and alternative projections f. For the trend crop requirements and low trend yields combination of alternative projections g, region 11 has a deficit of 21,364 acres in 2000. For the high trend crop requirements and trend yields combination of alternative projections g, the following changes occur: region 7 has a deficit of 7,212 acres in 2000, region 8 has a deficit of 7,585 acres in 2000, region 14 has a deficit of 5,979 acres in 2000, region 8 has a deficit of 4,722 acres in 2020, region 10 has a deficit of 18,391 acres in 2020, and region 13 has a deficit of 7,925 acres in 2020.

Commercial forest, pasture, and other land in farms conversion to cropland and prime cropland preservation alternative projections h

Alternative projections h combines simultaneously the assumptions of alternative projections c and alternative projections e. Alternative projections h assumes the least demanding set of alternative projections in terms of Iowa cropland resource use capacity. This set of alternative projections assumes commercial forest and pasture conversion to cropland, other land in farms conversion to cropland, highly productive cropland preserved from nonagricultural land use conversion, fragile cropland not removed from production, and no accelerated baseline nonagricultural land absorption.

For all four of the crop requirements and yields combinations of alternative projections h, no changes occur in any of the 16 regions having a net surplus or deficit of cropland acres from individual comparable alternative projections c and alternative projections e.

Fragile cropland restraints and prime cropland preservation alternative projections i

Alternative projections i combines simultaneously the assumptions of alternative projections d and alternative projections e. Alternative projections i assumes a combination of public policies that both improve the environment and conserve highly productive cropland.

For all four of the crop requirements and yields combinations of alternative projections i, no changes occur in any of the 16 regions having a net surplus or deficit of cropland acres from individual comparable alternative projections d and alternative projections e.

Summary of Alternative Projections and Comparison with Baseline Projections

This subsection summarizes statewide regional sums of surplus or deficit cropland acres under alternative projections. These statewide summaries of alternative projections are compared with corresponding calculations under baseline projections. Table 22 presents a comparison of the above acreage calculations.

For each year of projection and for each of the four combinations of baseline projections, the alternative projections and baseline projections are ranked: alternative projections h, alternative projections c, alternative projections a, alternative projections b, alternative projections f, alternative projections i, alternative projections d, and alternative projections g, from highest to lowest, respectively, in terms of statewide surplus cropland acres. It is clear from this ranking that the alternative projections of cropland conversion have a greater impact on creating a statewide surplus of cropland acres over

Table 22. Iowa statewide regional sums of surplus or deficit cropland acres under baseline projections and alternative projections

Projections	1980	1990	2000	2010	2020
Baseline 1	5,658,630	7,505,450	8,645,294	9,879,851	10,738,704
Alternative a	5,826,296	7,829,493	9,121,286	10,507,936	11,523,796
Alternative b	5,745,777	7,678,300	8,896,489	10,211,518	11,153,276
Alternative c	5,914,770	7,999,923	9,371,535	10,839,603	11,938,370
Alternative d	3,255,620	5,105,372	6,255,422	7,496,636	8,362,173
Alternative e	5,658,630	7,525,112	8,665,449	9,902,007	10,754,695
Alternative f	5,658,630	7,310,130	8,315,985	9,410,335	10,128,549
Alternative g	3,255,620	4,910,056	5,936,325	7,044,046	7,775,735
Alternative h	5,914,770	8,017,694	9,390,856	10,861,908	11,953,651
Alternative i	3,255,620	5,125,035	6,439,295	7,809,537	8,796,289
Baseline 2	-1,001,340	2,445,913	4,477,011	6,299,454	7,542,045
Alternative a	-830,216	2,830,418	4,981,683	6,952,045	8,354,254
Alternative b	-911,025	2,656,983	4,740,684	6,643,482	7,976,899
Alternative c	-740,183	3,020,890	5,247,705	7,295,642	8,778,807
Alternative d	-2,994,570	173,712	2,108,715	3,925,913	5,166,113
Alternative e	-1,001,340	2,514,671	4,517,409	6,343,755	7,577,449
Alternative f	-1,001,340	2,229,063	4,121,425	5,811,782	6,904,329
Alternative g	-2,994,570	-22,579	1,771,402	3,460,102	4,563,585
Alternative h	-740,183	3,069,062	5,287,782	7,335,881	8,799,852
Alternative i	-2,994,570	201,065	2,300,777	4,251,284	5,619,043
Baseline 3	3,179,770	4,387,459	4,844,106	5,210,533	5,213,755
Alternative a	3,368,392	4,730,324	5,348,162	5,874,425	6,037,530
Alternative b	3,283,607	4,567,003	5,107,453	5,559,380	5,649,693
Alternative c	3,466,989	4,906,028	5,613,023	6,222,041	6,470,175
Alternative d	846,926	2,009,655	2,474,090	2,846,477	2,855,765
Alternative e	3,179,770	4,420,814	4,884,439	5,262,365	5,268,626
Alternative f	3,179,770	4,179,208	4,492,562	4,718,025	4,561,286
Alternative g	846,926	1,808,556	2,138,766	2,372,284	2,241,792

Table 22. (continued)

Projections	1980	1990	2000	2010	2020
Alternative h	3,466,989	4,936,931	5,651,984	6,267,316	6,516,538
Alternative i	846,926	2,035,308	2,567,805	3,175,502	3,313,690
Baseline 4	-4,072,436	-1,771,788	-658,285	117,099	345,715
Alternative a	-3,893,211	-1,389,106	-135,609	869,520	1,293,459
Alternative b	-3,984,088	-1,583,497	-376,157	497,602	794,084
Alternative c	-3,806,346	-1,194,853	125,386	1,280,871	1,787,940
Alternative d	-5,980,051	-3,711,440	-2,690,729	-1,943,857	-1,732,892
Alternative e	-4,072,436	-1,702,560	-564,125	240,090	482,988
Alternative f	-4,072,436	-1,969,537	-1,034,527	-394,476	-339,724
Alternative g	-5,980,051	-3,905,887	-3,017,207	-2,403,452	-2,335,569
Alternative h	-3,806,346	-1,133,407	212,716	1,410,699	1,911,894
Alternative i	-5,980,051	-3,693,127	-2,500,642	-1,613,635	-1,268,803

corresponding baseline projections than alternative projections of prime cropland preservation. It is also clear from this ranking that alternative projections of fragile cropland restraints have a greater impact on creating a statewide deficit of cropland acres over corresponding baseline projections than alternative projections of accelerated nonagricultural land absorption.

For all nine of the trend crop requirements and trend yields combination of alternative projections and all nine of the trend crop requirements and low trend yields combination of alternative projections, there are no changes in the statewide regional sums of surplus or deficit cropland acres having a net surplus or deficit of cropland acres from comparable regional sums of regionalized baseline projections. For all nine of the high trend crop requirements and trend yields combination of alternative projections, there are no changes in the statewide regional sums of surplus or deficit cropland acres having a net surplus or deficit of cropland acres from comparable regional sums of regionalized baseline projections. For the high trend crop requirements and low trend yields combination of alternative projections, the following changes occur in the statewide regional sums of surplus or deficit cropland acres having a net surplus or deficit of cropland acres from comparable regional sums of regionalized baseline projections: alternative projections c has a statewide surplus of 125,386 acres in 2000, alternative projections h has a statewide surplus of 212,716 acres in 2000, alternative projections d has a statewide deficit of 1,732,892 acres in 2020, alternative projections f has a statewide deficit of

339,724 acres in 2020, alternative projections g has a statewide deficit of 2,335,569 acres in 2020, and alternative projections i has a statewide deficit of 1,268,803 acres in 2020. It is apparent that the high trend crop requirements and low trend yields combination of baseline projections are the most sensitive to alternative projection assumptions of the four baseline combinations of projections in terms of changing a statewide net surplus or deficit of cropland acres from comparable baseline projections.

In summary, the four combinations of the nine sets of alternative projections cause no changes in the near term of Iowa cropland acres having a net surplus or deficit of cropland acres from comparable regional sums of regionalized baseline projections. In the medium term, the high trend crop requirements and low trend yields combination of alternative projections of commercial forest, pasture, and other land in farms conversion to cropland cause a surplus of Iowa cropland acres from comparable regional sums of regionalized baseline projections. For the long term, the high trend crop requirements and low trend yields combination of alternative projections of fragile cropland restraints and the high trend crop requirements and low trend yields combination of alternative projections of accelerated nonagricultural land absorption cause a deficit of Iowa cropland acres from comparable regional sums of regionalized baseline projections.

VI. IMPLICATIONS OF STUDY FOR LAND USE PLANNING AND POLICY

A land use accounting model is developed for projecting regional land resource use capacity to meet different ranges of future food and fiber needs under differing assumptions of (1) agricultural quantity and quality land resource use, (2) agricultural technologies by land qualities, (3) nonagricultural quantity and quality land needs, and (4) public policies of fragile cropland restraints and preservation of prime agricultural cropland from nonagricultural land uses. The model provides an internally consistent set of regionalized land use projections for the state which are comprehensive in coverage of major nonagricultural and agricultural land uses.

The land use projection model makes maximum use of data that are available to all states. Survey methodologies for obtaining needed primary land use data are presented. The land use projection model is dynamic in that different solutions can be readily solved for on the computer under different assumptions as better information becomes available or under different policy programs. A desirable feature of the land use projection model is that it is consistent with the framework of national OBERS projections which are periodically updated. The OBERS projections use a uniform methodology nation-wide, hence, regional land use projections for the state of interest would become consistent with economic activity in the rest of the country.

The land use projection model provides a basis for planning and education that can be used by state and multi-county land use educational

and planning entities.

A report by the Western Agricultural Research Council for Western Governors (111, p. 11) states, "While better land data are needed at the national aggregate level for setting goals, the bigger and more functional need for data is at the county or multi-county level as an input to planning. Secondly, considerable analysis is needed by people with both planning and technical agricultural training to project possible alternative futures with and without better planning of agricultural land use." This Iowa study answers the above need for base land use information by public agencies engaged in planning for the use, management, and development of Iowa's land resources. The study provides systematic information on Iowa land resources that should serve as a valuable input into the development of a land use policy for the state. In addition, the study provides a land use projection model that can be readily adapted to other states.

In developing subcomponents of the land use projection model applied to Iowa, considerable effort is devoted to quantifying the land use process. But statistics in this context are only valuable as a means to an end; their use is to explain the structure of Iowa land use more fully and more accurately so that information, knowledge, and understanding are thereby increased. Regrettably, the reverse effect can easily come about if the chief results of such an investigation are submerged in a sea of data which obscure rather than reveal trends and their explanations. In developing and applying subcomponents of the land use projection model to Iowa, considerable data have been accumulated and

presented. The more central and fundamental statistical conclusions are recorded in summary form.

The proportion of Iowa total incorporated place area in residential land use has remained approximately stable over the past 40 years. Manufacturing land use proportion of Iowa total incorporated place area has increased 65 percent over this same time period. The proportion of wholesale, retail, and services land use of Iowa total incorporated place area has increased slightly, while the proportion in streets and roads has decreased. These land use proportion trends and other derived trends of per capita individual urban land uses are valuable in formulating future land use policy. For example, if zoning is to become effective in directing land use development, it must be cognizant of the amount of area which can reasonably be expected to be absorbed for various land uses.

Between 1960 and 1970, the amount of agricultural land within Iowa incorporated places increased 17 percent, and at the same time, urban area per capita increased. Growth in population of Iowa incorporated places is associated with incorporated place land annexation in spite of large amounts of agricultural land presently existing within incorporated places. Less than 2 percent of all Iowa's incorporated places had an actual net decline in land area, indicating the irreversible nature of the urban land use process, even though there is much agricultural land within Iowa incorporated places not physically urbanized.

There are relatively large stocks of agricultural land within Iowa incorporated places. These stocks comprise a potential land resource of

considerable value in accommodating additional urban land use needs. In fact, given projections of future urban land use needs, there is enough existing agricultural land within Iowa incorporated places to meet these needs (on a regional basis) for 14 of the 16 Iowa regions to the year 2000 without having to annex any additional acreage. If public land use policy includes as one of its objectives the desire to eliminate land use pressures and conflicts on the rural-urban fringe, then seeking a means whereby conversion of these large urban agricultural land stocks can be implemented should be considered.[50] State acquisition of these urban agricultural lands should be considered as a possible alternative in preserving prime agricultural land. A state urban development corporation that has the power to acquire these agricultural lands within incorporated places and to facilitate private development in creating planned extensions of the incorporated place to these lands could channel land use in directions serving long-run public interest.[51]

Derivation of average urban land absorption coefficients and marginal urban land absorption coefficients reveals that Iowa's incorporated place land absorption per capita is considerably higher than the Corn Belt average and much higher than the national average. This

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[50] Representative Neal Hines in his 1975 legislative proposal suggested a law prohibiting further construction on agricultural land, except farm buildings. Hines claimed that Iowa cities have "plenty" of vacant land within their city limits that could be developed without destroying more farmland (21).

[51] This policy proposal demands a land use projection model capable of projecting the need for such policy action.

study finds that large Iowa incorporated places use more than double the urban land per employee compared to the national average. The above trends reflect a relative surplus of Iowa urban land as a factor of production when compared to the national average.

A multiple regression study or urban growth in Iowa finds that change in urban population explains more than 70 percent of the variation of change in urban land use. Neither income nor average value of agricultural land and buildings explains much of the variation of change in urban land use. Over the ranges observed, demand for total new Iowa urban land implicitly appears both price and income inelastic. A policy implication of this conclusion is that present prices of agricultural land in Iowa are low enough, relative to urban demand, to not play any significant role in rationing agricultural land to urban land uses. For example, differential tax policies to encourage agricultural land use may have little effect on urban land absorption, even though they may give the farmer a more profitable enterprise and thereby the ability to resist the inducement of selling off agricultural land for development purposes.

An analysis of urban land absorption for different size incorporated places finds that the average land absorption coefficient generally increases, moving from the large population size class incorporated places to the smaller size class of incorporated places. Per capita land absorption differentials between different population size classes of incorporated places have important policy implications.

A federal-state study (89) of inter-census population changes shows

a small gain in Iowa between 1970 and 1973. Three years is far too short a time to spot a significant long-range trend in population, but it is an indication of a possible turning point in the long movement from rural to urban dwelling. This trend is part of a nation-wide shift from city to suburban and open country living near metropolitan areas (8). The shift is not a movement back to farming. Among the reasons found by Beale (8, p. 2) for increases in rural areas and small towns are decentralization of manufacturing and other industry and an increased preference for nonmetropolitan residence. With regard to this trend toward a more balanced population distribution, Halpern (28, p. 776) states, ". . . there is an opportunity for a different and more rewarding future for the nation than the discouraging vision of gargantuan megalopoli and widespread rural poverty." But there are also profound land use implications resulting from such trends. The analysis of urban land absorption by different population size classes of Iowa incorporated places indicates that such population trends could lead to significant increases in urban land absorption per capita. Public policies that affect population distribution should consider the above effects on land use in their overall objective function.

The percent of total land area within Iowa incorporated places of Iowa's total land area is roughly comparable to the national average, though Iowa urban acres per capita are greater than the national average. For highway and road land use and railroad land use, Iowa has both a much greater percent of total area in these uses and much greater acres per capita than the nation-wide average. For recreation land uses, Iowa

has a much smaller percent of total area and acres per capita than the nation-wide average.

Between 1960 and 1970, it is estimated that Iowa nonagricultural land uses increased 371,649 acres, or 19.7 percent over the 1960 base figure. Total nonagricultural land uses are projected to increase 1,084,310 acres between 1970 and 2020, or from 6.4 percent of Iowa's surface area to 9.4 percent. This represents a 47 percent increase over the 1970 nonagricultural land use base.

Urbanized counties in Iowa do not have more than their proportionate share of the better agricultural land. There is little evidence that Iowa urban land uses up good LCC agricultural land at a greater rate than poorer LCC agricultural land. Baseline projections estimate that Iowa will lose to total nonagricultural land uses .6 percent of the 1970 total cropland base between 1970 and 1980 and 2.9 percent of the 1970 total cropland base between 1970 and 2020.

The major conclusions of the overall land use projection model are summarized as follows. In the near term (1980), the baseline projections indicate that Iowa statewide cropland resource use capacity can fulfill both trend and high trend baseline crop requirements for trend yields, but not for low trend yields. For the trend crop requirements and low trend yields combination of baseline projections, there is a statewide deficit of 1.0 million cropland acres in 1980. For the high trend crop requirements and low trend yields combination of baseline projections, there is a statewide deficit of 4.0 million acres in 1980. The nine sets of alternative projections considered cause no change in

the conclusion that there is a deficit of statewide Iowa cropland acres in the near term under low trend yield baseline projections. Given low trend yield assumptions, there is likely to be a tight supply of cropland in Iowa in the next 10 years or so until yields have a chance to catch up with projected crop requirements. This conclusion results not from projected high export demand but from low trend yield projections.

In the medium term (2000), the baseline projections indicate that Iowa statewide cropland resource use capacity can fulfill baseline crop requirements for three of the four combinations of baseline projections considered, but not for the high trend crop requirements and low trend yields combination of baseline projections. Commercial forest, pasture, and other land in farms conversion to cropland alternative projections change to a surplus the 6.5 million acre statewide cropland deficit in the medium term under high trend crop requirements and low trend yields combination of baseline projections. It takes this set of projections (that allow for maximum land conversion to cropland) to turn the above 6.5 million cropland acre deficit to a surplus of .1 million acres in the medium term.

In the long term (2020), the baseline projections indicate that Iowa statewide cropland resource capacity can fulfill baseline crop requirements for all four combinations of baseline projections considered.

The land use projection model is much more sensitive (with respect to changing a statewide outcome in terms of net surplus or deficit cropland acres) to the ranges of projected yield combinations assumed than

to the ranges of projected crop requirements (export requirements) assumed. In general, as long as projected trend yields are met, land needed for nonagricultural uses can be provided with minimum impact on Iowa agricultural production capacity.

The nine sets of alternative projections cause no changes in the near term of Iowa statewide cropland acres having a net surplus or deficit of acres from comparable baseline statewide projections. In the medium term, the high trend crop requirements and low trend yields combination of alternative projections of commercial forest, pasture, and other land in farms conversion to cropland cause a surplus of Iowa cropland acres compared to similar baseline projections. In the long term, the high trend crop requirements and low trend yields combination of alternative projections of fragile cropland restraints and the high trend crop requirements and low trend yields combination of alternative projections of accelerated nonagricultural land absorption cause a deficit of statewide Iowa cropland acres from comparable baseline projections.

The alternative projections of commercial forest and pasture conversion to cropland and alternative projections of other land in farms conversion to cropland do not increase significantly the general productive capacity of Iowa statewide cropland in terms of causing a surplus of Iowa cropland acres compared to similar baseline projections in the near, medium, or long term. These two alternative projections also have little differential regional impact in the near and medium term compared with similar baseline assumptions. Public investments,

such as public drainage works associated with private conversions of agricultural land to cropland in Iowa, should consider public costs of such investments compared to long-term public benefits of relatively marginal increases in food and fiber resulting from such land conversions.

The public policy alternative of preserving highly productive Iowa cropland from nonagricultural land use conversion has a negligible effect on increasing Iowa's cropland resource use capacity in the near-, medium-, and long-term given ranges of projected yields and crop requirements. The differential regional impact of such a policy compared to similar baseline projections is also small. The public benefits of prime cropland preservation in Iowa may be small in terms of significant increases in output of food and fiber as long as there is continued technological progress, availability of inputs, and prices and costs favorable to using additional inputs to achieve increased production. This conclusion ignores other possible public benefits from prime cropland preservation such as those associated with increased environmental quality and with option demand benefits resulting from uncertainty in both the supply and demand of future food and fibers.

Only for high trend crop requirements and low trend yields combination of alternative projections in the long-term does accelerated nonagricultural land absorption cause a deficit of Iowa statewide cropland acres from comparable baseline projections. Given the opportunity cost associated with prime cropland preservation in Iowa and given subjective probabilities on the above outcomes, a public policy of prime cropland

preservation should ensure that this solution does not prove more costly than the problem.

A general conclusion is that the public may be misled in its impression that preserving prime agricultural lands has great importance with respect to maintaining the agricultural potential of Iowa. Differential assumptions with respect to future yields may actually be the determinant variable. Regardless of whether or not it is economically desirable or necessary to preserve agricultural cropland in Iowa, if the preferences of Iowans are considered,[52] there is a considerable number who would prefer to avoid the baseline land use situation now projected for 2020. Thus, the baseline projections serve as an indicator of a land resource use problematic situation, in terms of a divergence between a future desired land resource use situation and the projected land resource use situation.

The public policy alternative of improving the quality of the environment by removing from production Iowa cropland that has detrimental effects on the quality of air, water, vegetative cover, and wildlife does not place undue stress on the general productive capacity of Iowa statewide cropland, except in the long-term under the high trend crop requirements and low trend yields combination of alternative projections. Not all regions of Iowa are affected equally by such a policy, however. Over one-half of the 16 regions have a deficit of

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[52]Results of a survey of residents of region 5 confirm this viewpoint. When asked to react to a situation statement regarding preservation of land in agriculture, the citizens surveyed generally agreed to the proposal. (On a scale of 0-disagree strongly to 16-agree strongly, the mean response was 9.1) (55, p. 147).

cropland acres under the low trend yields combination of projections compared to similar baseline projections. Government costs of removing these private fragile lands from production must be measured against the public benefits of such a policy, taking account of regional distributions of costs and benefits.

In general, the Iowa cropland resource capacity situation should not be construed as a crisis requiring total agricultural land preservation or maximum conversion of agricultural lands to cropland. Under trend crop requirements and trend yields combination of baseline projections, Iowa has a statewide surplus of cropland acres for the near, medium, and long term. If society can count on reasonable advances in technological resource creation, this study's projections indicate that there will be no general problems of agricultural cropland shortages in Iowa.

VII. SUMMARY

The main objectives of this study are (1) to develop a model for projecting future nonagricultural land use demands under alternative policies, (2) to apply the model to Iowa and regions within Iowa, (3) to identify major economic determinants affecting demands for Iowa agricultural and nonagricultural land resources, and (4) to appraise selected alternative policies affecting land use changes.

A multiple regression of urban growth in Iowa revealed that change in urban population explained more than 70 percent of the variation of change in urban land use. Over the ranges observed, demand for additional Iowa urban land implicitly appeared both price and income inelastic. Per capita absorption coefficients of urban land in Iowa's incorporated places are considerably higher than the Corn Belt average and much higher than the national average. Relatively large stocks of agricultural land were found to exist within Iowa incorporated places. Projections of future urban land use needs indicated that sufficient agricultural and other land exists within Iowa incorporated places to meet urban needs for 14 of the 16 Iowa regions to the year 2000 without annexation of additional urban acreage.

Baseline land use projections showed that as long as projected trend yields such as those that occurred from 1947 to 1973 inclusive are met, land needed for Iowa nonagricultural uses can be provided with a minimum impact on agricultural production capacity. This statement must of course be qualified by the assumed yields projected in this study. Less optimistic yields would of course require more cropland to meet

agricultural product demand projections. This would mean that cropland converted to urban use would have a more serious impact on agriculture's ability to meet future projected demands for agricultural products. Similarly, more optimistic yield projections would require less cropland to meet agricultural product demand projections. This would mean that cropland converted to urban use would have a less serious impact on agriculture's ability to meet future projected demands for agricultural products.

Under the projected crop yield and demand projections used in this study, a public policy alternative of preserving highly productive Iowa cropland from nonagricultural land conversion had a negligible effect on increasing cropland production capacity. Similarly, a public policy alternative of improving the quality of the environment by removing Iowa's fragile cropland from production did not place undue stress on the productive capacity of cropland in terms of crop yields and agricultural product demand projected in this study. Of course, alternative assumptions underlying cropland, crop yields, and demand projections would affect the inferences regarding public policy. Nevertheless, the methodology developed and applied in this study appears useful to national, state and local entities in proceeding with land use planning analysis even though projection variables such as cropland yields and product demand are revised to reflect alternative values of the variables. This would also apply to projected population growth and demands for other use of land in the future.

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