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Title A SURVEY AND EVALUATION OF LAND RESOURCE CLASSIFICATION SYSTEMS IN THE UNITED STATES

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The purpose of this thesis is to examine the methods and criteria developed for rating actual and potential agricultural land in the United States. It is motivated by the apparent increasing competition for quality space created by the expanding population, and by the belief that land rating and classification are basic to an ordering of the occupance of the nation.

The thesis is a literature review and begins by examining the historical trends of land classification work in the United States. The several time periods when many land resource classifications were formulated are discussed. To provide the background necessary to regroup the land resource classification schemes according to criteria, it was necessary to determine to what extent regroupings and analysis of land classification schemes had been done. Two informative reviews were located, one published in 1941, and the other in 1948. In 1941 the National Resources Planning Board

identified five land classification types; two of these rate the agricultural productivity of an area. The 1948 study, a Ph. D. Thesis by W. H. Pine, identified two types.

The author reviewed many land resource classification systems for the United States and determined that they could be grouped into six categories according to the criteria used in classification. These are systems with a soil, climatic, biotic, physiographic, genetic, and cultural emphasis. The significance of each criteria as a basis for use in classifying the site potential for agriculture is investigated. This establishes the importance of the criteria. The grouping places a series of representative schemes into one or more categories according to their criteria emphasis.

From this analysis two conclusions were reached. First, there is a disproportionate emphasis on soil and genetic criteria. Second, land resource classification systems tend to be subjective rather than quantitative. The systems in use now are old and based on criteria that are not measured on comparable scales. Therefore, the relative agricultural productivity potential of widely separated areas of the United States cannot be accurately determined.

Future systems should be objective and include new knowledge of environmental relationships and measures. Problems created by rapid population growth and finite spatial limitations of this nation make it imperative to evaluate correctly all land on a local, state, and national level.

A SURVEY AND EVALUATION OF LAND RESOURCE CLASSIFICATION SYSTEMS IN THE UNITED STATES

by

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I. INTRODUCTION

The variability of the land that occurs on the earth is of primary importance to man. From this diverse surface originates not only his food and fiber, but also the basis of the entire material culture present in the world today. In varying degrees, according to technological level, cultural background, and the character of the land itself, the landscape is subjected to human judgments and decisions which control its uses.

Land resource classification systems constitute a tool in the hands of planners and persons in decision making positions, and they are useful in ordering the occupance of a region. At this time in the history of the United States, perhaps more than any other, there are growing problems of land occupance and competition for quality space. These problems justify a close look at the criteria used to evaluate the use potential of the landscape.

Purpose and Method

The purpose of this thesis is to examine methods that have been developed for evaluating the physical agricultural productivity potential of the earth's multivariate surface (land resource classification systems). In view of the need for restricting the topic to manageable size, only classification systems designed for use in the United States are considered. The study is, then, a literature review. Although it does not exhaust the literature, it does emphasize the representative types of land classification systems.

Four steps were followed in the research. First a bibliography of articles on land classification, soil productivity ratings, land resource classification, land capability classification, land utilization, soil ratings, and land economic surveys was compiled. The *Biological and Agricultural Index* served as the primary key to the literature. Other varied sources, including those in the author's personal collection, were also used. Step two consisted of identifying land classification systems that focus on physical land productivity. This sorting eliminated a large number of classification systems that had an economic orientation. Step three involved the investigation of those falling into the land resource category and the selection from these of representative types. This was necessary because many systems were only variations of a theme, and thus, in most cases the original system was chosen as representative. The final step was a detailed evaluation and comparison of these selected classification systems and also the criteria used by these systems in delimiting land class groupings.

Problems of Land Occupance

At the outset it is of value to explore land occupance problems and the needs arising from them. The overriding problems of "how land should be used and how rights to land should be distributed" (53, p. 8) are underlain by factors of population increase, economic and physical growth of cities, technology, and related implications of all of these.

In April of 1966, the population of the United States was over 195-million people, whereas sixteen years before, it stood at slightly more than 150-million. There was an absolute increase of 30.0 % from 1950 to 1966 (50, p. 1-4; 51, p. 1-2). Should the population increase continue at the same rate, in 1975 there will be over 212-million persons in the conterminous United States; all of whom will eventually seek the goods, services, and living standards available to us today. More people means that more space will be required to live in.

In the past, when man needed room for expansion he, like the more primitive animals, competed for space only within the biotic environment. Now, he must compete within an acculturated environment also. Within the limits of present technology, almost all of the earth's useable land is occupied. Therefore, man is competing with man and his own institutions for space. This is important when considering the occupance patterns of a region. To achieve the most rational development man must evaluate the land according to its use potential and consider how this use will affect the broader ecosystem of which man is a member.

The Los Angeles area is an example of self competition. Higbee says that in 1941, Los Angeles County contained 300, 000 acres of cropland and a population of 2. 65-million. This is a ratio of nine persons per arable acre. By 1957 this ratio had increased to 131 persons per arable acre; due both to an absolute increase in the numbers of people and to the reduction in cropland (16, p. 14). Similar encroachment of agricultural land is being felt over the entire nation. Higbee also states that from 1945 to 1960, the land removed from agriculture by the growth of the United States was equal to one-twentieth of all cropland (16, p. 167). As an example: in 1960, over 27-million acres were devoted to "urban areas" alone (census definition,) not including highways, railroads, and airports to serve these centers (49, p. 19). High taxes and monetary gains pressure the farmer out of agricultural production and the land becomes "developed" (16, p. 170; 47, p. 84).

Cities are not the only causes of land use conflict. Transportation networks which, according to Ackerman, permit intensification of space use beyond natural limits, tend also to set up occupance patterns (4, p. 26). Higbee mentions this powerful ordering force of the highway and says that

> The judgment of highway engineers has more to do with the present and future shape of America than that of any other group in government or private life (16, p. 191).

William Whyte concurs with this opinion, suggesting that the locations of new interchanges are locating the communities of the future which will sprawl over the land. He compares the limited access highways and its interchanges with the significance of river and railroad junctions of the past (57, p. 107).

The Federal-Aid Highway Act of 1961, provides for a 41-thousand mile system of interstate and defense highways to be constructed (55, p. 378, 381). This network will ultimately affect the occupance patterns of the entire nation. It will be administered by the various state highway departments, (where personnel are trained in engineering but not planning) (57, p. 107).

A recent study by Schmidt shows that the Interstate Highway 5 that passes north and south through the Willamette Valley of Oregon, takes approximately 39 acres per mile (41, p. 2, abstract). If this value were taken as an average for the entire interstate system, then over 1.5-million acres of land would be covered by new freeways. The location of these highways should, hopefully, be based on some rational evaluation of the use potential of the landscape.

In addition to land removed from agricultural production due to the direct effect of cities and highways, any technological improvement in resource converting techniques (Ackerman) will affect the utility of a given parcel of land (4, p. 26). This has the potential for creating conflicting land use problems such as those illustrated by the highway *vs.* agricultural land.

The improvement in one phase of resource-converting techniques, those applicable to agriculture, permitted yields to increase some 60% from 1920 to 1959. During the same time, the total cropland area of the nation decreased about 23-million acres (49, p. 7, 32). If one takes the long range view, however, increased yields per unit area may not answer all the food and fiber needs of the nation fifty or one-hundred years from now. The value of land must be seen in its true perspective as the continual basis of our culture and our national strength.

Definitions

Land

The word land is used in various ways. This is suggested by Chryst and Pendleton in the Yearbook of Agriculture for 1958, *Land.* They say:

> Land is many things to many persons--to the farmer, livelihood; to the townsman, space or a place to build his house; to the child, a playground; to the poet, a theme; to the patriot a symbol... (53, p. 2).

According to the cultural background and education of an individual, different aspects of the land have meaning. Kellogg believes that the words "land" and "soil" are often used interchangeably. These "...are old words, like 'stone,' 'house,' and similar common words, [and] are hard to define precisely..." (22, p. 500). He also emphasizes the difference between the two. Oftentimes, soil groupings and classifications are called land classifications (22, p. 501). This is a confusing situation. Soil is a term associated with plants, their growth requirements, and physical aspects of their environment. Land, on the other hand, is defined either physically as an expression of the environment (consisting of climate, soil, vegetation, culture, etc.) or culturally, as an expression of property, survey lines, and economic factors (24, p. 2).

We can follow the definition of Highsmith, who presents a concise summary of Kellogg's description. Highsmith says that "land" consists of the "surface expression of the sum of the characteristics presented by the earth's physical system at a given site" (17, p. 1). Such items as mineral deposits and underground water could also be included in a definition of "land"; however, for the purposes of this study, the surface expression of the physical systems (taken broadly) is sufficiently inclusive. Highsmith continues to say that when the concept of resources is added to the definition, then the definition must be modified.

Resources

The concept of what constitutes a resource has been considered by a number of scholars. According to James, the work of Zimmermann is the most detailed (21, p. 227). Zimmermann says that a resource "does not refer to a thing or to a substance but to a function which a thing or a substance may perform or to an operation in which it may take part" (58, p. 7). The substance reflects human appraisal and its usefulness to a culture. This is the same general idea that was mentioned in 1941 by Broek and in 1947 by Sauer. They, however, emphasize technical achievement in the appraisal process somewhat more than does Zimmermann (40, p. 18-19; 10, p. 322). More recently, Sauer in 1952, used the term "skills" which is closely allied to "technology" (39, p. 2, 3). For the purposes of this study, a statement which seems to encompass all of the ideas in a fresh way is one by Broek. In 1965 he stated that "man... perceives the value of some earth property [through his cultural framework of perception] and thereby creates a new resource. Through such technical achievements parts of the earth gain new value" (9, p. 72). (For the material under study, only the "natural" or "non-cultural" resources are considered--it is recognized that certain factors of culture can also function as resources) (21, p. 228).

Land Resources

Therefore "land resources" are site qualities or attributes of the earth's physical system that are assigned a value by man through cultural and technological appraisal. Highsmith says

> ... the focus of land resource is on the interpretation of the associated physical characteristics as a foundation for human activity or use; and in any given circumstances dynamic parameters of both the natural environment and the occupying society come into the consideration. Because of the variance in the conditions of both, especially the agency of man in time and space, land is subject to differing functions and/or values. The latter is even true of land of similar physical qualities (17, p. 1).

Therefore, a land resource classification system would be any logical attempt to rate the usefulness or value of a particular site. This is the criteria that is used for sorting the land classification schemes found in the literature into resource classification systems and those systems which are based largely on cultural factors. In the present study, only land resource classification systems for agriculture are considered.

Thesis Organization

The discussion of land resource classifications in this thesis is presented in five sections. The first two, included in chapter two, examine the kinds of land classification systems that have been identified by previous workers and reviews some of the historical characteristics of land classification systems. The third section (the first half of chapter three) consists of a detailed discussion of the various criteria that are used in land resource classification systems.

Section four is a review of the land resource classification systems themselves. Here the schemes are discussed according to the various criteria emphases that are present. Part five consists of the conclusions drawn from the review of the various land resource classification systems.

II. LAND CLASSIFICATION IN THE UNITED STATES

Even a brief survey of the agricultural literature of the United States discloses a wide variety of land classification schemes. In general, most of these schemes can contribute to a rational interpretation of the rural landscape (37, p. 455; 54, p. 1). They range from simple groupings (including one or more physical or cultural aspects of an area) to complex evaluation schemes (those which integrate use, potentials, markets, technology, and other items).

The many and varied classification types to be discussed may result from confusions in definition, as mentioned in the Introduction. Kellogg, in addressing himself to this problem, indicates that there should be a better division between the ideas of physical land and cultural land. He says, the term "land classification" should be used only for the cultural aspects of property, survey lines, and economic factors, and a more specific terminology, such as "vegetation classification," "relief classification," or other physical qualities, should be used for the physical classification of an area. He goes on to say that such should be specifically identified (22, p. 500).

Historical Land Classification Trends in the United States

In general, land classification activity in the United States has been carried out by public agencies and has been concentrated in three time periods. According to a National Resources Planning Board study (1940), the first concentration was between 1867 and 1869. During this time Powell, Hayden, King, and Wheeler made surveys of physical land characteristics in the arid and mountain regions of the public domain. These men were interested in the use potential of the landscape and recorded their observations of known natural resources (54, p. 13, 14).

The second concentration of classification activity occurred between 1933 and 1938 during the Depression. Land speculation and misuse after World War I created many land use problems. Attempts to resolve these problems account for the concentration (54, p. 19). Many of the classification schemes were resource oriented. Altogether the author found nineteen articles written in the 1930's that discuss land resource classification systems.

The third concentration of activity was from 1948 to 1951. Seventeen references to land resource classification systems written during this period were located by the author. The extent of other categories of land classification (cultural, economic, etc.) was not determined.

In general there has been a trend away from using only physical criteria (Powell, Hayden, and others,) and a trend towards the use of both physical and cultural criteria. Even in the 1940's this new trend was present and the NRPB noted classes of classification systems based on one another (cultural criteria and analyses are added to the physical evaluations). Only two works were found that summarized land classification types. One of these is the National Resources Planning Board Study published in 1941. The other, by Wilfred Harold Pine, is a Doctor of Philosophy dissertation, "Methods of classifying Kansas land according to economic productivity," which was completed in 1948 at the University of Minnesota. In 1961 the one chapter of Pine's work, which dealt with a review of land classification in the United States, was published verbatum (36). This is evidence of a lack of a more up-to-date review of classification systems.

Types of Land Classifications

In October 1940, the Land Committee of the National Resources Planning Board concluded investigations (headed by Charles C. Colby) into ways of classifying land. This committee chose seventy-five governmental projects (local, state, and national) as representative. From this sampling, five classification types were identified. They are

Type I. Land Classification in Terms of Inherent Characteristics.

Type II. Land Classification in Terms of Present Use.

Type III. Land Classification in Terms of Use Capabilities

Type IV. Land Classification in Terms of Recommended Use.

Type V. Land Classification in Terms of Program Effectuation (54, p. 3).

Type I, classification in terms of inherent characteristics, uses physical aspects of the land as a criteria for classification. Included are slope, soil type, climate, natural vegetation, water resources, and minerals (54, p. 3). Furthermore, each criteria can be broken down into significant subdivisions: For example, temperature and precipitation are subdivisions of climate (30, p. 9). The National Resources Planning Board (NRPB) found that sixty-eight of the seventy-five projects (over 90%) could be grouped either wholly or in part under Type I. Examples of Type I include topographic maps, soil survey maps, and forest or water resource inventories (54, p. 3). The topographic map classifies land according to its distance above sea level, with the contour lines bounding areas of the same class: For instance, the 250 and 300 foot contours include all areas from 250 to 300 feet above sea level. Slope can also be determined, but is not specifically classified.

The soil survey classification or map delimits soil types by physical factors (soil texture, depth, etc.). Classifications of a single site factor such as soil stoniness are also Type I. (Cadastral maps, which classify according to distance from certain established base lines, are other examples of single factor land classifications (30, p. 8, 9).

It should be emphasized that Type I which includes some land resource classification systems does not include combinations of major criteria (soil, climate, topography, etc.). These combinations are grouped under Types III and IV.

Classification Type II, land classification in terms of present use, is simply a grouping of the ways man is presently utilizing the surface of the earth. Generally one major use, such as settlement type, recreation, agriculture or forestry is stressed, rather than a combination of these. The delimiting criteria are grouped into three categories: 1) kind of use, 2) characteristics of use, and 3) status of occupancy (54, p. 4). (For example, if agricultural land use is being classified, category 1 would include delimiting pasture areas cultivated areas, highways, etc.; category 2 would include yields and type of crop; category 3 would include tax information, assessed valuation, etc.) One or more of these categories may be used together in delimiting land types.

Classification Type II is really not a land resource classification system. Present land use does not necessarily indicate the possibilities or potentials of a parcel of land for agriculture. The NRPB stated

> There is one element in common to Type I and Type II land classification which distinguishes them from other types. Both deal only with existing conditions: one, the inherent characteristics of the land; the other the present uses of the land. As a result, both are primary inventories. Appraisals of potentials are not involved; no recommendations are made; and no programs of action are formulated (54, p. 5).

Type III, land classification in terms of use capabilities, is based on an appraisal of the value or usefulness of a particular site. This is done in two ways: 1) the results of using the land a certain way are evaluated, and 2) the technology and management needed to produce a selected crop are determined. This type is more advanced than the other two and often uses both to form a new classification (30, p. 11). Although Type III rates the usefulness of the land, it does not specify a "best use."

Either subjective or quantitative criteria are used in Type III. An example of a quantitative rating system is one which uses average yields of a crop on a parcel of land, as an index of its potential. A subjective Type III system might also use the criteria of inherent capabilities, land use, and yields, but would not be based on a numerical rating of these items. A judgment of how the land will perform is made by using such terms as good, fair, or poor (54, p. 5; 30, p. 10, 11).

Historically, Type III is the same system that has been used by farmers for centuries to determine the producing capacity of their fields (54, p. 6). This classification comprised the largest number of land resource classification systems examined for this study.

Land classification in terms of recommended use is the fourth type recognized by the National Resources Planning Board. In this type the first three systems are integrated, and the potential uses of the land are rated according to inherent characteristics, existing land use, and potentials for production for agriculture or forestry. Examples of this type are maps of recommended uses on forest land or maps of irrigation development sites (54, p. 6). Type IV criteria also includes the cultural factors of land management and types of resource-converting techniques used. The Type IV classification and the Type V classification, (land classification in terms of program effectuation,) do not include land resource classification systems because they are defined mainly be cultural factors. Type V specifies, in map form, how and when Type IV recommendations are to be effectuated (54, p. 7).

A thesis written by Wilfred H. Pine in 1948 includes a section which briefly discusses types of land classification in the United States, mainly the Type III classifications of the NRPB. Pine finds that the classifications use either physical or economic criteria for measuring productivity. Each of the two criteria can be broken down still further to a subjective or objective classification type (35, p. 271). This idea comes from the NRPB; however, it is not expanded in their study. Pine does expand it, and states that

> Subjectivity is used here to mean that judgment was used primarily to evaluate criteria. Objectivity is used to mean that data such as yields for the land under consideration were used in rating the bodies of land. In many of the productivity classifications one or more factors, either physical or economic, were used to classify the land

> while other factors were used to test or prove the classification (35, p. 11).

Pine's economic productivity ratings are outside the scope of this study because they include cultural criteria such as market, taxation, land tenure, condition of buildings, and other factors. The physical productivity classifications, however, are of interest. Many examples of the subjective rating schemes are given in Pine's work.[1]

Pine lists a fewer number of objective than subjective rating systems for land. All these are highly quantitative and in them individual bias is reduced to insignificance. For example, in a classification by Murray, scientific measurement of soil slope and depth were taken at random over fields in Iowa. Then, yields of individual field crops were weighed and a correlation made to determine the significant factors influencing the yields (35, p. 20). It was found that depth of soil was the most important. Pine lists others of this type.[2]

The objective rating system sometimes uses statistics. A typical example is a study of R. T. O'Dell and Guy Smith; standard deviation is used in the analysis (35, p. 25).

Kellogg visualizes two categories of land classification: The

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[1] See reference 36, footnotes at bottom of pages 7-13.

[2] In reference 34, see footnotes at the bottom of pages 22-26.

natural classification (this corresponds to the NRPB Type I) and the practical classification (an example of which is a classification of soils according to their lime requirement). The latter type is based on the natural classification scheme, and is similar to NRPB Type III (24, p. 2). These categories

> ...are classified according to their capabilities for man's use with sufficient detail of categorical definition and geographic expression to indicate those differences significant to Man (24, p. 4).

III. LAND RESOURCE CRITERIA AND CLASSIFICATION SYSTEMS

The land resource classification systems (actual and proposed) for the United States can be grouped into six categories according to the criteria used in classification. The categories are as follows: 1) systems with a soil emphasis, 2) systems with a climatic emphasis, 3) systems with a biotic emphasis, 4) systems with a physiographic emphasis, 5) systems with a genetic emphasis, and 6) systems with a cultural emphasis. Most of the classifications contain more than one type of criteria.

Criteria for a system with a soil emphasis can be of two types: the first considers units such as the soil type; the second uses elements such as slope, texture, fertility, structure, depth, moisture content, and erodability as criteria for rating the land. Similarly, subdivisions of the climatic emphasis can be either general and highly subjective characteristics, or specific, using the climatic elements, chiefly temperature, precipitation, wind, and variations of these.

The biotic emphasis includes the natural vegetation, native animal life, and domesticated animal criteria. The latter is included because in a pasture situation livestock occupy ecological conditions similar to native animals. Physiography, the fourth emphasis, includes slope criteria of steepness and aspect as well as the landform conformation.

The genetic emphasis is defined by criteria that are dependent on the genetic or physiological limits of a domesticated plant. These include the yields of a species or groups of species of plants, and the adaptability of a specific crop to a particular environmental situation.

The cultural emphasis of criteria is present to some extent in a number of land resource systems. They are, however, of secondary importance to the consideration since the physical expression of the earth's surface is the prime interest. Under culture emphasis, criteria such as management technology, markets, and transportation often occur in the classification. Their principal value is as a framework in which to view the landscape and as an indicator of land usefulness for agriculture. No classification considered in this study could have a predominant cultural emphasis.

It will be demonstrated later that each of the land resource classification systems may have more than one orientation; however, the schemes will be discussed according to the principal orientations that are evident.

Before considering the classifications themselves, a basis for judging the criteria used must be set up. To do this, each criteria under the respective emphasis will be discussed and its importance in classification and frequency of use will be noted.

Classification Criteria

Soil

The criteria that appear most frequently in land resource systems are those associated with soil (54, p. 3). There are several reasons for this. First, the soil is considered to be one of the more permanent elements of the landscape. T. D. Rice says,

> Unless the land is subjected to unique management, the physical properties of the soil remain essentially unchanged. Through all changing social and economic conditions, the selection of crops and the methods of farming will be subject to the limitations imposed by the soil (37, p. 458).

R. E. Storie concurs with the opinion that the soil is more permanent than cultural factors. He also adds climate and the availability of water to the permanent features of the landscape. He believes that for the purposes of rating the usefulness of the land, the system of classification should not rapidly become obsolete. This would happen if cultural criteria were used (44, p. 415).

Another reason for the importance of soil as criteria is the belief that the soil survey supplies most of the basic data that is needed for land classification (22, p. 499). Rice says that the value of a soil is entirely dependent on the kind of vegetation it will support, and because it exerts such a controlling emphasis on plants, the varied soil elements are an integral part of the land classification process (37, p. 455).

Thirdly, soil criteria occur frequently because a number of workers consider soil to be the summation of all the physical factors of environment at a given site. Kellogg expresses his opinion as follows:

> Any plan for land classification or land utilization, which is not based on a scientific classification of the soil, is likely to be of questionable value for any practical use where growing plants are concerned... It is the natural land type--a sort of natural landscape--defined principally by the climate, soil topography, and stoniness that is evaluated as a whole (24, p. 5).

Kellogg also warns against using vegetation or other physical features to make up land classification schemes. He says that these will indicate the correct situation only locally, because, with vegetation, for instance, an indicator species might invade poor soil under certain climatic conditions. This is further evidence of his belief that soil is dominant (22, p. 511).

J. Kenneth Ableiter also follows this line of reasoning and says that the soil type designation includes all the landscape factors of climate, native vegetation, relief, parent material, soil formers, and time where these have been essentially uniform--everything, in other words, that impinges on the usefulness of a parcel of land (2, p. 14).

A. B. Lewis does not specifically list reasons for the necessity of soil classification. He simply states that they are necessary for the classification of land capability (30, p. 22). Carl Sauer emphasizes that the information regarding suitability of soils for cropping should be based on the soil itself. Supplementary information regarding potentials of soils that might be gained from natural vegetation, for example, is not as good as the data gained directly by a soil survey. More and more, natural vegetation is being disturbed. This limits the possibilities for using this criteria (33, p. 83, 84).

One additional reason for soils criteria emphasis may lie in historical inertia. Sauer writes about the lengthy use of proverbs about soil texture. These proverbs emphasize the differences between clay, sand, and loam (33, p. 84). Perhaps they can be called early land classification schemes.

Soil characteristics are of great importance in influencing the value of a parcel of land. These may determine the type of crops or kind of livestock that is chosen by an agriculturist. Lewis emphasizes that soil texture, depth, drainage, or moisture characteristics and chemistry are important factors (30, p. 3). Klages states that the properties of texture and structure influence three items: 1) the extent to which roots will penetrate into the soil, 2) the chemical situation and micro-biological activity, and 3) the ease of water penetration and storage in the soil. On a more generalized level, the soil horizons themselves tend to vary in root environment. This is a potential limiting factor in crop production (26, p. 326).

Soil chemistry includes a variety of items. Basically the soil is a source of nutrients for plant life, and deficiencies of required materials during the growing season may necessitate artificial application to maintain fertility. The degree to which this is possible is a function of the extent of the deficiency and the climate. An example of this type would be a nitrogen deficiency (26, p. 326). Certain chemicals present in the soil such as salts, may also have a limiting or toxic effect on plants.

Klages also points out that the soil reaction is of great importance. He says that most of the plants that form the basis for agriculture have their optimum growth in soils that are nearly neutral in reaction and any deviation from this would require correction in so far as technology and management could remedy the limitation. Such conditions might influence tilth quality, the formation of hardpans thus preventing root growth, and the base exchange capacity of the soil (26, p. 329, 330).

The moisture relationships within the soil are caused by variations in texture, depth, and structure. Water must infiltrate within the soil to charge the area's ground water supply and prevent rapid erosion if slopes are steep. An example of this type of influence on surface vegetation is the advantageous condition of a sandy surface on the soil. Here, rapid infiltration causes the capillary connections between the soil surface and subsurface to break and the surface dries out. Then the only water loss from the soil is through slow evaporation or transpiration--not the rapid capillary-fed evaporation present before the break of capillary connection (26, p. 333). Along similar lines, the ease with which a plant can obtain water from the soil depends on the soil characteristics as well as the genetic capabilities of the plant that is grown.

Climate

The climate emphasis does not recur nearly as frequently as the soil emphasis; however, it is of equal importance in rating the agricultural usefulness of a particular site. Storie lists climate and the availability of water as being additional stable elements (other than soil) that determine land value (44, p. 4).

From the days of primitive agriculture it has been known "that climate influences the distribution of vegetation and of crops. . . "(46,

p. 1). The climatic elements of light, heat, and moisture not only influence, but limit the choice of crops, and even agriculture itself (30, p. 3). Although climate is an important factor to be considered in land resources it is not an integral part of many classification systems. There are several reasons for this. According to Thornthwaite, the use of climatic criteria in correlation with other physical factors has not been very useful in solving agricultural problems (46, p. 3). He says that

> Agriculture specialists and botanists have usually tried to make use of. . . regular climatic observations but too often have found that they do not, except on rare occasions, provide answers to the questions under investigation (46, p. 2).

The scale of the criteria has much to do with this. Soil types, sub-types, and soil elements are highly localized phenomena and detailed measurements of these are made. Climatic data on the other hand are an abstraction of a mosaic of microclimates and temporal variations. At the same scale, the site variations in climates will generally exceed that of soils.

Examples of the site differences that can occur among microclimates are south-facing slopes, hilltops, plowed fields, and rocky areas (46, p. 2). It is interesting to draw an analogy between the use of all specific or all generalized criteria in classifying, with the use of dissimilar units such as feet or miles in a mathematics problem. One unit logically should be used throughout, or as in this case, at least similar levels of generalization. Kellogg, who uses the soil to measure environmental factors including climate, may be sampling more correct climatic data than by using conventional data gathered under standard conditions (24, p. 5).

The specific climatic measures that are important in land classification schemes are usually average precipitation and temperature. Some variations of these data are noteworthy. These include the number of frost-free days per year or season, the number of heat units, and the potential evapotranspiration. The measure of heat units or the sum of the temperatures above a given threshold for the growing season of plants was developed to relate plant development to the amount of heat received (46, p. 10). This method has its shortcomings in that the heat units vary from year to year in a single locality as well as with planting dates (46, p. 3). The method is old, being devised by Reaumur in the seventeenth century in France (46, p. 1). One outstanding example of its use in a land resource classification system is the scheme devised by C. Hart Merriam. In this scheme the northern boundaries for various "life zones" are delimited "by the sum of the positive temperatures for the entire season of growth and reproduction" (32, p. 54). (Six degrees Centigrade or 43^{o}F. was used as the threshold temperature, below which, physiological activity in plants and reproductive activity in animals did not occur) (32, p. 54). More recently a better measure, potential evapotranspiration, has been developed for the use of agricultural climatologists. It has yet, however, to be used in a land resource classification system for agriculture (46, p. 10).

As with soils, the effects of various climate criteria are important. In addition to the recognized need of a plant for light, moisture, and temperature conditions within its genetic tolerance ranges, there are other influences. Rainfall lack or abundance is a factor in the development of acid or alkaline soils due to the presence or absence of leaching. (Soils and vegetation are responsible to some extent also) (26, p. 330.) Another example of the climate's influence on the soil is the role that temperature plays in the genesis of soil types and in determining the nitrogen level of a particular soil (26, p. 327).

The potential of the land to produce plants is not the only aspect influenced by climate. Domestic as well as wild animals are also affected. Findlay indicates that in daytime temperatures of over 80°F. cattle seek shade and cease feeding. This results in nocturnal feeding, particularly if these temperatures are encountered throughout the day (13, p. 20). He mentions also that yields of milk and its butterfat content are highly dependent on temperature. Temperatures above 70 to 80°F. for Holsteins and Jerseys, and above 80 to 90°F. for Brown Swiss cows cause a reduction in milk yield. Temperatures above 70° decrease the butterfat percentage

(13, p. 23). Other animals such as swine and sheep also exhibit different responses to high temperatures and humidity. The swine is the less tolerant of the two (13, p. 27). Part of these influences are due to genetic capabilities of the organisms however, it seems that the potential for climatic criteria in land resource classification systems for agriculture has not yet been realized.[3]

Biotic

The criteria used in delimiting this emphasis include natural vegetation and animal life and domesticated animals. Classification systems that included these criteria are few. Only eight of those consulted made any mention of either vegetation or animal life. That vegetation information can be potentially useful to land classification was recognized by H. L. Shantz and Raphael Zon in the Atlas of American Agriculture.

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[3] A number of classification systems which relate climate to soils, vegetation, and other physical aspects of the environment were found. These, termed "Bioclimatic" systems rate the usefulness and potentials of a given site; however, they are not concerned with agriculture. Several are very similar to land resource classification systems analyzed in this paper. One of these, a scheme by C. Troll and others (World Map of Climatology, edited under the sponsorship of the Heidelberger Akademic der Wissenschaften by F. Rodenwalt and H. J. Jusatz (2nd ed.) published by Springer-Verly, New York, Inc., 1965, 28 p.) is only one step away from Bennett's foodcrop classification. Here, natural vegetation rather than foodcrops are emphasized. There are other examples of these.

> The natural vegetation of a country, when properly analyzed and classified, may serve a very concrete and practical purpose. As a new country becomes settled, the natural vegetation must be replaced gradually by agricultural crops, orchards, pastures, and man-made forests. The suitability of the virgin land for various crops is usually indicated very clearly by the natural vegetation. After a correlation is established between the different forms of natural vegetation and various agricultural or forest crops, it provides a means of dividing the country into natural regions of plant growth, which can be used as indicators of the potential capabilities of the virgin land for agriculture and forest production (43, p. 3).

Both of these workers view vegetation in the same way that Kellogg views soils. They consider the native vegetation as expressing the summation of the physical environment and believe it is the best basis for classification of the landscape (43, p. 3). Rice also emphasizes the fact that vegetation represents a mosaic of environmental factors.

> Vegetation is the resultant of several forces, of which the soil, although important is not always dominant. The soil may not be able to impress its qualities on the vegetation when opposed by an adverse climate (37, p. 455).

He does concede that soil is a limiting factor at times, but that vegetation is more important. To him, soil is not the all-encompassing agent that Kellogg envisions.

One problem with natural vegetation as a criteria is that very little natural vegetation is actually left--only relic bits and pieces. Animal life would be a good indication of productivity in a natural ecosystem, and inferences concerning agricultural situations could be extrapolated from this. The biotic criteria that have been used in land resource classification systems for agriculture are of four types: Merriam uses natural vegetation and animal life in the same way as suggested by Zon and Shantz (32). A number of systems look at the vegetation available for forage. Grazing capacity, another way of looking at the vegetation for forage, is also used. A measure of the kind of land cover (what plants are there) and a comparison of this with existing cropland is used also. The present author believes that vegetation would prove more useful, particularly in recent classifications, if seral stages of vegetation and the concept of sub-climaxes and their significance as seen by Eyre were used in land classification (12, p. 7-24). This would remove the dependence on a "natural" situation that does not really exist.

Physiographic

> Even where temperature, moisture, and soil conditions are such as to allow crops to mature during one or more seasons of the year, variations in the character of the land [physiography] are still sufficient to bring about wide differences in the most suitable kinds of crop and animal products (30, p. 3).

This statement by A. B. Lewis is indicative of the importance of physiographic criteria in assaying the potential of a parcel of land The importance of physiographic criteria was recognized by the

National Resources Planning Board Study. Topography, in conjunction with soil, is mentioned frequently (54, p. 3). The same situation was found to be true in the present study: nine systems use criteria such as relief, slope, aspect, elevation, and so on; and almost every system that used soil included slope steepness among the soil factors. It should be noted, however, that slope steepness is also a physiographic factor in addition to being a soil factor.

According to Klages, the physiographic factors include information on geologic structure, topography, and altitude (26, p. 334). The first of these, geologic structure, was not used at all in the land resource classification systems investigated. Perhaps it should have been used, as it would certainly influence the resulting land form. Topography, however, was used as a criteria. The importance of topography is emphasized by Billings:

> Topography refers to the configuration of the earth's surface: the hills, the valleys, the mountains, the shore; their slope angles and directions, and their elevations... Topography does not directly affect an organism; it works through other factors. The north- and south-facing slopes of a ravine in Ohio affect plant distribution and growth by their being shaded or sunny, respectively on an early spring day... Topography provides the setting; it is the other environmental factors that work on the organisms (8, p. 28).

The lay of the land influences cropping in various ways: Rough terrain, or steep slopes may prohibit the use of machinery, and often, hand labor is too costly to be practical. Slopes that are steep tend to have a rapid runoff and little moisture is available for plants. Also, in the rocky areas, the soil will not support vegetation (53, p. 11). In fact, surface form is a major limiting factor in the cropland enterprise in the West (18, p. 50).

The third part of the physiographic criteria is altitude. This determines the local climate, influencing both temperature ranges and the moisture regime (26, p. 335). A classification system emphasizing this aspect of the environment is the simple topographic map.

Genetic

The genetic criteria used in land resource classification systems include the yields and adaptability of a crop or groups of crops and the yields of milk, wool, and other animal products. Criteria such as these are a type of measure of the environmental system at a given site. They are called genetic criteria because the yields depend on the crop and species of plant selected. Clausen, Keck, and Hiesey say the that way a plant looks or its "phenotype" results from the combined action of both the environment and the genetic makeup of the plant (11, p. 1, 2). Transplant experiments conducted from 1922 to 1940 showed that yields were dependent on the degree of adjustment to the environment permitted by the plant's heredity (11, p. 427). Clausen, Keck, and Hiesey also say:

> If the plant's heredity is such as to enable it to accomodate itself to the new environs and compete, the plant may prove to be a success in the new climate (11, p. 425).[4]

We are, therefore, dealing with a flexible situation. The measures of yields or adaptability are useful only to the extent that it is recognized that changes in genetic potential of a plant or animal will change the yields under any fixed environment (this is particularly important when comparing the productive capacity of two areas widely separated latitudinally). This is becoming an increasingly important factor because the United States is at the threshold of the "golden age of biology." Even now we are starting to tailor-make plants and animals for environmental situations. This can be illustrated by comparing the environmental effects on two groups of cattle species. (This same example was used in the discussion of climatic criteria to emphasize its influence on an organism.) With regard to milk yield, Findley found that a decline occurred around 70 to 80°F. for Holsteins and Jerseys; however, for Brown Swiss cows, the critical temperature was different--85 to 95°F. (13, p. 23).

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[4] The implication here is that the climate is of greater importance than the other environmental factors. This is not valid because the experiments undertaken generally tested only climatic criteria. It is assumed that a similar response would occur under tests for soil differences, and so on.

Cultural

No land resource classification system with a predominantly cultural emphasis is considered in this study. There may, however, be cultural criteria integrated into the rating system. These criteria include the type of management, agricultural technology, market data, and transportation interconnections, and so forth. (For this study, the inherent cultural emphasis that is present in all classification schemes, because they are devised by humans who have prior experiences, values, and cultural backgrounds, is not to be in the same frame of reference considered.) A rating system might be based on these items to determine the agricultural potential of an area, however, there are two problems involved. First, the values of cultural parameters change through time with economic and technical evolution. Thus, by using cultural criteria, classification systems would tend to become outdated with changing conditions (27, p. 1; 38, p. 458). The market for a certain crop might drop and because of this, another would be grown. In terms of the new crop, the old system for rating the land might not hold true because of difference in the environmental requirements of the two plants.

Second, social and economic conditions themselves become factors in determining the value or usefulness of a parcel of land but they are not factors of physical productivity. For example, the distance from a market might be great enough to cause a highly productive landscape to be relegated or classified to a less valuable position for this reason alone. The high rating might be placed on land close to markets but with lesser natural potential (30, p. 3, 11; 22, p. 512). This is not what is desired in a land resource rating scheme as it does not measure the physical productivity potential of the land.

The cultural criteria is useful, however, in providing a reference frame with which to view a group of data. This is particularly true of classification systems that use productivity or yields criteria. These correspond to the Type III systems, classification in terms of use capabilities (National Resources Planning Board) (54, p. 6). In this type of classification the technology necessary to produce a specific crop or prevent erosion is used as primary criteria for classifying the land. In this way, it is a valuable addition to rating the land potential for agriculture.

Classification Systems

Representative land resource classification systems will now be discussed according to the type of criteria used in classification. Some systems contain predominantly one orientation, and others contain several. Examples of the former include many of the systems utilizing soil criteria, such as the various quantitative systems of Storie (44). When more than one criteria is used, there may or may not be a dominant orientation. An example of this type is one by Ableiter and Barnes using soil, plant genetics, and cultural criteria (3).

Soil Emphasis

Classification schemes that show a dominant soil criteria emphasis are either qualitative or quantitative types. An example of a qualitative system is the one by Selby and Fryer. This system was published in 1937 for land classification in the Willamette Valley. Two objectives were stated:

> (1) to make a classification of the agricultural lands of the Willamette Valley into broad areas of fairly uniform adaptability for crop production; and (2) for the areas thus classified, to compare kinds of crops grown, types of farming, size of farms, intensity of cultivation, and yield of crops (42, p. 2).

The soil type or groups of soil types are used to delimit categories. Depending on the physical makeup of the soil, each soil type is better suited for one particular agricultural practice. For example, the Chehalis and Newburg soils are well adapted for intensive cropping. Therefore, in Selby's system, the soil types are grouped into six categories that express the potential of the land. (A secondary genetic orientation is also present. The crops grown in an intensive cropping system would have a genetic tolerance range sufficient for the soil they were growing in) (42, p. 213).

A qualitative system earlier than Selby's is one that was designed for Langlade County, Wisconsin. The main emphasis is on soil criteria; however, physiographic, biotic, and climatic elements are also present. Lands are classed according to their suitability for agricultural development: A, B, and C are used to represent good, fair, and poor agricultural land. Specific delimiting soil criteria are the texture, water holding capacity, availability for tillage, and drainage. The soil types are subjectively placed into one of the three categories and a map shows their distribution (28, p. 36).

In 1935 Kellogg wrote about a method of land classification in which he delimited what he called a "natural land type." The classification is soil oriented. He believes that soil is the basic criteria but that other physical features such as climate, vegetation, and relief, must also be considered. In actual practice, however, Kellogg dispenses with the latter features, as he feels the soil expresses them all. This classification groups similar soils into potential uses for cropping, grazing, forestry, recreation, mining, and urban development. Since the system was devised to aid in the planning of land utilization, tax assessment and social aspects are also covered. However, only the land resource measure is of present interest (23, p. 283-286).

In 1937 Moon wrote of land classification work in the Tennessee

Valley. He states that many different land classifications could be interpreted from the basic soil survey. Among the ten types listed were maps of general productivity, crop adaptation, and land management. He indicates that the methods are highly subjective but does not elaborate about this (33, p. 490, 492).

Other land resource classification systems with a soil emphasis are more quantitative and scientific in their approach. The three following examples are all variations of one system initially devised by Storie called the Soil Productivity Score Card. Soil criteria is used almost exclusively; slope is referred to only as a characteristic of the soil. The most recent modification of the Storie method was published in 1962 by the University of Wisconsin. It consists of a chart for the agriculturalist to use in rating the productivity of his soil. Criteria such as stoniness, degree of erosion, texture, wetness, droughtiness, organic matter content, soil reaction, and available phosphorous and potassium are considered. Values from one to eight are assigned for each criteria (for example, a soil with a 2 to 4% organic content receives 6.5 points; a 4 to 6% content would receive a higher number of points). Totals are made for each field or soil group and a productivity measurement established. Scores which total over 75 are highly productive. Some physiographic and climatic criteria are also present (7).

The Storie method of rating soils is also a numerical scheme.

It was first published in 1933 and has been revised and modified by Storie himself, and other workers (as seen in the previous example). This system uses the soil profile characteristics to rate the soils. According to Storie, the classification is

> . . . a numerical expression of the degrees to which a particular soil represents conditions favorable for plant growth and crop production under good environmental conditions. In arriving at the relative index of soils three general factors are considered. These are (A) the character of the soil profile; (B) soil texture; and (C) other modifying factors, such as drainage, alkali, and other miscellaneous conditions. Each of these three factors is evaluated on the basis of 100 percent for the most favorable or ideal conditions. . . (44, p. 4).

He acknowledges that since only soil criteria are used, the classification system is not complete and does not totally evaluate the land. He is aware of the importance of climate, availability of water, transportation facilities, markets, and social conditions (44, p. 4). (Slope is included with soil criteria.)

The final rating of the soil potential, according to Storie, is made by multiplying each factor by the other two (A x B x C). This is advantageous as it allows any one factor to exert a limiting effect over the other two (44, p. 5). This is not possible with the scorecard system where values are only summed. A 1950 publication by Storie gives a synopsis of more recent developments in the system. He mentions four variations: the general soils rating, (which is similar to that just discussed,) a crop productivity system, a system for rating forest land, and one for grazing land. All four emphasize soil, however, not as heavily as the 1933 system. The most outstanding change in the first is the emphasis on slope as factor "C" and the addition of an "X", or miscellaneous factor, that is concerned with management. This includes such items as drainage, alkali level, nutrient level, acidity, erosion, and micro-relief.

The other three variations do not have a soil emphasis, and so will be discussed later. Generally they include additional criteria emphasis such as climate and yields. All are handled by the Storie method of multiplying factors to obtain a numerical rating (45, p. 336-339).

Another example of a modification of the Storie method of rating land is the system published by LeVee in 1951. The same kind of factor multiplication is used: he multiplies the soil profile rating with the slope rating, topography, the erosion rating, and the special factor rating (29, p. 3).

There are other land resource classification schemes that clearly emphasize soil, but include other orientations. A recent example was published in December, 1965 by M. E. Austin. This system is a qualitative one which, in addition to soils, has a physiographic, climatic, land use, and water availability criteria. These various criteria are used to regionalize the land of the United States according to its resource potential for agriculture, forestry, recreation, and other uses. The representative soil series within an area are the main soils criteria. The resulting regions are mapped at a scale of 1:1, 000, 000 (5, p. 1, 2).

Another land resource classification system that has more than one orientation is the U. S. D. A. Soil Conservation Service Land Capability Classification Scheme. This system is heavily oriented to soils; however, physiographic criteria, management, and yields are also important. Klingebiel and Montgomery say the following about this classification:

> [the system]...is one of a number of interpretive groupings made primarily for agricultural purposes... In this classification the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Nonarable soils (soils unsuitable for long-time sustained use for cultivated crops) are grouped according to their potentialities and limitations for sustained production of permanent vegetation and according to their risks of soil damage if mismanaged (27, p. 1).

The land capability classification has three levels of generalization. The first level is the capability unit which emphasizes yields and management of certain soils. The second level is the subclass. Here, the soil's limitations are grouped. These include erosion hazards, wetness, rooting zone limitations, and climate. The last of these is only used in a very generalized way and is not considered later in this paper when climatic orientations are discussed. The third level is the most generalized and classes the soils into eight capability units. Classes I through IV are suitable for producing agricultural crops, pasture, or forest. Classes V through VII are

> suited to the use of adapted native plants. Some soils in classes V and VII are also capable of producing specialized crops [fruits, ornamentals] . . . Soils in class VIII do not return on-site-benefits for inputs of management for crops, grasses, or trees without major reclamation (27, p. 3).

This classification is the basic forerunner of farm and ranch planning done with the assistance of Soil Conservation Service technicians within Soil Conservation Districts. The first two levels of the classification are essential for this planning work, to achieve the goal of placing each parcel of land in the highest order of use commensurate with maintenance or improvement of its capability (20).

The Soil Conservation Service, in cooperation with various state governments also has used the land capability classification system to produce a series of studies for rating the landscape. Two examples are the Hill and Powers, "Land capability for soil and water conservation in Oregon " (19), and the Parrott and Baker, "Land capability for soil and water conservation in Idaho" (34). These studies initially conducted on the county level, divide the state into drainage basins and rate and tabulate the amounts of land within each type. A colored map showing the distribution of land types is included in each work.

Between 1958 and 1961, as part of the National Inventory of Soil and Water Conservation Needs, the Soil Conservation Service Land Capability Classification was projected to cover the non-Federal agricultural lands of the nation. Data were published by states, including county and state totals, as well as in a national summary. The latter carried the misleading title "Agricultural Land Resources" (52).

Many other classification schemes contain a secondary soil emphasis with the primary orientation being perhaps genetic, climatic, or some other orientation.[5]

Climatic Emphasis

As stated earlier, a few land resource classification schemes use climatic criteria at all and fewer still have a climatic emphasis. One of these few is the system devised by M. K. Bennett to delimit Foodcrop Climates. Published in 1960, this system is on a world scale but is quite applicable to the United States. Bennett says that he does not classify climates for their own sake, but "according to their relative hospitality to production (unirrigated) of major food crops, . . . "(6, p. 285).

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[5] See references 2, 14, 15, 29 and 44. See also reference 54, pages 26-34, classification numbers 5, 7, 9, 12, 23, 24, 28, 30,51, and 57.

The climatic criteria that are used to delimit foodcrop climates are varied and include average temperatures, accumulated temperature, the number of frost free days, and the amount of precipitation (6, p. 285, 286). Throughout the world there are six different foodcrop climates, two areas where foodcrops are not grown, and one area above five thousand feet where the heterogeneity of climates makes mapping impossible. The six foodcrop climates are the summer drought, cool temperate, mild temperate, warm temperate, subtropical and tropical. (All but the tropical occur in the United States.) The non-foodcrop areas are either too dry for persistent cultivation of foodcrops (ten inches or less precipitation per year) or they are too cold (under 90 days frostfree). The foodcrop climates themselves are bounded by using the boundary criteria of non-foodcrop areas and various temperature criteria that are significant to the growth of the selected foodcrops (6). [6]

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[6] "We take as 'major foodcrops' typically those which nowadays yield relatively the largest quantities of dry matter edible by man; they tend also to occupy large acreages though not in proportion to dry matter produced because of differences in yield per acre. A defensible category of major foodcrops includes but is not necessarily limited to such starch crops as wheat, rye, rice, corn, barley, oats, millets, and sorghums, white and sweet potatoes, manioc, yams, banana-plantains; such pulse crops as various oil palms, rape, soybeans, peanuts, sunflower, cotton; sugar crops such as sugar cane and sugar beet; and flavor crops such as apples, citrus fruits, grapes, onions, and tomatoes. Cocoa, coffee, and tea may be included even though the last two provide no edible dry matter. Grasses cultivated for forage and important in agriculture, which

Bennett recognizes six temperature and three moisture provinces. The latter are subjectively defined according to production variations caused by too little, too much, or an ideal moisture supply. A slight genetic orientation is also included in this system. The 33 food crops selected all have certain genetic limitations which were important in selecting the temperature limits for the various temperature provinces (6).

Three other classification systems that were examined also had a climate criteria emphasis. One of these was discussed by LeVee. He says that the Soil Conservation Service in New Mexico is using a land capability classification that uses the effectiveness of the annual precipitation and the spatial distribution of precipitation throughout the state. He says that

> According to that method, the climatic zone number is also the number of the highest capability class that would be recognized within a zone except for the limited cases where the moisture available to crops is greater than it is for the zone as a whole (29, p. 12).

This system is based on the regular Soil Conservation Service classification. For example, a soil that has an "excellent" rating is placed in a Class III rating if the climatic rating is Class III. In the regular Soil Conservation Service capability classification, climate is

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have a wider climatic range, are not here regarded as major food-crops; they do not provide food directly edible by man although indirectly they provide animal foods" (6, p. 286).

considered only as a special factor of limitation--and that in a very general manner.

The Storie index for rating soils was discussed previously; however, the method for rating soils for timber (an agricultural activity in the United States South) also uses climate as one of the rating factors. Rainfall, temperature, and aspect are included in the criteria. This was the only form of the Storie index found where climate played a part (45, p. 337).

Probably the earliest example of the use of climatic criteria in land resource classification systems is the scheme devised in 1898 by C. Hart Merriam. This system, published by the United States Biological Survey, was based upon studies of native plant and animal life. Using these studies, Merriam defined a number of life zones or agricultural belts, and listed suitable crops for each (32, p. 13). The boundaries of these zones or belts were subsequently defined by climatic criteria for expediency (32, p. 54). In some senses this study is a precursor to other land resource classification systems. By looking at the variety of crops which are suitable for the various zones, we can get a good idea of the agricultural land resource potential at a particular place, exclusive of soil differences (32). The zones of agricultural importance in the United States are the Canadian, Transition, Upper Austral, and Lower Austral. Three others, the Arctic-Alpine, Hudsonian, and Tropical, are not important. The first two are too cold for agriculture and the last is found only in equatorial regions (32, p. 18-53). Each of the boundaries is defined as follows:

Table 1. Governing temperatures of the zones.

Regions	Zones	Governing temperatures			
		Northern limit		Southern limit	
		Sum of normal mean daily temperatures above 6°C. (43°F.).		Normal mean temperature of six hottest consecutive weeks.	
		°C.	°F.	°C.	°F.
Boreal	Arctic	--	--	10[1]	50 [1]
	Hudsonian	--	--	14[1]	57.2[1]
	Canadian	--	--	18	64.4
Austral	Transition	5,500	10,000[2]	22	71.6
	Upper Austral	6,400	11,500	26	78.8
	Lower Austral	10,000	18,000	--	--
Tropical		14,500	26,000	--	--

[1]Estimated from insufficient data.
[2]The Fahrenheit equivalents of centrigrade sum temperatures are stated in round numbers to avoid small figures of equivocal value.
Source: (32, p. 55).

Other land resource classification systems have varying degrees of climatic orientation. Generally, however, this orientation is not specified in detail.[7]

[7]See references 5, 7, 24 and 29. See also reference 54, pages 26-34, classification numbers 30 and 67.

Biotic Emphasis

Only a few land resource classification schemes emphasize primarily biotic criteria, such as native vegetation, animal life, and the grazing capacity for domesticated animals. The most recent example is a 1950 rating scheme by Storie which uses the carrying capacity (cow-acres) of each soil type. Here, soil criteria is only the frame of reference on which the system is based. The example given, which is for California upland soil types, identifies six classes of grazing suitability. The soil types vary in their physical features, and this is reflected in the type of vegetation cover (climate is another factor). If the vegetation is luxuriant, there is a high carrying capacity and gradations of vegetation below this level have a correspondingly lower capacity. Ranges within each class are as follows (45, p. 338):

Class I, (Very Good) = 12 acres or less per cow

Class II, (Good) = 12 to 18 acres per cow

Class III, (Fair) = 19 to 30 acres per cow

Class IV, (Poor) = 31 to 48 acres per cow

Class V, (Very Poor) = 49 to 72 acres per cow

Class VI, (Extremely Low) = 72+ acres per cow

According to Nunn, a similar rating system is used in Montana. Here, the base is "the number of acres needed to graze a 1,000-pound steer during a ten-month season for grazing land" (53, p. 336).

In 1948 Weeks described the criteria used in the range surveys conducted by the Bureau of Land Management. He says that not only is the grazing capacity considered, but also the forage value of various species and the type of management used in the area (56, p. 174).

In an earlier classification scheme by Kellogg and Ableiter, the biotic criteria is used along with soil and physiographic criteria to assay the natural capability of a parcel of land. In order to evaluate lands that are to be used for grazing, the amount of grass cover is measured. This information is added to the slope designation. Strongly rolling or steeply sloping hill land is classed as either D or E in the overall system. For example, if there is over 95% grass cover, the rating remains D or E. From 75 to 95% grass cover is indicated by D_1 or E_1 and from 50 to 75% cover, the symbol is D_2 or E_2. If less than 50% is covered by grass, the rating becomes "rough and broken land," which is regarded as having no important vegetative cover (23, p. 283-286; 24, p. 10, 11).

The complete rating of the land under the Kellogg and Ableiter scheme (using vegetative, soil, and physiographic criteria) is actually a subjective and qualitative rating based on an ideal numerical value of 100%. Extended observation and analysis by people familiar with the area in question constitute the method by which individual percentages are arrived at (24, p. 13).

One final example of the use of biotic criteria in land resource classification systems is the old scheme developed by C. Hart Merriam. Although we have seen that the system is largely oriented toward climatic criteria, the original basis, according to Merriam comes from "the study of the geographic distribution of our native, or indigenous, fauna and flora. . . " (32, p. 13). For additional systems that also utilize biotic criteria refer to reference 54, pages 26-34, classification numbers 16, 28, 57, and 60.

Physiographic Emphasis

None of the land resource classification schemes investigated have a single or dominant physiographic emphasis. There were, however, many systems that included physiography either as one of several emphases, or as a minor one. As was mentioned earlier, slope information is often integrated with basic soil data. The most recent classification scheme found that had a physiographic emphasis, was the one by Austin (1965). Here, both elevation and topography are a part of the qualitative rating scheme. Both of these categories of information (along with others) are used to regionalize the United States. For example, in the Willamette and Puget Sound Valley region the elevation ranges from sea level to 1500 feet and the topography is a gently sloping to level plain. This type of classification differs from most in that the final productivity rating of the region is left to the judgment of the individual reading the system. The facts are there and must be interpreted (5, p. 1-3).

A quantitative system of soil productivity which was discussed earlier is the scorecard method of Burger and Hole. In this system, slope is one of ten criteria that are used to rate the agricultural potential of the land. There are four possible categories of slope. The steepest slopes, (over 15%), are given zero points. Slopes from 8 to 15% are given one point, from 4 to 8%, six points, and level land, 0 to 5%, receives eight points. These are added to the other values given to a field to make up the total field rating (7).

The slope of the land is an important consideration also in the 1951 proposal of a land resource classification system by LeVee. His scheme uses a modified Storie method; a slope rating constitutes one of the major factors that is multiplied to obtain the total land rating (31, p. 3). (This is a percentage assigned to various slope values.) LeVee says

> Slope is evaluated from the standpoint of the ease or difficulty of holding soil in place and handling the land. No attempt has been made to evaluate the affect of slope on air drainage (31, p. 1).

Kellogg and Ableiter, who quantitatively rate land, have five groupings under the heading of "lay of the land" or physiography.

> A. Nearly level to level land on which external drainage is poor or slow. About 0 to 2-1/2 percent of slope.

B. Gently undulating land on which external drainage is good but not excessive and where there is very little erosion. All types of ordinary agricultural machinery may be used, but with difficulty for the heavier types. There is some likelihood of water erosion with intertilled crops. About 7-1/2 to 15 percent of slope.

D. Strongly rolling land on which agricultural machinery cannot be used. External drainage is rapid, but a good grass cover usually maintains itself. About 15 to 25 percent of slope.

E. Steeply sloping and hilly land with such excessive external drainage that grasses are not well supplied with water. Frequently these slopes are partly barren of cover... More than 25 percent of slope (24, p. 10).

Kellogg and Ableiter also say that the individual class boundaries may vary within the area being classified. The example they give is the Palouse country of Washington where special machinery can use slopes greater than 50% (24, p. 11).

In most of the other land resource classification systems, physiography is one of several emphases. Three examples of this are the Soil Conservation Service Land Capability Classification (27, p. 4), the Parrot and Baker classification for Idaho (34, p. 14), and the system devised by Moon (33, p. 490).[8]

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[8] See reference 54, pages 26-34, classification numbers 5, 7, 9, and 24 for additional schemes with a physiographic orientation.

Genetic Emphasis

There are many land resource classification systems that have an orientation to genetic criteria. Generally, it seems that the genetic emphasis is always paired with one or several other orientations such as soils and genetics, or genetic and cultural criteria.

A recent scheme that could be said to have a genetics criterion is the one by Bennett (1960). Although climatic criteria define the boundaries of the different foodcrop areas, the original choice of temperature and moisture conditions stems from the consideration of significant limiting temperatures of the plants chosen as foodcrops. The classification was set up within the genetic capability range provided by these plants. Because the presentation map is small scale, improvements in genetic potential of a particular crop such as wheat would not appreciably affect the classification system; however, if the system were to be made applicable on a larger scale, differences would be evident (6, p. 285).

In 1959 the soil survey staff of Kingfisher County, Oklahoma, published a table of yield estimates and ratings o. soil types according to productivity. (Physiography and management are also considered.) The number of bushels or tons per acre of seven crops (wheat, oats, barley, grain sorghum, forage sorghum, alfalfa, and mungbeans) were used as criteria in the classication (25, p. 1, 5). The crops selected for this and other productivity ratings are generally grains and grasses. According to Marbut, these are the most important crops utilized by man (31, p. 291). Grains and grasses also make up a large part of the foodcrops listed by Bennett (6, p. 286).

Yields are incorporated into the system for reclassifying Montana lands for tax purposes (the classification has an economic orientation however, only the physical basis of the system is of interest). This classification system is based on the number of bushels of wheat that can be harvested on a particular field. There are five rating grades for non-irrigated land. Number One has from 22 to 24 or more bushels per acre, Number Two ranges from 16 to 21 bushels per acre, Number Three ranges from 12 to 15 bushels per acre, Number Four, from 8 to 11 bushels per acre, and Number Five, under 8 bushels per acre. Here, only yields are considered, and soil and other information do not enter in the productivity rating, the expression of the genetic potentials caused by varying environmental conditions of the strain of wheat selected is significant (14, p. 81).

Nunns writes that the University of Nebraska used estimated yields per acre of corn, wheat, oats, alfalfa, and pasture to rate various soils and land (53, p. 363).

In 1950 Ableiter and Barnes wrote about determining the potential productivity of well-defined local (farm size or smaller) soil types. This productivity can be indicated by the amounts of predicted yields of the soil types under specified systems of management (3, p. 363). In the example rating table for Tama County, Iowa, corn, oats, clover, timothy, and alfalfa, make up the chosen crops. The genetic capability of strains of these crops influences not only the tolerance to environmental conditions and resulting yields, but also the response of a particular crop to the system of management used (3, p. 361).

Storie's classification, which uses yield data, rates the soils and the suitability of specific crops for the individual soil type. He states that depending on the soil conditions and how it is managed, a crop may have several ratings for each soil (45, p. 337).

Additional examples of systems with a genetic emphasis are similar to those cited and it serves no further purpose to continue to discuss examples. A few more schemes with a genetic orientation, however, are found in references 1, 29, 31, and 54. In the last citation see classification numbers 43, 51, 57, and 60 on pages 26-34.

Cultural Emphasis

The cultural criteria of management types, agricultural technology, marketing data, and transportation linkages are important in land resource classification systems in two ways. 1) They are essential to establishing the values of criteria used in the classification schemes. (For example, if the yields of a crop or group of crops are used to classify a soil type, then it is important to know and understand the type of management or lack of it that produced the yields.) 2) Cultural emphasis is also used as a secondary factor within many classification systems.

An example that shows both types of cultural orientation is the Soil Conservation Service Land Capability Classification. In this system, the smallest category of grouping is the capability unit which is defined as "... a grouping of soils that have about the same responses to systems of management of common cultivated crops and pasture plants" (27, p. 3). This is an example of the use of cultural criteria as a secondary factor in classification. The capability unit represents a simplified and condensed soil grouping. The other two levels, the capability subclass and capability class, are higher levels of generalization about the soil types (27, p. 2). Also, in this classification scheme, the cultural criteria is used as a reference frame. One of the assumptions that must be made before the land can be rated is that a moderately high level of land management exists. "The level of management is that commonly used by the reasonable men of the community" (27, p. 4).

In the system used to determine the estimates of yields in

Kingfisher County, (see additional discussion under "genetic" heading) the criteria of management level is important. Two levels are defined, which, of course, affect the resulting yield data. The lowest level of management is "customary management (A) and is defined as those practices followed by most of the farmers in the county. . . " (25, p. 3). This includes such items as proper seeding rates, planting dates, recommended crop varieties, weed and insect control, and so on. The second level, "Improved management level, (B) is defined as those practices that are designed to alleviate the limiting factors of crop production" (25, p. 4). Management practices such as application of lime, drainage, and soil conservation methods used to counteract some fault in the land, are grouped under this category.

The system of Ableiter and Barnes, discussed under "genetic criteria," uses the management system on a piece of land (as well as the soil types) to estimate average yields per acre. Crop rotation, application of fertilizers, and necessary engineering aids other than grass waterways are mentioned. This enables the farmer to estimate the productive potential of a certain soil under a specific type of management (3, p. 361).

Land resource classification systems that measure the physical productivity potential of lands that are to be irrigated, often use some cultural criteria. Most systems of this type, however, are not physical land resource classification systems because the cultural criteria are weighted heavily. A borderline example is the Bureau of Reclamation's classification scheme whose purpose is stated as being

> . . . conducted for the specific purpose of establishing the extent and degree of suitability of lands for sustained irrigation. Suitability as herein used connotes a reasonable expectancy of permanent, profitable production under irrigation. It is measured in terms of anticipated relative payment capacity by consideration of potential productivity capacity, costs of production and costs of land development (48, p. 2. 1. 1).

In this classification, the economic factors are used to assay the dollar value of the physical setting. The differentiation of various land classes are primarily made by soil factors, topography, and drainage. Supposedly, other factors such as climate are used; however, in practice, this is not done (48, p. 2. 4. 1). Four classes are identified: land in the first three has decreasing ability to repay costs of development, and class IV comprises lands that have excessive deficiencies of one or more physical factors (48, p. 2. 5. 1).[9]

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[9] See reference 54, pages 26-34, classification numbers 5, 7 9, 12, 16, 23, 28, and 51.

IV. CONCLUSIONS

The ultimate aim of any land resource classification system should be the provision of a devise for ordering the occupance patterns of the landscape in the United States. This means that classification systems must be objective and comparable on both large and small scale, if we are ultimately to know accurately the quantity and quality of the types of land we possess.

After reviewing the various land resource classification systems for the United States, two conclusions can be drawn. The first of these is that there is a disproportionate emphasis placed on soil and genetic criteria over climatic, biotic, and physiographic criteria. This is probably because soil and productivity data are measured and incorporated into a scheme for rating the use potential of the landscape for agriculture with greater facility than climatic and biotic data.

The biotic emphasis, as previously stated, could be more useful as an indicator of site conditions if the climax, subclimaxes, and seral stages of natural or disturbed vegetation were rated. Also the physiographic criteria of slope aspect is needed in addition to slope steepness, which is often the only physiographic element considered.

The second conclusion that can be drawn is that there seems to be a tendency for classification systems to be subjective rather than quantitative. In the initial stages of research for this paper many qualitative schemes were located and much sifting was required to turn up any quantitative systems. Because land resource classification systems have a disproportionate soil and genetic emphasis and tend to be qualitative, and because there is a wide range of scale in the basic measurements for each criteria (thus making some data non-comparable) the usefulness of most schemes is limited. In fact, a majority of systems for classification are useful primarily on a local level because they omit information such as detailed climatic criteria which would make the classification applicable to a state or multi-state area. Such classifications are inherently unsuited for use in evaluating the land resource basis of the entire nation.

These conclusions, then, indicate two areas of need that must be fulfilled if land resource classification systems are to attain their optimum usefulness. First, there is a need for immediate action to improve classification criteria. Most of the land systems were developed in the 1930's and late 1940's, thus they do not incorporate new knowledge of growth requirements of plants and animals or of the environmental relationships involved. Classifications are needed now that use this recent information, because of man's increasing competitiveness for space within an already acculturated environment. Classification should precede development.

The second need involves the development of widely applicable classification criteria. There need to be systems developed that consider all criteria that measure the multivariate environmental complex. This is a present trend; however, it must be carried still further, particularly on the quantitative level. For example, climate should be better integrated into land resource classification schemes using data that are of comparable scale to soil and genetic data. Microclimate data is being improved, but it should be extended.

The system which is most widely used to classify land in the United States is the Soil Conservation Service Land Capability Classification. This system, while useful in management planning and conservation effectuation to maintain or improve the land resource base of a site, is not useful for generalization on a nationwide level. Like other systems, it only rates the potential of the land under one set of environmental and biotic conditions. Thus results from different regions of the United States (different bioenvironmental conditions) are not comparable. For example, Class I land in Montana is not the same in biotic potential as Class I land in the Imperial Valley of California. Also, tabulations of national or even state acreages of the various land classes are misleading because land under each class varies from region to region.

Population growth and the finite spatial limitations faced by this and other nations make it imperative to develop a sound system to evaluate land on local, state, regional, and national levels. Although such an ideal may be difficult to achieve, it must be strived for in order to assure the ordered use of the finite land space of this growing nation.

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