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LAND CLASSIFICATION

FOR LAND-USE PLANNING

by

G. V. JACKS

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LAND CLASSIFICATION
FOR LAND-USE PLANNING

Land Classification and Land-use Planning

Land classification in the sense here used relates to the grouping of lands according to their suitability for producing plants of economic importance. Such land classification must form the starting point of land-use planning, which is very much in vogue at present, although few land-use plans based on systematic land classification have been put into operation. As we shall see, there is no sharp distinction between land classification and land-use planning, and sometimes it is necessary or convenient to initiate a plan before a classification is made. Land classifications group lands according to their native characteristics, present use, yield capacity and so on [6], and these classes are then assessed with reference to their suitability for the different uses contemplated in the plan. Classification for land-use planning may be purely qualitative—lands being classed according to their suitability for different kinds of use rather than according to their inherent or man-made productivity—or quantitative, when estimates are made of the relative productivities of different classes of land under definite uses.

A land classification for planning purposes must be related to the objective of the plan. "The foremost essential in a possible list of Essential Elements in Land Classification" wrote Schoenmann [75] ".should be a clear and complete definition of why the proposed classification is needed and how it will be used when completed." "The first requirement for the successful development and application of any technical system of land classification" wrote Kellogg [45] "is a clear understanding of the problems for which the classification is needed." According to such statements it might be concluded that no general principles of land classification can be propounded, and that every land-use plan requires an *ad hoc* classification.

It can, however, be stated that every land-use plan—except, perhaps, in countries fully developed economically and socially—for exploiting the agricultural and forest resources of a region for the lasting benefit of the occupiers must be based on the conservation of soil fertility. Plans can, of course, be made for the rapid exploitation of the capital resources of the land, but even under the stress of war none has been proposed with this objective. It may be assumed that nearly all the kinds of land-use plan with which we are here concerned have a common primary objective—soil conservation. They may have very different secondary objectives relating to the ways in which the land can be exploited for the benefit of the occupiers, but these secondary objectives are dependent on the attainment of the common primary objective.

The United Nations Conference on Food and Agriculture that sat at Hot Springs, Virginia, in 1943 made certain recommendations for the long-term organization of agriculture that may be taken to reflect the common aspirations of land-use planners everywhere [92]. The Conference recommended, *inter alia* :

(a) that the inherent natural and economic advantages of any area should determine the farming systems adopted and the commodities produced in that area ;

(b) that farming systems should be so designed as :

(i) to maintain soil fertility at levels which will sustain yields and ensure adequate return for labour ;

(ii) to protect crops and livestock from major pests and diseases ;

(iii) to favour steady employment throughout the year ;

(these three ends, in general and save in exceptional circumstances, can best be assured by balanced mixed rotational farming and by avoidance of single-crop production, or monoculture ;)

(c) that production of nutritionally desirable foods which can be obtained from elsewhere only with difficulty or not at all is a special obligation of the agriculture of every country ;

(d) that in every region subject to drought (occasional or in the form of sharply marked periodic dry seasons) suitable measures should be undertaken, partly by storage and partly by diversification of production and development of water resources and cultural practices ;

(e) that land used or likely to be required for agriculture should be protected from erosion ;

(f) that the spread of existing knowledge by education and the development of new knowledge by research should be constantly promoted, and that in these matters nations can co-operate to great advantage.

Nearly every objective in this list requires, directly or indirectly, the maintenance of soil fertility. In one region the emphasis will be on, say, the control of erosion, in another on the maintenance of continuous employment, but the different aspects are interdependent ; steady employment helps to sustain the public interest without which soil-conservation measures are likely to fail in their purpose. The planner and land classifier, however, will usually concentrate on the predominant factor in land utilization, but will not forget the others.

The purpose of land classification for land-use planning has been described as to determine " the types of production, use and service that can be obtained from the land that will yield the highest social and economic benefits to the people dependent thereon " [12], or " the uses of land that are the best for all of us together, that is, for the general public " [6]. Its function is to present " the best known facts about land use that in turn would be of assistance to the people on the land in making decisions for themselves " [12]. It matters little what social, economic or political goal the planner has in view. In the United States land-use plans are made on the assumption that they will operate in an individualistic, competitive

society, in Russia on the assumption that they will operate in a state-controlled, communistic society. In each case a different path must be trodden to reach the desired goal, but whatever the form of society aimed at, the land must be used in such a way that its fertility is at least maintained, for no form of stable society can persist long in a deteriorating environment. Land classes for land-use planning purposes, therefore, must be distinguished primarily by the different uses to which they can be put without losing, or by the different measures which must be taken to conserve, their fertility. Soil conservation is the physical objective of all agricultural land-use planning, and provides a common basis for the formulation of certain general principles of land classification. Every land-use plan is essentially a measure of soil conservation. When it is nothing else the corresponding land classification is comparatively simple, for the criteria for distinguishing land classes are merely the characteristics significant for soil fertility; but when the land-use plan has, as is usual, some other specific object such as the production of a certain crop, regional self-sufficiency, the liquidation of debt, the development and use of water power, the establishment of commercial farming, or what you will, then a special *ad hoc* system of land classification has to be devised for each objective, and no general principles can be laid down.

Land classification for land-use planning is therefore based primarily on soil-fertility characteristics, and secondarily on whatever characteristics of the land are significant to the specific objective of the plan. For example, the specific objective might be to develop a perishable crop which requires immediate transport to the consumer. Here roads and railways would be important characteristics in land classification, but the basal classification would still be a fertility classification indicating which areas would safely and successfully produce the crop in question, and which should be devoted to alternative uses. There is no relationship between the two sets of characteristics—the physical, chemical and biological properties of the land on the one hand, and the available transport facilities on the other. Two (in many actual cases, several) distinct classifications are involved which have to be combined into one. This is one of the main reasons for the indefiniteness of many land classifications; they are compounds of several which are not necessarily interrelated.

It is usual to distinguish between the physical, and the economic and social, classification of land. Kellogg and Ableiter [46] and many others insist that the physical must be considered quite separately from the economic and social characteristics of land. The physical or "inherent" characteristics include the geology, climate and topography and are permanent in the sense that they cannot be profoundly altered by man. Geology, climate and topography are combined in the factor soil which, though to some extent modifiable by man or other living organisms, is the main factor in a physical classification. A physical land classification is permanent, and once made can serve as the basis on which to superimpose an economic and social classification which will need to be modified with

changes in economic and social conditions (e.g., market conditions and communications) as well as with the changes in the objective of the plan that may occur as the plan unfolds. Soil fertility, however, as distinct from the separate physical factors that comprise soil, is not immutable. Man can easily change the level of fertility up or down, but whether or not he does so is determined mainly by economic factors. In theory, every soil can be brought by appropriate measures to the optimal state of fertility, but in practice the application of the required measures is often limited by economic factors. The Sahara could be made fertile by irrigation and manuring, but it would not pay. Chemically and physically poor sandy soils might be classed as suitable for intensive market gardening if favourably situated with regard to markets and supplies of manure, but quite unsuitable if market facilities were poor or costs of manure were high. The significance of these factors will vary continuously with the social and economic development of the country or region.

Soil fertility thus has as much claim to be considered an economic as a physical characteristic of land.

Much of the work on land classification has been carried out by economists. As we are writing primarily for the agriculturist we shall approach the subject more from the agricultural than from the economic standpoint, but it is important to recognize that the determination in practice of optimal land use is essentially an economic problem. In the last analysis the success of any land-use plan depends on its economic soundness. Gray and Regan [27], writing as economists, state that: "Land classification is aimed at determination of economic best use from both the entrepreneurial and the social standpoints; although the best use of land does not imply ignoring the best use of the other factors of production.

"An important task in land classification is determining the advisability of the advance, the continuance, or the retreat of agriculture—or in conventional terms, the location of the extensive margin of cultivation;—for the one or the other of these trends has important implications with respect to institutional patterns, capital and debt structure, public finance, and numerous other considerations."

Astor and Rowntree [4] distinguish between the optimum and maximum fertility level of an agricultural soil. Optimum fertility levels are determined by the ratio between input (i.e., total costs of production) and output (i.e., total sales). They vary not only between one crop and another, and one soil type and another, but also between the same crops and soils in different localities. Maximum fertility is determined simply by yield, either yield per plant or yield per acre, and the weight of the crop is not always as important as the quality.

The factors to be taken into account in an economic and social classification will vary both as to their nature and the weight to be attached to each, with the social objective of the plan. In some instances markets, in others communications, in others tradition and custom, in others political

questions may constitute the dominant factor, and there will always be many variable and fluctuating subsidiary factors. Veatch [97] includes among the essential economic data uses of land, kind of ownership, land values, transportation facilities and markets for present and potential products; and among social data, distribution and kind of population, both rural and urban, and economic status (standard of living) of rural classes. Allin [3] includes among the land-use factors which must be taken into consideration in America " such things as the passing of the physical frontier, the change of this nation from a debtor to a creditor status, the loss of foreign markets, the approach to a stable population, and the evident conflicts that have arisen in our economy between capital and labor." By its very nature social-economic land classification must be labile and indefinite.

In undeveloped country where the social factor has not operated appreciably, a physical land classification is applicable without great modification to land-use planning. Indeed, the purpose of land-use planning in such countries is to avoid the costly trial-and-error process of crop adaptation that has hitherto prevailed. The idea is, instead of planting a crop on inferior land because it is near a railway, to plant it on the most suitable land and then bring the railway to it. In long-settled countries the social-economic factor tends to predominate in land-use planning. Land use has largely adapted itself in the course of time to the physical environment, and any planning that may be thought necessary is concerned mainly with adjustments to changed social and economic conditions.

A land-use or " use-capability " classification, if it is to have permanent or long-term validity, should also allow for probable developments in technique and science, e.g., the production of frost-resistant crop varieties, new kinds and sources of fertilizer, new methods of cultivation [25]. Land in England that until recently was commonly regarded on account of its heavy texture as permanent-pasture land proved itself during the war to be first-class arable land easily cultivable by modern machinery. But although a classification should allow for such developments they cannot, of course, usually be foreseen.

It is, in fact, impossible to forecast with any accuracy either economic or scientific developments, and a practical land classification which takes them into account must necessarily be vague. " There is ample evidence " writes Hudson [39] " that the end product of land classification consists largely of ascertaining trends in land use within definite areas and that the function of land-use planning agencies is to facilitate and direct these trends towards a definite goal rather than to impose some preconceived land-use plan. The goal towards which land-use trends is guided is . . . ' the utilization of lands for their greatest value'."

The nature of land-use planning is described by Lilienthal, writing of the T.V.A. plan to develop the land and resources of the Tennessee Basin [49].

> In the unified development of resources there is such a Great Plan: the Unity of Nature and Mankind. Under such a Plan in our valley we move forward. True, it is but a step at a time. But we assume responsibility not simply for the little advance we

make each day, but for that vast and all-pervasive end and purpose of all our labors, the material well-being of all men and the opportunity for them to build for themselves spiritual strength . . . .

Not one goal, but a direction. Not one plan, once and for all, but *the conscious selection by the people of successive plans*. It was Whitman the democrat who warned that " the goal that was named cannot be countermanded."

If this conception of planning is sound, as I believe, then it is plain that in a democracy we always must rest our plans upon "here and now," upon "things as they are." How many are the bloody casualties of liberal efforts to improve the lot of man, how bitter the lost ground and disillusionment because of failure to understand so simple and yet so vital an issue of human strategy. So frequently have men sought an escape from the long task of education, the often prosaic day-by-day steps to "do something about it," by pressing for a plan—usually in the form of a law—without considering whether the people understand the reason for the law's plan, or how they are to benefit by it.

An unwillingness to start from where you are ranks as a fallacy of historic proportions; present-day planning, anywhere in the world for that matter, will fall into the same pit if it makes the same gigantic error. It is because the lesson of the past seems to me so clear on this score, because the nature of man so definitely confirms it, that there has been this perhaps tiresome repetition throughout this record: the people must be in on the planning; their existing institutions must be made part of it; self-education of the citizenry is more important than specific projects or physical changes.

The points made by Lilienthal are worth emphasizing. Firstly, that a land-use plan is dynamic; it changes as it unfolds. We can see the goal—the highest attainable level of fertility—but we are lucky if we can see more than one step forward at a time. Secondly, that the people must play as intimate a part in the execution of the plan as the crops and animals they tend. This is a political matter; a people controlled by an autocrat is a more pliant agent in executing a plan than a nation of individualists. Thirdly, that the present state of society should determine the next step forward. Here again, an autocracy can take greater liberties than a democracy, but whatever the polity an appreciation of the facts of human ecology is essential.

There are not enough examples of successful land-use plans to enable us to dogmatize upon whether " the people must be in on the planning ", but the evidence available—mainly from the United States—indicates that the active, as distinct from the passive, participation of the people in all the operations can be a decisive factor in assuring success. If the people are to participate actively they must understand what is being planned, and they must understand the land classification on which the plan is based. Several writers have stressed the importance of having a system of land classification that is crystal-clear to the ordinary layman. Such a system is not likely always to satisfy the taxonomic pundits; but from the practical standpoint more is usually gained than lost by using a classification which does not need, and sometimes will not bear, thinking about. A unique feature of land-use planning is that the people not only make and execute the plan, but themselves constitute one of the chief things to be planned.

Gross [28], in an analysis of the failure of the nation-wide county land-planning programme launched in the United States in 1938 by the

Mount Weather Agreement, attributed failure in the first place to the fact that no desire to solve community and county problems was created in the population of the areas in which the planning programmes were to function. " Experts can work out beautiful expositions of problems, they can present exclusively alternate solutions, but unless a self-interest to achieve these results is established, the expensive work of the expert has little or no value." In Gross's opinion the prime task of the land planner is not to solve certain immediate problems, but to develop a community determination to solve them. It is a task which the experts in geography, agriculture, soils, economics and so on are not always qualified to perform. If county land planning recovers from its present demise the specialist in a future planning organization " should be made cognizant of his purely advisory capacity."

That land-use planning is essentially an exercise in human geography is obvious. It is an exercise to the performance of which many non-geographical sciences have much to contribute, but the approach to it must remain geographical. Colby [16] distinguishes four phases of the land-planning process (1) survey and classification, (2) appraisal, (3) design, and (4) effectuation, and gives the following description, taken verbatim from his paper, of a geographer's approach to it.

> The survey and classification phase of land planning calls for a critical examination of the occupance pattern as it is to-day. For this work, the topographic and other customary maps and the census and other statistical materials are useful, but they do not deal with all of the features and conditions which in association make up the occupance pattern. Such maps and materials, moreover, are not sufficiently detailed, for as McMurry has pointed out, "as soon as land planning work leaves the theoretical plane, and the problems assume practical application minute detail is essential." Land planning requires an analysis in map and other forms which distinguishes the component elements in any part of the occupance pattern separately or in their relation to the whole. Fortunately, two recent advances in technique make this practical. Aerial mosaics, the great contribution of air photography to mapping, provide the base. Site analyses, recorded in the fractional code, an analytical technique developed co-operatively by geographers in the last decade, furnish the primary materials. When once these materials are in hand classification of the associated elements or of any individual elements becomes possible.
>
> Detailed site analysis has the disadvantage of being too slow and costly for many types of land planning. In attempting to solve this problem, experiments have been tried with the sampling method, the traverse method, and the unit-area classification. In the sampling method, sample surveys are made at either planned or random intervals. In the traverse method, the surveys follow lines or strips across the area under examination. Both of these methods involve perplexing statistical questions. The unit-area type of work contains an element of classification as well as analysis. For the writer, the idea of unit-area classification carries back to a field conference in 1925. At that time I became hopeful that we might be able to perfect a technique by which one could recognize the entity of any point or area and then map that entity as far as it extended. The idea was tried out in rapid traverse work over long distances with some success and was reported at a meeting of the Illinois Academy of Science in 1933. In the past year further experiments with the method were set up but the results were unsatisfactory until the problem was allocated to the geography section of the Tennessee Valley Authority. After some experimentation, the men of this section learned how to combine the idea with the aerial mosaic—site analysis technique. The site was widened to an

appropriate area, classification was added to the analysis and the unit-area type of land classification became a reality.*

The second phase of land planning calls for an appraisal of the occupance pattern in order to discover its points of strength and its points of weakness. This involves a study of the spacing of individual elements in the pattern and the relation of each individual pattern to the composite pattern. It also demands that proposals for changes in any individual pattern be weighed as to the probable effect on other individual patterns and on the composite pattern. The ramifications of this type of work are many. It leads to investigations of the assets and liabilities of any area for particular uses. It asks if particular sites are deteriorating under use, and if so how rapidly. It implies analyses of slope and soils of a new degree of intensity. It calls for much greater knowledge of climates of slopes and thermal belts than we have at present. In this connection practical experience is placing in action some of the investigations advocated by the Mississippi Valley Committee, or by the Land Use Committee of the Science Advisory Board. This phase of land planning also studies the adjustment or cultural features to natural features, seeking areas or points of satisfactory or of unsatisfactory adjustment. Finally, land planning raises the all-important question as to whether or not the occupance pattern in its present status serves and promotes the physical and social welfare of society. Many of these questions call for painstaking research on the part of geographers or other scientists. Some call for evaluation by men of long experience in business. Land planning does not care who does the work, but it does care greatly for the results.

The third phase of the planning process is that of design or active planning for the attainment of stated objectives. In land planning this means the formulation of a design for the development of a progressively better occupance pattern. Design begins with a preliminary intellectual conception of something to be done or produced. It implies a penetrating knowledge of the existing occupance pattern and a full understanding of the objectives to be attained. In the acquisition of this knowledge, geography, as we have seen, plays a highly important part. It may be assumed, and we have some evidence to support the assumption, that the momentum of understanding gained by geographers during the survey, classification, and appraisal phases will enable them to make valuable contributions in the formulation of the design. Purposive planning, after all, may be thought of as the formulation and prediction stage of a sequence of scientific exploration. In land planning the sequence includes observation, analysis, classification, appraisal, formulation and prediction. Geography, with its contributions to the early stages of the process, may be expected to contribute significantly in the later stages.

Land planning by its very nature may be expected to introduce a rational element into social planning. Land planning, like geography, insists on the areal concept. It demands that the social structure be held in its physical setting. It strikes at reality and tends to hold reasoning within a rational frame of reference. It is the intelligent application of the principles of geographical science and other sciences to the problems and interests of society.

In the final phase of the planning process, that of effectuation, geographical science has, as far as I can see, little or nothing to offer. The question of putting plans into effect is a matter of administration and rests on the interest and desire of the general public. The men who administer planning programs need not be scientists; in fact, it is better if they are not interested in promoting a particular science. They do need to be, however, administrative artists in applying the findings of science to the solution of problems of public welfare.

The best known and probably the most successful land-use plans in operation are those of the American soil-conservation districts. In July, 1945, 3,404,000 farms covering 734 million acres were included in the 1,328 soil-conservation districts which had then been set up [78]. The prime objective of every soil-conservation-district plan is the same—to save the

* See p. 47.

soil from exhaustion and erosion. Quite a simple physical classification, defining land in terms of its erodibility, suffices as the basis of the plans (see p. 42). Social and economic factors do not enter into the land classification, but they do enter into the effectuation of the plan, and may necessitate modifications in the " ideal " plan based on strict adherence to the physical land classification. The plans are made and carried out by the occupiers of the land themselves who can call upon outside experts to give advice and direction, if required.

Bennett [8] states that the guiding principle of the Soil Conservation Service in planning land use has always been that the effective prevention and control of soil erosion and the adequate conservation of rainfall require the use and treatment of the various kinds of land, each according to its special needs and capabilities.

In applying this general rule, however, it must be borne in mind, firstly, that the use and treatment of any land are determined not only by physical characteristics, but also by such factors as available facilities—implements, power, labour, finance—and the preferences, skill and intelligence of the occupier. The occupier, as well as his land, may require " treatment".

Secondly, each parcel of land has to be considered in its physical relation to adjoining land; optimal use of high-lying land may be determined as much by the use of the lower-lying land as by its own physical characteristics.

Other examples of land-use planning according to a land classification are afforded by some Russian collective farms (kolkhozes). These plans have to fit in with the larger production plans of wide regions that in turn are co-ordinated into a national plan by the central planning authority (Gosplan). The kolkhoz is required to produce certain amounts of certain crops, and is expected to adopt certain rotations and farming practices which have been shown to conserve soil fertility in the region concerned. A fair amount of freedom in land use is permitted, but the general framework of farm management is predetermined. Under such circumstances a physical land classification to suit the preconceived plan, which may be modified within limits to fit the land classes, can readily be made. Social and economic factors enter to a variable, but usually only to a minor, extent.

Both the soil-conservation districts and the kolkhozes represent particularly straightforward examples of land-use planning because the objectives are clearly defined and are definable directly in terms of land use. Where the objective is less clear, or less clearly related to definite uses of land, the land classification tends to be correspondingly vague. An objective such as the common welfare, the public good, the improvement of the standard of living, or merely the optimal utilization of the land forms an insufficient basis for a land classification; it is necessary to state how the objective is to be attained—for example, by an economy based on cocoa, sugar, mixed farming, etc. The Scott Committee on Land Utilization in Rural Areas [57] was instructed to consider the planning of post-war England and Wales.

It assumed* that English agriculture would be characterized by a continuance of the "traditional" type of English farming (balanced, mixed farming with small, individually owned farms predominating), and on this assumption recommended as a basis for land planning the adoption of the classification of the Land Utilization Survey (p. 57) that distinguishes classes according to former use under the traditional system. Here the relationship between the system of land classification and the means by which the planning objective is to be attained is obvious. If an entirely new system of agriculture had been proposed, a classification according to former use would not have been appropriate.

For land-use planning, therefore, there is a very close connexion between the objective of the plan, the means proposed to attain it, and the appropriate system of land classification. There is no such thing as a general land classification, but there is a common physical classification appropriate as a basis for all land-use plans aiming to promote and perpetuate the public welfare, and therefore requiring the maintenance of soil fertility. Superimposed on this basis is another social-economic classification which is, in effect, part classification and part planning. It is often difficult to know where the process of land classification ends, and that of land planning begins.

Types of Land Classification

The Land Committee of the United States National Resources Planning Board, in its *Report on Land Classification in the United States* [62], distinguishes five types of land classification at present in use. These types are not fixed or exclusive; many of the land-classification projects mentioned in the Report can be assigned to two or more types. But while the types are somewhat arbitrarily defined to suit the special circumstances of contemporary land classification in the United States recognition of them brings out the general fact of the dependence of land classification on the use which is to be made of the system. The five types 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 programme effectuation.

Of the 75 miscellaneous projects analysed in the Report, 68 are of, or include, type-I classification. We have already referred to this type as a physical classification. It is the least dependent on the use to be made of the classification and is, moreover, almost essential to the further development of any practical classification of land for agricultural or forest use. The inherent characteristics to which most attention is usually paid are soils and topography, though other natural land qualities assume equal or greater importance in special cases (e.g., subsoil and water table in irrigation

* Majority Report. A Minority Report by Prof. S. R. Dennison makes rather different recommendations.

planning). Land classification according to inherent characteristics must obviously be the fundamental classification in undeveloped or partly developed regions where man-made qualities such as present land use, urbanization, political and economic factors, etc. have minor significance.

Type-II classification, according to present use, may also be considered as "fundamental", at any rate in long-settled regions where sufficient time has elapsed for both the inherent and the man-made qualities of the land to have reached an equilibrium as regards their influences on land use. The classification of the Land Utilization Survey of England and Wales (p. 57) is a type-II classification, and as such is applicable to a plan which aims to rationalize rather than to change the time-tested, traditional system of land use. The Land Utilization Survey originally defined its classes solely in terms of present use and made no claims for the system as a land-planning tool. Later, the purely type-II classification was expanded for planning purposes into type IV (recommended-use classes).

Both type-I and type-II classifications are essentially inventories of actual conditions. They take no account of potentialities. The modern American soil survey, which is evolving into a land classification, is a combination of types I and II with a recent admixture of type III (use capability).

For type III a specified use is assumed (e.g., cereal culture, pasture, forest), and land is assessed according to its potential productivity in that use. First-rate forest land may be fourth-rate cereal land. For crop use, land may be assessed according to the estimated yield of the crop under a given system of management that may be based on the average, optimal or any other standard. The system of management can be a determining factor in the classification. For example, land might be classed as high-yielding under dry farming owing to excellent water-holding characteristics, and as low-yielding under irrigation owing to defective drainage. In forestry, the classification of site quality according to actual production or according to production estimated from the nature of the vegetation is an example of type III.

An alternative form of type-III classification is according to the measures which must be taken to bring the land to a certain standard condition, e.g., immunity from erosion. This form is much used in the U.S. soil-conservation surveys. The knowledge required for a type-III classification always includes much of that which is obtained in making a type-I classification.

Type-IV classification (in terms of recommended use) is in effect a combination of the preceding types. It is not so much an actual classification of land as the formulation of a land-use plan on the basis of the inherent properties, present use and capabilities of the land. The same is true of type V—land classification in terms of programme effectuation—which involves indicating on a map the different stages and methods whereby land-use recommendations are to be carried out. Both in type IV and type V complex political and social questions such as the form of govern-

ment, the aspirations of the community, the legal power of the planning authority and the rights of landowners are involved. The five types represent a series of increasing complexity and afford a good illustration of the way in which land classification, starting in its simplest and most fundamental form as a soil classification, may become merged into land planning without any sharp distinction between them.

The Physical Classification of Land

In a posthumously published and, unfortunately, unfinished paper C. F. Marbut [53] makes a clear distinction between a " natural " and an " economic " classification of land:—

> In the broadest sense possible the classification of lands may be considered from two points of view. In one, lands are considered as natural bodies, are differentiated into units and the latter arranged into classes on the basis of inherent natural characteristics. Such a classification has no necessary relationships to man or his institutions. The other classification, however, has a definite relationship to man. It may be called an economic classification. It is a classification based definitely on the relationship of different kinds of land to man and his industries. In the first case, in the physical classification, the units are being defined on the basis of definite character, and express therefore essential and inherent, permanent characteristics. In the second case, or the economic classification, being based on a relationship that varies with the status of man and his institutions at any given time, the classification is not permanent. The definition of land units for the same parts of the earth's surface differs from time to time, depending on the changes regarding man and his institutions in a given spot at any particular time. The lack of permanence is due to the changing character of man's institutions, not to changes in the inherent characteristics of lands.

Marbut asserts that land may be used by man in three main ways :

(1) as mere areas of solid earth on which to live ;
(2) as areas varying in desirability because of relationships to other kinds of land, or to man and his institutions ;
(3) as sources of usable material.

As we are here only concerned with land use for plant production our land classifications are not concerned with the first two uses, and need be related only to those characteristics of land which determine the kind and amount of plants produced. As a basis for such a classification Marbut proposes the following definition of land. *Land is a term connoting all the features of man's natural geographical environment with which he deals in crop production.*

Marbut proceeds to establish the bases for a classification according to the permanent physical properties of land that are significant in plant production. Such a classification is the equivalent of a potential land-use classification, lands being grouped according to their physical capacity for producing different kinds of plants, regardless of whatever use is or has been made of them. " No attempt has been made to determine the kinds of land here discussed by any sort of indirect approach such as the type and apparent success of the local agriculture, the kinds of crops grown or the yields obtained or the character of the natural vegetation. Such an approach to the problem is consciously avoided because the essential

character of a physical classification requires a direct approach through physical character. It is well known and generally agreed by students that such indirect methods may give certain definite results. It is possible to identify ' good ' or productive land by a study of the character of the natural vegetation growing on it or that grew on it. It is equally possible to arrive at the same conclusion through a study of the existing agriculture. Notwithstanding this possibility a serious objection to such methods lies first in the fact that the result obtained is wholly empirical and neither the facts nor the conclusion presents the possibility of drawing any other conclusion than that the land is productive for the plants grown."

On the other hand, a classification based on inherent physical characteristics provides a basis for drawing conclusions regarding the use of land for more than one purpose.

The most important of the " features of man's geographical environment with which he deals in crop production " are soil and climate, these constituting the main part of the physical environment in which plants grow.

On the plant side the two main factors to be considered are (1) adaptability to, and (2) productivity in, the environment. It is well known that certain plants attain their optimal development in certain regions (e.g., corn in the Corn Belt in the U.S.A.), whereas in other regions owing to the presence of some limiting factor such as too short a growing season, too much or too little moisture, too hot or too cold a temperature, growth is partially or completely inhibited. The factors influencing adaptability are mainly, but not entirely, climatic. Within any one, more or less homogeneous adaptability or climatic region, however, great variations in productivity for a given crop may occur, associated mainly, but not entirely, with variations in the soil factor. Variability of productivity is greatest in regions of optimal adaptability where the possible range of production per unit land area is from zero to the maximum known. In the so-called marginal zones soil or productivity factors are less significant.

A third factor unrelated to adaptability or productivity that has to be considered is accessibility—not to markets, since this is a purely physical classification, but for agriculture. Accessibility concerns mainly the relief of a region. Some lands, for example, are too steep, or have too broken a topography for crop production, even though the climatic and soil conditions are favourable, because of difficulties of cultivation or the hazards of erosion. Accessibility in this sense is less a limiting factor in forestry than in agriculture.

The physical land characteristics significant in plant production may thus be grouped as (1) those which control the kinds of plants grown (mainly climate), (2) those which control the productivity of the land for the plants grown (mainly soil), and (3) those which determine the accessibility of the land for crop production (mainly topography). It will be seen that the proposed classification, though physical, is expressed in agronomic terms—in terms of the significance of the physical characteristics for agriculture.

It is not at present possible, owing to our inability to assess quantitatively the agricultural significance of physical factors, to make more than a very general classification of land on this basis. Marbut's proposals appear to involve a first differentiation of lands according to adaptability, the adaptability regions being then subdivided according to productivity and finally accessibility. This corresponds roughly to a classification scheme in which the highest category is determined on a climatic, the next on a soil, and the third on a topographic, basis. How Marbut intended to define the lower and, in practice, more important categories is not indicated in his paper.

This outline of a classification scheme shows that Marbut intended it to be a true classification—that is, lands are arranged in categories and classes showing the physical relationships between the different groups. The taxonomic importance of this feature of a classification is stressed by the Land Committee of the National Resources Board [62]. "Tidal marshes, sandy soils, oil fields, and golf courses might be present in an area, but they are not related phenomena and cannot be assigned to classes in a logical system of classes. Tidal marshes, rocky headlands, and sand dunes, however, are related phenomena and can be assigned to classes in a systematic division of shore features. In similar fashion, golf courses, railway yards, and airports are classifiable in terms of the several categories of urban land use."

Land Inventories

Some systems of land classification make little attempt to indicate relationships between classes. Provided they fulfil their purpose they are none the less useful for that, but they would perhaps be more correctly described as land inventories rather than land classifications. Those who employ inventory-type classifications usually define a land type in terms of a summation rather than a synthesis of the separate characteristics. Thus Kellogg and Ableiter [46] define a natural land type as "land having a particular set of defined natural characteristics, principally of soil, climate, relief, stoniness and native vegetation." Veatch [96] says that "the natural land types [in Michigan] consist of various combinations of the soil types, relief features, and topographic forms such as hills, basins, lakes, and swamps." According to Veatch, for instance, a land type could be defined as consisting of soil type A, relief B, topography C and so on, and another as consisting of soil type X, relief Y, topography Z, etc. These definitions or descriptions suffice to give valuable information about land-use potentialities, but they do not indicate how class A B C is related to class X Y Z.

The definition of the type unit for classification is a point at which the physical and social-economic classifications of land tend to clash. In a physical classification the boundaries of a unit land type are naturally those at which the physical factors change, though it is sometimes difficult to determine the actual physical boundary to be marked on a map, or

whether a change in one factor only while all others remain constant justifies the delineation of a land-type boundary. For an economic classification or a classification for taxation purposes a property is often the most appropriate land unit. In some German systems of *Bodenbonitierung*, for example, points are awarded for physical land features, and the points are integrated over an entire property to arrive at the valuation for the property rather than for its constituent land types. Kellogg [44] points out that an important factor determining the best use of an individual farm unit is the manner in which the various soil or land types are associated with one another. "For example, in a hill-valley section frequently good cropland and land suited only to pasture are so mixed that the latter may be used to good advantage in a farm unit having some good cropland, without which a different use, such as forestry or extensive grazing, might be more desirable." The orientation of physical land types in relation to property boundaries may be a determining factor in planning land use.

What is usually described as the physical classification of land is, in fact, more a physical inventory than a classification. There are no universally established physical land classes, as there are universal soil classes or easily identifiable plant families and genera. It is impossible to compound the total physical characteristics into a single entity *land*, because one of the most important characteristics of land—at least for planning—is not physical, but economic.

Haggerty and Meyers [29] list the following characteristics as required to make a physical inventory of land as a basis for land classification.

- Soil:
  - Profile
  - Texture
  - Structure
  - Chemical reaction
  - Content of organic matter and essential plant nutrients
  - Stoniness
  - Internal drainage
- Topography:
  - Elevation
  - Lay-of-the-land
  - Degree of slope
- Native Vegetation:
  - Type
  - Amount or volume
  - Quality
- Flood Relationships:
  - Frequency
  - Intensity
  - Duration
  - Occurrence
  - Physical effects
- Land Condition:
  - Erosion
  - Deposition
  - Depletion
- Water Resources:
  - Kind and extent
  - Dependability
- Climate:
  - Precipitation
  - Temperature
  - Frost-free period
  - Climatic hazards

Haggerty and Myers recognized, however, the desirability of not merely describing land types, but of grouping them into classes according to the nature of the adjustment required to fit the land-use plan.

In Germany the main items of a land inventory were soil, topography, water resources, climate and economic conditions. The soil was further inventoried according to genetic type, texture, depth, stoniness, cultural condition and reaction. Much more attention was paid in Germany than is paid in the United States to economic items—market facilities, transport and communications, labour supply, system of land tenure, size and shape of farms, etc. An additional item which was to have been systematically inventoried was the content of available potash, phosphate and lime. A special service—*Bodenuntersuchung-Sonderaktion*—was at the beginning of the war engaged in making these determinations. The aim was to sample and analyse every quarter hectare of agricultural land. Between 1936 and 1942 over 4,450,000 determinations of lime status, 3,000,000 of phosphate status and 625,000 of potash status were made on soils of the German Reich [30].

The U.S. Soil Survey

Nearly all the factors listed by Haggerty and Myers [29] are now inventoried in the standard U.S. soil survey which has, in fact, developed into a combination of a soil survey proper with a land-type inventory. To an ever-increasing extent the U.S. Soil Survey is becoming a land survey, and it is possible that if ever a universal system of land classification is developed it will emerge out of the present work of the U.S. Soil Survey. Milne [56] quotes the Chief of the Soil Survey as stating that its results " form the factual basis in the development of sound programmes of land use." Soil surveyors are constantly reminded that it is the land rather than the soil that is to be investigated, classified, inventoried and interpreted, primarily though not exclusively by the soil profile.

As the survey becomes more practical—more of a land and less of a soil survey—there is, for example, a tendency to give more weight to texture in the definition of soil type. The American soil type is a combination of a *series* and a *class*, the series defining the general morphological characteristics of the soils comprising it, and the class the texture of each soil at the surface. Thus the *series* name Hagerstown describes an indefinite number of soils identical in all important characteristics except texture (*class*). Hagerstown loam, Hagerstown sandy loam, etc. are distinct but related soil *types* differing principally in texture. But it has been found that whatever may be the scientific justification of classing a clay and a sand (say) in the same series, in actual agricultural use there is likely to be a more pronounced difference between the behaviour of a clay and a sand of the same series than between two clays or two sands of different series. In other words, texture, which cannot be accorded a position of very great importance in a genetic or morphological system of soil classification, becomes a dominant factor in a " use " classification.

The trend of soil classification in the United States from a morphological to a use basis is reflected in the growing recognition of *monotype series*—i.e., the inclusion of texture in the definition of a soil series, or the identifi-

cation of soil series with soil type. Soils formerly regarded as belonging to the same series by reason of common genetic and morphological characteristics are now classed as different series by reason of their different use capabilities as indicated by their respective textures. At most three, and more commonly one or two, textural classes are now included in one series.

While the soil type is thus tending to disappear as a separate taxonomic category—or to be merged into the series—other categories are appearing, some lower than the series (e.g., *phases*), others higher (e.g., *associations*). The phases of a soil series or type are distinguished by some use characteristic such as stoniness, degree of erosion or slope—slope being judged not by its steepness, but by its effect on land utilization. An association is a group of soils, either similar or dissimilar, geographically associated in a regular pattern over a landscape feature. It is similar to the *catena* described for tropical landscapes by Milne [55].

To " charge the soil type with the maximum load of land-use meaning " [60] is the prevailing trend in soil survey in America at the present time, but Krusekopf [48] considers that most soil surveyors, while duly inventorying important land characteristics such as slope, stoniness, erosion, etc., have failed in their task of interpreting the primary morphological features of the soil in terms of land use. The soil surveyor, in fact, has the difficult task of maintaining an objective, scientific approach to soil classification and at the same time making the results of his work useful and intelligible to those who know nothing of the restraints imposed by pedological discipline. Milne [56] describes the soil surveyor's approach to land classification in the following words :—

> The soil surveyor regards himself as a student of the land who, being a soil scientist first, distinguishes his land types primarily by soil profile. He knows that considerations regarding the use of land may be in error if they leave the soil profile uninvestigated, and his own first duty, as a key man in this sense in the rationalization of rural production, is the expert recognition of the varieties of soil profile that exist in his piece of country and their reduction to a manageable number of series and types. In this stage of his work he is a pure pedologist, adding to soil knowledge or establishing the validity of existing concepts on new ground ; he may classify and describe soil types in whatever terms the technicalities of the subject require.
>
> As he goes about in the field plotting soil-type occurrences, he must, however, bear in mind that he will have the further duty of making clear, for all who follow him on land questions, what the significance of his data is. He must endeavour to work to the condition that after he has finished, no further visiting of the ground shall be necessary for the ascertainment of omitted or obscured facts regarding land type. He must, therefore, pay attention to a good deal besides soil profile. His land types are finally to be so defined (having regard to the limitations of the scale on which he is working) that the most desirable use of them can be inferred by other specialists (such as agronomists, foresters, or the administrators whom these advise) simply by superimposing their own particular technical knowledge on the pattern he has provided. Qualities such as topographic character and slope (expressively summarized in the American language as "lay of the land") ; stoniness ; other kinds of irregularity of surface such as animal burrows (or, in Africa, termite mounds) ; depth available for root-development ; nature of plant cover, if uncultivated ; susceptibility to accelerated erosion ; degree of erosion already suffered ; exposure to wind or liability to river overflow—all these are

relevant, and all must be incorporated along with soil profile and texture of top soil into the "natural land-type units" which are to form the items in the completed inventory.

The natural land types having thus been determined on the basis of their physical and, to some extent, their biological characteristics—the latter from the viewpoint of describing each land type as a distinctive "habitat"—their description can be carried further (in inhabited country) by recording whatever can be ascertained of man's experience in using them. There is clearly a wide field of relevant enquiry here: crop-plant behaviour, crop yields and qualities; thriftiness of stock, stock-carrying capacity, rates of natural increase; population densities, human health, and attainable standards of life earned on the land . . . .

It will be seen that the "natural land type" signifies a great deal more than the "soil type" does. Not only must the soil surveyor working to those objectives be a good judge of a pit section or auger boring, and a painstaking plotter of boundaries, he also needs to have a good eye for country, and a quick appreciation of a situation in physical geology. He must be a receptive observer of many kinds of natural phenomena, especially those of vegetation and plant succession. His acquaintance with crops and cultural practices, and his judgment in sifting the results of enquiry, must be enough to enable him to estimate what have been, and what will be, the probable interactions between man and the soil in both directions; for in long-occupied territory the "natural land type" cannot easily be disentangled from the existing pattern of "social land units" and customary usage; the top soil has become the "M-horizon," and to understand it requires more than mere expertness in soil morphology.

The results of soil survey, then, whilst being based on sound pedology, must be so reported as to convey a maximum of information about potentialities in land use.

The importance attached by the Soil Survey to the collection and presentation of miscellaneous information relating to land use is indicated by the following quotation from Kellogg [44], describing the nature of the soil-survey report.

The soil-survey report which accompanies the soil map describes the area surveyed, the characteristics and capabilities for use of the soil types and phases shown on the map, and the principal factors responsible for soil development. It is an integral part of the complete publication and not simply an adjunct to the soil map. Except as a base map, the soil map without the report is of little use to persons unfamiliar with the specific nomenclature employed. First of all, the report contains a complete description of the soil types shown on the map and their relationship to one another. As the objective of the work is to provide information directly relating to the agricultural use of the land, those characteristics of importance in the use of the soil for growth of plants are stressed.

Much of this information is obtained by observation during the course of the survey, but by no means exclusively so. Climatic, chemical, economic, agronomic, and all other data bearing on the nature and capabilities of the soil from other sources are used to the extent that such information is available and can be interpreted in relationship to the soil types occurring in the area. To the extent that the location of the soil areas in respect to markets and similar factors have an important bearing on the use of the soils, these relationships are identified and discussed.

More detailed instructions given by Kellogg, and reproduced in the Appendix (p. 86), for the preparation and arrangement of soil-survey reports illustrate the very wide scope of the survey which is, in fact, a land survey based on a straightforward soil classification—a social-economic inventory superimposed on a physical classification. It is rather more than a land classification, but it can provide much of the information required in land-use planning. In recently issued soil-survey reports a section has been devoted specifically to land classification, the classification adopted being

usually the arranging of the soil types in the order of their " productivity grades " (p. 69).

Land Types and Soil Types

Whether the soil type—in the American sense—can serve as a unit for land classification obviously depends on the objective of the latter. In so far as that objective is to adapt crop production to the quality of the soil, soil types and physical land types will tend to be coextensive. Moon [60] maintained that for the Tennessee-Valley soil-survey project, the objective of which was " to provide data of value to problems of land use and management, particularly for the production of useful plants," the soil type provided a natural unit for land classification. The classification required was one of soil productivity, and the class-distinguishing criteria were therefore all the soil characteristics, both internal and external, significant for productivity. Among the internal characteristics Moon includes physical, chemical and biological properties, and among the external characteristics moisture conditions, topography, conditions of erosion, stoniness, and depth to solid rock.

But whereas in the determination of soil types the relative significance of the different characteristics is constant, in the determination of land types the significance of each characteristic depends on the purpose of the classification. " It is not only necessary that all these soil characteristics—internal and external—become a part of the basis of classification, but that each of them be assigned a place appropriate to its relative significance to the natural physical adaptation and use capabilities of the soil—if the soil type is to fully express itself as a factor in land classification for plant-production uses." A factor such as depth of soil or stoniness may become " critical " at a certain intensity, and must then be given special emphasis if the soil type is to express its full significance to land classification. The soil type's fitness, states Moon, to serve as a unit for land classification is determined by the extent to which the variability in relative significance of the different soil characteristics is adapted to the objective of the classification.

By taking external as well as internal characteristics into consideration —i.e., by classifying land rather than soil, but on the basis of the soil type—the number of classes is very greatly increased, as also is the cost of the survey. The utility of the survey is increased proportionately. Moon lists ten maps which can be plotted from the soil-survey map as prepared in the Tennessee Valley :—(1) a general productivity map, (2) a potential land-use map, (3) a lay-of-the-land map, (4) a general erosion map, either of conditions resulting from past erosion or of natural susceptibility to future erosion, (5) a map of stoniness, (6) a natural zoning map, (7) a relative evaluation map, (8) a detailed natural-drainage map, (9) a crop-adaptation map, (10) a land-management map.

Veatch [95] says that in most of the American soil-survey reports the soil types described are in reality land types, but appear to be neither because of the attempts in the text of the report to describe them as soil

instead of land types. But while a soil type may be identifiable with a land type it does not follow that the same soil type in two different localities will represent the same land type. This lack of identity is due to the intrusion of external features and the varying emphasis placed on them in the determination of land types.

Land types and genetic soil types

Stremme [85] goes further than American workers in identifying land and soil types, and maintains that the genetic soil type is a scientific unit corresponding to natural land-use types. In Germany, where it may be assumed that land use has in the course of time largely adjusted itself to land type, the dry-steppe soils are used predominantly for wheat, roots, spring barley and lucerne, oats are grown largely on Bunter Sandstones, Marls and Clays, potatoes on heath soils, meadows on mountain soils, rye on *Eschböden* (artificial soils made from podzolized forest or heath soils by treating them with turf or stable manure, and forming a distinct type in north-west Germany), winter barley and clover on grey forest soils. Although oats, rye and potatoes occur on all soil types, other crops have become almost " selective " enough to be used as indicator plants of groups of related soil types.

Studies of the yields obtained on the genetic types distinguished by Stremme and his collaborators on purely morphological grounds showed that four classes of soils could be distinguished according to average gross yields of the commoner crops :—

1. Most steppe-like soils are exceptionally good for grains, grasses and cultivated crops.
2. The moist and better brown forest soils and the better moor-like (*anmoorig*) soils are good for grains and cultivated crops and very good for grasses.
3. The poorer, moderately podzolized, brown forest soils are medium-quality grain (except wheat) soils, indifferent to good potato and fodder-beet soils, sometimes good grassland soils.
4. The rust-coloured (podzolized) forest soils and the poorer moor-like and moor soils are very bad for grains, and bad for potatoes, roots and grasses.

Sellke (cited by Stremme) independently distinguished four soil-type groups, slightly different from the above, according to yield data :— (1) steppe-like soils ; (2) brown forest soils, rendzinas ; (3) cultivated podzolized and heath soils ; (4) mountain soils.

Several attempts have been made in Germany to evaluate the genetic soil types according to their productivity. The genetic type being a much wider conception than the American soil type, a correspondingly wide range of productivity rating is to be expected. Stremme gives tables by Sellke, Ostendorff, Taschenmacher and Przeperski showing that there are significant differences between the ranges of variation of productivity, expressed on a percentage scale, of different genetic types. Thus, according to Ostendorff,

the rating of steppe-like soils in Danzig and East Pomerania varied between 100 and 70, of brown forest soils between 75 and 40, of weakly, moderately and strongly podzolized soils between 55 and 20, 44 and 20, and 30 and 0, respectively, and of mountain soils between 30 and 0.

These figures, giving the highest and lowest productivity of each type, were derived from a study of over 1,100 soils. Although the range of variation is too wide for them to be used for deducing the productivity of an unknown soil from its morphology, they indicate nevertheless that there is an inherent relationship between the genetic type and the agricultural value of a soil. Stremme could discover no such relationship between soil class and productivity when soils were classified into geological, petrological or textural groups.

Sellke states that the importance of the genetic soil type as compared with the soil variety (*Bodenart*—textural distinction) in the evaluation of productivity increases with the age of the soil. In very young soils texture may be, but in mature soils the entire morphology of the profile becomes, the determining factor in productivity. In mountain districts greater variation is caused in forest growth by differences in slope and exposure than by differences in the geological substrate.

The Russian view on the relation between land types and genetic soil types is given in general terms by Gerasimov *et al.* [22] who appear to identify genetic soil types with geographical landscape types—i.e., the soil type is a " concrete " expression of the totality of the landscape. This view has more theoretical significance in the definition of natural landscape types than practical significance in land-use planning. Magnitsky [51] has briefly, and not very clearly, indicated how the first broad grouping of soils on a genetic basis can be subdivided for land-use planning purposes. The soil macro-complexes are classified not only on their natural characteristics, but also taking into consideration past and present land use (agricultural history), and particularly its effect on soil productivity. The soil types (? land types) are distinguished according to productivity (yield data) and the measures required to raise them to the level of fertility demanded in the land-use plan the nature of which is determined, presumably, by both the qualities of the land and political considerations.

The soil macro-complexes are subdivided into " meso-complexes " the precise nature of which is not explained. The subdivision is made according to the intensity of agriculture practised (whether present or planned is not clear), the nature of the agro-technique required to ensure high yields, and the agricultural system to be adopted.

Magnitsky's paper is the only reference we have found to the procedure of land classification in the U.S.S.R. We have found no description of the application of this or other procedure in practice. It would appear from Magnitsky's paper that the soil macro-complex (association of genetic types) determines the broad features of the plan—whether the region is to be used mainly for grain, fruit, livestock farming, etc.—the plan is then

worked out in greater detail, and the soil macro-complexes then subdivided into meso-complexes to fit the requirements of the plan.

Land-use Classes

Kellogg [43, 44] defines a land classification according to use capabilities as "one in which bodies of land are classified (on the basis of physical, or both physical and economic considerations) according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic expression to indicate those differences significant to man." In such a classification the "natural" aspects are subordinated to the practical. The emphasis is on the use rather than on the land. Kellogg puts all land in use into eight use groups (1) cropping, (2) grazing, (3) forestry, (4) recreation, (5) mining, (6) urban development, (7) wild-life preservation, and (8) protection (flood control, anti-erosion, etc.). (7) and (8) are usually combined with some of the other six, and combinations such as forestry-grazing, grazing-cropping, forestry-protection are common.

The use class of any land unit is determined as much by economic and social factors as by inherent environmental factors. These factors, by their nature transitory and variable, must be considered separately from the permanent, inherent factors. "Any change in utilization alters the position of the land in the classification of the social land units; whereas the more fundamental classification of the natural land types is essentially permanent. For example, should the boundaries of some proposed grazing or forestry district include present cropping land, a reclassification would need to be made giving this land its rating in the new use group in place of its rating in the cropping use group. Where the fundamental physical data are kept clearly separated from the economic or social, as the logic of the method demands, such changes are easily made without additional field work" [46].

Tyler [91] distinguishes between the physical classification of *land types* and the economic classification of *land areas*. A complication is introduced by the fact that the boundaries of the natural land types and of the economic land areas do not necessarily coincide.

Kellogg [43, 44] offers the following outline of a scheme of land classification.

1. Objective: Classification and extension of data regarding land; planning of land utilization.

(Detailed expression also furnishes basic physical classification for objective under 2.)

Climate
Soil
Relief
Stoniness
(Vegetation)

} Natural land type.
To be classified into categories according to relative physical capability in possible types of utilization.

2. Objective : Rural zoning ; tax assessment.

Natural land types (detailed expression)
Relationship to social groups
(a) Economic
(b) Social

} Social land unit.

To be classified :

(1) Into use groups :
(a) Cropping
(b) Grazing
(c) Forestry
(d) Recreational
(e) Mining
(f) Wildlife preservation
(g) Protection
(h) Urban

or definite combinations :
(i) Crop—grazing
(j) Crop—urban

(2) As to capabilities within the use group.

If the classification is to be used for land-planning purposes there must obviously be some correspondence between the "natural" and "use" classifications, that is, the criteria used to distinguish natural land classes must be related to those used to distinguish use classes—e.g., soil-fertility characteristics.

Kellogg outlines the procedure (particularly for soil surveyors) to be adopted in actually classifying and mapping land-use capabilities :—

(1) The first essential includes the accurate mapping, in detail, of the physical features of the land. The basic data are those regarding the soils that are mapped in accordance with the modern system of soil classification. Cognizance is also taken of relief, stoniness, native vegetation, and any other physical features of local importance in land use. These may be regarded as the external characteristics of the soil type. Combinations of these features give the natural land types which cannot be assigned definite ratings of productivity in the various use groups. In order that these natural land types may be interpreted in accurate terms, it is essential that the maps show sufficient detail, both as to definition of the categories and as to cartographic expression. *Individual land types of a size sufficient to influence significantly the capabilities of separate units of operation need to be separated.*

(2) Coincident with, or subsequent to, the mappings of the natural land types, the inherent productivity, including "responsiveness" to cultural practices, of these types must be determined in each of the possible use groups. The ratings should not reflect transitory economic considerations but should be based on the essentially permanent physical factors of productivity. These ratings must represent the generalization of all information available, including that obtainable inductively considering the nature of the land, and that acquired deductively from analyses of practical experience and experimentation. Conveniently these ratings of each land type may be expressed in terms of percentage of a standard, taken as the best land, from a physical point of view, in each of the use groups.

(3) The next step in the procedure is the determination of the use group for each tract of land. Especially in areas that have been settled for many years this determi-

nation will be made largely on the basis of the physical qualities of the natural land types. Other factors, such as accessibility to markets and the size of contiguous areas of similar land types will also be important, especially in a new or rapidly changing section. For example, an area having a natural land type ever so well-suited to cropping cannot be placed in the cropping use group, should the area be too small for a unit of operation or isolated from other land suitable for cropping. This and similar considerations make it necessary sometimes to place land naturally suited to crops in the forestry or grazing use groups, and subsequently the land must be rated in that use group.

(4) Finally, each social unit of land is rated in the use group (or use groups) in which it belongs. The ratings of the natural land types within the use groups are basic, but these need adjustment according to economic or geographic considerations which may influence production on these social units. Such considerations include accessibility to markets, nature of the existing vegetation on forest and grasslands, and similar factors. By an analysis of production on the standard or ideal land, and the marketing costs at various distances on the different classes of roads, a schedule may be prepared showing the percentage reduction in the basic rating of the land for various locations. Similar schedules may need to be calculated in respect to the other factors.

As a final result, each piece of land can be given a rating in terms of the percentage of the standard for the area or region. If the classification is then used for purposes of tax assessment, the proper local officials need to place an appraisal value on the standard land, and every piece of land in the area takes its appraisal value strictly in accordance with its productive capacity. Ratings given by such a land classification need to have added to them an appraisal of buildings and improvements for loan purposes or for tax assessment where such improvements are taxed. It must be emphasized again that the physical data should be kept separated from the economic, including the basic ratings of the natural land types ; as a result of any changes in economic conditions, the necessary adjustments of the ultimate land classification can be made easily without additional field work.

The productivity ratings referred to above are described on p. 69 and following.

Bausman [7] lists five different measures of land classes commonly used in land-classification studies. None of them is a complete measure, but each serves as a check on the others. Soil types are the most widely used and generally the most effective measures of land classes. Their chief weakness is that they do not reflect the effect of location on land use ; not only the effect of distance from market or town, but also the effect of location relative to other land types. A parcel of poor land would have a higher use capability on an otherwise good farm than it would have on a poor farm.

Crop yields afford a good measure of land classes if the land is used for cropping. They are of little use on pasture or forest land. Bausman points out that on many poor farms the proportion of cropped land is low, but it receives all the manure produced and consequently gives higher yields than would be expected from its " inherent " properties.

Size and condition of buildings are a fairly good measure of land classes. Good land usually requires larger buildings for storage and shelter than does poor land. As often as not the *condition* of the buildings is more a reflexion of the personal habits of the occupier than of the quality of the land. On farms near towns or owned by urban dwellers or supported by urban capital, the size and condition of the buildings bear little relation to the class of land.

Net farm income may be used as a measure of land classes, but the data are usually costly to obtain and become unreliable when any appreciable proportion of the income is derived from enterprises not closely associated with land quality—e.g., poultry, flowers, market gardening.

Bausman favours intensity of land use as the most reliable single measure of land classes, on the grounds that the occupiers will, over a period of years, discover by trial and error the optimal land use under prevailing conditions. He recognizes, however, that there is usually a lag in land-use adjustments that needs to be taken into account. The relative validities of the different measures vary widely from situation to situation, and there are no general rules for assessing them.

Agricultural Regions

As Marbut (p. 13) pointed out, the climatic factor in land-use classification is related to crop adaptability. So far as adaptability is concerned, in most areas coming under a single plan the climatic factor can be regarded as constant, except in mountainous or topographically dissected regions. Local climatic variations assume increasing significance as the intensity of land utilization increases, but since intensive farming cannot be carried on for long unless land use is adapted to the environment most intensively farmed countries have not felt the need for land-use planning. Use is already reasonably well adapted to the land. Climate has, indeed, found more use as a basis for demarcating broad agricultural regions than in detailed land classification. It is the dominant factor determining the suitability or otherwise of a region for a particular crop.

Stamp [82] states that in Europe temperature—particularly in the growing season—is the most significant climatic element governing the adaptability of a region to the culture of one or other crop. Passing from south to north, summer temperatures decline, and successive limits are reached for the ripening of rice, maize, wheat, oats and barley. Thus a physical or geographical limit is set to types of agriculture based on these different food grains.

Winter cold is another factor influencing types of crop culture. The intense winter cold of south-east Europe renders autumn sowing of grain impossible, and spring wheat takes the place of winter wheat. The spring-wheat region of Europe is practically coextensive with the black-earth or chernozem zone, characterized by a semi-arid, highly continental, steppe climate. Similarly, the northern limits for the olive, orange and lemon are determined by the incidence of winter frosts, and the northern boundary of the zones of culture of these fruits coincides with that of the Mediterranean climatic region.

Rainfall in Europe is usually adequate, and sometimes excessive, for agriculture. Where it is insufficient—in the south and south-east—irrigation is practised. Where it is excessive pastoral farming or no agriculture (forest), and where it is adequate arable farming, predominates.

In the delimitation of agricultural regions the soil factor tends to follow the climatic factor, since the genetic soil type is primarily a climatic phenomenon. It does not, however, follow that the boundary between two recognized soil or climate zones will also be a boundary between two agricultural or land-use regions. It is soil poverty, however, which brings the rye-growing region into parts of Europe that climatically would have been regarded as a wheat-growing region. The limit of wheat- or maize-ripening is not necessarily related to the distribution of any natural plant association and its corresponding soil type. Certain close correspondences do occur—e.g., between the spring-wheat and chernozem zones, and between the olive and Mediterranean-climate (terra-rossa) regions—but the boundaries of both agricultural regions and of soil or climatic zones are naturally very ill-defined. The transition belts from one agricultural or soil zone to another are often very wide. It is convenient, therefore, to make the agricultural and climatic (or soil-type) boundaries coincide as far as possible on a map so as to emphasize the indubitable significance of climate in determining crop adaptation. Thus, several of the boundaries in Jonasson's map of the agricultural regions of Europe [42] correspond closely to the boundaries of the soil zones in Sibirtsev's soil map which was drawn partly from climatic data as well as from direct observations of the soil, but was later considerably modified by Stremme [87].

While climate exercises the most obvious control over the distribution of broad agricultural types it is by no means always the determining factor. Economic, political and social controls may be equally or more potent, particularly in populous regions.

> Almost as obvious as the broad resemblance between maps of climate and agriculture, are the marked discrepancies. Dry interior Asia-Africa has not the same agricultural system as dry interior Americas and Australia. The types covering wide acreage in the humid middle latitudes of the northern hemisphere are not extensively spread in the southern. Most conspicuous of all, the agriculture of east and south Asia, notably China and India, does not parallel counterpart climates in the other continents. Differences spreading over such broad areas cannot be attributed to variations in soil or slope, which are miniscule in comparison. They do correspond to what may be loosely defined as Occidental versus Oriental society and progressive versus backward culture. Some of them correspond also to marked contrasts in density of population [98].

The actual boundaries of agricultural regions, so far as they can be defined at all, are determined not solely by physical conditions (temperature, moisture, topography, soil), but are rather the result of the pressure of population against these conditions, the pressure varying with the stage of civilization and technical achievement attained by the people [5].

The effects of industrial development, when highly concentrated as in western Europe, may outweigh those of climatic or physical controls. Most of industrialized Europe—Great Britain, Northern France, Belgium, Holland, Denmark, Germany, and parts of Czechoslovakia and Poland—are included in what Jonasson [42] calls the Dairying, Hay and Root-crop Region. The agriculture of this region is characterized by intensive, highly diversified mixed farming, with livestock predominating. There is nothing

in the climate or soils particularly favourable to this kind of farming, which has evolved in response to the demands of dense, urban populations. Ellsworth Huntingdon (cited by [82]) and Jonasson consider that the physical environment is peculiarly favourable for high production, though it may be noted that Marbut [52] considered that humid forest soils (pedalfers) like those of western Europe were in general much less adapted by nature for sustained food production than the semi-arid grassland soils (pedocals). Huntingdon supports his statement by average yield data for the most common western-European crops. If the average yield for Europe is 100, that of Belgium is 179, of Holland 170, of Denmark 168, of Switzerland 155, of England and Wales 146, of Germany 127, and of France 105. It may be noted, however, that this order of productivity has less to do with the quality of the soil than with the consumption of fertilizers per unit of arable land. The order of fertilizer consumption per arable acre before the war was Holland, Belgium, Germany, Denmark, Great Britain, France [17]. If the manurial value of imported animal foodstuffs were taken into consideration, figures for fertilizer consumption in Denmark and Britain would be considerably raised, and the order of fertilizer consumption would approximate to the order of productivity. There can be little doubt that both the type of utilization and the high level of productivity of western Europe are less closely related to physical than to social and economic controls. Intensive mixed farming has developed because it is the only known system that could support a dense industrialized population. One of the most valuable root crops in the European root-crop region is sugar beet—an example of the effective influence of a political control, since beet sugar can nowhere compete freely with imported cane sugar.

Jonasson [42] claimed to be able to distinguish seven zones of production around large urban centres, and reflecting the influence on land utilization of distance from market. These zones do not usually exist in their entirety in actual fact, owing to the intrusion of other than commercial factors in the determination of land utilization, but they are apparent in part around cities like Moscow, Indianapolis and Buenos Aires. Stamp [82] states that they can also be traced in Britain. The zones, extending, ideally, concentrically from the urban centre are :—

I. Horticulture
   - Zone 1. Greenhouses and floriculture.
   - Zone 2. Market gardening—fruit and vegetables.

II. Intensive agriculture with intensive dairying
   - Zone 3. Dairy products, fat cattle and sheep, forage crops.
   - Zone 4. General farming—grain, hay, livestock.

III. Extensive agriculture
   - Zone 5. Bread cereals.

IV. Extensive pasture
   - Zone 6. Rearing of cattle, horses and sheep.

V. Forest culture
   - Zone 7. Peripheral areas, forests.

Baker [5] states that " not only are the physical conditions the principal factors in determining the utilization of the land in a region and the crops grown; but also they become more important as population increases, the knowledge and practice of agriculture advance, transportation facilities are improved, and the supply of capital and labor is increased and better distributed; in brief, as agriculture and forestry become more highly organized and commercialized."

This statement seems at first sight at variance with the view previously expressed that a highly developed industrialism masks the effects of physical conditions on land use, but Baker was referring to the United States which still are more agricultural than industrial. They have only quite recently, with the development of transport on a continental scale, emerged from the stage of self-sufficient farming to that of commercial farming, an early phase of which is the concentration of crops in the regions where they can be most economically grown. Formerly, for example, fibre flax was grown for home consumption on almost every farm, but now it is imported, and flax is grown commercially almost wholly for oil, and is restricted to the sub-humid areas of the North-west where the physical conditions are peculiarly favourable. Again, with the commercial development of cotton, competition has restricted the crop to the area where it can be most economically grown. There is a general tendency for the farming community to concentrate in the more fertile areas and to abandon the less fertile, owing to the greater capacity of the former class profitably to utilize large amounts of capital and labour. Thus between 1910 and 1920 the most fertile farm lands of Illinois increased in value by 79 per cent, while the least fertile lands increased by only 41 per cent.

The general tendency at the present stage of American civilization is for economic forces to operate in the same direction as physical conditions in the determination of land use. The increasing use of farm machinery, also, is emphasizing the significance of topography; accessibility for agriculture and adaptability to mechanization, and inaccessibility and non-adaptability usually go together.

Three stages may be distinguished in the normal evolution of " agricultural regions ". At the beginning of settlement there is a pioneer stage in which the land is made to produce anything which will allow the settler to exist and hold his own against a still untamed Nature. This stage tends to be exploitative, since the system of land use is dominated by the individual's struggle for existence. Both physical and economic controls operate, but not very specifically. Crops are grown because the cultivator needs them for his day-to-day existence rather than because the land is specially suited to them. It was during the pioneer stage that much of the soil exhaustion and erosion of the modern world originated.

A subsequent stage may be distinguished as a social and economic organism emerges, and a sense of permanence in the occupation of land, extending beyond the span of a man's life, becomes apparent. Land use becomes more closely adjusted to local variations in the environment, more

conservative and less exhaustive. It is at some time during this stage that the relative influence of physical controls is maximal—and that the need for land-use planning is most likely to be felt. Parts of the United States at the present time afford good illustrations of the transition from exhaustive to conservative land use, and of the application of land-use planning to meet the problems raised thereby.

At a still later stage the influence of economic and technical controls increases relatively to that of physical controls. Men have learnt not only to adapt their crops to the environment, but also to modify the environment to suit particular systems of agriculture—for example, by intensive manuring as in western Europe, or by terracing and other soil-conservation measures as in Japan and Java. Further desirable adjustments in land use that could be assisted by planning are mainly to economic and technical developments.

The estimation of population capacity

Hollstein [37] has attempted a quantitative distinction of agricultural regions according to the maximum populations the regions are capable of supporting off their own produce when the land is utilized at an equal, but arbitrary, level of intensity. He maintains that climate is the principal natural factor determining the possibilities of land use. This becomes more evident, the broader and more general the picture of land use. Nevertheless, single factors such as distribution of rainfall throughout the year or in hot or cold seasons, relation of temperature to rainfall, distribution and quality of sunlight, etc. that cannot be incorporated into a climatic classification are often so important for land-use determination that none of the accepted systems of climatic classification is adaptable as a basis for land evaluation. In other words, no practical relationship has been found between the separate climatic factors (rain, temperature, sun, wind, etc.) that will express the crop-producing potentialities of the land.

Hollstein measures productivity by the capacity of a region to produce human foodstuffs. Since food production varies greatly in quantity according to the type of agriculture (e.g., mixed or specialized farming) grain-producing capacity is taken as standard. Grains are the most important food crops, and their short growing periods and other characteristics make them particularly suitable as measuring rods of productivity. Grains are cultivated everywhere, and all the common grains have approximately the same calorie value per unit weight (3,300 per kg.), consequently the grain yield is also a measure of the energy-producing capacity of the land. If land is used entirely for the production of animal food the calorie value of the animal products ultimately obtained for human consumption is about one-fifth of what would be obtained by growing vegetable food for direct human use. Under intensive horticulture the calorie value can increase from four to eight times that under grain cultivation.

As basis for his calculations Hollstein uses the actual yields obtained in the cultivated parts of the regions concerned, and from these data he calculates the calorie value per unit area of land.

By dividing the calorie value by the arbitrary figure 2,500 the number of "human feeding days" per unit area is obtained. Multiplying this by the fraction of the total land area that is cultivable, a "quality number" (*Wertzahl*) for the region is obtained. It will be seen that the operative values are the average grain yield and the proportion of cultivable land; the interpolation of calorie values and human feeding days involves merely multiplication and division by two constants which do not affect the relative significance of the quality numbers obtained. E.g., in the south-China plains a yield of 35 dz./ha. of grain provides the calorie requirements of 1,265 men per square kilometre. 80 per cent of the total area is cultivable, thus the population capacity is reckoned as 1,012 per square kilometre. The actual population density is 900—85 per cent of the calculated population capacity, and 71 per cent if the whole area and not only four-fifths of it had been utilizable. The "utilization factor" (*Ausnutzungsfaktor*) is 0.71. In one part of Shantung population density (821 per sq. km.) is greater than population capacity (723) calculated on a basis of four-fifths of the land being optimally used for food production, but taking the province as a whole the ultilization factor works out at 0.55.

Goodson [24] points out that one result of this method of calculating potential productivity is to discriminate in favour of regions where maize is grown, since maize has a much heavier yield capacity than wheat or barley. (It also requires about double the labour input of the smaller grains, a factor which does not enter into Hollstein's calculations.) Consequently, south-eastern Europe gets a higher assessment than actually much more productive countries in western Europe. And by assuming an intensity of use at present unattainable in the Amazon and Congo basins these regions get the highest ratings of any in the world.

Goodson also draws attention to the difference between the estimates of Hollstein (373,300,000) and of Griffith Taylor (20,000,000) of the numbers of population supportable by Australia.

Population and land quality. Attempts have occasionally been made to relate the population of rural communities, free from industrial or urban influences, to the inherent properties of the land. Mohr [59] established quite a close relationship between population density and soil quality in some islands of the Netherlands Indies. The nature of the volcanic deposits which cover much of Java and the age of the soils derived therefrom had a predominant influence on population density, sometimes even greater than that of industrialization or urbanization. Volcanic soils in the early stages of formation are usually the most fertile, and Mohr showed how the depositions from the latest eruption (1931) of Mt. Merapi mainly to the south and south-west of the volcano were reflected in the higher populations in these directions. In general, districts with the most juvenile volcanic soils have the densest populations. Heavy rainfall, by leaching the soils, has a contrary effect, hence the younger the soil and the lower the rainfall (provided it is sufficient) the denser the population. Somewhat similar relationships between soil and population were observed in other islands

of the archipelago, but were not so clear as in Java, owing to the less extensive distribution of young volcanic soils. Where these did occur, however, the populations tended to be densest.

Smits [77] considered that topography had a still more potent influence than the origin of the soil on population density, the densest populations being found in narrow valleys and on gentle slopes (of volcanoes) where primitive and small irrigation works could be installed. The banks of large rivers in the coastal plains (of the Netherlands Indies) where the land was subject to regularly occurring floods in the rainy season were also marked by high population density.

The Use of Natural Vegetation as an Indicator of Land Quality

Several suggestions have been made to use plant indicators to assess the suitability of land for producing particular crops, but the method does not seem to be much used, partly because the indications given in one region cannot always be relied on to be valid elsewhere. According to Shantz [76] correlations between the natural vegetation and the crop-producing capabilities of land in any area can be satisfactorily determined only after careful study of the different vegetation types in relation to their physical environments, and such correlations will need to be modified before they can be applied in another region where the physical conditions are different. With this proviso, Shantz, writing in 1911, considered that natural vegetation afforded the best basis then available for classifying land. At that time soils were distinguished on a textural or geological, not on a genetic, basis.

More recently, Hollstein [37] has expressed the opinion that the vegetation is a better indicator of crop-producing capacity than is the genetic soil type. He points to the difference in capabilities between the Eurasian steppes and the South American pampas, both of which, he says, have soils of the chernozem type, yet the former have a hard winter and short growing season that greatly limit the choice of crops, while the latter enjoy mild winters, can produce a great variety of crops, and sometimes two harvests in a season. It is, however, possible that a detailed comparison of South American and Eurasian black earths would have revealed as significant differences between them as exist between their respective climates and vegetations. There is in general a close correspondence between natural vegetation and genetic soil type. The advantage of using the vegetation rather than the soil as an indicator is that small, but significant, differences are more immediately obvious in the vegetation. Specific plant indicators—e.g., *Albizzia* spp. as indicators of suitable soils for tea [41]—in particular are easy to identify and to interpret, again with the proviso that the indications may be unreliable outside the area where they have been established by direct observation. Analogous soil indications—e.g., high hydrolytic acidity for tea soils—are usually insufficient by themselves. The soil, on the other hand, is more durable than the vegetation,

and often retains many of its original characteristics after all trace of the natural vegetation has been destroyed.

One of the chief characteristics required of a reliable plant indicator is that it should be exacting in its habitat requirements [73]. Plants with a wide range of growth conditions are obviously unspecific as regards habitat. Clements [13] maintains that the dominant species which constitute a climax are the best indicators " since they bear the unmistakable impress of the climate in the corresponding life-form, viz. tree, shrub, and grass." Climax indicators, according to Clements, express the type and degree of climatic control and the problems confronting man in maintaining the climax or modifying or permanently replacing it by cultural forms of land utilization. The whole plant community, since it integrates the response to the habitat of several dominant species, is a better indicator than are individual species.

Shantz [76] also deprecated the tendency to base judgments about land quality on the presence of individual indicator species; the composition of the plant cover as a whole forms a much more reliable basis. " In considering the correlation of natural vegetation with crop production many of the difficulties experienced in correlating vegetation with the physical environment are eliminated. Broadly speaking, the native plants obey the same physiological rules as do cultivated plants having the same general requirements with respect to moisture, heat, and light. Hence, it should be comparatively easy to infer from the differences in the native vegetation produced by differences in the physical environment what would be the effect of similar differences upon cultivated plants."

Working in Eastern Colorado he found good correlation between land capability and vegetation. Land carrying a pure short-grass cover was found to be supplied with water in the surface foot or two of soil only, and usually only for a short period during spring and early summer. Land with a uniform cover of tall grasses was supplied with water to much greater depths, and offered favourable conditions for plant growth for a longer period. A mixture of short and tall grasses indicated intermediate conditions of water supply. More detailed study showed that the areas of greatest agricultural value were those with a wire-grass (*Aristida longiseta*) vegetation, an association very rich in both shallow-rooting and deep-rooting species. The conditions indicated are a fairly deep, pervious soil capable of absorbing all the rainfall and heavy enough not to blow badly when broken. Sampson [73] points out that the pioneer settlers selected short-grass in preference to wire-grass land for farming because the soils appeared to resemble those with which the settlers had become familiar in the east. Of almost equal value to the wire-grass association were certain phases of the grama-buffalo-grass vegetation in which *Bouteloua oligostachya*, *Buchloë dactyloides* and *Psoralea tenuiflora* were dominant. Areas characterized by other associations—e.g., the *Gutierrezia-Artemisia* association, lichen formation, and species associated with " blow-outs "—were defined as less fit or unfit for agricultural purposes. These occupied

mainly bare, rocky or alkaline land which could usually have been adjudged non-agricultural without reference to plant indicators.

As might be expected, within an area of uniform climate there was good correspondence between vegetation and soil texture (referred to by Shantz as soil type), but the correspondence broke down in areas of varying climate. The modern conception of soil type embraces both climate and texture, and a wider and more general correspondence between vegetation and the soil types now distinguished would be anticipated.

Shantz concluded that differences in the vegetation could be used to indicate changes in one factor of the environment only when all the other factors remained unchanged, and that indications of soil moisture were more easily obtained than of any other factor. In this connexion it should be borne in mind that Shantz was working in a region where lack of moisture was the prevalent limiting factor.

Aldous and Shantz [2] developed a complete system of use-capability land classification based on the natural vegetation for the semi-arid region of the United States west of the 100th meridian. When the classification was started settlement was so recent over much of the region that no agricultural history was available, and climatic data were also lacking over many areas. 102 vegetation types (plant communities) were distinguished, and classified into two major categories (1) dry-farm land, capable of producing cultivated crops without irrigation, and (2) grazing land, on which pasture or the natural vegetation was more valuable than possible cultivated crops. (1) was further subdivided into good, bad and indifferent (a) grain land and (b) forage land, and (2) into good, bad and indifferent pasture. We have not come across any record as to whether or not this twenty-year-old classification has proved its worth in practice.

Hilgard [34] lists the following plants which when growing in dense stand in California, indicate a soil alkalinity too great for cultivated plants :— tussock grass (*Sporobolus airoides*), bush samphire (*Allenrolfia occidentalis*), dwarf samphire (*Salicornia subterminalis*), saltwort (*Suaeda torreyana*), greasewood (*Sarcobatus vermiculatus*), alkali-heath (*Frankenia grandifolia campestris*), cressa (*Cressa truxillensis*), salt grass (*Distichlis spicata*).

St. Clair-Thompson [72] suggested that plant indicators could be used to determine the suitability of forest land for cocoa in the Gold Coast. He distinguished four types of climatic forest climax in the Gold Coast. These were :—

(1). Rain or evergreen forest—*Cynometra-Tarrietia* association. Cocoa does not thrive, possible owing to lateritization of the soil.

(2). Wet mixed deciduous forest—*Lovoa-Guarea-Pentadesma* association. Cocoa thrives, except in edaphic climaxes dominated by *Lophira*.

(3). Moist mixed deciduous forest—*Khaya-Entandrophragma* association. Favourable for cocoa cultivation.

(4). Dry mixed deciduous forest—*Triplochiton-Cistanthera* association. Cocoa cultivation highly speculative.

Lengthy lists of indicator species for each climax are given, for details of which reference must be made to the original paper.

The assumption often made by pioneer settlers that the more luxuriant the tree growth the greater will be the productivity of the soil under cultivated crops needs to be qualified under certain conditions—e.g., a tropical rain forest may indicate a lateritized soil incapable of producing more than one or two crop harvests. Again, the policy of " settling men where the big trees grow " proved disastrous in Victoria where the big trees were required to protect the watershed of the Murray River [21].

After reviewing the evidence available Sampson [73] concludes that " the character of the natural plant cover may serve to segregate virgin lands into categories favourable or unfavourable for crop production. The reliability of such guidance, however, is roughly proportional to the knowledge of the ecological relations between the native vegetation, the cultivated crops, and the environmental complex."

The intuition of an experienced observer who has taught himself to interpret the indications of vegetation and soils can often provide more reliable estimations of the performance of land under cultivation than any rules of interpretation that can be expressed in words.

Plant indicators of forest-site quality

Cajander [11] states that there are two kinds of forest classification, based either on some characteristic of the stand or else on the natural qualities of the site. Stand classifications are based on the yields of the stands, which may vary greatly on similar sites according to the tree species, management of the forest, etc. These classifications are quite subjective. Site classification, on the other hand, is objective, in that it represents an attempt to combine into one class all areas with the same capacity for growing timber, irrespective of what they are actually producing.

The principle of Cajander's system is that the inherent quality of a forest site is expressed in the nature and composition of the ground flora, and can be defined by the presence or predominance of certain indicator plants which are, in fact, indices to soil conditions. The main soil groups will be indicated by the tree species, but the important variations within any group will be indicated by the ground flora, and in such a way that if, say, any three plant associations under a given tree species represent descending grades of site quality, they will do so in the same order wherever they are found under any kind of forest.

A complete classification of Finnish forest types has been developed from these principles ; it is considered sufficiently reliable to be used widely in State assessments of forest-land values.

The classification can only be applied to mature and normally developed forests in which the natural vegetation has not been disturbed by human interference.

The following are the most important types distinguished in the Finnish softwood forests. They are given in ascending order of site quality.

Cladina type. Occurs on very dry pine heaths, with a thin layer of raw humus. The ground is usually greyish white, owing to the abundance of lichens (especially *Cladonia alpestris*).

Calluna type. *Calluna vulgaris* is usually the dominant species in the ground flora, accompanied by a rich moss and lichen vegetation. Pine is the most common forest species, but spruce and birch frequently occur as admixtures, and occasionally as dominants.

Vaccinium type. Moss vegetation is continuous, and lichens are common; grasses are fairly abundant. The dwarf-shrub vegetation is dominated by *Vaccinium vitis idaea*, accompanied by *Myrtillus nigra* and *Calluna vulgaris*. The forest is usually pine, but spruce and birch may be dominant (more frequently than in the *Calluna* type), and occasionally alder (*Alnus incana*).

Myrtillus type. Herb vegetation is abundant, with *Myrtillus nigra* dominant, and nearly always accompanied by *V. vitis idaea*. There is a luxuriant moss cover (*Hylocomium* and *Dicranum* spp.), but lichens and grasses are unimportant. Spruce is the natural forest species, but pine, birch, alder and poplar also occur.

Oxalis-Myrtillus type. Mosses are scantier, but herbs and grasses are more abundant than in the three preceding types. The herbs and grasses contain many hygrophilous species, in particular, wood sorrel (*Oxalis acetosella*) which gives its name to the type. Exacting bushes, such as *Rubus idaeus, Daphne*, etc. are often present. Besides the common species of softwoods, a sprinkling of hardwoods may be met with, including ash, maple and oak (*Q. pedunculata*).

Oxalis-Majanthemum type. Thin-leaved herbs and ferns (e.g., *Oxalis acetosella, Majanthemum bifolium*) and flowering plants such as violets are abundant. Mosses, grasses and dwarf shrubs are common, but not abundant. Spruce would be the only dominant tree species in virgin forests, but in Finland, owing to burning, cutting, etc. large areas are covered by birch, alder, poplar and other hardwoods.

The recognition of the different types is an art which can only be acquired by practice. The appearance and composition of the soil cover change with the time of year, but with the more well-defined types an experienced observer has no more difficulty in placing them than a botanist has in determining a plant species at different stages of growth.

That there is a close connexion between this purely ecological classification of forest types and both the actual yield capacity and soil properties of a locality has been demonstrated by several Finnish workers. Cajander's theory of forest type assumes that in all areas of the same type the combined action of climate and soil is equivalent, and consequently within one climatic region differences in type must be due to differences in soil properties. Table 1, compiled from figures representing averages of several hundred samples, shows how certain soil properties are connected with the forest type. The figures, except for soil reaction, are relative, taking those for the *Myrtillus* type as 100, and refer to the top 20 cm. of soil.

TABLE I

Yield figures and selected soil data relating to Finnish forest types [11]

Type	Relative yield (75-year old pine)	Loss on ignition	Amount of electro-lytes	CaO	P_2O_5	K_2O	N	pH
Cladina	27	49	44	36	161	118	34	3.6
Calluna	52	88	84	54	118	96	64	4.2
Vaccinium	83	81	55	79	161	100	71	4.6
Myrtillus	100	100	100	100	100	100	100	4.8
Oxalis-Myrtillus ...	115	117	159	117	54	109	137	5.2
Oxalis-Majanthemum	—	143	157	140	28	114	223	5.0

Cajander's ideas are most readily applicable in countries like Finland, where climatic conditions are comparatively uniform. His system has not been found so suitable for forest assessment even in the neighbouring country of Sweden. There a closer connexion has been found between forest type (vegetation) and stage of soil formation (podzolization) than between forest type and forest yield. The different vegetation types influence the leaching process caused by water percolation in the soil to markedly different degrees, due to the quality of the humus layer they produce. The strongest leaching is exercised by the *Myrtillus* type, then by the *Vaccinium* type, and the weakest by the *Cladina* type [88]. Usually, therefore, but not always, similar vegetation types are associated with the same soil type.

Hilgard [34] found, as might be expected, a general relationship between soil quality and the nature of the indigenous tree flora. Certain tree species, e.g., *Quercus minor* and *Q. marylandica*, appeared to grow equally readily on rich and poor soils, but in such cases the trees tended to assume characteristic and different shapes according to the quality of the soil. The shape was believed to reflect the lime content of the soil.

Coile [14] considers that the fundamental hypotheses behind the use of ground vegetation for evaluating forest sites—namely, that the ground vegetation reflects the inherent quality of the site better than does the tree vegetation, and that forest types so distinguished are largely independent of the composition, age and density of the forest stand—are open to question except under special conditions of climate and topography. Because the ground vegetation does not have so extensive and ramifying root systems as trees, it is unlikely fully to reflect the conditions under which the trees are growing. Moreover, the assumption that the nature of the ground vegetation is independent of that of the tree species has obviously only a very limited validity. But enough evidence has been collected to show that certain ground-vegetation types are associated with the more fertile, and others with the less fertile, forest-soil conditions. Such differences in fertility are, however, as easily associated with readily distinguishable topographical or soil characteristics as with the ground vegetation.

The use of indicator vegetation types as an aid in the selection of tree species to plant on open land falls into a different category, and is justified where experience has shown that certain types are specific to certain sites on which a given tree species is known to thrive. It may happen, however, that the climax species indicated by the ground vegetation will not thrive when planted directly onto open ground, owing to differences in microclimate between open and forested sites. The ground vegetation may indicate the climax, but not the intermediate ecological stages which may need to be traversed before the climax is reached.

Hesselman [32] has shown that certain herbaceous plants are indicative of specific soil conditions—e.g., *Epilobium angustifolium* and *Rubus idaeus* indicate high nitrifying capacity in Sweden. He suggested that the ground vegetation indicated the kind of treatment required rather than the inherent quality of the forest site.

Under the conditions prevailing in the United States Coile concludes that "if a classification of forest sites is desired, it should be based upon fundamental and permanent features of site, namely soil and relative topographic position of the soil mass. Characteristics of the soil mass, the substratum, and topography, which are related to the availability and total volume of water present for use by forests, should be the primary criteria in any classification of site. Markedly different chemical characteristics of soil may be secondary criteria of classification. In regions of appreciable relief, and in northern regions with less relief, aspect of land should be brought into the classification. The following characteristics of site should be considered.

1. Aspect.
2. Relative topographic position and slope.
3. Texture and thickness of the surface soil or A horizon.
4. Texture and thickness of the B horizon.
5. Nature of the substratum or soil parent material and its depth if relatively shallow."

The classification envisaged is apparently one in which the site factors enumerated would be evaluated and awarded "points" after their significance had been determined from existing forest stands.

Grassland indicators

On most pasture and range land indicators express the present condition of the land resulting from past treatment rather than its inherent or potential productivity, though indicators do express the latter in some degree on virgin grassland. "Range indicators" says Taylor [89] "are the clues to range happenings. All that can be used as guides to recognition of the real state of affairs—non-use, satisfactory use, abuse—either in the past or present, may be classed as indicators." Indicators, not solely plant indicators, are often specific to certain localities, and generalizations are impossible, but certain general observations can be made about the indication of range deterioration [73].

Range deterioration well under way is shown by: weakened vitality of the principal forage plants; limited, or the absence of, reproduction of the most palatable species; close grazing of species of low palatability; a thinning ground cover of the entire vegetation; replacement of the good forage plants by those regarded as of little value; evidence of relict forage plants; incipient gullying and evidence of increasing soil erosion. Evidences of past range damage are: a relative absence of formerly abundant forage plants; foliage and branches of the taller browse plants trimmed back as high as the animals can reach; dead remnants of the browse species of low stature; abnormal abundance of those species which persist and reproduce after more palatable species have disappeared; accelerated soil erosion accompanied by numerous V-shaped gullies. Indicators resulting principally from unsatisfactory soil conditions that may be used in conjunction with other indication are: truncated soil horizons; lack of a normal amount of organic soil between groups of herbs or shrubs; the conspicuous presence of hummocks, indicating general erosion in the absence of gullies. Doubtful or less reliable indicators of a deteriorating range are: local denudation of the soil, sometimes caused by soil slipping or displacement, or by congregation of herbivores on a restricted area; increase in poisonous plants resulting from a favourable successional reaction; general appearance and condition of the grazing animals, as where overstocking of an area for a single season is the principal contributing factor; condition of the timber reproduction, such as damage from defoliation or destruction of the "leader" by insects.

These observations refer mainly to conditions in the western United States.

A good deal of work has been done in Germany, Switzerland and Scandinavia [54] on the estimation of site quality of meadows and pastures by the composition of the herbage association. The general inference from much of this work is that the plant association reflects most clearly the moisture condition of the habitat, and rather less clearly the reaction and nutrient content of the soil. The investigations have considerable ecological significance, but it is unlikely that they will have much application to practical problems of land classification. The indicator plants are used to classify the meadows or pastures as productive assets rather than the land. Thus Petersen [69] distinguished six meadow types by the dominance of certain grasses in the meadow. The best class contains meadow foxtail, meadow fescue, timothy, canary grass, manna grass, meadow grass. A middle class contains quack grass, soft brome grass, meadow grass. The lowest class contains sedge grass, *Scirpus*, *Deschampsia*, sheep's fescue. A definite hay yield, both quantitative and qualitative, is associated with each class; one centner of good hay is reckoned as equal to two centners of poor hay. The highest class yields 100 dz./ha.

Pentz [67] states that the success of any particular type or system of farming in South Africa is closely related to the type of vegetation on the area. Experience has shown that successful farmers are those who have

adapted their farming to the natural vegetation. Much of the current maladjustment of South African agriculture to the environment has been the result of booms and subsidies (e.g., on maize) which have encouraged the wrong kinds of farming. ." In the majority of cases where there has been a boom, the areas which were suited to the production of the commodities required have suffered very little, except from the high valuation of land. It is those areas where conditions were not suitable for economic production that most damage was done to the land and vegetation, and where most failures occurred."

Pentz maintains that the only sound foundation for South African agriculture is to apply farming systems on the vegetation types to which they are suited, and this can only be done by a detailed botanical survey of the country. In such an experimental survey of the Estcourt (Natal) area the following points were observed :—(1) number of vegetation types ; (2) area of, (3) climatic conditions and (4) soils and topography associated with, each type. An investigation was conducted into present and possible farming systems, and their effects on the land and costs (*a*) in relation to each vegetation type, and (*b*) in relation to a combination of types in order to determine whether together they could form a complete farming unit.

Four main types were distinguished—thorn veld, tall-grass veld, highland sourveld and mountain veld. A careful study of all conditions prevailing on the thorn veld ruled out crop, sheep or dairy farming, and pointed to cattle farming as the most suitable system. Ordinary ranching, however, would require too much land, and stock breeding is recommended as the most suitable on both ecological and economic grounds. The tall-grass veld is likewise cattle land, although with its open plains and well-distributed rainfall it appears ideally suited to crop farming. It has, however, shallow and erodible soil, and can only be safely cropped on intensive and highly scientific lines. The vegetation, topography and climate indicate a seasonal type of husbandry, i.e., grazing the veld in the summer and carrying the animals through the winter with hay and silage produced from surplus summer growth. The highland sourveld has a very severe climate, and stock farming depends on the quantity of food that can be conserved from the veld during the summer to carry the stock through the winter. Sheep farming is a possibility, but it is suggested that the land is better suited to the intensive production of beef types. Both here and in the thorn veld the farmer would dispose of every animal, except breeding stock, as soon as possible. The mountain veld is unsuitable for farming, but contains the head waters of the rivers, and must be protected from denudation if farming in the areas below is not to suffer.

Pentz states that by thus adapting farming to the vegetation the whole area could be organized as a complete unit for beef production, so that each farmer could farm without exploiting his land and have a ready market for his produce. The highland sourveld would produce breeding stock for the breeder in the thorn country who would produce weaners for sale

to the grazier in the tall-grass veld who would supply a well grown-out animal ready for feeding for export.

In the above example, only potential grazing land is considered, but there is no reason why similar ecological indications should not be used to determine the use capabilities of potential crop land.

Systems of Land Classification

There follow descriptions of several systems of land classification, selected to indicate the points common to all systems and points peculiar to each system. The most obvious common point is the acceptance of some measure of soil productivity as the basis of the classification. In the systems described the differences in soil productivity between classes are mainly qualitative—i.e., class I is described as either better or worse than class II, or they are described merely as classes without indicating any relationship between them. The types and objectives of the classifications in this section may be described briefly as follows.

1. Physical classification correlated with economic data.
2. Land-capability classification for soil conservation.
3. Fractional-code method. Physical and social inventory.
4. Economic classification according to attainable intensity of use.
5. Classification for extensive wheat production according to profitability.
6. Physical classification for land-settlement purposes, without regard to economic and social factors.
7. Classification by soil types according to inherent productivity.
8. Classification according to present use.
9. Classification for land-settlement purposes according to present use, yields and soil-moisture conditions.
10. Classification for irrigation purposes.

1. Michigan

The need for land-use planning in Michigan appeared acute after the first world war when a large and increasing area of land in the northern part of the State became idle, and forest fires were frequent and unchecked. The importance of the land inventory as a prerequisite to land classification and planning was clearly recognized in developing land-classification procedure [50]. The Michigan Academy of Science, after much deliberation, decided that a land classification must precede the operation of any land planning, and that the classification must be based on a factual inventory of all the essential items on which the intelligent utilization of land should be based. The first emphasis was laid on the economic aspect, as confidence was waning in the methods and points of view of technical agriculturists who " had permitted confidence in their technical skill, and undue optimism—if not illusion—as to the economic practicabilities of agriculture, to bolster the assumptions, allegations and subreptions of professional land-boomsters " [50].

The Land Economic Survey was set up in 1922 as a branch of the State Department of Conservation. Its specific purpose was to inventory facts; it refused to make land classifications to be used as a basis for land-use recommendations. The facts collected were those pertinent to the understanding of problems relating to forestry, agriculture and recreation, the three major land uses in the area surveyed. Data were collected on (1) population distribution and changes, (2) political organization and changes, (3) assessed valuations and tax rates, (4) tax delinquency, (5) land ownership and intent in ownership, (6) economic activities, trade and trade areas, (7) miscellaneous data.

The data of the Land Economic Survey are reported to have been of great use in connexion with matters such as the establishment of State forests, the determination of acquisition policies and land-use planning, but by themselves they do not form an adequate basis for a land classification. For this purpose a more rapid, simple and less detailed determination of land types was required. The concept of the "land type" as a unit of inventory and classification, consisting of various unique combinations of soil types, relief and drainage features and topographic forms, has been much developed by Veatch [95, 96] at Michigan State College of Agriculture. Obviously, the number of combinations of physical features is almost infinite, and the art of the land classifier consists largely in defining the prototypes and relating the innumerable variants to those. Veatch [96] lists the following as types of land or combinations of natural conditions that have influenced the determination of present land use and farming systems in Michigan.

1. Uniformly smooth or level land with fertile, durable soils dominant, but in combination with smaller bodies of less fertile but arable land. Such land can be laid out in large rectangular fields, and large machinery units can be used advantageously.

2. Arable soils and level land associated in small bodies with hills and slopes. The soils vary distinctly in fertility, moisture content and crop adaptations.

3. Uniformly level dry surface in combination with sandy soil of low fertility.

4. Uniform mineral soil dotted with peat depressions and lakes, or peat and muck swamps dotted with ridges and hills of dry mineral soils.

5. Fertile soils, excessively stony, in combination with steep slopes or poor drainage.

6. Arable rolling land with gentle or moderately steep slopes containing a dominant amount of productive loams, but with small bodies of inferior soil.

7. Uniform soils, medium fertility, lying on level dry plains, dotted or intersected with lakes and swamps.

8. Complex associations of wet and dry soils which are dominantly low in productivity. The land is smooth or has only low relief features.

9. Hills or dunes of deep infertile sands subject to shifting by the winds.

The land type usually embraces several soil types. A descriptive inventory of a land type (taken from the legend of Emmet County land-type map) reads as follows:

Brutus land type.—Vegetation (Major) maple, elm, aspen, ash, hemlock (Minor) cedar, spruce, balsam. Surface, level and gently rolling. Soils (Major) Selkirk, Brimley, Ogemaw (Minor) Saugetuck, Newton, Rubicon. Drainage, slow to poor.

Land types are first determined by reconnaissance field observation, and afterwards delineated with reference to soil types from standard soil maps. Individual soil types are not, however, distinguished within a land type on the land-type map. It will be seen that the type is essentially an inventory of physical conditions significant to land use. Its primary purpose is to provide a simple and intelligible presentation of soil data by grouping soil associations and their physical characteristics into units applicable to planning purposes. It is claimed that such grouping forms a rational physical basis for correlation with economic and social data.

2. U.S. Soil Conservation Service.

The conservation surveys of the U.S. Soil Conservation Service involves the mapping of four main land characteristics—soil, slope, condition of erosion and present use [62]. Soils are mapped by the standard methods of the U.S. Soil Survey, each soil type being allocated a number in the map legend. Slopes are measured in percentages and grouped into percentage ranges which vary with the erodibility of the soil. Thus the slope classes of two different soils (No. 1 being the more erodible) have the following significance :—

Soil No. 1		*Soil No. 2*	
Slope class	*% slope*	*Slope class*	*% slope*
A	0–3	A	does not occur
B	3–8	B	" " "
C	8–15	C	15–25
D	15–25	D	25–35
E	does not occur	E	35 and over

Erosion conditions are expressed by numerical symbols indicating the kind and degree of erosion. The symbols are standard for the Soil Conservation Service, e.g., 3 indicates 25–50 per cent, 33 indicates 50–70 per cent, loss of topsoil, 7 indicates occasional gullies more than 100 feet apart. Land types are distinguished by a three-part symbol, the first part of which refers to the erosion conditions, the second to the slope and the third to the soil type—e.g., 337–B–16. A new land type is mapped wherever one part of the symbol changes. Present land use is mapped separately and is indicated by capital letters—L cropland, H farmsteads, P pastures, F woodland, X idle land. Present use is not here involved in the land classification, but it shows to what extent the land is being inadvisedly used and where readjustments are required.

On the basis of the three characteristics—soil type, slope and erosion conditions—land is classified according to its use capability or suitability for agricultural use. Eight classes are distinguished [36] :—

Suitable for cultivation with

I. no special practices ;
II. simple practices ;
III. intensive practices.

Suitable for occasional or limited cultivation with

IV. limited use and intensive practices.

Not suitable for cultivation, but suitable for permanent vegetation with

V. no special restrictions or practices ;
VI. moderate restrictions in use ;
VII. severe restrictions is use.

Not suitable for cultivation, grazing or forestry

VIII. usually extremely rough, sandy, wet or arid land that may have a value for wildlife.

These use-capability classes are defined very generally to begin with, and sharper definitions are given in accordance with the conditions and practices prevailing in the region being surveyed. The classes are determined solely on the basis of physical characteristics of the land, i.e., of the soil and climate [64]. The chief characteristics are (1) susceptibility of the soil to erosion when cultivated, (2) natural soil productivity, (3) factors interfering with cultivation, e.g., stoniness, hardpan, (4) climate, particularly temperature and precipitation.

As an illustration of the factors considered in determining a land class [36] Class-I land is described as " land highly suitable for cultivation, for it does not have a permanently high water table ; neither is it stony or spotted with rock ledges ; nor does it possess any other physical characters which interfere with the use of tillage implements. Furthermore clean-tilled crops like corn, cotton, or tobacco, the growing of which is often likely to result in soil washing, can be raised on this land without danger of appreciable erosion. Finally, it retains and supplies sufficient moisture and plant nutrients to maintain those physical, chemical, and biological conditions of the soil that favor continued production of moderate to high yields of farm crops."

" Special practices " apparently include any conservation measures such as rotations, strip cropping, terracing, drainage, not ordinarily used in the locality. A simple rotation that is customary in one place is not a special practice, but the same rotation where it is not customary is a special practice.

Field mapping is usually done on aerial photographs in detailed conservation surveys on a scale of four inches to one mile. Smaller scales are used for reconnaissance surveys.

A trained soil surveyor determines and maps the soil, slope and erosion conditions, but the actual classification or grading of the land types mapped is the result of consultation between surveyors, planning technicians, agricultural scientists and farmers.

This type of land classification is exceptionally easy to translate into land-use recommendations. Table 2 illustrates how this is done [62].

TABLE 2

Use recommendations based on use-capability classification

Land-use capability class	Land use	Cropping systems	Supporting conservation practices	Soil treatments
I.	Cultivation	Row crop 2 years, small grain, hay	None	Manure
II.	do.	Row crop, small grain, hay	Contour strips, 75'-125', or terraces	Lime+manure
		Row crop, small grain, hay 3 years	Contour cultivation	do.
		Row crop, small grain, hay 4 years	None	do
	Pasture	None	None	do.
III.	Cultivation	Row crop, small grain, hay	Contour strips and terraces	do.
		Row crop, small grain, hay 2 years	Contour strips, 60'-100'	do.
		Row crop, small grain, hay 4 years	Contour cultivation	do.
	Pasture	None	None	do.
IV.	do.	None	Controlled grazing. Contour furrowing for adapted soil, slope and vegetative cover	Lime+phosphorus
	Woodland	None	Protection and management	None
	In case it is necessary to cultivate Class-IV land, special intensive practices will be planned to meet the conservation needs.			

The systems recommended in the third column are determined not only by the land class, but also within limits by the capacity and preferences of the occupier of the land.

The type of classification described might be defined more correctly as of soil rather than of land. It is a classification with a definite and limited objective—the control of soil erosion. Factors like inherent fertility, crop adaptability and economics are only incidental, the overriding consideration in using the classification for land planning being whether or not the adoption of a certain practice will result in erosion or, more generally, soil deterioration. There are, however, very large regions all over the world where erosion control must now be the primary purpose of land planning, and for such regions a relatively simple land classification, similar to that used by the U.S. Soil Conservation Service, should be useful.

One might with some justice describe the purpose of a soil conservation survey to be planning for permanent settlement. It is a straightforward, easily defined objective. Without adequate soil conservation permanent

settlement and long-range land planning become impossible. A land classification based on the requirements of soil conservation should therefore constitute at once a "fundamental" and a "practical" classification—practical because it considers the economic and technical aspects of land utilization, and fundamental because it relates these to the limitation imposed by the natural environment. In Western Europe which, as Eisenhower [19] has stated, is the only developed region of the world that is practising total soil conservation, the pre-war pattern of land use was the resultant of farming systems evolved primarily for soil conservation and modified within the soil-conservation framework by economic, political and social factors. It seems inevitable that those countries which are attempting consciously to plan their evolution towards the settled state must also base their land-use planning primarily on soil conservation. The land classification here described has the great merit of simplicity of determination and expression of land classes, and might serve as a model for many other classifications with the same or a similar objective.

The land-capability classification is fairly permanent, but changes either in the land (caused, e.g., by erosion) or in the methods of use or protection (e.g., irrigation developments, drainage, erosion control) may make reclassification necessary.

With the aid of a land-capability map, a present-use map and a recommended-use table as given above it is a fairly simple matter to replan land use on a conservation basis. Figs. 1 to 3 show how this was done for a farm in South Carolina [36]. Normally, of course, a farm is not planned independently, but in relation to the physical nature and use of surrounding land.

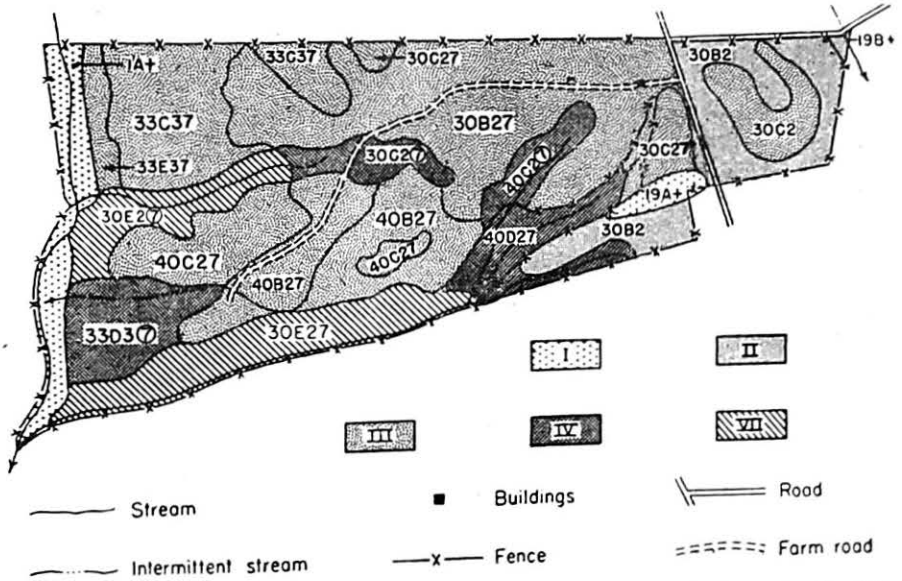

FIG. 1.—Land-capability map of a 151-acre farm containing land of Classes I, II, III, IV, and VII. Symbols show the soil types, slopes, and erosion classes. Soils are: 1, alluvial soils, undifferentiated; 19, Seneca sandy loam; 30, Cecil sandy loam; 33, Cecil clay loam; and 40, Appling sandy loam. Slopes are: A, less than 2 per cent; B, 2–7; C, 7–10; D, 10–14; E, 14–25; and F, 25 or more. Erosion classes are: +, alluvial land along streams; 2, sheet erosion, 25 to 75 per cent of topsoil removed; 27, the same with occasional gullies; 37, sheet erosion, more than 75 per cent of topsoil removed, and occasional gullies. A circle around a gully symbol indicates gullies too deep to be crossed with tillage implements.

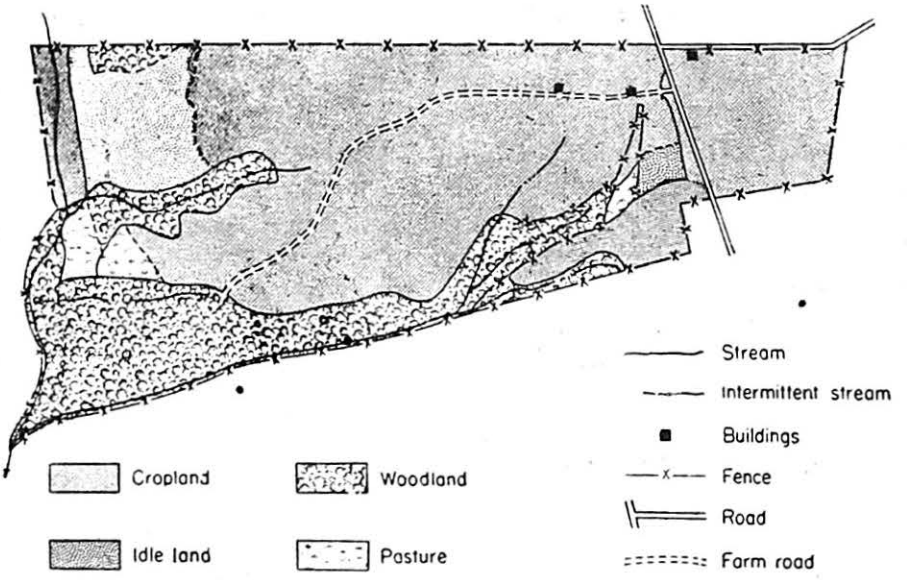

FIG. 2.—Land use on the farm shown in Fig. 1 before the new farm plan was made.

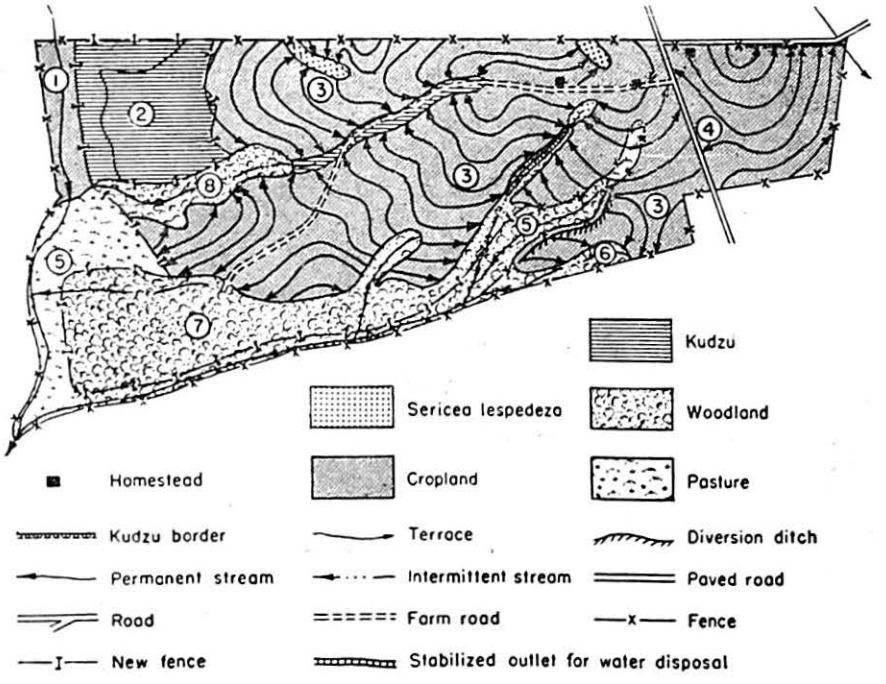

FIG. 3.—Land use in the farm-conservation plan.

3. Tennessee Valley Authority

The unit-area method of land classification has been developed by Hudson [38] and collaborators for use by the Land-Classification Section of the Tennessee Valley Authority. It represents an attempt to bridge the gap between methods of detailed field analysis and of reconnaissance. The T.V.A. required a method of land survey by which the whole Tennessee Basin could be rapidly and accurately covered. The best reconnaissance methods were too general to yield adequate data; other methods were too slow and expensive [62].

The method finally evolved is an adaptation of the fractional-code method—i.e., the qualities of the land significant in planning are represented by digits, one set of digits relating to physical conditions composing the denominator, and another set relating to "human" conditions the numerator, of a fraction which describes and defines the land class. In the unit-area method fractional-code notations are applied to land units of not less than 200 acres. It aims at giving "an accurate quantitative portrayal of the occupancy pattern".

The complete symbol of a land unit comprises three parts, namely, a long fraction, a short fraction and a Roman numeral, e.g., $\text{II}\ \frac{3}{3}\ \frac{2D323}{2331233}$.

Detailed classification has been made mainly of agricultural land, though the method can be extended, if required, to forest, urban, recreational and other areas.

For agricultural land the physical conditions of slope, drainage, erosion, stoniness, rock exposure, soil depth and soil fertility are first determined. These are expressed in the above order and according to the criteria given in Table 3 as the digits of the denominator of the long fraction. The unit is then classified on the "human" or cultural features of major agricultural use, agricultural emphasis, field size, amount of idle land, and quality of farm buildings and equipment (Table 4). The corresponding digits comprise the numerator of the long fraction.

The short fraction is a summary of the long fraction. The denominator represents the judgment of the field man, based on all observable physical factors, whether recorded or not, as to which of five quality classes the land unit belongs; the numerator likewise represents the field man's judgment of quality class based on observable cultural data. In Tables 5 and 6 only the criteria for assessing classes 1 and 5 are given for the sake of brevity. From these the close relationship between the short and long fractions will be apparent.

TABLE 3

Major land uses or " human " items on the basis of which homogeneous land uses are delimited. Noted by the digits in the numerator of the long fraction

First Digit	Second Digit	Third Digit	Fourth Digit	Fifth Digit
Major Land Use	Agricultural Emphasis	Field Size	Amount of Idle Land	Quality of Farmsteads and Equipment
1. General farming	A. Corn	1. Large	1. Little	1. Excellent
2. Animal industry	G. Grain (small)	2. Medium	2. Limited	2. Good
3. Cash-crop farming	B. Beef cattle	3. Small	3. Considerable	3. Medium
4. Part-time farming	D. Dairying	4. Very small	4. Excessive	4. Poor
5. Subsistence farming	S. Sheep			5. Very poor
6. Forest land	H. Hogs			
	M. Mules and/or horses			
7. Recreational area	P. Poultry			
8. Rural-village area	T. Tobacco			
9. Urban area	C. Cotton			
0. Manufacturing and mining areas	W. Truck			
	O. Orchard			
	N. No emphasis			
	F. Forage			

TABLE 4

Major physical conditions of the land on the basis of which homogeneous units are delimited. Noted by the digits in the denominator of the long fraction

First Digit	Second Digit	Third Digit	Fourth Digit
Slope	Drainage	Erosion	Stoniness
1. Relatively level	1. Thorough	1. Little or no observable erosion	1. Free from stones
2. Relatively level to undulating	2. Adequate	2. Little denudation by erosion	2. Moderately stony
3. Undulating to moderately hilly	3. Poor	3. Sheet erosion and ephemeral gullies	3. Stony
4. Hilly	4. Very poor	4. Excessive sheet erosion and gullying	4. Very stony
5. Steep	5. Excessive	5. Excessive gully erosion	

Fifth Digit	Sixth Digit	Seventh Digit
Rock Exposure	Soil Depth	Soil Fertility
1. Little or no rock exposure	1. Deep (6 feet or more)	1. Exceptionally fertile
2. Limited rock exposure	2. Moderately deep (3 to 6 feet)	2. Fertile
3. Considerable rock exposure	3. Shallow (1 to 3 feet)	3. Moderately fertile
4. Excessive rock exposure	4. Very shallow (less than 1 foot)	4. Very low in fertility
5. Rock exposure barren		5. Very low in fertility

TABLE 5

Criteria for classifying land on the basis of the agricultural quality of present physical conditions

(denominator of the short fraction)

Class 1. Units of 200 acres or more that are characterized by the following physical indices, appearing individually or in combination: (1) level or moderately undulating surface; (2) adequate or thorough drainage; (3) little or no observable erosion; (4) deep stone-free soil of exceptional fertility; (5) little or no rock exposure.

Class 5. Units of 200 acres or more that are characterized by the following physical indices, appearing individually or in combination: (1) steep slopes; (2) very poor or excessive drainage; (3) denudation by sheet or gully erosion beyond the point of cultivation and economically feasible rehabilitation other than by reforestation; (4) shallow or stony soils, very low in fertility; (5) excessive rock exposure.

TABLE 6

Criteria for classifying land on the basis of the quality of the present agricultural use

(numerator of the short fraction)

Class 1. Units of 200 acres or more that are characterized by the following use indices, appearing individually or in combination: (1) medium and/or large uninterrupted fields; (2) fields free from weedy or brushy cover; (3) little or no idle land; (4) excellent farmsteads and farm equipment; (5) any other evidence of an excellent standard of living.

Class 5. Units of 200 acres or more that are characterized by the following use indices, appearing individually or in combination: (1) very small and/or interrupted fields; (2) sparse, weedy or brushy field cover; (3) excessive amounts of idle land; (4) very poor farmsteads and farm equipment; (5) any other evidence of a very low standard of living.

Finally, the land is put into one of five classes according to the severity or absence of problems and needs for readjustments. These classes are indicated by the prefixed Roman numerals I to V. "In part, these Roman numerals represent a summary of their accompanying short and long fractions; but again the entire complex in all its pertinent observable respects is carefully considered and appraised before the field judgment is made." The ten criteria for distinguishing each class are the same as the corresponding criteria given, for Classes 1 and 5, in Tables 5 and 6. The classes are briefly defined as follows:—

Class I. Units in which no significant agricultural problems are apparent. These units are characterized by an excellent standard of living and by land exceptionally well suited for both general and specialized types of agriculture.

Class II. Units in which the apparent agricultural problems are not critical, but can generally be solved by education and demonstration. The units are characterized by a good standard of living and by land well suited for general and specialized agriculture.

Class III. Units in which agricultural problems are moderately critical, but can be solved by intensive education and demonstration. Characterized by a medium standard of living and by land which can be used for general or special crops under proper management.

Class IV. Units in which agricultural problems are very critical, and can usually be solved only by a marked readjustment and/or reorientation of economic activities.

Class V. Units usually only suitable for forest use, alternatively for recreation, game preserves; also waste land. Characterized by a very low standard of living and by land unsuitable for agriculture.

The long fraction can be regarded as an inventory of the physical and agricultural conditions, the short fraction and the Roman numeral as assessments or appraisals of the inventory.

A new body of land is delimited whenever a change occurs in one or more of the items recorded. The fractions and numerals are recorded in ink on aerial mosaics, and subsequently each unit area is put into one of three general classes :—(1) land suited to intensive uses (with emphasis on cropping); (2) land suited to extensive use (with emphasis on pasture); and (3) land suited to non-agricultural uses. This classification is based on data not only from the unit-area survey, but from all other available sources.

Non-agricultural or forest land is classified and mapped simply by the appropriate figure 7, 8, 9, or 0 of the first digit of the numerator of the long fraction (Table 3). No further characterization is made. Forest land is identified by the numeral 6 in the numerator of the long fraction, and in the denominator the same seven physical conditions are noted as for agricultural land, e.g., $\frac{6}{4122114}$. Forest types are not distinguished by the Land-Classification Section, as these are the concern of the Forestry Division of the T.V.A.

The suitability of this method of land classification and mapping for the Tennessee-Valley region is due to the fact that a considerable amount of detailed field work has been carried out, that aerial photographs are available as base maps, and that it is possible to conduct operations on a fairly large scale. The method has been successfully used, with the necessary modification in the significance of the digits, in New Zealand where similar favourable conditions for its application obtain [18].

4. New York State

Land-classification studies have been made of many counties in New York. Their main purpose has been to classify and map the land according

to its adaptability to different degrees of intensity of use. To plan a land-use programme on the basis of such a map it is necessary to have knowledge of the natural factors limiting intensity of use, the factors which have determined present intensity of use, and those chiefly affecting the economic status of the farming community. It has been shown that in New York commercial, social and financial amenities such as roads, electricity supply, schools and credit facilities have a preponderating influence on the intensity of land use. At the same time the growth of such amenities is much influenced by the quality of the land.

In the New-York system the lowest land class is numbered I, and is natural forest land so poorly adapted to agriculture that it has seldom—and then unsuccessfully—been cultivated. Class-II land is also better suited to forest, nevertheless much of it has been brought under cultivation. Classes III to VII are suited to continuous agriculture of increasing degree of intensity of use.

The first operation in making a land classification is the preparation of a " property-classification " map. Farms are classified, usually by inspection from a moving car, according to the *apparent amount and condition of the farm capital.* The main evidence is obtained from the size and condition of farm buildings, but the state of roads and the distribution of utility services and amenities are also taken into account. It is considered that farmers " are continually struggling to adjust their farming operations to the character of the land in such a way as to earn as much as they can and to accumulate the largest possible amount of capital. Variations in the amount and condition of the capital which experienced farmers have been able to accumulate and maintain on the land, therefore, measure the combined economic effect of lay-of-the-land, climate, soil, and markets, and are one of the most reliable indications of the intensity of use to which the land is adapted " [62].

A land-use map, indicating actual intensity of use, is then prepared. Maps of topography and soils, both being important factors influencing intensity of use, are also required.

The delineation of land-class boundaries is done primarily from the property-classification map which roughly indicates the amount of capital a land type is capable of accumulating. A first adjustment of the boundaries is then made with the aid of the topographic map, since the actual boundaries of land classes are more likely to correspond to topographic than to property features. Further adjustments are made in turn from the land-use map and from the soil map ; consideration of the distribution of soil types sometimes results in radical modifications of the land classes distinguished on the basis of property condition and present intensity of use. Finally, the land-class map is checked in the field against type of use, condition of buildings, topography, etc. It is stated that differences between land classes are usually immediately apparent to those who are accustomed to land-class maps, though not always to others.

The maps are supplemented by statistical data which show the quantitative differences between the land classes. Of particular significance are the differences between classes as indicated by comparative farm-business data. It has been found, for example, that the gross and net incomes of farmers on the better-class lands have been consistently higher than those on the lower classes since 1908, the earliest date for which farm-management data are available.

5. Western Canada

Land in the prairie provinces has two main uses—wheat production and grazing. The former has been and will probably continue to be the major use in Saskatchewan, though grazing may surpass it in Alberta [15]. Distinction between land classes is based on the quantity of wheat available for sale per quarter section, converted to net productivity. There are four steps in the classification :—

1. determination of gross productivity per quarter section of land ;
2. conversion of gross productivity into terms of net revenue ;
3. classification of parcels on the basis of certain ranges of estimated net revenue ;
4. modification of such classification on the basis of the characteristics of individual parcels.

Saskatchewan [79]. Each quarter section is assessed in the light of all relevant physical and economic information available, special weight being given to the history and past productivity of the land. It is assigned to one of five classes, class I being submarginal, class II marginal, and classes III to V increasingly favourable for wheat production.

The classification hinges on the definition of marginal land—class II. Marginal land is defined economically as " land which . . . would, if operated with average managerial ability, in a unit of average size and typical organization, be expected to pay expenses—including depreciation and taxes—and provide a living for the operator and his family. It would not yield sufficient to pay for the use of the land either as rent or interest."

Farm-management studies have shown that marginal wheat farming—i.e., so that the operator gets the cash equivalent of a hired man's wages—corresponds to a production of wheat available for sale of 350 to 475 bushels per quarter section. These are therefore taken as the lower and upper limits of productivity of class II. Class-I land produces less than 350 bushels available for sale ; class III from 476 to 720 ; class IV from 721 to 900 ; and class V over 900 bushels available for sale.

This initial classification shows the relative productivity not of specific land or soil types, but of quarter sections. In the final classification this is modified by taking into account factors such as the effect of physical land characteristics on farm economy, variability of yield, progress towards permanent settlement, and main causes of success or failure.

The productivity is calculated primarily from (1) the annual yields per acre estimated from data obtained for different soil types for the years 1921—1936 multiplied by (2) the number of acres of cultivable land per quarter section. 1.5 bushels per acre is deducted from the estimated yield to allow for seed and farm use, and it is assumed further that on the average 45 per cent of the total cultivable area will be used annually in the production of wheat for sale.

As might be expected, there is quite good correlation between these mainly economically determined land classes and the financial and economic status of the occupiers in each class. Thus the land class is quite closely reflected in the price paid for land, tax assessment per acre, condition of buildings, percentages of mortgages foreclosed, and percentages of privately-owned and owner-operated land within a class. These characteristics are clearly associated with the relative yields of wheat on the different land classes. The wheat yield is an expression of the land's economic performance, and the land-classification map based thereon would, with minor adjustments, become a land-price or tax-assessment map, for example. This, presumably, is its purpose. It is claimed that the classification gives a general picture of productive capacity, and would reflect with reasonable accuracy the relative productivity of the land in other uses than wheat. It is questionable, however, whether this would be so unless the other uses were operated on an economy similar to that of extensive wheat production.

There is apparently no close correspondence between the distribution of land classes and soil types. Sands and gravels predominate in classes I and II, while most of the heavy clays occur in class V. The purely economic criteria by which land classes are distinguished make it unlikely that any close correspondence should exist, since many other variable factors besides soil contribute to land's economic performance. To a limited extent it was possible to equate different combinations of soil and topographic conditions within a land class, e.g., in classes I and II very poor, coarse, alkaline flat and " blow-out " soils may be associated with a flat topography favourable for cultivation, or somewhat better loams with rolling or broken topography.

Alberta. A similar system of classification, and for similar purposes, has been used in Alberta where, owing to large and frequent fluctuations in weather and wheat prices, agricultural settlement and production have been very unstable. It is felt that the classification of the land on an optimal-use basis is the first step towards planning to establish greater rural stability.

The general approach to land classification is described by Stewart and Porter [83] as follows. " The use of land depends upon the decisions of individual farmers; and the decisions of farmers depend on their expectations of the returns they can secure from land. Stable land use requires that, over a period of years, farmers can expect to meet their expenses, and secure for themselves returns sufficient to induce them to continue

production without expansion or contraction. Under given prices, and with prevailing methods of production, some land may be incapable of providing for these necessary costs (submarginal land); other land will be just sufficiently fertile to cover costs (marginal land); more fertile land will yield a net revenue over the essential costs. Land may therefore be classified on the basis of its estimated capacity to yield net revenue."

The classification used by Stewart and Porter is fundamentally an economic one, and depends on an estimate of the net revenue obtained from the land under wheat. The determination of the net revenue is the crux of the method. The classification assumes that the land is not in use, and that farmers are considering the contracts and payments they should make in connexion with securing the land.

The procedure of classification involves the following steps.

(a) Determination of a physical productivity rating for each parcel, based on (i) the average long-run yield of wheat for the soil type of the parcel, (ii) the acreage of tillable land, and (iii) the typical proportion of tillable land in wheat.

(b) Conversion of this measure of gross physical productivity into terms of estimated net revenue using (i) long-term average prices for wheat and other farm products, and (ii) a budget of costs derived from farm-management survey data.

(c) Preliminary classification on the basis of certain ranges of estimated net revenue. Four classes are distinguished:

Class I. Estimated annual production of marketable wheat per quarter available for sale less than 375 bushels, and estimated revenue less than costs (submarginal).

Class II. Estimated annual production of marketable wheat per quarter available for sale 375–517 bushels, and estimated revenue equal to a range of costs (marginal).

Class III. Estimated annual production of marketable wheat per quarter available for sale 518–795 bushels, and estimated net revenue up to $237 per parcel of 480 acres, and based on a wheat price of 92 cents a bushel.

Class IV. Estimated annual production of marketable wheat per quarter available for sale 796–999 bushels, and estimated net revenue of more than $237 and less than $411 per parcel.

This classification provides a uniform basis on which to compare parcels in widely scattered areas with significantly different general features. Modification of the preliminary classification of parcels is necessary to allow for particular features of individual parcels, for example, topography, stoniness, erosion, climate and other physical characteristics. Adjustments are based on descriptive notes made in the field, aerial photographs and re-examination in the field.

6. ONTARIO

Hills [35] has outlined a system of land classification applicable to land-settlement problems in a thinly populated, slightly developed region of the Great Clay Belt of northern Ontario. Owing to lack of communications and the density of the natural plant cover soil survey was impossible, and the area was mapped in land types distinguished according to the criteria of land form, geology, drainage, soils and natural vegetation. Related land types were grouped into land classes.

Nine land classes were established, distinguished by the Roman numerals I to IX. No qualitative significance attaches to these numerals. The classes are objectively determined. Thus " Land class No. I occurs on the better drained areas dissected by stream courses or on comparatively low ridges where heavier materials cover a ' core ' of rock-knob or glacial debris. In this class are found soil profiles exhibiting a considerable degree of podzolic leaching. Land classes II and III are half-bog soils with a maximum peaty layer of approximately 18 to 36 inches, respectively. Land class IV includes the deep peat or muskeg. Land class V is a complex condition in which variable depths of intermediate and heavy textured materials overlie the fluvio-glacial sands and gravels. Under average conditions, the heavier surface layers supply fertility, and the lower open layers provide good drainage with the result that the most productive soils are found in local areas within this type. Outwash materials of intermediate texture are included in Land class VI. Ridges of coarse sandy and gravelly materials constitute Land class VII. Although these deposits are similar to the underlying materials of Land class V, the soils are droughty and low in fertility because of the absence of the heavier surface layer. Fairly compact, loamy, till soils constitute Land class VIII while the outcrops of the Precambrian rocks, with their shallow mantle of light soil are mapped as No. X." For some reason, No. IX has been omitted.

The agricultural or forestal capabilities of these classes are being determined on the basis of physical data, present use and past experience—chiefly, it would seem, of experience. " For example Land classes I, II and portions of V have the highest agricultural potentials. Local conditions of soil drainage and climate in No. V are most favourable for the production of potatoes. Classes III and VI have only fair agricultural potentials. Few soils similar to those in Land class VII are used extensively for agricultural production in America at the present time. Land classes IV and X have practically no agricultural value. For forestal purposes areas of classes I and V indicate the best saw-timber sites. In the mature stands of black spruce on Land class II, 2-log trees (which make 32 feet of pulpwood) are dominant while 1-log trees are common on Land class III. Portions of Land class VII are good pine lands."

Political, economic and cultural factors do not enter into the determination of land classes or of their use capabilities, but come into operation in formulating a plan of development based on this land classification. The plan, for example, might be to develop the best classes of land first.

This would require modification in practice according to costs of development, proximity to social and economic services, pressure of population, market facilities, etc., in each area. The political factor of whether costs of and responsibility for development were assumed by public or private authorities would also affect the execution of the basic plan.

7. New Zealand

Grange [26] has attempted to classify land in the North Island, New Zealand, according to its inherent productivity, on the basis of the soil survey. The soils are firstly classified into genetic groups which are then subdivided into stages—young, immature, semi-mature, mature—and finally into series and types as in the American system. The stage subdivision is in effect an inherent-productivity classification within a genetic group, young soils being the most, and mature soils the least, fertile. The soil map itself has but limited practical use, as there are more than 500 different types in the North Island, but from it single-factor maps (e.g., of lime or phosphate requirement, erosion, texture) are being prepared which have a direct application to advisory work. The soil types have also been grouped into six fertility or use-capability classes, with special reference to pasture utilization, namely [63] :—

Class I.—Level or undulating land, not too elevated, with deep soils and favourable moisture conditions, and which are, or can be, converted into high-quality farming land.

Class II.—Ploughable land which can be converted into only fair- or medium-quality farming land on account of some limiting factor to productivity.

Group (a) : Soils in which moisture is a limiting factor.

Group (b) : Soils in which some other factor such as texture, structure, drainage, elevation, or depth of soil is a limiting factor.

Class III.—Ploughable land which has severe limitations to productivity and requires further investigation before development is attempted.

Class IV.—Hilly or steep land which will maintain grass pasture with little or no top-dressing. Both topsoil and subsoil are of high fertility, and erosion is not a serious problem.

Class V.—Hilly or steep land of moderate to low fertility. Light top-dressing is required to maintain a cover of grass, and careful management is necessary to prevent serious erosion.

Class VI.—Hilly or steep land which has severe limitations to utilization, such as low fertility or erodibility. This class is probably more suited to forest than to grass.

8. Great Britain

In a country of long and politically stable settlement, present land use (except in apparently abnormal periods such as wartime) constitutes a

natural basis for a land-planning classification. Such a statement implies that land planning is not required, or would not involve much drastic modification of present use, in a country which has enjoyed long political stability, and in general this is borne out by facts. The countries of Western Europe are politically the most mature and before 1940 seemed the most stable in the world; they did not evince the same interest in land planning as the politically immature countries of the New World or of Central and Eastern Europe. A prolonged period of undisturbed national development allows an equilibrium to be approached between the numerous interacting forces affecting the utilization of the land. "In Britain much of the land has been settled and farmed for upwards of a thousand years, some of it for two thousand. The present utilization does therefore reflect the combined influence of the varied factors concerned: the physical factors of relief, soil and climate; the more purely economic and social factors of markets, prices, transport, labour; the historical factors of land ownership, local usage, tenure, and even tradition or custom. It is only when the attempt is made to analyse present land use by reference to only *one* set of factors that dangerous fallacies of interpretation may be promulgated" [81].

No nation-wide soil survey has been carried out, and the only comprehensive scheme of land classification is that adopted by the Land Utilization Survey of the University of London, and based originally on existing land use, i.e., during the period 1931–1938. This period witnessed the lowest intensity of land utilization since the Industrial Revolution. The land is divided into ten major types numbered 1 to 10. Whilst types 1 to 4 inclusive are land of high agricultural value, types 8 to 10 land of low agricultural value, and types 5 to 7 land of intermediate quality, there is not a steady gradation in utility and value from 1 to 10. First-class arable land and first-class grazing land may be equally valuable, but the two types of utilization require different physical conditions. Certain types primarily suitable to arable farming and crop production are distinguished by the addition in brackets of the symbol A (arable); others naturally suited to pasture or meadow are distinguished by the symbol G (grassland). Still others can serve in either utilization (A–G), but the poorer types of land agriculturally sub-marginal under most economic conditions are normally under heath, moor or rough pasture, and are given the suffix H (heathland).

The ten classes are grouped into three Major Categories, distinguished by the following characteristics of site and soil:

Major Category I—good-quality land

Site (1) not too elevated,
(2) level, gently sloping or undulating,
(3) favourable aspect.

Soil (1) deep,
(2) favourable water conditions,
(3) texture, mostly loams, but including some peats, sands, silts and clays.

Major Category II—medium-quality land

Land of limited productivity by reason of the unfavourable operation of one or more site or soil factors, e.g.,

Site (1) high elevation,
(2) steepness,
(3) unfavourable aspect.

Soil (1) shallowness,
(2) defective water conditions.

Major Category III—poor-quality land

Land of low productivity by the extreme operation of one or more site and soil factors. Four groups of extreme factors are recognized.

(a) extreme heaviness and/or wetness of soil, giving poor-quality heavy land or land in need of extensive drainage works ;
(b) extreme elevation and/or ruggedness and/or shallowness of soil, giving mountain moorland conditions ;
(c) extreme lightness of soil with attendant drought and poverty, giving poor-quality light land ;
(d) several factors combining to such an extent as to render the land agriculturally useless or almost so—such as shingle beaches or moving sand dunes.

The complete ten types and the estimated percentages of England and Wales occupied by each are :—

Major Category I—good		48.8
1. First-class	5.5	
2. Good general-purpose farmland—		
2 (A) Suitable for ploughing	20.3	
2 (AG) Crops or grass	6.3	
3. First-class, restricted use, unsuitable for ploughing	3.6	
4. Good but heavy land	13.1	
Major Category II—medium		31.4
5. Medium light land—		
5 (A) Suitable for ploughing	5.9	
5 (G) Unsuitable for ploughing	0.8	
6. Medium general-purpose farmland	24.7	
Major Category III—poor		16.1
7. Poor heavy land	2.1	
8. Poor mountain and moorland	11.5	
9. Poor light land	2.1	
10. Poorest land	0.4	
Residue—closely built over		3.7

That present land use in Britain is, broadly speaking, indicative of land quality is shown by the remarkable constancy of land use over long periods of time on the best and worst types, and the maximum of change on the intermediate types. Historical records show that the best arable land has often remained under the plough almost continuously for a century or more, while the worst types have remained uncultivated. Neither the long, pre-war slump in arable farming nor the war-time boom appreciably affected the utilization of these types. The intermediate types, on the other hand, include those which largely went out of cultivation during the last seventy years and were the first to be ploughed up during the war.

These classes were originally distinguished according to present use, not directly according to soil, climatic or geographical characteristics except in so far as these have determined present use—as in many cases they have to a very large extent. The purpose of the Land Utilization Survey was merely to inventory land use, not to classify land. But as public interest in land planning has grown, a need for a complementary land classification has also become apparent, and has been filled by adapting the land-use inventory. It will be seen from the above descriptions of the classes that they are distinguished not solely on a use basis, but also according to the characteristics of soil and site. There is implied in this classification, as in all others, the outline of a land-use plan—i.e., the classes are distinguished, and the criteria for distinguishing them are selected, with more or less definite uses in view. The plan here postulates the reservation of the most productive lands for agriculture, consequently, the classes are distinguished mainly by agriculturally significant criteria. Stamp [81] suggests :—

(1) that the good agricultural lands, categories 1 to 4 inclusive, which occupy about half of the surface, should be reserved for agricultural use, and that other forms of utilization should only be permitted in exceptional cases, each specific case to be fully justified ;

(2) that schemes requiring extensive tracts of land such as national parks, afforestation, green belts, main highways of parkway type, water-supply and power schemes, should be restricted as far as possible to the poor lands ;

(3) that the integration of national needs in industry, housing, communications, including provision of sites for garden cities and satellite towns should be particularly on land of intermediate quality (5 and 6), since poorer land is only in some areas suitable or available, it being borne in mind at the same time that some of the poorest land is particularly adapted for heavy industry.

For a highly developed country like Britain it is probably impossible to make more detailed recommendations for land use on the basis of a physical and present-use classification, since it is economic rather than physical factors which are often the determinant.

A more detailed ecological classification of grasslands has been made by Stapledon and Davies (cited by [81]) who distinguish the following eleven classes:

(a)	First-grade ryegrass pastures in which perennial ryegrass contributes 30 per cent or more to the sward.	Chiefly lowland types
(b)	Second-grade ryegrass pastures containing 15 to 30 per cent of perennial ryegrass.	
(c)	*Agrostis*-with-ryegrass pastures: being basally *Agrostis*, but perennial ryegrass contributing up to 15 per cent.	
(d)	Ordinary *Agrostis* pastures sometimes containing mere traces of ryegrass.	
(e)	*Agrostis* pastures with excess of rushes and sedges.	
(f)	Fescue pastures, including (i) mountain fescue, (ii) open downland, and (iii) lowland heaths carrying fescue swards.	
(g)	*Nardus* pastures often with excess of heath rush (*Juncus squarrosus*).	Chiefly rough and hill grazing
(h)	*Molinia* pastures.	
(j)	Cotton-grass and deer-grass moors.	
(k)	Heather moor.	
(l)	Fern, gorse and the like.	

Osmond [65] has proposed the use of indices in regional land classification, defined in terms of the three factors site, soil and climate that influence the growth of crops and a fourth—the development factor—which embraces the influences of human activities and of such natural phenomena as are not included in the first three factors.

Each factor in a region is classed as either good (1), intermediate (2), or poor (3). A region is defined by a four-figure index made up of the class figures of the four factors in the order site, soil, climate, development. Thus 1213 indicates that the region has a good site, fairly good soil, good climate, but poor development due, for instance, to past agricultural neglect or to poor drainage. The index shows that if the conditions indicated by the figure 3 can be remedied the area could become of use to agriculture, whereas if the figure 3 had been first in the index (referring to site) improvement might have been precluded in any planning scheme.

The chief site factors considered are elevation, slope and topography; the chief soil factors are depth, water-holding capacity, nutrient content

and structure ; and the chief climatic factors are rainfall and temperature during the growing season. The indices are given not to soil types or individual farms, but to regions. No definition of a region is given, but presumably the word is used in the modern sense used by geographers.

The indices do not represent a classification, but regions can, if desired, be classified into three categories A, B and C on the basis of the indices—e.g., regions with indices 1111, 1211, 2111 would go into category A, 2221 and 2121 into category B, and 3212 and 3333 into category C.

9. Prussia

A land classification based on the soil survey and used by the Preussische Geologische Landesanstalt is described by Mückenhauser [61] who points out that the ordinary soil map leaves out much information essential to the land planner—for example, the cropping capacity and water economy of the soils. To include such details would make the map too complex for general purposes. Special evaluation maps (*Auswertungskarten*), for the making of which expert knowledge of both soils and the objectives of the land-use plan are necessary, are used to convey the information. In general the planner wants facts about the cropping capacity and water economy of the soils and the nature of the subsoil foundations (*Baugrund*). It has been found convenient in Prussia to express these facts on two special maps, one showing soil utilization and another showing water and subsoil conditions.

The soils are first classified as arable, grassland, forest or wasteland soils, with the recognition that certain grassland soils, for example, could be transferred to the arable class by drainage, etc. The arable and grassland soils are then divided into five and two classes respectively, according to the average yields obtained from them, and these classes are given standard colours on the map. In the legend of the map the commonly grown plants of each soil class are indicated in four separate columns—for grains, inter-tilled crops, fodder and green-manure crops, and trees—and two further columns give a general idea of the cost (*Aufwand*) of maintaining soil fertility, and suitability for settlement.

The various colours for the second map are chosen so that all yellow, red and brown tints indicate land not requiring drainage, grey tints land with impeded drainage, and blue tints land with a water table nearer than 1½ metres to the surface. The corresponding soil-moisture conditions, drainage and irrigation requirements, and subsoil conditions from the building standpoint are indicated in the map legend. Parts of the legend are shown in Tables 7 and 8.

TABLE 7. Legend of soil-utilization maps of the Preussische Geologische Landesanstalt

Colour on map	Soil class according to cropping capacity	Average yield	Appropriate plants				Cost of maintenance	Suitability for settlement
			Grains	Intertilled crops	Fodders and green manures	Trees		
I. ARABLE SOILS								
1. Red	Good arable	24-27 dz./ha. wheat	Wheat, oats, barley, rye	Beet, beans, oil plants	Lucerne, clover, beans	Mixed forest	Moderate liming and manuring	Very good
3. Light brown	Rather poor arable	20-23 dz./ha. rye	Rye, oats, some barley	Potatoes, swedes	Clover, blue lupin, seradella	Mixed forest	Some expenditure on improvements needed	Suitable
5. Yellow	Bad arable	10-13 dz./ha. rye	Rye	Potatoes	Yellow lupins	Pine and birch	Heavy outlay on improvements	Unsuitable
II. GRASSLAND SOILS								
1. Dark blue	Fairly good grassland	40-50 dz./ha. hay	Sundry grasses and legumes			Ash, birch, spruce	Moderate improvement needed	Well suited for grass
2. Light blue	Poor grassland	25-35 dz./ha. hay	„ „ „ „			Ash, birch, spruce	Greater outlay needed	Suitable
III. FOREST SOILS								
1. Dark green	Good forest					Beech, oak, ash, pine		Unsuitable for settlement, usually owing to steep topography
2. Light green	Poor forest					Pine, birch, hornbeam, (larch, spruce)		

TABLE 8. Legend of the water and subsoil map

Colour	Moisture conditions of soil	(a) Drainage (b) Irrigation	Quality of subsoil for building foundations
Yellow	Dry	(a) Not needed (b) Irrigation profitable	Dry, load-bearing
Light brown	Good	(a) Not needed (b) Not needed	Dry, load-bearing
Light grey	Periodically damp	(a) Very beneficial	Reinforcement of cellar necessary. Load-bearing
Light blue	Damp. Water table 0.8—1.2 m. deep	(a) Necessary	Reinforcement necessary. Load-bearing

Stremme and Ostendorff [87] have attempted to classify land in East Prussia especially, and in Germany generally, according to the area of a holding required to give a minimum standard of living to the occupier. This is in effect a classification according to soil productivity, since the same standard of living is procurable from a smaller area the more productive the soil is. Soils are grouped in genetic classes subdivided into textural classes. The minimum area for existence (*Mindestbetriebsgrösse*) is calculated for each soil class from the gross yield of all crops cultivated on the soil, in two ways. In the first the yield is multiplied by the average price of the produce without reference to the cultivation or cropping system. This gives the average money yield per hectare, from which the area required for minimal existence can be calculated. The classification is simple and said to be applicable without serious modification to the whole of Germany. In the second way a correction is applied to allow for the standard of management practised and attainable.

A further adjustment is made to allow for the different tractive powers required to work soils of different texture. Estimates are based on a peasant family of seven, but allowance has also to be made for the number of horses needed to till the land, which is 4 on heavy soils and 2 on sandy or moor soils. In the Marienburg district of East Prussia, the minimum area varied between 9 and 20 hectares, the smallest (9 ha.) being on a steppe-like brown forest soil, sandy loam overlying loam. This was two-

horse land. The minimum area for a similar, but heavier, four-horse soil was 13.7 ha., and the lowest minimum area for any four-horse land was 12.7 ha.

The number of agricultural holdings into which the whole of East Prussia could be divided on a "minimum-area" basis would be between 234,053 and 161,690 corresponding to minimum areas of 11.2 and 14.3 ha., respectively. The actual number of holdings in 1925 was estimated at 234,228 with an average area of 11.2 ha. The most equable redistribution of the land among the then occupiers would have involved the enlargement of 162,000 and the reduction of 23,000 existing holdings.

10. Land classification for irrigation purposes

The classification of irrigated land or land intended for irrigation presents certain peculiarities since one of the "natural" factors of the environment—moisture—is artificially transformed, and the transformation may profoundly modify another "natural" factor, soil. Moreover, a faulty determination of the suitability of land for irrigation may involve a large and irrecoverable expenditure of money, and cause permanent damage to the soil.

The physical factors which determine suitability for irrigation are climate, soil, relief, drainage and water supply [99]. If any of these is unfavourable, irrigation is likely to be a failure. Geographical, economic and social factors, such as location of the land, extent and distribution of land types, accessibility of water supply, markets and transport, determine whether it is feasible to supply irrigation water to potentially productive land, and what farming systems will succeed. In some areas the character of the population must also be taken into account.

The ideal physical features of an irrigation area are (1) a smooth land surface, (2) a gentle slope sufficient to facilitate irrigation and adequate drainage, and (3) deep, fertile loam soils. The first step in the land-classification system evolved by the U.S. Bureau of Reclamation [62] is to determine whether the location and area of the land which approaches these conditions in the region surveyed justify the execution of an irrigation project. The boundaries of the arable land which can be irrigated with the available water supply are then tentatively determined, and a detailed topographical survey, on a scale of 1 : 4,800, is made, to form the basis for planning the lay-out of irrigation canals, etc. Finally, a soil survey is made in which, in addition to the usual soil characteristics, special attention is paid to salinity or alkalinity, permeability of the underlying rock, and sub-surface drainage.

The actual classification of lands for irrigation purposes is made with particular reference to the three factors soil, topography and drainage. Five or six land classes, designated by numerals and letters to show limiting factors, are distinguished. 1 is the highest, and 6 the lowest, class. The reason for placing land in a lower class than 1 is indicated on the field maps

by placing the letter S (soil), T (topography), D (drainage), or R (loose rock in the arable horizon) after the class number. For example, the symbol 2ST indicates that the land is put in the second class because of inferior soil and rough or steep topography. Further distinctions are sometimes made to indicate low water-holding capacity.

Both deductive and inductive methods are used in the classification. Observations on the success or otherwise of existing irrigation schemes are used in judging what is likely to happen under similar conditions of soil and topography elsewhere. Comparable conditions where the results of irrigation are known are not, however, always to be found. In these cases the soil or land types are evaluated by awarding "points" for the different significant factors. Frequently a combination of deductive and inductive methods is used.

The following are the specifications for the six land classes distinguished by the Bureau of Reclamation [62, 66]. They are generally applicable throughout the western United States.

First-class lands are those constituting the highest type of arable lands, suitable in all respects for cultivation and production of crops by irrigation. They are smooth-lying with slopes up to 5 per cent, soils at least 4 feet in depth, medium or fairly fine in texture, mellow, open structure, allowing easy penetration of roots, air and water, having free drainage yet good water-holding capacity and free from accumulation of soluble salts.

Second-class lands are of intermediate character, suited to the cultivation and production of quite a wide range of crops. They are not so desirable nor of such high value as lands of class 1, because they are more costly to prepare owing to slightly unfavourable topography, more costly to farm because more irrigation water must be used, or because water is difficult to apply. Soils may be comparatively shallow (12–18 inches of good plough soil, 36 inches of soil penetrable by roots and water). Drainage may be impeded and soils may contain moderate concentrations of soluble salts (0.5 per cent or less), and display alkalinity up to pH 9.0 or less in the top 2 feet. Texture of soil may be too sandy or it may be a heavy clay. Topography may be of an uneven or rough slope of less than 5 per cent or smooth slopes of from 5 to 10 per cent.

Third-class lands are of inferior or low quality and poor productivity. They have a restricted crop adaptation owing to such soil deficiencies as shallow depth (6 to 12 inches over gravel and loose rock, 36 inches penetrable by roots and water); extremes of texture (sandy or heavy clay); or presence of sufficient loose rock on the surface and in the plough zone seriously to interfere with cultivation. In some instances they are lands having impeded drainage and moderate concentrations of soluble salts. In some areas they are lands of uneven topography where erosion might occur.

Fourth-class lands are those which sometimes have a specific limited utility. They are made up of heavy compact soils with tough impervious layers in the subsoil. Sometimes they can be artificially drained. For the most part these lands are considered as non-arable.

Fifth-class lands are sub-marginal. They often include lands which are waterlogged and have an accumulation of an injurious amount of soluble salt, or lands which are subject to correction only through construction of flood-control or drainage works.

Sixth-class lands are permanently non-arable, consisting of lands which have a rough, broken or eroded surface, rendering them unfit for cultivation. Other areas consist of rough regions of raw shale, or shallow soils over shale and sandstone. Here also are included lands which are too high for delivery of irrigation water in this class.

Besides the detailed surveys, reconnaissance surveys on a scale of 1 : 24,000 are made to determine the general extent and location of cultivable areas, or for use on areas under consideration for supplemental water supply, and semi-detailed surveys (scale 1 : 12,000) the results of which are used in conjunction with engineering investigations to determine the feasibility of projects, or the extent and character of lands utilized within a given drainage area [62].

Page [66] states that the purpose of the land-classification work of the Bureau of Reclamation is to determine exactly where and in what quantities irrigable lands can be found for subdivision into tracts of sufficient size and productive capacity to support single families and to repay irrigation costs. The economic aspect of land classification is therefore important. The determination of costs is mainly an engineering problem, but the determination of potential earning power after irrigation has been installed is a problem of land classification, as earning power depends on type and yield of crops that can be produced, besides market requirements, transport facilities, etc. Experience in the United States has been that the stability and economic security of an irrigation settlement depend on charges for water being based on the quality of the land rather than entirely on the quantity and cost of delivery of water supplied, since the same quantity of water will give different returns on different qualities of land, and if charged at the same rate would make one farm unit economically feasible, and another unfeasible [62]. Hence, " paying classes " are distinguished, consisting of land types each of which can be subdivided into economic farm units of approximately equal size, ranging from 40 to 80, and not exceeding 160 acres.

Blanch and Stewart [9] describe a scheme of classification for a region already extensively irrigated (the Uinta Basin, Utah) with a view to securing the best distribution of the available water and the best utilization of the irrigable land. The classification starts from the premise that society profits more when the available water is used on the best lands.

Two classifications are presented: (1) a present-use classification, and (2) a desirable-use classification. The first shows the apparent need for adjustment of water to land, based on present (1943) conditions, the second shows what would be the most desirable combination of land and water over an extended period of time, as indicated by analysis of all available information. In the present-use classification three sets of factors were taken into consideration, namely:

Soil factors: alkali, drainage, topography, slope, erosion.

Irrigation-water factor: quantity of water received, and distribution throughout the growing season.

Location of land: with respect to community institutions and source of water supply.

Other factors such as climate and transport facilities were taken as uniform over the area surveyed.

The area was divided into 130 sub-areas, usually of not less than 300 acres and uniform with respect to the three factors listed above. The sub-areas were then classified as (A) satisfactory soil and water conditions, (B) adjustments in soil and water use desirable, (C) adjustments imperative, (D) land mostly not irrigated, but good enough to irrigate.

In the desirable-use classification the same factors were considered as in the present-use classification. Since water is the only factor that lends itself to redistribution the problem was one of determining how the available water could be most effectively used. The available supply is not adequate for all the irrigated land, but it is adequate to irrigate the most productive soils. Hence the sub-areas were regrouped on the assumption that each received a full water supply. Three desirable-use classes (out of the nine in a system applicable to all rural land in Utah) were distinguished, namely, class II range or pasture, class V extensive arable, and class VI more intensive arable.

Comparison of these two classifications is said to have given clear and precise information about the most desirable adjustments to be made in the irrigation of the region and the economic feasibility of the adjustments.

A system of classification for irrigable lands in South Africa was described in Technical Communication No. 15 [40]. "Irrigable-value" soil maps are made on a scale of 1 : 6,000, using detailed topographical maps, when available, as base maps. Soil profiles on representative sites are studied and classified into four grades of "permeability profile", as follows:—

I. An eight-foot depth of soil free from undesirable layers such as hardpan, dense clay, coarse sand, etc.

II. At least four feet of soil of grade I resting on soil containing interfering layers, or on semi-permeable hardpan or clay, very open sand, etc.

III. At least four feet of soil of grade I resting on *solid* rock or other impenetrable formations, or 30 inches of soil of grade I resting on semi-permeable or gravelly layers.

IV. Shallow soils which do not conform to the above grading, such as less than four feet of soil on impenetrable rock, or less than 30 inches of soil on semi-impenetrable or markedly interfering layers.

The soils are also classified according to the average salt content of the profile (so-called brak) :—

Grade I. Soils showing an average salt content (deduced from electrical-resistance figures and checked by actual analysis of the water extract of the soil type) of less than 0.15 per cent.
II. Average salt content from 0.16 to 0.35 per cent.
III. „ „ „ „ 0.36 to 0.55 „ „
IV. „ „ „ over 0.55 per cent.

These two factors are combined to deduce the final irrigable value thus :—

	Profile	*Salt*	*Irrigability*
Grade	I	I	I
	II	I	II
	I	II	
	II	II	III
	III	I	
	I	III	
	other combinations		IV

The grading may further be influenced by such factors as development of soils and agricultural experience, site of concentration and nature of brak salts, abnormal pH values, general topography, etc., but these are usually only applied in doubtful cases, their main use being in connexion with the giving of advice to farmers.

The Estimation of Productivity

The simplest land classification to understand—and simplicity is an important virtue in the execution of a land-use plan—is one in which classes are distinguished by numbers expressing some significant land property, particularly productivity. In some examples already given, land classes are distinguished as Class I, II, III and so on, but there is nothing to indicate how much better or worse Class I is than Class II. The numbers are merely expressions of the classifier's judgment. Many attempts have been made to arrive at a more objective and quantitative estimate of productivity. The methods used may be classed generally as inductive (e.g., by adding or otherwise integrating " marks " awarded to certain properties of the land or soil that influence productivity) or deductive (e.g., deduced from yield data), but many methods in actual use are a combination of both types.

It is important to appreciate what is meant by productivity. It is the capacity of a soil to produce crops in general, or one specific kind of crop, and is the resultant of the qualities of the so-called natural factors of the environment—especially soil, climate and topography—*plus* human

labour or " management ". The productivity of any untouched soil for cultivated crops is nil ; it is possible to speak of the productivity of natural grass and forest land, but even here labour must be expended before the produce can be used. The relative importance of " management " in the total productivity may be almost negligible in an open range, and predominant over that of all other factors in irrigated agriculture. As already stated productivity is a partly economic concept, and can only partly be expressed in terms of the inherent characteristics of land. " Every time one says that a certain piece of land is productive . . . there is implied in that statement a prediction of agricultural prices and management costs just as much as if they had been stated in dollars and cents " [45].

Productivity ratings

In recent years there have been included in the county soil-survey reports of the U.S. Department of Agriculture tables showing the " productivity ratings " of all the soil types of the areas surveyed. The productivity rating is " the crystallized expression of the experience of the people who have used or are using the land " [1]. Ratings are given to specific soil types as defined by the U.S. Soil Survey. In the soil-survey reports tables are given of productivity ratings or indices in relation to all the main crops of the district, e.g.,

Soil type	Corn		Wheat		Rye		Alfalfa		Sugar beet		Productivity grade	
	A	B	A	B	A	B	A	B	A	B	A	B
Miami loam	70	90	70	100	80	100	70	90	60	70	3	1

The figures under A and B refer respectively to the percentage of the standard yield of the crop obtainable with (A) common practices of management (average farming) in the area, and (B) the best current practices. The standard yields are selected " to represent the approximate average yield obtained for that crop on the more extensive and widely developed soils of the regions in the United States in which the crop is a principal product "[1]. The standards refer to average yields obtained without the use of amendments, although it has been arbitrarily agreed that nitrogen fixed by legumes and manure produced from feed grown on the land are not to be considered as amendments. E.g., the standard for corn is 50, and for wheat 25, bushels per acre ; for clover and timothy it is 2, for alfalfa 4, tons. Under average management for the county in question the Miami loam will yield 35 bushels of corn and 17½ bushels of wheat, and under first-rate management 45 bushels of corn and 25 bushels of wheat. The difference between the (A) and (B) ratings is a measure of the soil's response to good management.

The " productivity grade " indicates the soil's general productivity for the common crops of the region, and is obtained by a simple percentage weighting of the crop ratings according to each crop's importance in local agriculture. Soils with a weighted average between 100 and 90 are graded 1, between 90 and 80, 2, and so on. Those with low A and high B productivity

grades would be described as low in fertility (plant-nutrient content), but productive (responsive to management). Productivity grading is admitted to be a somewhat arbitrary procedure, depending, as it does, on the validity of the system of weighting. From the example given above it would appear that the Miami loam is used predominantly for cereal growing since its productivity grade corresponds to its productivity ratings with respect to cereals.

Formerly the "inherent" productivity based on the qualities of the soil and environment, and the "actual" productivity based on crop yields obtained under an average level of management, were estimated, but the inherent productivity has now been discarded on the grounds that few soils have any agricultural productivity at all without at least some management, and its place has been taken by the "potential" productivity, which is that obtainable by the best management. The inherent productivity has to be obtained inductively, since there are no yield data for "unmanaged" soils, and there is no true connexion between this and the deductively obtained actual productivity. Calculation of the ratings is based entirely on agricultural experience as indicated by crop yields. Study of the soil is required only to identify soil or land types. The yield figures from which the ratings are determined are estimated from data obtained by the soil surveyor from interviews with farmers and county officials, AAA records, elevator records, personal observations, etc. The chief difficulty in determining ratings from yield data is to establish a standard of management and to estimate the degree of divergence from the standard on each farm. The usual standard of management is defined as that which will maintain soil productivity at or near the level of the "nearly virgin" soil. It is important to note that productivity ratings are not convertible to crop yields except under certain definite conditions. The ratings are meaningless unless a physical definition is given of the system of management assumed. At present sufficient data are not available of yields obtained under standard or comparable systems of management to give the ratings a fixed character. Nevertheless, "provided the soil types and phases are properly defined, the concept of the productivity rating makes available a means for synthesizing the great background of research work and experience in one figure of expected yield under a defined system of management" [45].

Tyler [91] maintains that productivity ratings, if they are to be used for agricultural land classification, should be based to a greater extent than hitherto on actual yields obtained over a period of years. A difficulty here is that many, if not most, fields, which are the units for yield measurements, contain more than one soil type. Another difficulty is that in areas where the use of soil amendments is common, accurate data of yields obtained without amendments are not usually obtainable.

The Storie Index

An inductive method of rating the agricultural value of soils has been suggested by Storie [84]. Regardless of actual cropping experience with

the soils Storie compiles the ratings from percentage values accorded to certain characteristics of the soil profile. Three " factors " are used, one referring to the general character (excluding texture) of the profile and particularly to the stratification and degree of weathering, one referring to the surface texture, and a third to " soil-modifying conditions " such as drainage, acidity and alkalinity, erosion, etc. The values of these three factors expressed as percentages of the optimal conditions for plant growth are multiplied together to obtain the rating, and the product is expressed as a percentage of the maximum. The advantage of multiplying instead of, as is more usual, adding the points credited to each soil characteristic is that thereby any one abnormal factor can dominate the final rating. Thus a soil may have excellent profile conditions rated at 100 for the first factor, excellent texture rated at 100 for the second factor, but bad alkali accumulation rated at 10 for the third factor. The product of the three gives a percentage rating for the soil of 10, according with the fact that despite other favourable conditions the alkali renders the soil unproductive. On an addition basis the rating would have worked out at 70 per cent.

Canadian rating systems

Saskatchewan. Mitchell [58], who points out that the rating system must be adapted to the type of agriculture practised, has used in Saskatchewan a system similar to Storie's and designed to indicate a soil's ability to produce grain. He used three factors : (A) soil profile (texture 40, structure 30, natural fertility 30 ; maximum 100 points) ; (B) topography (maximum 100, minimum 10 points, according to slope conditions) ; (C) climate 25, salinity* 25, stoniness* 25, tendency to drift* 25 ; maximum 100. The productivity index is obtained by adding the component marks of each factor, multiplying the total marks for the three factors, and expressing as a percentage. It is provisionally suggested that an index of 30 is the margin for arable land.

The index is being used in an assessment of rural municipalities as the basis of a " natural " land classification. Superimposed on this is a " practical " classification which takes into account factors such as freight costs, distance from markets, etc.

Alberta. The Alberta Soil Survey prepares land-class maps to accompany the soil maps [10]. The land-class map interprets the physical data of the soil map in terms of productive capacity. Economic factors are not considered, although it is recognized that certain factors such as price have influenced the kind of crops grown in the past, the yield records of which are used as a measure of probable productivity. Eight land classes are distinguished—three pasture (the poorest), one marginal arable, and four arable (the best).

The soil type on the soil map is distinguished by a 3-digit number referring to the soil-colour zone (reflecting rainfall and fertility), the mode

* Full marks for none, and deduct proportionally.

of deposition of the parent material and the nature of the soil profile, i.e.—*First (or hundreds) digit*: brown soils 1; dark brown soils 2; shallow, or southern black 3; black 4.

Second (or tens) digit: residual 0; sorted residual 1; glacial, unsorted and variable 2; resorted or uniform glacial 3; gravelly outwash 4; alluvial 5; alluvial or aeolian 6; aeolian or lacustrine 7.

Third (or units) digit: 0–7, distinguished according to profile characteristics, among which salinity is specially noted.

To determine the land classes these digits are given percentage ratings, and other ratings are given for texture, topography, erosion, stoniness, alkali, and any other local factor affecting productivity. The ratings are multiplied together and expressed as a percentage of the total possible, e.g.—

Characteristic	*Description*	*Rating*
Colour	brown to dark brown	50
Deposition	glacial	80
Profile	normal	100
Texture	light loam	70
Alkali	absent	100
Stones	numerous	60
Topography	very hilly	40

Multiplied together, these give a percentage rating of 6.7, placing the land in Class 2 (Class 8 is best)—fair to good pasture. The method represents "an effort to meet present-day requirements by taking an inventory of soil resources and interpreting the data in terms of a probable productivity classification. This information should be of material aid in any programme of land-use planning."

Ranking coefficients

Kendall [47] proposed a rather different method of rating the relative productivities of English counties. He took the county as land unit, since he was using the official yield figures of the Ministry of Agriculture, and these are compiled on a county basis. The county has obvious disadvantages as a unit since its boundaries have no relationship to those of geographically, economically or agriculturally determined areas. Kendall developed four different measures of productivity, using available statistics of the ten major crops—wheat, barley, oats, beans, peas, potatoes, turnips and swedes, mangolds, hay from temporary grass and hay from permanent grass.

(1) *The productivity coefficient.* This coefficient was obtained by regarding the average yields as the coordinates of a point in 10-dimensional space. From the counties of England 48 points were obtained, and the line which fitted these points best (the sum of squares of the perpendicular distances of the 48 points from the line being a minimum) was used to rank the

counties. This coefficient involves very intricate calculations, and does not seem to have any advantage over the other three more simply determined coefficients.

(2) *The ranking coefficient.* Each county was ranked for the average yield of each of the ten crops, and the coefficient of each county was the mean of these rankings. Counties with high yields had low ranking coefficients, and *vice versa.*

(3) *The money-value coefficient.* Obtained from the average value produced per acre from the ten crops.

(4) *The energy coefficient.* The average gross digestible energy produced per acre.

Neither the productivity coefficient nor the ranking coefficient takes any account of the area devoted to each crop in the counties. As there are obviously large differences between counties in this respect, the use of equal weights for all crops gives an unfair comparison between counties, particularly as the correlations of the yields of grass and fodder crops with those of cereal crops are often negative. The money-valued coefficient has some advantages over the two previous ones—for example, account is taken of the volume of production. One disadvantage is that certain parts of the country are better suited for the more profitable crops—because of proximity to markets—and the coefficient will tend to measure this factor. Kendall's last coefficient—the energy coefficient—has more to recommend it, but it is unfortunate that he chose to work in terms of gross digestible energy. This has the effect of favouring the wheat-growing counties, since about half of the energy value attributed to wheat is due to straw of which most of the nutritive value is available for fuel purposes only. Moreover, pasture which is hayed is only assessed with respect to the hay produced, and as hay is of the order of half the total output for the year counties with a large amount of hay have low coefficients. This is probably the reason for the differences in the grading of Somersetshire, for example, which was given a high grade by the productivity and rank methods, but a low grade by the others.

On the basis of the four coefficients for each of four years, Kendall classified the counties as excellent, good, moderate, indifferent or poor. This was done for each of the four years 1925, 1930, 1935 and 1936. On the whole, counties with good reputations for productivity came out consistently high in the ranking list, and those with poor reputations consistently low. Intermediate counties fluctuated rather widely from year to year, and from coefficient to coefficient. Kendall was estimating actual rather than potential productivity [24]. Actual productivity will obviously vary from year to year according to weather, price level and other external influences.

German soil ratings—*Bodenbonitierung*

Much work has been carried out in Germany on the quantitative assessment of soil quality. After the first world war a general reassessment

of taxable land values was necessary and had to be carried through rapidly. Several schemes for rating agricultural land were proposed, a common feature of all being that productivity deriving from skill in management was not taken into consideration. It was thought that a man should not be penalized by higher taxes for improving his land. Assessments were based on the yield capacity determined by the natural conditions of soil, climate, topography and water, and the local conditions of farm economy, especially market and labour conditions, as well as the nature of the holding (compact, scattered, distance of farmhouse from the fields, etc.). These were almost the identical bases on which A. von Thaer, the father of German *Bodenbonitierung*, had constructed his first land-valuation tables in the early years of the nineteenth century [90].

The general procedure in Germany was to classify the land of an estate firstly as arable, pasture, meadow or forest land, and then make further separate classifications inside each class. The classifications are based entirely on the properties of the soils. The influence of economic and commercial factors and of factors such as size, lay-out and nature of the farm is assessed quite separately, and then superimposed on the soil classification, usually by allotting a certain percentage of possible points to internal or soil factors and a certain percentage to external factors. Assessment of arable land is made mainly inductively, from the properties of the soil, and of grass and forest land deductively, from yield data.

In order to secure a uniform standard of rating, a " national standard estate " (*Reichspitzenbetrieb*), that of Frau Else Haberhauffe, Eickendorf, near Magdeburg, was given a rating of 100. Local standard estates in different parts of Germany were rated relatively to the national standard, and in this way a series of suitably located standards was set up to which all ratings could be referred [74].

Schattenfroh [74] states that the allotment of " points " for the separate conditions must by its very nature be so subjective that the points can only be regarded as a rough guide. Only experience can teach the assessor his job. The natural and economic factors are quite independent. Relative prices or rentals of land give good indications of the effect on productivity of variable natural conditions under similar economic conditions, or of variable economic under similar natural conditions. The usefulness of a system of land assessment based on awarding points for various factors in productivity depends on the correct judgment of the relative points values to be allotted to the totality of natural and economic factors, respectively.

According to Schattenfroh the points value of the economic factors should ordinarily be about 60 per cent of that of the natural factors for flat agricultural land. This, presumably, refers specifically to German conditions in the inter-war period. Near large cities and industrial centres the relative value of economic factors rises and may exceed that of natural factors. In the open market, however, economic and particularly commer-

cial factors exert a much greater influence on the price actually paid for land than do the intrinsic qualities of the soil.

Several points systems are cited by Schattenfroh. In Fackler's Bavarian system [20] points are awarded as follows :—

For soil conditions	up to 30	points
,, climate	,, ,, 20	,,
,, other natural factors	,, ,, 60	,,
,, economic factors	,, ,, 10	,,
Total	120	

Soil condition is determined mainly by texture and humus content (highest is humous loess—*Schwarzerde*) with marks added or subtracted according to the depth of the arable horizon, the nature of the subsoil and the general cultural condition. Economic factors appear to be confined to the distance of the farm from the nearest railway station or town.

Bömer [74] allots points for Westphalian farms as follows :—

Nature of arable layer	20	
Depth of arable layer	10	
Groundwater conditions	10	
Surface topography	8	
Total for soil factors		48
Climate (temperature and rainfall)	18	18
Marketing conditions	17	
Type and state of culture	7	
Distance of fields from farmstead	5	
Labour conditions	5	
Total for economic factors		34
		100

Thus whereas Fackler estimates soil influences at 25 per cent and economic influences at less than 8 per cent, Bömer estimates the former at nearly 50 per cent and the latter at 34 per cent.

Rothkegel and Herzog [71] worked out a system which was accepted in 1928 by the German Treasury for the valuation of agricultural estates. Different scales of valuation are used for arable and grassland. For arable land, eight soil groups are distinguished with points values varying from 100 (loamy chernozem) to 6 (coarse sand, pure clay, high moor). Pastures are marked directly according to the length of the grazing season and the carrying capacity.

For meadows the scale is based on the quantity and quality of the natural meadow plants, and hence on the quantity and quality of the harvest. Points values vary from 100 (corresponding to an attainable harvest of 75 double centners of good hay per hectare) to 12 (corresponding to 20 dz./ha. of poor but eatable hay).

Besides the soil characteristics in arable land, and the yield and ecological characteristics in grassland, an apparently rather arbitrary and subjective estimation is made in Rothkegel and Herzog's system of the actual and potential effects on productivity of climate, exposition, possibilities of drainage and irrigation, and cultural condition of the soil. In the assessment of economic factors special attention is paid to means of transport and communication.

Criticizing this system Schattenfroh states that it represents an attempt to establish a scientific basis for tax assessment, but that it is much too complicated for ordinary practice, and could not be operated except by highly trained assessors. The range of marking for soil quality, from 100 to 6, is, moreover, too wide and leaves too much to the assessor's personal judgment. In group I (mild loams) the range is 22 points, and in group VI (heavy clays) it is 50 points. Similar ranges occur in the grouping of pastures and meadows. Consideration of the subsoil, also, is left largely to the assessor's discretion.

Schattenfroh himself devised a scheme (modified from an earlier one of Weisslein) for Bavaria, in which soils were first grouped into four classes according to texture—heavy soils (marked 0–8), loams (marked 9–12), light soils (marked 1–8) and humus soils (marked 0–10). The depth of arable soil is ignored, because this depends more on the means of cultivation at the disposal of the farmer than on inherent soil properties, and few farmers in Bavaria could afford to cultivate deeply and thus to take advantage of a potentially deep soil. The humus content is evaluated as a percentage addition to the points mark, e.g., 10–20 per cent addition for a 5 per cent humus content, and 30–50 per cent addition for 15–20 per cent of humus. Acid soils get a percentage deduction, and calcareous soils a percentage addition. The deduction for acidity is greater in regions devoted predominantly to acid-sensitive crops (wheat, barley, sugar beet, clover) than in rye, oats and meadow regions. A percentage deduction for stoniness is made according to the quantity of stones and the soil texture. Other additions or deductions are made for climate (according to quantity and distribution of rainfall and the length of the local compared with the regional frost-free period), for compactness of the holding and distance from a market. Extensive tests of the system in practice, however, indicated that the relative importance and quantitative assessment of humus content, acidity, lime status, stoniness, groundwater relationships, etc., varied greatly from place to place.

The number of other German points systems for soil evaluation that have been proposed is legion [33]. Van Aartsen [93] has described several not mentioned here, and has compared the German systems as a whole with the American productivity ratings.

Görz [25] states that there is now no dispute that the soil must be the starting point of any modern system of agricultural land evaluation, but that some authorities favour the *Bodentyp* (genetic soil type) whilst others favour the *Bodenart* (textural soil variety) as the basis of the classification.

From the important practical standpoint of getting the man-in-the-field to understand what is being done, there is much to be said for using the soil variety, and all the numerous German systems for the points evaluation of land lay particular weight on soil texture. Görz, however, points out that a classification based solely on soil-variety distinctions is only valid so long as a certain extensity of utilization allows differences in value between different soil varieties to be clear. As land utilization becomes more intensive these differences tend to lose their significance, while that of soil-type differences increases relatively. A practical soil evaluation must take into consideration and combine both practical experience and the scientific premises of the valuation system in a form which is immediately comprehensible to the practical man. For the same reason, information about land quality obtained from practical experience and the "feel" of the soil (*Fingerspitzgefühl*) should be expressed in a simple quantitative form.

These practical requirements are best satisfied by means of a points system. According to Görz, points are allotted in the standard *Bonitierungssystem* for texture (varying from loam 10.0–8.8 to sand 4.1–2.0) and for soil condition or type, marked from 10 (mild loess) to 4 (podzol with ortstein). The rating is obtained by multiplying the texture marks by the type marks. Thus at one end of the scale a loess loam gets 100 points, and at the other end a sandy heath podzol gets 8 points.

Points values for soil types and varieties are obtained from the gross and net yields obtained from large numbers of different soils accurately described and classified by experienced assessors.

Herzog [31] gives more factual details about how the official system of soil assessment had developed by 1939. In 1939 there were 2,000 soil assessors in the Reich besides numerous other workers indirectly engaged. The purpose of the assessment was to form a basis for taxation, but as the work proceeded the possibilities of using it for advisory purposes and for land-use planning came increasingly into the foreground. The intention was that every quarter hectare should be sampled (and even smaller areas where the soils were very variable), the soil conditions described and a map prepared.

The assessment is arrived at by giving a soil marks according to certain characteristics, but the marks appear to be given for the combined characteristics as a whole, not for each one separately. Different characteristics are used for arable land and grassland, respectively.

Arable soils are first classified into 8 textural varieties (*Bodenarten*: S=sand, Sl=slightly loamy sand, lS=loamy sand, SL=very loamy sand, sL=sandy loam, L=loam, LT=heavy loam, T=clay), and moor (Mo). The second differentiating characteristic is the origin : Lö=loess, D=diluvium, Al=alluvium, V=non-transported weathered material. The suffix g attached to V (Vg) indicates very coarse or stony material. A third differentiation is made according to the condition (*Zustandsstufe*) or stage of development of the soil. The most immature soils represent stage 7, fully mature soils stage 1, at which the productivity of the soil is, other things being

equal, greatest. Many soils never reach stage 1, owing to peculiarities in local conditions, such as topography, rainfall and groundwater relationships, others revert by processes of degradation from stage 1 to less productive stages. It is not clear how the stage of development is determined.

For grassland soils only four *Bodenarten** (S, lS, L, T—also Mo) are distinguished and three *Zustandsstufen.* The origin of the soil is not taken into consideration, but marks are given according to mean annual temperature (three classes a, b and c) indicating the length of the growing season, and moisture relationships (five classes).

The description and rating of a soil profile are given in symbols, e.g.—

$$\frac{\bar{h}\text{–}\bar{\bar{h}} \text{ mi fs L } 2.5\text{–}3}{\bar{h}' \text{ mi fs L } 3} \qquad \text{L 2 Lö 83}$$
$$\overline{\overline{ka}} \text{ fs L}$$

According to the symbols on the right, this is a loam derived from loess, *Zustandsstufe* 2, rating 83 (relative to the best agricultural soil in Germany, rating 100). The symbols on the left describe the horizons of the profile in more detail. The top horizon is a medium to highly humous ($\bar{h}$–$\bar{\bar{h}}$) mild (mi) fine sandy (fs) loam (L), underlain by a weakly humous ($\bar{h}'$) mild fine sandy loam, underlain again by a strongly calcareous ($\overline{\overline{ka}}$) fine sandy loam. No indication is given in Herzog's paper as to the meaning of the figures following the symbol L in the profile description ; they do not seem to refer to the same *Zustandsstufe* indicated in the symbols on the right.

A profile description of a grassland soil is as follows :—

$$\frac{\text{zer gt Hmo } 1\text{–}2}{\text{r u. to Hmo}} \qquad \text{Mo II a } 3\text{—}31$$

i.e., a well (gt) decomposed (zer) highmoor (Hmo) overlying a raw (r) and (u.) peaty (to) highmoor. For rating purposes the soil is a moor (Mo), *Zustandsstufe* II, climate a (= mean annual temperature 8°C. or over) moisture condition 3, rating 31.

The profile descriptions can be very varied. There are 46 symbols referring to soil characteristics, 9 to water relationships, 18 to types of cultivation and other peculiarities, and about a dozen "other abbreviations". The ratings are calculated from Tables 9 and 10.

The ratings have no absolute significance, being merely relative numbers expressing differences in gross yields which can be obtained under ordinary, average management. In estimating the ratings, moderate climatic conditions—8°C. mean annual temperature and 600 mm. rainfall—level or gently sloping topography, and market conditions corresponding to those in central Saxony are assumed.

It has been proposed, however, to use the ratings to put a cash value on soil for taxation purposes. It is argued [70] that the productivity of land is the result of a combination of the factors soil, capital and labour, but it is impossible to determine what part of the yield of a field is attributable

* Gericke [23] showed from a statistical analysis of more than 2,000 experiments that soil texture had practically no effect on hay yields.

to soil productivity, and what parts to machinery, buildings, stock, labour, and so on. Although the value of the " bare soil " of a field or of a soil type cannot therefore be estimated from the results of farming, that of the soil of a complete farm can be. The soil of the farm is given a percentage productivity rating relative to the best soil (100 per cent) in Germany. The land is capitalized on a basis of 4 per cent of the net profit, which is 210 RM. per ha. for soil with rating 100—i.e., 5250 RM. per ha. (in 1944).* Land rated at 20 would thus have a capital value of 1050 RM. The capital value of the buildings and the living and dead equipment of the farm is calculated and divided by the number of hectares in the farm. This is subtracted from the capital value of the land per hectare determined from the net profit (*Reinertrag*), giving the value of the soil. E.g., land rated at 20 might have a value of 490 RM. per ha. for buildings, 300 RM. for stock, and 140 RM. for other equipment, total 930 RM., leaving 120 RM. for the value of the soil. Land rated at 100 might have a value of 1450 RM. per ha. for buildings, 500 RM. for stock, and 300 RM. for other equipment, leaving 3000 RM. for the value of the soil (total 5250 RM.). It is claimed that this method of soil assessment provides a sound basis for calculating land taxation.

* In 1929 the capital value of 100-rating land was 4140 RM. per ha. [74].

TABLE 9. Arable-land rating (German system)

Soil variety	Origin	Stage of development						
		1	2	3	4	5	6	7
S	D		41–34	33–27	26–21	20–16	15–12	11– 7
	Al		44–37	36–30	29–24	23–19	18–14	13– 9
Sl (S/lS)	D		51–43	42–35	34–28	27–22	21–17	16–11
	Al		53–46	45–38	37–31	30–24	23–19	18–13
	V			42–36	35–29	28–23	22–18	17–12
lS	D		59–51	50–44	43–37	36–30	29–23	22–16
	Lö		62–54	53–46	45–39	38–32	31–25	24–18
	Al		62–54	53–46	45–39	38–32	31–25	24–18
	V			50–44	43–37	36–30	29–24	23–17
	Vg							
SL (lS/sL)	D		67–60	59–52	51–45	44–38	37–31	30–23
	Lö		72–64	63–55	54–47	46–40	39–33	32–25
	Al		71–63	62–55	54–47	46–40	39–33	32–25
	V		67–60	59–52	51–44	43–37	36–30	29–22
	Vg				47–40	39–32	31–24	23–16
sL	D	84–76	75–68	67–60	59–53	52–46	45–39	38–30
	Lö	92–83	82–74	73–65	64–56	55–48	47–41	40–32
	Al	90–81	80–72	71–64	63–56	55–48	47–41	40–32
	V		76–68	67–59	58–51	50–44	43–36	35–27
	Vg				54–45	44–36	35–27	26–18
L	D	90–82	81–74	73–66	65–58	57–50	49–43	42–34
	Lö	100–92	91–83	82–74	73–65	64–56	55–46	45–36
	Al	100–90	89–80	79–71	70–62	61–54	53–45	44–35
	V		82–74	73–65	64–56	55–47	46–39	38–30
	Vg				60–51	50–41	40–30	29–19
LT	D		78–70	69–62	61–54	53–46	45–38	37–28
	Al		82–74	73–65	64–57	56–49	48–40	39–29
	V		78–70	69–61	60–52	51–43	42–34	33–24
	Vg				57–48	47–38	37–28	27–17
T	D			63–56	55–48	47–40	39–30	29–18
	Al		74–66	65–58	57–50	49–41	40–31	30–18
	V			62–54	53–45	44–36	35–26	25–14
	Vg				50–42	41–33	32–24	23–14
Mo				45–37	36–29	28–22	21–16	15–10

TABLE 10. Grassland rating (German system)

Soil variety	Stage	Climate	Moisture conditions				
			1	2	3	4	5
S	I (45–40)	a	60–51	50–43	42–35	34–28	27–20
		b	52–44	43–36	35–29	28–23	22–16
		c	45–38	37–30	29–24	23–19	18–13
	II (30–25)	a	50–43	42–36	35–29	28–23	22–16
		b	43–37	36–30	29–24	23–19	18–13
		c	37–32	31–26	25–21	20–16	15–10
	III (20–15)	a	41–34	33–28	27–23	22–18	17–12
		b	36–30	29–24	23–19	18–15	14–10
		c	31–26	25–21	20–16	15–12	11– 7
lS	I (60–55)	a	73–64	63–54	53–45	44–37	36–28
		b	65–56	55–47	46–39	38–31	30–23
		c	57–49	48–41	40–34	33–27	26–19
	II (45–40)	a	62–54	53–45	44–37	36–30	29–22
		b	55–47	46–39	38–32	31–26	25–19
		c	48–41	40–34	33–28	27–23	22–16
	III (30–25)	a	52–45	44–37	36–30	29–24	23–17
		b	46–39	38–32	31–26	25–21	20–14
		c	40–34	33–28	27–23	22–18	17–11
L	I (75–70)	a	88–77	76–66	65–55	54–44	43–33
		b	80–70	69–59	58–49	48–40	39–30
		c	70–61	60–52	51–43	42–35	34–26
	II (60–55)	a	75–65	64–55	54–46	45–38	37–28
		b	68–59	58–50	49–41	40–33	32–24
		c	60–52	51–44	43–36	35–29	28–20
	III (45–40)	a	64–55	54–46	48–38	37–30	29–22
		b	58–50	49–42	41–34	33–27	26–18
		c	51–44	43–37	36–30	29–23	22–14
T	I (70–65)	a	88–77	76–66	65–55	54–44	43–33
		b	80–70	69–59	58–48	47–39	38–28
		c	70–61	60–52	51–43	42–34	33–23
	II (55–50)	a	74–64	63–54	53–45	44–36	35–26
		b	66–57	56–48	47–39	38–30	29–21
		c	57–49	48–41	40–33	32–25	24–17
	III (40–35)	a	61–52	51–43	42–35	34–28	27–20
		b	54–46	45–38	37–31	30–24	23–16
		c	46–39	38–32	31–25	24–19	18–12
Mo	I (45–40)	a	60–51	50–42	41–34	33–27	26–19
		b	57–49	48–40	39–32	31–25	24–17
		c	54–46	45–38	37–30	29–23	22–15
	II (30–25)	a	53–45	44–37	36–30	29–23	22–16
		b	50–43	42–35	34–28	27–21	20–14
		c	47–40	39–33	32–26	25–19	18–12
	III (20–15)	a	45–38	37–31	30–25	24–19	18–13
		b	41–35	34–28	27–22	21–16	15–10
		c	37–31	30–25	24–19	18–13	12– 7

Climate a = over 8.0°C. mean annual temperature
b = 7.9—7.0°C. „ „ „
c = 6.9—5.7°C. „ „ „

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APPENDIX

Outline of a U.S. Soil-Survey Report

(Reproduced from [44])

In order to achieve some uniformity in the treatment and arrangement of subject matter in the report, especially for the convenience of those using large numbers of these reports, the outline which follows has been prepared. This outline cannot be followed blindly, as each area has its own particular features and problems requiring emphasis, and certain sections, given only broad headings, must be carefully organized in subdivisions.

General Arrangement of Material in the Soil-Survey Report

1. Description of the area surveyed.
    - (A) Location and extent of the area.
        - (1) General location within the State or Territory.
        - (2) Distance of county seat or principal town from one or more important places.
        - (3) Size of area in square miles.
    - (B) Physiography.
        - (1) Mention of the physiographic division of the United States in which the area is located.
        - (2) General description of the physiography and geology of the area.
    - (C) Relief.
        - (1) Discussion of any modification of the physiographic surface by natural dissection.
        - (2) Sketch map of relief areas if such a sketch is of material assistance to the discussion.
    - (D) Elevation.
        - (1) General elevation of the area and ranges in elevation.
        - (2) Altitude of some of the main topographic features.
        - (3) Altitude of towns or other known points. (Cite authority for data.)
    - (E) Vegetation.
        - (1) General but brief discussion of the vegetation, including especially the original and present forests, grasses, or shrubs. (Ordinarily there should be no detailed description of species unless this is important where many comparatively uncommon plants are mentioned. The common names should be used, but a glossary of botanical names should be given, especially where noncrop plants need to be discussed at length.)

(F) Organization and population of the county.
  (1) Date of settlement.
  (2) Important historical data.
  (3) Source and distribution of the population.
  (4) Nationality of the settlers. (To be supported by census data.)

(G) County seat and principal towns.
  (1) Name of county seat.
  (2) Principal towns and their relation to the agriculture of the area.

(H) Transportation, markets, and other cultural features.
  (1) Railroads and highways and the service rendered by them.
  (2) Any service rendered by steamship lines.
  (3) The disposition and marketing of farm products.
  (4) Conditions of public roads.
  (5) Schools, churches, telephones, and other features relating to rural culture and social life.

(I) Industries.
  (1) Important nonagricultural manufacturing industries, mining, and other industries affecting the area should be mentioned and any relationship these have to the agriculture of the area noted. (The plants engaged in processing agricultural products, such as flour mills and cheese factories, are discussed under H (3).)

2. Climate.
  (1) General type, that is, oceanic, continental, etc.
  (2) Variations among seasons.
  (3) Distribution of rainfall during the growing season.
  (4) Influence of physiography and bodies of water on climate in different parts of the area.
  (5) Climate as a factor in the production of special crops.
  (6) Discussion on value of the data on average dates of frost and average frost-free periods.
  (7) Discussion on value of data on average annual means for precipitation.
  (8) Conditions, favorable or unfavorable, for farm work.
  (9) Tables from Weather Bureau of temperature, precipitation, and frosts.
  (10) Discussion of unusual weather conditions, such as winds, storms, and hail.

3. Agricultural history and statistics.
    (A) Early agricultural development of the area.
    (B) Important changes that have taken place in the use of the land since settlement.
    (C) Census data on the agriculture of the area as far back as available and up to and including latest census reports.
    (D) Present condition of agriculture.
        (1) Use of fertilizers, lime, and other amendments.
            (a) Amount and cost.
            (b) Kind of fertilizers used.
        (2) Labor.
            (a) Kind and availability of labor. (Do not discuss the specific wages paid in different farm operations as conditions change from year to year.)
        (3) Size of farms.
            (a) General range in the size of farms and the size of the average farm. (To be checked by census data.)
            (b) Any trends toward change in size of farms and the reasons for such change.
        (4) Tenure of farms.
            (a) Percentage of farms operated by the owners and by tenants.
            (b) Systems of rental, such as cash rent, share of crop, or other.

4. Soil-survey methods and definitions.
    (1) Description of methods used in mapping soils.
    (2) Definition of terms used in the description and classification of soils.

5. Soils and crops.
    (1) General characteristics of the soils of the area.
    (2) Systems of agriculture practiced.
    (3) Relationship between soils and agriculture.
    (4) Grouping of soils on the basis of capability for use.
    (5) Brief description of each group.
        (a) Agronomic relationships.
        (b) Characteristics common to soils in the group that determine use.
        (c) The names of series in the group and the characteristics of the types of the series brought into this group.

(d) Description of each type and phase of the group, including all the following features, if applicable.

1. Describe each horizon as to :—
   a. Color.
   b. Texture.
   c. Structure.
   d. Consistence.
   e. Thickness.
   f. Reaction.
   g. Content of organic matter.
   h. Stoniness.
   i. Root penetration.
   j. Salt or alkali.
2. Important variations within the type.
3. Location and extent of soil.
   a. General location of the larger areas and definite location of areas of minor types.
   b. Estimate in square miles of areas of each type.
4. Relief.
5. Geologic origin of parent material.
6. Drainage (external and internal).
7. Native vegetation, if important.
8. Uses to which soil is put and crop yields woven in with capabilities of soil. Approximate acreage in different crops.
9. Management of the soil. Systems of management compared with those of area as a whole. Susceptibility to erosion or deterioration from other causes under wrong management.
10. Methods of drainage or irrigation.
11. Water supply if related to soil type.

6. Land uses and agricultural methods.

(A) Capabilities of soils for use.

(1) Crops, (2) native pasture, (3) forests.

(2) Successful and improved methods of management as demonstrated within the area.

(3) Results obtained by experiment on soil types or closely related types, including :—

(a) Use of various fertilizers, lime or other chemical treatments.
(b) Rotations.
(c) Farm implements.
(d) Prevention of erosion.
(e) Tillage.
(f) Drainage.
(g) Varieties of plants.
(h) Plant diseases, insect pests, and noxious weeds.

(This discussion should be specific in respect to the separate soils.)

7. Drainage, irrigation, or alkali amelioration (not always necessary). (Indicate exact meaning of the term " alkali " in each particular report.)

8. Productivity ratings.
(Instructions on this chapter will be supplied in each instance.)

9. Morphology and genesis of soils.
(A) Location of the area with reference to the great soil groups.
(B) Parent materials.
(C) Factors of environment influencing soil development.
(D) Description of normal regional profile and a few of the more important variations.
(E) Character of intrazonal and azonal soils.

10. Summary.
(A) Brief discussion of area and its agriculture.
(B) Uses made of soils and reason for such use.
(C) General statement of the character of the soils.
(D) Brief description of the soil groups and their relation to agriculture.
(E) Names of the principal soils, their characteristics, and their influence on the agriculture.

This outline should be followed in preparing the report, unless some special individual feature of an area makes some change imperative in order to achieve a logical presentation of the material.

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