

LAND USE IN SEMI-ARID MEDITERRANEAN CLIMATES

*Unesco/International Geographical Union Symposium
Iraklion (Greece), 19-26 September 1962*

UTILISATION DES TERRES EN CLIMAT SEMI-ARIDE MÉDITERRANÉEN

*Colloque Unesco/Union géographique internationale
Héraklion (Grèce), 19-26 septembre 1962*

U N E S C O

ARID ZONE RESEARCH — XXVI
LAND USE IN SEMI-ARID MEDITERRANEAN CLIMATES

RECHERCHES SUR LA ZONE ARIDE — XXVI
UTILISATION DES TERRES
EN CLIMAT SEMI-ARIDE MÉDITERRANÉEN

Titles in this series / Dans cette collection :

- I. *Reviews of research on arid zone hydrology*
Compte rendu des recherches relatives à l'hydrologie de la zone aride
- II. *Proceedings of the Ankara Symposium on Arid Zone Hydrology*
Actes du colloque d'Ankara sur l'hydrologie de la zone aride
- III. *Directory of institutions engaged in arid zone research [en anglais seulement]*
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- XXV. *Methodology of plant eco-physiology. Proceedings of the Montpellier Symposium*
Méthodologie de l'écophysiologie végétale. Actes du colloque de Montpellier
- XXVI. *Land use in semi-arid Mediterranean climates / Utilisation des terres en climat semi-aride méditerranéen*

The reviews of research are published with a yellow cover; the proceedings of the symposia with a grey cover.

Les comptes rendus de recherches sont publiés sous couverture jaune; les Actes des colloques, sous couverture grise.

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FOREWORD

Unesco's arid lands programme, whose beginnings date back to 1951, was expanded considerably in the period 1957-63, when it appeared as a Major Project in the Organization's programme. That this period has now come to an end has not meant any slackening in the concrete action taken to assist research in the arid zone domain.

With a view to procuring the constant renewal of contacts between scientists throughout the world engaged in this research, Unesco arranges frequent symposia on specific subjects to afford such scientists an opportunity of presenting and discussing the results of their work. It was under this head that Unesco gave the International Geographical Union (IGU) assistance towards the execution of the project adopted at the Stockholm meeting in August 1960 by the Arid Zone Commission for a symposium on the classification and mapping of geomorphological and land use aspects of lands in Mediterranean-type semi-arid climates. The meeting duly took place at Iraklion, in Crete, from 19 to 26 September 1962, at the invitation of the Royal Hellenic Geographical Society.

Following this meeting, Unesco decided to publish the bulk of the papers read in the "land use" portion of the

symposium, and they form the present volume of the "Arid Zone Research" series.

Professor Amiran, who presided over this portion of the symposium, was kind enough to undertake the task of preparing the book, which is in three parts. The first deals with the classification of Mediterranean-type climates in semi-arid regions and their water resources, whilst Sections II and III contain, respectively, collected regional studies and papers on land use and urbanization.

For those readers more interested in the symposium's work on geomorphology and the mapping of the arid zone, it may be helpful to indicate that the resolutions of the Crete symposium were published in the Newsletter of the International Geographical Union, Vol. XIV, No. 1 (1963), pp. 8-11. A collection of papers presented to the Section on geomorphological mapping has been published in Bulletin de la Société hellénique de Géographie, Per. III, tome IV, Athinai 1963, 203 p.

Special thanks are due to General Botzaris, the president, and to Dr. Haralambous, the secretary-general of the Royal Hellenic Geographical Society and to the Iraklion local authorities who worked actively for the success of a symposium attended by experts from fourteen countries.

AVANT-PROPOS

Le programme de l'Unesco relatif aux terres arides, dont les premières activités remontent à 1951, a vu son importance s'accroître considérablement au cours des années 1957 à 1962, période pendant laquelle il figurait comme projet majeur dans le programme de l'Organisation. Au terme de cette période, les efforts concrets entrepris afin d'aider les recherches dans le domaine intéressant la zone aride n'en n'ont pas été ralentis pour autant. En vue de maintenir un contact sans cesse renouvelé entre les hommes de science qui se consacrent dans le monde entier à ces recherches, l'Unesco organise de nombreux colloques sur des sujets particuliers afin de donner à ces savants l'occasion de présenter et de discuter les résultats de leurs travaux. C'est ainsi que l'Organisation a prêté son concours à l'Union géographique internationale (UGI) afin de réaliser le projet, adopté à la réunion de Stockholm d'août 1960 par la Commission de la zone aride, d'organiser un colloque sur la cartographie géomorphologique des régions arides et sur les problèmes d'utilisation des terres en climat semi-aride de type méditerranéen. Cette réunion s'est tenue à Héraklion, en Crète, du 19 au 26 septembre 1962, sur l'invitation de la Société royale hellénique de géographie.

A la suite de ce colloque, l'Unesco décida de publier la plupart des communications présentées dans la section du colloque consacrée à l'utilisation des terres. Ces communi-

cations ont été groupées dans le présent volume de la collection « Recherches sur la zone aride ».

Le professeur Amiran, qui a présidé aux travaux de cette section du colloque, a bien voulu se charger de préparer l'ouvrage, qui comporte trois parties. La première traite de la classification des climats de type méditerranéen dans les régions semi-arides et de leurs ressources en eau ; la deuxième et la troisième partie sont consacrées aux études régionales d'une part et d'autre part à l'utilisation des terres et à l'urbanisation.

Pour les lecteurs qui s'intéresseraient plus particulièrement aux travaux du colloque relatifs à la géomorphologie et à la cartographie de la zone aride, il paraît utile de signaler que les résolutions du colloque de Crète ont été publiées dans le Bulletin (Newsletter) de l'Union géographique internationale, vol. XIV (1963), n° 1, p. 8-11. Un certain nombre de communications présentées dans la section consacrée à la cartographie géomorphologique a été publiée dans Bulletin de la Société hellénique de Géographie, Per. III, tome IV, Athinai 1963, 203 p.

Des remerciements tout particuliers sont dus au général Botzaris et à M. Haralambous, respectivement président et secrétaire général de la Société royale hellénique de géographie, ainsi qu'aux autorités locales d'Héraklion qui se sont activement employées à assurer le succès de ce colloque, réunissant des experts appartenant à quatorze pays.

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The editor has been greatly assisted in his work by Miss Hanna Margalit of the Department of Geography of the Hebrew University of Jerusalem who also gave much help in the preparatory stages of the symposium, and by Mrs. A. Gonen who assisted in preparing the final draft of these *Proceedings*.

D. H. K. AMIRAN

REMERCIEMENTS

Je souhaite remercier ici, pour l'aide qu'ils ont bien voulu m'accorder, M. Michel Batisse du Département des sciences exactes et naturelles de l'Unesco et le professeur H. H. Boesch, secrétaire-trésorier de l'Union géographique internationale, grâce auxquels il a été possible d'organiser le colloque d'Héraklion et d'assurer la publication de ce volume. On doit à M. Peveril Meigs, président de la Commission sur la zone aride de l'Union géographique internationale, les travaux préliminaires concernant le colloque et l'établissement de son programme. Le général Botzaris, président de la Société royale hellénique de géographie a contribué de manière décisive au succès de cette réunion et des excursions sur le terrain organisées à cette occasion. De nombreuses personnalités et institutions, officielles ou privées, de Grèce continentale et de Crète, en particulier la Société d'études crétoises, ont fait un accueil chaleureux aux participants du colloque. Des remerciements tout particuliers reviennent au Dr D. Haralambous, secrétaire de la Société royale hellénique de géographie, qui a bien voulu se charger de l'organisation des réunions et du secrétariat du colloque.

En préparant ces communications pour leur publication, j'ai été considérablement aidé par M^{lle} Hanna Margalit du Département de géographie de l'Université hébraïque de Jérusalem et par M^{me} A. Gonen, qui m'a donné sa collaboration pour préparer le manuscrit final de cet ouvrage.

D. H. K. AMIRAN

INTRODUCTION

by

D. H. K. AMIRAN

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The papers published in this volume were presented and discussed at the Symposium on the Geography of the Arid Zone held by the Commission on the Arid Zone of the International Geographical Union at Iraklion, Crete, from 19 to 26 September 1962. The Royal Hellenic Geographical Society and the Society for Cretan Studies acted as hosts to the meeting.

As the subject for discussion land use in *semi-arid* lands was selected, and not that of arid areas proper. The reasons for this are twofold: one, only an insignificant number of men live in arid areas proper; two, settlement of fully arid lands depends on conditions over most of which man has no control, such as oases, mineral deposits or service along trans-desert trade-routes. Changes in mineral economy or changes in the function of trade-routes will bring about the decline and abandonment of settlements based on them. By its nature, settlement in fully arid areas has a spotty distribution pattern and is areally unconnected. Whereas settlement in humid lands has a number of alternate bases for its economy, permitting it to shift emphasis from one to the other with fluctuations in a given factor, settlement of arid lands lacks this alternative; it is devoted to a single specific purpose. The cessation of such a factor therefore creates ghost towns—in which, unfortunately, the majority of deserts abound.

Settlement of semi-arid lands and their land use is by contrast of much more normal character. But this too has to be viewed against the background of general development trends in other areas. One should not consider the semi-arid zone in isolation. Our economies today are progressing towards ever higher standards of living and higher economic levels, as well as high levels of efficiency. Low-g geared economies have an ever poorer chance of competition. This process is vastly accelerated today to meet the great challenge of opportunities offered by expanding and labour-consuming industries in all developing countries. As a corollary rural depopulation in marginal rural economies and marginal lands is a world-wide trend. In semi-arid lands

where nature maintains a very delicate balance between land, intensity of its use and proper conservation of the land under use, a stagnating agriculture must of necessity lead to over-use of lands without sufficient conservation measures. The result is deterioration of soil quality, soil erosion, depletion and deterioration of water resources, destruction of vegetative cover, in short deterioration of land and a decrease in its carrying capacity.

Considerations for land use in semi-arid areas therefore present us today with the following alternatives:

1. Increasing urbanization, making use of all the specific advantages of semi-arid lands and established even in the more arid sections of the area, a subject which is dealt with in full in the paper by L. D. Stamp on p. 167 of this volume.
2. Agricultural development at a high level of technical competence and economic efficiency, making use of the particular advantages the semi-arid zone offers.
3. Decline of rural settlement, which very probably in many areas will increase its momentum.

In dealing with land use in semi-arid lands, our bias is obviously against the third of these alternatives and in favour of the first two. Setting the question of urban development aside, specialized rural and agricultural development means the ever-increasing importance of a regulated water supply, as basic for irrigated agriculture. Under climatic conditions obtaining in semi-arid zones, no agriculture will be competitive unless based on irrigation.

This poses one of the basic questions in land use of semi-arid lands: decision-making on water use. Industrial and domestic (urban) water will demand increasing precedence over agricultural water, owing to its general weight in the economy of a given area. Allotment of water must be geared to this order of precedence, and in semi-arid lands even more than in humid lands. Fortunately for urban and industrial consumers, limitations of price are considerably less stringent than for agriculture. Often it will be possible to ease the general

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price structure slightly by taking advantage of the higher purchasing power of industrial and urban consumers.

Parallel with this, problems of used water and sewage disposal become ever more important in semi-arid lands. The more so as sufficient water is rarely available to flush the soil of injurious material precipitated. Permanent damage to potential agricultural soil by residues of injurious mineralization must be prevented at all costs.

The special subject of the papers presented to the Iraklion Symposium and published here was types of land use characteristic of semi-arid lands where irrigation is a major element in land use. Furthermore,

methods and procedures for mapping such land use were discussed. Such mapping has to be viewed against the background and general framework of the World Land Use Survey as designed by the Commission on the World Land Use Survey of the International Geographical Union, Professor L. D. Stamp, chairman.

Contributors to this symposium included scientists who have carried out such land use mapping in their respective countries or elsewhere. Special attention should be given to the work of Professor Carmelo Colamonico, of the University of Naples (Italy), and his colleagues, in producing the "Carta della Utilizzazione del Suolo d'Italia" (which will include twenty-six sheets). This is the first enterprise in land use mapping of a Mediterranean country of considerable size.

INTRODUCTION

par

D. H. K. AMTRAN

Professeur de géographie, Université hébraïque de Jérusalem (Israël)

Les communications publiées ci-après ont été présentées et ont fait l'objet de discussions au cours du colloque sur la géographie de la zone aride organisé par la Commission de la zone aride de l'Union géographique internationale, qui s'est tenu à Héraklion (Crète) du 19 au 26 septembre 1962, sur l'invitation de la Société royale hellénique de géographie et de la Société d'études crétoises.

Le thème d'étude choisi était l'utilisation des terres dans les régions *semi-arides* et non dans les régions arides proprement dites. Ce choix a été dicté par deux raisons : d'une part, les régions véritablement arides n'ont qu'un nombre insignifiant d'habitants, et, d'autre part, leur peuplement dépend de conditions sur la plupart desquelles l'homme n'a aucun pouvoir : existence d'oasis et de gisements de minerais, possibilités d'utiliser des voies commerciales transdésertiques, etc. Des modifications de l'économie minérale ou du rôle des voies commerciales peuvent entraîner le déclin et l'abandon de certains centres de peuplement. Le peuplement des régions absolument arides est essentiellement sporadique et il n'est pas lié à la topographie de la région. Dans les régions humides, les bases économiques du peuplement sont multiples, de sorte que leur importance respective peut varier avec le temps sans que le pays cesse d'être habitable, mais, dans les régions arides, le peuplement n'est rendu possible que par un seul facteur et si l'action de celui-ci ne se fait plus sentir, la zone considérée redevient désertique, ce qui explique l'existence des agglomérations fantômes qui, malheureusement, abondent dans la plupart des déserts.

Dans les régions semi-arides, le peuplement et l'utilisation des terres ont un caractère beaucoup plus normal. Cependant, là encore, il faut examiner la situation de ces régions non pas isolément, mais en liaison avec l'évolution générale des autres régions. A notre époque, dans les pays prospères, le niveau de vie, le niveau économique et le niveau d'efficacité s'élèvent sans cesse, tandis que les économies peu développées deviennent de moins en moins compétitives. Le rythme

de ce processus va s'accéléralant du fait des multiples possibilités offertes dans tous les pays en voie de développement par l'expansion industrielle et les besoins de main-d'œuvre qui en résultent. Le dépeuplement des campagnes, dans les pays à économie rurale marginale et dans les zones marginales, constitue en conséquence un phénomène universel. Dans les régions semi-arides où l'équilibre entre les ressources du sol, l'intensité de leur utilisation et leur conservation est très fragile, l'emploi de méthodes agricoles périmées aboutit nécessairement à une exploitation excessive des terres qui ne permet pas d'assurer leur conservation. Ceci provoque la détérioration et l'érosion du sol, l'épuisement et la dégradation des ressources hydrauliques, la destruction de la couverture végétale, bref la détérioration des terres et la diminution de leur capacité de production.

Il ressort donc des études relatives à l'utilisation des terres des régions semi-arides qu'il nous faut choisir aujourd'hui entre les possibilités ci-après :

1. Favoriser l'urbanisation en tirant profit de tous les avantages particuliers qu'offrent les terres semi-arides même dans leurs secteurs les plus arides (L. D. Stamp traite cette question dans sa communication qui figure à la page 167 du présent volume).
2. Développer l'agriculture en faisant appel à des techniques très perfectionnées et d'une grande efficacité économique, en tirant parti des avantages particuliers que peuvent offrir les régions semi-arides.
3. Laisser les zones rurales se dépeupler, à un rythme qui ira très probablement en s'accéléralant dans de nombreuses régions.

Il est clair que la troisième de ces possibilités est à rejeter et qu'il est souhaitable de chercher à réaliser les deux premières. Un développement rural et agricole spécialisé (toute question de développement urbain étant mise à part) exige qu'on accorde une attention sans cesse accrue à la régularisation de l'approvisionnement en eau, qui est indispensable à l'irrigation. Dans les conditions climatiques qui caractérisent les régions semi-arides,

l'agriculture ne peut pas être concurrentielle sans irrigation.

On en arrive ainsi à aborder l'une des questions essentielles qui se posent en matière d'utilisation des terres des régions semi-arides, c'est-à-dire celle de la répartition des ressources en eau. La consommation industrielle et domestique (dans les villes) aura de plus en plus priorité sur la consommation agricole, en raison de son importance générale pour l'économie de chaque région. La répartition de l'eau doit être effectuée en fonction de cet ordre de priorité, dans les régions semi-arides plus encore que dans les régions humides. Heureusement pour les consommateurs urbains et industriels, ils disposent de ressources financières beaucoup moins limitées que les cultivateurs. Il est donc souvent possible d'assouplir légèrement le barème des prix grâce au pouvoir d'achat relativement élevé des consommateurs industriels et urbains.

Parallèlement, les problèmes relatifs aux eaux usées et aux eaux d'égout prennent une importance particulière dans les régions semi-arides, d'autant plus qu'il y existe rarement assez d'eau pour entraîner les substances nocives qui se sont déposées sur le sol. Il faut à tout prix empêcher la dégradation permanente des terres cultivables due à l'accumulation de résidus minéraux.

Les communications présentées au colloque d'Héraklion et publiées dans le présent volume portent essentiellement sur les méthodes d'utilisation du sol caractéristiques des régions semi-arides où l'irrigation joue un rôle capital en matière d'agriculture. Elles traitent en outre des techniques et des procédés employés pour l'établissement des cartes d'utilisation des terres. Ce problème doit être étudié dans le cadre général de l'inventaire mondial de l'utilisation du sol entrepris par la Commission sur l'inventaire mondial de l'utilisation du sol (Union géographique internationale), qui est présidée par le professeur L. D. Stamp.

Parmi les auteurs des communications présentées à Héraklion figuraient des hommes de science qui ont établi, dans leur propre pays ou à l'étranger, des cartes d'utilisation du sol. Il convient d'accorder une attention toute particulière aux travaux du professeur Carmelo Colamonico, de l'Université de Naples (Italie), et de ses collègues, qui préparent la *Carta della utilizzazione del suolo d'Italia* (laquelle comprendra 26 feuilles). Il s'agit là de la première entreprise de grande envergure en matière de cartographie relative à l'utilisation des terres dans un pays méditerranéen.

SECTION I

SEMI-ARID REGIONS
OF THE MEDITERRANEAN TYPE:
THEIR CLASSIFICATION,
CLIMATES AND WATER RESOURCES

RÉGIONS SEMI-ARIDES
DE TYPE MÉDITERRANÉEN :
LEURS CLASSIFICATION,
CLIMATS ET RESSOURCES EN EAU

CLASSIFICATION AND OCCURRENCE OF MEDITERRANEAN-TYPE DRY CLIMATES

by

PEVERIL MEIGS

Chairman, Arid Zone Commission, International Geographical Union

In a meeting devoted to geomorphology and land use, it may seem strange that the first paper should deal with climate. But climate is a convenient and logical factor for summarizing landscapes: convenient because the measurement and summarization of climatic data is pretty well standardized throughout the world, and logical because climate exercises a dominant influence upon the details of land configuration and use. This paper is designed as background to show the extent of the landscapes that are the primary concern of this meeting: those with dry climates of the Mediterranean type with the dry season in summer. I will try, therefore, to compare some of the principal climatic classifications in use today and sketch the extent of lands having arid and semi-arid climates of winter rainfall type.

This is a venturesome task in a group many of whose members live in the Mediterranean lands and have studied them throughout their lives. Two of you, Professors Gaussen and Emberger, have devised systems of classification of these climates and constructed large-scale maps of their distribution, and I hope we will hear more of these during the coming sessions. My own first-hand experience in these climates consists of twenty years of residence and study in California and Baja California, Mexico, and brief trips to other arid Mediterranean areas. I expect to learn much more from you and from the landscapes of Greece during and after this symposium. In addition, I have made some regional and statistical studies of climatic data throughout the world and have had close contacts with Thornthwaite and numerous disciples of Köppen and de Martonne. The more I study the more I sympathize with Bagnouls and Gaussen (1957), who said that anarchy reigns in climatology. One climatologist after another devises his own system of classification which may work well for a special purpose, or for a special part of the world, but which usually has certain drawbacks. Yet the various systems agree on the core areas of the main climates; there is some overlapping at the margins, and in transitional climates such as the semi-arid. Some of

the differences are more apparent than real, as a result of differences in use of terms. Usage differs on such common terms as desert, true desert, semi-desert, steppe, sahel, arid, semi-arid, and subhumid. This is not the occasion to try to reach agreement on these terms. In the present sketch, I will concentrate upon the winter-rain type climates to the arid side of the true Mediterranean climate, regardless of the degree of their aridity.

One of the simplest classifications of dry climates states simply that 10 in. (250 mm.) is the dividing line between arid and semi-arid; 20 in. (500 mm.) between semi-arid and humid. Although this limit is scorned by many scientific geographers and climatologists, it actually is not bad for Mediterranean climates and agrees well with the standard climatic classifications. It breaks down, however, when we turn to the tropical margins of the desert where a greater amount of rainfall is required to make a locality humid.

Most classifications today use combinations of temperature and precipitation, in order to make some allowance for the increasing evaporation with higher temperatures. De Martonne (1926, 1942) and Köppen (1923) both used figures of annual precipitation and temperature. The basic de Martonne formula:

$$I \text{ (index of aridity)} = \frac{P}{T + 10}$$

gives a true sliding scale without artificial break points. Köppen's formula has rigid break points, but at least these are varied according to the season of maximum rainfall. For Mediterranean semi-arid climates his outer limit is: $R \text{ (rainfall)} = T + 22$. The margin between arid and semi-arid would be $R = T + 11$. Köppen's formulas were an attempt to assign climatic values to the limits of the main vegetation types of the world.

Another philosophy analyses the temperature and precipitation ratios of the individual months. The monthly indexes are then summarized into an annual

figure. Thus, de Martonne's index becomes the total of twelve monthly indices each of which is calculated according to

$$\frac{12p}{t + 10}.$$

Thornthwaite's (1948) basic system is more complex, but it still uses only the mean monthly temperatures and precipitation to arrive at a figure for estimated potential evapotranspiration. Recently he has introduced factors of soil to the point where his latest indices can no longer be considered purely climatic (Thornthwaite and Mather, 1957).

An early version of the concept of evaporation balance was devised by Albrecht Penck (1910), who used the geomorphic factor of hydrographic balance for a broad climatic classification. De Martonne (1942) drew a world map upon such a basis.

Some systems have been devised for special purposes. Emberger (1955) uses mean annual precipitation, mean daily maximum temperature of the warmest month, and mean daily minimum temperature of the coldest month, all combined into a single "moisture quotient" using formula:

$$Q = \frac{2P}{(M + m)(M - m)} \times 1000.$$

Unlike the formulas of Köppen, Thornthwaite, or de Martonne, the quotient of Emberger cannot be used by itself to make a valid climatic map. His maps appear to be based upon his profound knowledge of vegetation, not upon the mapping of climatic data. After mapping the vegetation zones, he determines the associated moisture quotients and other climatic values within the zones. Thus, the northern limit of his arid zone in north-west Africa varies from a moisture quotient of 16 to one of 40. In characterizing the climate of his stations, he uses the actual mean daily minimum temperature of the coldest month, as well as the moisture quotient. His maps for north-west Africa, which he calls bioclimatic zone maps, are of fundamental value for all geographers and climatologists. Because of the accuracy and detail of his mapping, the maps form a valuable test of the vegetation validity of any climatic system. A simple check shows, for example, that de Martonne's index of 10 would serve fairly well as the northern limit of Emberger's Mediterranean arid bioclimatic zone.

Vapour pressure has been used as a major climatic factor for several classifications, most recently by Garnier (1960) for the humid tropics. This factor has special significance for physiology, but considerably less for morphology, vegetation, land use, or the general landscape, where precipitation is more important. The classification gives precipitation a secondary place.

Of late there has been a tendency, which looks very reasonable, to use the length of the dry season as a major element in a climatic classification. Lauer (1952)

has done this for Africa and South America, emphasizing the tropics but touching also the Mediterranean areas. The most thorough work in this direction has been by Professor Gaussen (Bagnouls and Gaussen, 1957), whose work for Unesco on Mediterranean climates I hope will be exhibited at this meeting.¹ Using a definition of a dry month as one in which p is less than $2t$, he classifies the winter rain climates as:

Hot desert	12 months dry
Hot subdesert	9 to 11 months dry
Mediterranean	1 to 8 months dry

The Mediterranean is broken down into four subdivisions:

Xerothermomediterranean	7 to 8 months dry
Thermomediterranean	5 to 6 months dry
Mesomediterranean	3 to 4 months dry
Submediterranean	1 to 2 months dry

Where data are available, the dry periods may be shortened through the inclusion of factors of dew and fog in the moisture balance. He has made large-scale climatic maps of the Mediterranean lands (Gaussen, 1958) not only around the Mediterranean Sea, but for similar climates in other parts of the world.

Only by the construction of detailed large-scale maps such as those of Emberger and Gaussen can the various systems of climatic classification be compared adequately. Thanks to this sort of mapping, we know from the north-west Africa region, for example, that the Mediterranean semi-arid zone of Emberger agrees well with the semi-arid climate of Thornthwaite as mapped by Carter (1954). Gaussen's thermomediterranean includes part of this semi-arid zone, but extends also into Emberger's Mediterranean subhumid climate. We can see too that Thornthwaite's arid includes Emberger's Mediterranean arid and Gaussen's xerothermomediterranean (7 to 8 dry months). Gaussen's classification thus shows more degrees of aridity than the other two classifications. His desert and subdesert zones represent the drier parts of the arid areas shown by the other two authors.

As more and more large-scale climatic mapping becomes available, it is hoped that systematic comparisons of the type suggested here will be made. Sirri Erinc (1950) gave us a model of comparative method for Turkey, using de Martonne and two Thornthwaite systems. The subject is worthy of a carefully planned symposium of its own.

I would like now to review briefly the distribution of the Mediterranean-type dry climates, the world stage upon which the attention of our symposium is to be concentrated. No attempt will be made to distinguish between the various subdivisions of these climates, but simply to mention the areas where there are arid or semi-arid climates with precipitation concentrated

1. Proofs were exhibited of large-scale bioclimatic maps of all Mediterranean-type regions, by Emberger, Gaussen, Kassas and de Philippis, to be published by Unesco. The subdivisions are basically those of Gaussen as listed here.

during the winter half of the year, on the basis of several existing small- and large-scale maps (Meteorological Office, 1958; Meigs, 1960; Min. Obras Publicas, 1942; Sanson, 1945; Min. Labori Pubblici, 1949; Mariolopoulos, 1955; Birot and Dresch, 1956). This is basically a west-coast type of climate, getting most of its rainfall from the westerly storms associated with the southward movement of the polar front during the winter season, and experiencing the drought related to the approach of the dry side of the oceanic highs during the summer season.

Quite logically, the Mediterranean type of climate is most extensive along the Mediterranean Sea, which gave birth to the name. Quite logically, too, the dry phase of the Mediterranean climate is most extensive on the south and south-east sides of the sea, towards the North African and Asian deserts. This climate borders the north African coast everywhere except in the most humid parts of Tunisia, Algeria and Morocco, and continues southward into the Sahara until the rainfall becomes meagre and irregular in occurrence. At the east end of the Mediterranean Sea, the dry climates with winter rain come down to the coast in Sinai, southern Israel, and south-eastern Turkey, and extend inland throughout the Middle East, including the plateau of Turkey (Erinç, 1949, 1950) as well as the northern half of Arabia.

On the north side of the Mediterranean Sea, semi-arid climates occur in the south-eastern parts of all the major peninsulas and adjacent islands, including Corsica, Sardinia, and Sicily, where there is some protection from the rain storms from the west (Min. Obras Publicas, 1942; Sanson, 1945; Min. Labori Pubblici, 1959). Even France has semi-arid spots on the deltas of the Rhone and Aude Rivers. Only in Spain is there a desert climate on the European coast, near Almería: the driest spot in all Europe. The south-eastern part of the Greek

mainland, some of the Cyclades islands, and eastern Crete are all classified as semi-arid (Mariolopoulos, 1955; Birot and Dresch, 1956). Athens is semi-arid according to de Martonne, Thornthwaite, and Emberger. Gaussen classifies Athens as thermomediterranean (6 months dry), a borderline type. According to Köppen's original system, Athens is barely on the humid side of the line. A subsequent version of Köppen would put it on the semi-arid side. Contrary to the hypothesis of Huntington (1910) and others, the evidence indicates that Greece is no more arid now than in early historic times (Mariolopoulos, 1955; Meigs, 1961).

Eastward, these climates border the Persian Gulf and most of the Red Sea, extending along the Makran into Pakistan, but not as far as Karachi, where summer rains prevail. The deserts and steppes of the interior of Iran, Baluchistan, Afghanistan, and Russian Turkestan, are predominantly of the winter-rainfall type. In South Africa only a little of the south-west coast and the Karroo have this type of climate. In Australia, it occurs along the coast and a short distance inland in the south-west and in the south. In North America, this climate reaches the coast in southern California and northern Baja California, Mexico. Southern Baja California has a tropical rainfall régime. The winter rain type extends inland to include the Mojave Desert, the Great Basin, and the Columbia Plateau. In South America, this type of climate borders the coast of Chile at the south end of the Atacama Desert, and across the Andes in the western part of Argentina.

I believe that all of these areas and many of the sub-areas are represented at this symposium. Even the South American Mediterranean deserts have been studied by at least one of you. With such an assemblage of talent, with such a wide basis for comparing observations, I look forward to a stimulating symposium.

DISCUSSION

J. H. G. LEBON. The criteria of aridity cited in the paper ignore the distinction between *wholly arid* and *near arid* climates. The former occur where rainfall is less than 2 in. (50 mm.) *per annum*, and, where such intense drought prevails, arid geomorphic processes operate extensively, and there is no vegetation. *Near-arid* climates (receiving from 2 to about 10 in. (250 mm.)) have land-forms due partly to running water and bear sparse vegetation, which can support the herds of pastoral nomads.

P. MEIGS. Subdivisions such as Professor Lebon suggests are indeed valid. In the present paper, however, I have deliberately lumped into a single category all arid and semi-arid climatic types that fell within the central theme of our symposium: those with rain in winter and driest season in summer, as shown on the accompanying map.

R. F. LOGAN. While in accord with Professor Lebon's comments on Dr. Meigs' paper, I would suggest no change in the present arid - semi-arid concept, but rather the addition of a "super-arid" type, of less than 2 in. or 3 in. annual precipitation, similar to the suggestion of J. Meckelein.

At the same time, we must not overlook the fact that even in "super-arid" situations, fluvial erosion may be dominant. In the Namib of South-West Africa, where annual average precipitation is only 0.6 in., showers of 2 in., once in several years, produce strong fluvial action.

P. MEIGS. This is precisely in accordance with a subdivision that I established in 1953 in an article in Unesco's *Arid Zone Hydrology, Reviews of Research*, p. 204-205, and which appears on their bioclimatic maps. I called it the "extreme arid" subdivision, with less than about 2½ in. of rainfall per year.

S. ERINÇ. If we are dealing with the classification and occurrence of the Mediterranean-type semi-arid and arid climates, we have, first of all, to draw boundaries of the Mediterranean climate on a genetic basis. I am of the opinion that Mediterranean climate stops in the north where precipitation maximum occurs in summer. As to its southern limit, it runs where winter maximum is replaced by summer maximum.

Only after this definition may we proceed to the classification of areas of different degrees of aridity. In this connexion, however, we have to take into consideration the peculiarity of the Mediterranean climate which results in a combination of arid (desert) conditions in summer and humid conditions in winter. This is because climatic conditions of the Mediterranean basin are determined by tropical (desert) air masses in summer, and polar masses in winter. Under these conditions, a classification regarding the aridity must be based upon two important factors: (a) duration of arid conditions in summer; (b) degree of aridity in the same period.

In so far as Turkey is concerned, my colleague, Dr. Tümertekin, has published several maps showing the duration of arid and semi-arid periods expressed in months. And I observe that his results do not completely agree with the map presented by Dr. Meigs. Finally, I would not agree to the inclusion of areas such as southern Arabia and Western Pakistan and northern parts of West Turkestan because these areas are characterized, so far as I know, by summer or early summer rainfall maximum, and therefore should not be included in the Mediterranean climatic region.

P. MEIGS. I have not tried to show climatic subdivisions, but simply the area with winter rain and too dry to be called true Mediterranean. For Turkey I relied upon the maps by Professor Erinç. There are very distinct winter rainfall régimes in such places as Quetta and Pasni in Western Pakistan, and Muscat and Jidda in southern Arabia. In the latter region there are not enough weather stations to draw very precise limits.

F. F. DAVITAYA. The report and the map presented by Dr. Meigs are very important. The point is that direct measure-

ment of evapotranspiration from the earth's surface is difficult, and indirect determination of the aridity index is too complicated. In the U.S.S.R. the hydrothermic coefficient suggested by Professor G. T. Selyaninov in 1928 is widely used:

$$C = \frac{\Sigma P}{0.10 \cdot \Sigma \Theta}$$

where ΣP is the amount of precipitation in the period with daily average temperature above 10°C ., and $\Sigma \Theta$ accumulated temperatures (the sum of the mean daily temperatures above 10°C .) in the same period.

There is a good connexion between the above-mentioned coefficient and the radiation index of aridity suggested by M. I. Budyko:

$$Ri = \frac{R}{L \cdot r}$$

where R is the radiation balance, L latent heat of evaporation and r the amount of precipitation.

The merit of the first of them is its simplicity—temperature and precipitation observations are made almost everywhere.

In my opinion, the map presented by Dr. Meigs needs some corrections: in the Crimea, the arid zone with winter rains is not so wide as it is shown on the map; in the Transcaucasus, arid zones with winter rains are absent; in the Transcaspiian sea areas the maximum of the precipitation is mostly in spring. This maximum moves from the south (March-April) to the north (June-July) in the same areas.

The summer maximum of precipitation is in the territories to the north of the Aral Sea.

P. MEIGS. Professor Davitaya's corrections for the Transcaspiian area are appreciated, and the map is being adjusted accordingly. In some places, as in the Crimea and southern France, the size of the applicable climatic areas is so small that they would hardly be visible on a map of this scale unless slightly exaggerated.

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REMARQUES SUR UNE DIVISION GÉOMORPHOLOGIQUE DES RÉGIONS ARIDES ET LES CARACTÈRES ORIGINAUX DES RÉGIONS ARIDES MÉDITERRANÉENNES

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DE DIVERSES MÉTHODES POUR CLASSER LES RÉGIONS ARIDES

Une division des types et variétés de déserts a été tentée généralement à partir de données climatiques et biogéographiques et d'indices d'aridité qui ont eu pour but d'exprimer le déficit du bilan hydrique, responsable de l'aridité, essentiellement l'évapotranspiration. Nombre de ces indices sont de simples coefficients hydrothermiques, combinant les deux facteurs précipitations et températures. Les premiers de Lang, Köppen, de Martonne sont fort élémentaires. On a tenté de les préciser en exprimant la longueur de la saison sèche (P. Birot), la rudesse biologique en introduisant les maxima moyens du mois le plus chaud ou les minima moyens du mois le plus froid (L. Emberger) et en classant les valeurs du quotient en fonction de ces derniers, pour préciser des mesures appelées étages à l'intérieur d'une unité climatique. H. Gaussen et d'autres ensuite, pour préciser l'importance de la saison sèche, combinent un indice xéothermique avec des courbes ombrothermiques à partir de définitions empiriques mais pratiques de mois chauds ou froids, humides ou secs. Mais, en somme, il s'agit toujours de moyens détournés pour exprimer l'évaporation réelle que les instruments, ni les indices qui en utilisent les résultats (J. Dubief, R. Capot-Rey), ne permettent pas de préciser de façon satisfaisante. Ces moyens ont l'avantage d'être simples; aussi utilise-t-on encore l'indice de de Martonne et, de plus en plus, les indices et courbes de H. Gaussen. Pour leur donner plus de rigueur, au moins apparente, des recherches ont été poursuivies par des climatologues et géographes soviétiques qui ont eu le mérite de préciser la balance thermique par le moyen de la radiation solaire, de la réflexion et d'autres facteurs; mais leurs indices n'ont pas reçu d'application internationale, à l'inverse des divers indices de Thornthwaite qui, on le sait, ont fait l'objet de critiques. Ils ont inspiré la préparation de la carte des régions arides, par Peveril Meigs, pour l'Unesco, dont l'utilité est

évidente. Mais il s'agit encore d'une division climatique des régions arides, inspirée en somme, comme les indices de Thornthwaite, par le souci de contrôler réciproquement les données climatiques et les aspects et conditions biologiques de la couverture végétale.

Les géographes peuvent souhaiter disposer de critères plus complets pour définir les types de déserts. Ils ont en somme généralement adopté le point de vue des climatologues et biologistes soucieux de définir une notion bioclimatique, l'aridité, notion d'autant plus complexe qu'elle n'est pas zonale, bien que les plus grands déserts soient les déserts tropicaux. Il peut paraître au moins insuffisant de définir par des indices, et, par suite, à l'aide de moyennes, des climats caractérisés par de grands contrastes de températures, au-dessus de 0 ou de part et d'autre de 0, et par une extrême irrégularité des précipitations dans leur répartition, non seulement annuelle, mais interannuelle. En outre, on cherche à expliquer, par ces indices imparfaits, une végétation qui est remarquable par sa pauvreté et ne joue un rôle croissant dans le paysage que dans la mesure où l'on s'écarte davantage des régions arides. En fait, soucieux d'analyser, de classer et d'expliquer des paysages, et soucieux également d'utiliser ces analyses et explications pour rendre les régions arides moins inhumaines, les géographes peuvent estimer utile de ne pas partir des aspects négatifs de ces paysages, insuffisance des précipitations dans le bilan bioclimatique, absence ou pauvreté des sols et de la végétation. On a qualifié les paysages arides minéraux: la roche affleure ou ses débris. La structure, lithologique et tectonique, et la morphologie sont déterminantes puisque les processus d'érosion dominants en régions arides, thermoclastie, hydratation, ruissellement non concentré sont plus efficaces qu'en aucune autre zone morphoclimatique pour différencier les moindres nuances de la résistance des roches et opposer minutieusement roches dures et roches tendres. Ce sont donc les données structurales et morphologiques que les géographes peuvent tenter d'utiliser pour définir les types et les sous-types de régions

arides et les cartographier. Certains s'y sont essayé comme H. Mortensen, W. Meckelein, les géographes soviétiques, F. Joly entre autres. Mais les tentatives n'ont pas été généralisées à l'ensemble des déserts et n'ont pas fait l'objet de représentations cartographiques à petite échelle.

LES PRINCIPAUX TYPES MORPHOLOGIQUES DE RÉGIONS ARIDES

RÉGIONS ARIDES PLANES DE BOUCLIERS

Les déserts afro-arabes (Sahara, Kalahari, désert syro-arabe) auxquels on peut joindre le Thar et les déserts australiens, sont des déserts chauds de plaines : les reliefs importants n'y tiennent qu'une place réduite et ont généralement une altitude insuffisante pour que le désert fasse place à un demi-désert, ou disparaisse, ou, moins encore, soit surmonté par un désert d'altitude. Seuls le Hoggar, le Tibesti, le Sinaï, les hauteurs de l'Arabie Heureuse portent la marque d'une végétation semi-aride, de l'influence morphologique de la neige et du froid. Ces déserts plats correspondent à de vieux boucliers cristallins où l'on distingue de nos jours une suite comparable de granitisations et qu'on a réunis en un continent hypothétique, la Gondwanie. Que la Gondwanie soit une hypothèse vraie ou fausse, il importe peu ici. Du moins les déserts y ont-ils un air de parenté. Les conditions paléogéographiques du paysage y sont comparables : immenses pédiplaines, dans le cristallin, surmontées par des reliefs résiduels, plateaux de couverture généralement tabulaires, ou faiblement inclinés, de dépôts pour la plupart continentaux et gréseux, limités par de gigantesques cuestas, vastes cuvettes tectoniques remblayées. L'évolution paléoclimatique plioquaternaire y est également, semble-t-il, concordante ; les températures n'y furent jamais froides, mais purent être fraîches ; les précipitations y furent suffisantes pour que de grands fleuves aient coulé non seulement dans les vallées de montagne mais aussi dans les plaines, partiellement occupées par des lacs, au moins à deux reprises. Ces fleuves ont accumulé le matériel sableux des grands ergs dans leurs cuvettes d'épandage. Mais l'évolution des marges tropicales fut certainement différente de celle des marges tempérées : contrastes violents entre périodes très arides, au cours desquelles le désert migrerait vers les tropiques, et périodes humides qui ont pu résulter soit d'un balancement des précipitations zonales, soit au contraire d'une convergence des pluies tempérées et tropicales. En conséquence, les déserts de boucliers tropicaux sont caractérisés par des traits communs dont les principaux sont les suivants :

1. Les formes d'érosion, de dénudation l'y emportent de beaucoup sur les formes d'accumulation. Contrairement aux affirmations de E.-F. Gautier, ce n'est pas ici qu'il

convient de rechercher les meilleurs exemples d'ennoyage désertique. On ne saurait en être surpris : les roches du socle sont des roches granulaires, ou schisteuses, beaucoup plus rarement des roches éruptives ou d'épanchement, ou des quartzites résistants. Les roches de couverture sont des grès ou des calcaires, le plus souvent peu épais, parfois marneux. La désagrégation par thermoclastie et hydratation fournit en conséquence des produits fins, poussières, limons, sables susceptibles d'être mobilisés par le ruissellement en nappe ou diffus, et par le vent. Les surfaces planes sont donc des surfaces d'érosion, pédiments à inselbergs, glacis de dénudation, pédiplaines, s'étendant vers l'amont par recul des versants, plutôt que des surfaces d'ennoyage.

2. Les formes planes d'érosion voisinent avec des formes planes structurales, du type des hamada, limitées par des escarpements. Des croûtes, siliceuses vers les marges tropicales, calcaires ou, rarement, gypseuses, peuvent également déterminer des plates-formes structurales.

3. Des dépôts de pente grossiers ne se trouvent qu'au pied de versants de roches se délitant en gros débris. Ils sont généralement de gravité. Des terrasses d'oueds dans les vallées de montagne ou dans les piémonts sont des héritages de périodes humides. Les dépressions sont remblayées surtout par du sable ; des cuvettes argileuses, salines, les sebkha sahariennes ne sont pas rares, surtout sur les marges tempérées, mais les dépressions de type takyr sont rares. Le sable est dans l'ensemble abondant : épandages sableux, dunes accrochées aux obstacles sont fréquents. Les ergs sont très variés de formes, les dunes longitudinales dominent dans la zone des vents réguliers (alizés) ; les massifs dunaires sont plus confus aux marges tropicales, à la fois par suite de l'instabilité plus grande des vents saisonniers et d'une fixation plus avancée. Ces ergs sont anciens, ce qui contribue peut-être à expliquer la relative rareté des barkhanes.

4. Ces régions arides de boucliers comportent naturellement des nuances. Mais l'uniformité générale des conditions structurales et paléogéomorphologiques est telle que les sous-types sont climatiques. On peut distinguer des déserts hyperarides, vrais déserts selon la définition de L. Emberger (Sahara central, désert libyen, Roub al Khali). La distinction entre aride et hyperaride est d'ailleurs fréquemment adoptée par les climatologues et botanistes, d'après les données climatologiques et les indices. La préciser sur le terrain est plus délicat. W. Meckelein l'a tenté en Libye. L'Extremwüste ne porterait plus la trace d'oueds, ni même de ruissellement en terrain plat, mais une certaine action chimique y expliquerait la présence de sols poudreux et de sols polygonaux. Dans le Vollwüste prédomineraient les actions physiques et le vent serait encore

beaucoup moins actif que dans le demi-désert où le ruissellement serait également plus efficace. C'est dans la steppe sèche méditerranéenne que serait manifeste une érosion linéaire, se formeraient des croûtes. Ces distinctions, pour intéressantes qu'elles soient, prêtent à discussion et ne sont sans doute pas généralisables hors du Sahara. Mais il semble qu'à propos du désert saharo-arabe, le plus vaste et le plus étendu en latitude sans que de puissants massifs viennent perturber les différenciations zonales, on puisse admettre des distinctions morphologiques généralisables surtout entre le vrai désert aride et hyperaride d'une part, les régions semi-arides de l'autre. Dans le premier cas, les vallées ne sont pas parcourues par une crue chaque année, à moins qu'elles ne soient allogènes, le modelé est l'œuvre surtout du ruissellement diffus ou en nappe, les sols, s'il en existe, sont hérités. On peut chercher des nuances entre un aride et un super-aride qui serait caractérisé par une dégradation accrue de l'écoulement et de la végétation. Toutefois la notion d'aréisme apparaît très abstraite : l'aréisme résulte essentiellement de la platitude ; c'est l'absence de pente qui, en définitive, supprime l'écoulement, et non l'insuffisance des précipitations moyennes puisque aussi bien il peut pleuvoir partout sur la surface du globe. L'écoulement est gêné, en outre, par un reg épais et privé de ses éléments fins par la déflation, car les déserts extrêmes paraissent, en somme, être les déserts les plus anciens. L'influence du vent est plus discutable. Certes, la déflation est active surtout là où du matériel fin est mobilisable, et plus dans les demi-déserts que dans les vrais déserts. Dans les vrais déserts, le stock principal de matériel fin est accumulé depuis les périodes humides du plioquaternaire. Là aussi il est, dans une grande mesure, un héritage. On l'admet maintenant pour tous les déserts. Mais si, au Sahara, du matériel fin n'est plus accumulé, c'est parce que les vents en divergent. Les vents exportent les poussières hors du Sahara, vers le Sahel ou vers les rivages méditerranéens, comme il est normal dans un désert tropical. Aussi la pauvreté apparente de l'action éolienne dans les déserts extrêmes provient peut-être du fait qu'il n'y a plus de matériel fin disponible, remaniable. Le fech-fech poudreux est souvent protégé par le dallage de reg, ou trop cohérent pour pouvoir être aisément mobilisé. En outre, la platitude de vieux regs ne favorise pas la turbulence du vent.

En dehors du bouclier gondwanien, il existe sans doute des déserts de grandes plaines, par exemple en Asie moyenne soviétique, dans le Grand Bassin des États-Unis, ou en Patagonie. Ce ne sont pas des déserts extrêmes. Ils sont même, comparés à l'Extremwüste, très atténués. Ce sont des déserts tempérés, froids, et dominés par de hautes chaînes. Ainsi s'explique que l'influence de l'écoulement fluvial y soit encore, y fut surtout, très sensible : les fleuves montagnards y ont accumulé des dépôts grossiers ou fins en ravinant ou

ennoyant les dépôts tertiaires, et l'on peut expliquer par l'érosion fluviale les couloirs longitudinaux du Kara Koun, hypothèse abandonnée pour interpréter les feidj et les gassi des deux grands ergs nord-sahariens. Ce sont déjà plus des déserts d'ennoyage que des déserts du type plaines de boucliers. Ils font transition avec les déserts de bassins et montagnes.

RÉGIONS ARIDES DE BASSINS, PIÉMONTES ET MONTAGNES

Dominés par de hautes montagnes, ces déserts ont des aspects déterminés par elles. Ces montagnes sont généralement assez hautes pour qu'un étagement bioclimatique ou bien fasse disparaître le désert en altitude, ou bien détermine au-dessus du désert bas, de bassin et piémont, et d'un ou plusieurs étages forestiers, un désert d'altitude, ou bien enfin transforme progressivement les déserts inférieurs en désert d'altitude froid, sans interposition d'un étage forestier. Quoi qu'il en soit, la morphologie des déserts de bassin et piémont dépend de la montagne, des rivières qui ont des crues de fonte de neiges ou de glaciers et sont assez puissantes, du moins en période de crue, pour en évacuer d'abondants débris de gros calibre produits par la gélifraction, des torrents de versants qui assurent, eux aussi, le transit des débris. Mais la montagne, en outre, modifie le climat de la plaine, selon que la plaine et le versant dominant sont au vent ou sous le vent, augmente ou diminue les précipitations, la vitesse du vent et sa turbulence. De la sorte, si des formes d'érosion du type pédiment et glaciais ne sont pas absentes, les formes d'accumulation, d'ennoyage prennent une importance bien supérieure. C'est au sujet de ces types de régions arides qu'il eût fallu définir l'ennoyage désertique, et non à propos du Sahara.

Mais, s'il en est bien ainsi quelle que soit la montagne, pour autant qu'elle soit volumineuse et haute, il est évident que les combinaisons de montagnes et de piémonts et bassins désertiques sont aussi nombreuses et variées qu'il y a de hautes chaînes dans des zones climatiques diverses. Or ces régions arides de bassins, piémonts et montagnes sont schématiquement au nombre de quatre, plus compliquées les unes que les autres, mais différemment. Les deux régions américaines, déserts andins, déserts nord-américains, des chaînes côtières et des Rocheuses ont une orientation méridienne : les variétés de régions arides s'expliquent certes par la structure et le relief, la brutalité des contrastes andins, le morcellement et l'étalement en longitude des chaînes occidentales de l'Amérique du Nord et les étagements et dissymétries climatiques qui en sont la conséquence. Mais, en outre, les deux chaînes s'allongent sur plusieurs zones bioclimatiques.

Andes. Elles rassemblent la collection la plus schématique de déserts répartis en latitude et en altitude le long de la diagonale aride andine : désert chilo-péruvien

subéquatorial et littoral, surmonté par les déserts d'altitude tropicaux étagés jusqu'aux paramos secs de l'Altiplano; déserts et semi-déserts tropicaux du versant argentin, passant au désert continental frais patagon. Mais, quelles que soient les nuances climatiques, la puissante chaîne soulevée qui a acquis son altitude à la fin du tertiaire, impose sa marque aux déserts: déserts ennoyés à la fois par les énormes épandages des oueds andins qui fossilisent la base des versants, et par les agents météoriques qui recouvrent plus ou moins les versants de débris. Mais cette action des agents météoriques est très variable depuis les déserts littoraux, sans variations de température et, par suite, sans thermoclastie, jusqu'à l'Altiplano et la Puna, où il fait frais toute l'année, et les hauts massifs qui dépassent 4 700 mètres où il gèle toutes les nuits. La haute montagne, de plus en plus froide vers le sud, fournit et a fourni plus encore de débris. Les reliefs dunaires tiennent peu de place et se réduisent souvent à des épandages, formes mineures, et à des barkhanes isolées ou en chaînes. Le sable est généralement peu abondant, à cause de la lithologie, et il n'a pu être accumulé et trié longtemps comme au Sahara. Les regs sont de même beaucoup moins évolués. Les distinctions entre hyperaride et aride sont ici valables. Mais il ne semble pas que les critères utilisés pour le Sahara soient applicables. L'oued, le chenal d'écoulement, fait toujours partie du paysage et son action passée, et même actuelle, pour épisodique qu'elle soit, apparaît majeure.

Régions arides nord-américaines. Elles sont beaucoup moins allongées en latitude, mais beaucoup plus étalées en longitude. Les latitudes ne sont que tropicales et tempérées. Mais la variété des types de déserts n'est pas pour autant beaucoup moindre que dans les Andes. Les Rocheuses ont une structure et un relief plus compliqués et les nuances climatiques, les contrastes d'exposition en sont multipliés. Elles sont morcelées en massifs de superficie, d'altitude, de composition lithologique très variables, entre des régions tabulaires ou des bassins remblayés, souvent tectoniquement instables jusque pendant le quaternaire. Elles se présentent ainsi comme une marqueterie de massifs, bassins et plaines. La montagne est partout présente, parfois puissante par son volume et son altitude, sans toutefois qu'il existe des déserts d'altitude comparables à ceux des Punas et de l'Altiplano. Aussi bien la montagne est-elle souvent si humble qu'elle ne détermine pas de différenciation bioclimatique d'altitude. Les plateaux, les bassins et les plaines tiennent bien plus de place que dans les Andes, Argentine exceptée. Aussi la différenciation des types de déserts est-elle compliquée: on a décrit des déserts à pédiments puisque aussi bien c'est dans les Rocheuses que ces formes ont été décrites, discutées. Ils sont fréquents, surtout dans les régions cristallines, de massifs très morcelés, chaudes, où l'action de l'écoulement organisé est secondaire, ou, tout au moins, associée à celle du ruissellement en nappe ou diffus. Mais les pédiments

se terminent dans d'immenses playas ou bolsos où le remblaiement est d'autant plus épais que des mouvements du sol quaternaires ont soulevé les montagnes relativement aux niveaux de base locaux, souvent affaissés le long de fractures, dans le style des Basin Ranges. Aussi les débris accumulés peuvent-ils avoir des origines très diverses, alluvions caillouteuses lointaines, débris mal triés, de calibre variable, d'origine proche, limons et argiles, et déterminer autant de nuances dans les types de piémonts et plaines endoréiques. Les formes sont donc très variées et il paraît assez difficile de les utiliser pour tenter un classement entre déserts et déserts extrêmes. Ceux-ci semblent très exceptionnels. Le Colorado Desert lui-même, au fond du golfe de Californie, est assez couvert de végétation et il semble que partout soit sensible un écoulement concentré ou bien en nappe et diffus. Mais, plus que dans les Andes, les accumulations sableuses et les systèmes dunaires sont modestes et rares: sans doute est-ce parce que les affleurements granitiques ne sont pas assez étendus et, plus encore, qu'en conséquence les séries gréseuses sont beaucoup moins importantes qu'au Sahara où les Tassili primaires, le Continental intercalaire ou terminal ont fourni une part importante du matériel sableux.

Régions arides de l'Asie moyenne soviétique et de l'Asie centrale. Elles composent un troisième groupement de régions arides de montagne. Il rappelle les Andes par certains caractères structuraux, de puissantes chaînes très élevées, portant de hautes surfaces d'aplanissement et par suite des déserts d'altitude, et dont les neiges et glaciers, les versants relativement humides, du moins quand ils sont exposés au vent, ont alimenté et alimentent encore de grands fleuves, de régime nivoglacière. Mais ces hautes chaînes n'excluent pas des montagnes plus modestes et elles dominent des bassins et plaines tectoniques. Or, les altitudes actuelles résultent de mouvements récents. Déserts jeunes, donc, comme dans les Andes, où cependant les bassins sont souvent perchés. Mais, autre différence majeure, les régions arides asiatiques sont allongées en latitude tempérée et sont froides. Elles sont donc caractérisées par la présence de déserts d'altitude, mais où la gélification et les formes d'accumulation, d'ennoyage par solifluction périglaciaire, moraines glaciaires, dépôts fluvioglaciaires, jouent un beaucoup plus grand rôle que dans les Andes; les syrts du Tian Chan et du Pamir sont beaucoup plus couverts que les Punas et l'Altiplano. Comme dans les Andes pacifiques, les déserts d'altitude se prolongent par les déserts de piémont, en se transformant par étages, sur les grands versants à l'abri des vents humides. Les plaines, elles aussi, sont si ennoyées que longtemps les géomorphologues soviétiques ont nié l'existence de pédiments. Certaines sont anciennes et démesurées, comme les plaines aralo-caspiennes occupées par des sédiments marins et lagunaires tertiaires, au point que le plateau d'Oust Ourt est une immense hamada. Mais

les versants des grands massifs ont été ennoyés par du loess que les géographes soviétiques considèrent comme un dépôt diluvial et proluvial, selon leurs propres termes, c'est-à-dire un dépôt d'origine locale, résultant du remaniement et du transport de débris gélivés par le ruissellement diffus ou concentré intermittent. Le loess se limite, en Asie moyenne, aux piémonts. Les autres formations de remblaiement sont les épandages caillouteux de rivières souvent très chargées en débris grossiers ou des torrents d'origine proche. Ils composent des regs alluviaux ; mais, vers l'aval, les sédiments sont de plus en plus fins, argileux ou sableux, souvent interstratifiés. Ainsi s'expliquent les importantes accumulations sableuses, fixées, du Kara et du Kizil Koum. Les sables ont été accumulés par les fleuves et sont d'origine plus ou moins lointaine. Les formes mêmes des koumy portent encore la marque non seulement de l'accumulation fluviale, mais aussi du creusement linéaire dans la masse argilo-sableuse, notamment dans le Kara Koum. Les déserts de l'Asie centrale sont beaucoup plus complexes, bien qu'aux chaînes puissantes s'opposent toujours des bassins, plus fermés encore, souvent immenses comme la cuvette du Tarim, et très déprimés puisque la cuvette de Turfan est à une cote négative. Mais souvent des montagnes annexes, morcelées, ne sont pas assez élevées pour que se manifeste un étagement bioclimatique en altitude. Les bassins sont toujours remblayés par d'importantes rivières, souvent sur de très grandes épaisseurs qui témoignent et de l'importance des mouvements tectoniques quaternaires et de l'efficacité de l'érosion. Certains de ces bassins, celui du Tarim surtout, sont considérés comme des déserts extrêmes et le massif de dunes vives du Takla Makan est un des plus étendus et des plus redoutables du monde. Du moins, ne saurait-il être défini par les mêmes critères que l'hyperaride saharien. Il est aussi riche en sable que l'hyperaride saharien est pauvre, en principe, et l'action des fleuves est sensible non seulement par la présence des sables, mais aussi parce qu'on reconnaît leur cours à l'intérieur même du massif dunaire.

Régions arides et semi-arides méditerranéennes. Enfin, ces régions font transition entre les régions planes de boucliers et les régions arides de montagnes. Elles sont au contact brutal entre le socle afro-arabe rigide et les régions de sédimentation complexe et d'orogénie tertiaire du domaine dit alpin. Aussi incluent-elles à la fois des franges du socle saharien ou syro-arabe et des régions de plis tertiaires, mais où l'influence de blocs rigides se fait encore fréquemment sentir. Les structures lithologique et tectonique des montagnes méditerranéennes sont très variées : fragments de socle, soulevés ou intégrés dans des plis de fond, chaînes de style dit jurassien, combinant plis, souvent confus, et failles, chaînes de style souple à écailles, nappes accumulées, style compliqué par des épanchements diapiriques d'argiles salines. Le résultat est une combinaison très variée de chaînes majestueuses, mais qui n'ont jamais

l'ampleur ni la hauteur des Andes ou du Tian Chan, de massifs « anciens », de montagnes morcelées et de bassins, plaines hautes et basses. Or, les climats méditerranéens sont eux-mêmes des climats de transition. Ils sont arides essentiellement par la sécheresse d'un long été. Mais les transitions de l'extrême-aride au semi-humide sont beaucoup plus rapides que sur les marges tropicales du Sahara, pour des raisons à la fois climatiques et morphologiques, et les reliefs, en outre, introduisent de multiples nuances dans ces transitions. C'est pourquoi on trouve dans les régions méditerranéennes une gamme très complète des formes arides et semi-arides. Leur cartographie est donc d'un intérêt exceptionnel, accru encore par la nécessité de l'appliquer à des pays souvent très peuplés ou en plein essor démographique, où l'agriculture est la principale ressource.

LA CARTOGRAPHIE GÉOMORPHOLOGIQUE DES RÉGIONS ARIDES

Ces remarques ont pour but de souligner combien la géographie comparative des régions arides a encore à progresser et comment il est encore malaisé de préciser les divisions bioclimatiques insuffisantes par des divisions géomorphologiques. La cartographie géomorphologique permettrait de sélectionner les faits essentiels et d'en exprimer la répartition spatiale, par suite d'aborder avec plus d'ampleur la question d'une classification des types de déserts, puisque aussi bien les critères reconnus au Sahara ne sont pas nécessairement valables dans les Andes, les Rocheuses, l'Asie moyenne ou centrale.

La cartographie géomorphologique des régions méditerranéennes ne devrait pas permettre de rechercher des critères géomorphologiques distinctifs entre extrême-aride et aride, à moins qu'on n'étende ces régions jusqu'au Sahara central et au Nadjd ; du moins devrait-elle apporter des précisions sur les distinctions dans l'espace et en altitude entre aride, semi-aride et semi-humide, et sur les procédés à adopter pour les exprimer. En tenant compte des caractères généraux de la morphologie aride et des caractères propres aux pays méditerranéens, il semble que la cartographie géomorphologique méditerranéenne devrait répondre aux préoccupations suivantes :

1. Exprimer la structure géologique puisque partout l'aridité a pour conséquence morphologique majeure la mise en valeur différentielle des conditions structurales. Les cartes géomorphologiques ne doivent pas pour autant être une reproduction des cartes géologiques. Les préoccupations ne sont pas les mêmes. La carte géomorphologique doit représenter le matériel rocheux, en exprimant, non un classement pétrographique, mais le comportement des roches à l'égard des agents atmosphériques. Sur une carte à petite échelle, on ne peut

qu'opposer un massif cristallin consolidé et des séries sédimentaires, classées en grands groupes de résistance différente. A grande échelle, il est davantage possible de représenter par exemple la résistance différentielle de roches granitiques, en fonction de leur composition minéralogique, de la taille de leurs grains, de leur fissuration; dans les séries sédimentaires, il convient de distinguer avec soin les bancs de grès, quartzites, calcaires de faciès divers, marnes ou argiles, leur épaisseur, leur fissuration. La tectonique doit être exprimée par des signes représentant les axes des plis anticlinaux ou synclinaux et aussi par ceux qui sont adoptés pour représenter les escarpements par les pendages, les contacts anormaux, les types de failles, le sens des décrochements et leur inclinaison. Il peut être utile d'exprimer l'instabilité tectonique en représentant avec soin les discordances et déformations des sédiments les plus récents.

2. L'expression de la structure est obtenue par une représentation très soignée des formes structurales, surfaces planes du type hamada, délimitées par les escarpements bordiers, cuestas et barres rocheuses, gradins de versants, crêts principaux et secondaires, chevrons de versants d'anticlinaux. La carte peut faire voir la brutalité anguleuse des profils, fonction non seulement de la pétrographie, mais aussi de l'épaisseur et des pendages des couches: les signes représentant les escarpements peuvent exprimer à la fois la nature de la couche et les hauteurs relatives.

3. Le modelé des versants résulte de l'action des agents atmosphériques, thermoclastie et cryoclastie, de phénomènes d'hydratation, très secondairement d'altération chimique et du ruissellement qui évacue les débris. Ces divers agents, en fonction de la structure lithologique, fournissent plus ou moins de débris, d'un calibre variable, par suite susceptibles ou non d'être pris en charge, transportés, abandonnés, selon que varie, moins la capacité que la compétence des agents de transport, eau et vent. La représentation cartographique des surfaces nues ou ennoyées est donc d'une importance majeure, tant théorique que pratique. Les éboulis sont assez rares dans les régions méditerranéennes, mais qu'ils soient actuels ou inactuels, sont un élément intéressant des versants. Qu'ils soient de gravité, que les éléments soient classés, orientés, est une donnée importante pour l'interprétation paléoclimatique. Les diverses formes de solifluction indiquent ou des paléoclimats plus humides, ou des formes de montagne; ou bien elles caractérisent les marges subhumides des régions arides.

4. Surfaces de dénudation et d'accumulation. Leur expression varie évidemment selon l'échelle adoptée. Elle concerne aussi bien les versants de reliefs différenciés, de vallées, que des piémonts ou des plaines, des pédiments et des glacis d'érosion ou de dénudation.

Mais les types de pédiments et de glacis de dénudation sont nombreux. Ils diffèrent par l'extension: glacis terrasse, piémont, voire pédiplaine; leurs surfaces recoupent des roches variées ou, au contraire, soulignent les contrastes de résistance lithologique; ils font un angle brutal avec le versant ou la concavité est continue; ils sont sillonnés par des ravines ou par des oueds; ils ont une pente variable; ils peuvent être très aplanis ou comporter des reliefs du type tors, koppies, etc., des rochers ou boules, surtout s'il s'agit de pédiments; ils peuvent se prolonger vers l'amont à l'intérieur des vallées, sous la forme d'embalements; ils peuvent être multiples, emboîtés, séparés par des ressauts, voire des escarpements s'ils sont encroûtés; ils peuvent être absolument nus, même pas couverts par un dallage de débris, ou couverts par un reg de dissociation, éluvial ou alluvial. C'est là déjà un sol squelettique, mais ce sol peut être plus évolué s'il s'agit d'un reg; ils peuvent être couverts de sable aspergé ou par des alluvions. C'est ici que les difficultés se présentent car elles ne sont pas seulement cartographiques: Comment définir un glacis couvert, distinguer un glacis de dénudation et un glacis d'accumulation? Comment interpréter leur genèse? J. Tricart a proposé les termes de glacis de dénudation, glacis d'épandage quand la couverture est peu épaisse, discontinue, et glacis d'ennoyage. Ces termes sont discutables, car ennoyage suppose un relief ennoyé et épandage indique un mode de dépôt, non une épaisseur. Mais il conviendrait néanmoins de distinguer une *couverture fonctionnelle*, mobilisable dans les conditions actuelles de l'écoulement, une *couverture fossilisant* un glacis et des *glacis d'accumulation* où le socle rocheux n'affleure pas, ou, du moins, ne joue aucun rôle dans le relief, cônes et épandages de piémont, terrasses, remplissage de cuvettes subsidentes, etc. L'emboîtement permet souvent d'exprimer une chronologie, au moins relative. Mais souvent il n'est possible que de représenter la granulométrie du dépôt, ce qui est déjà fort important.

5. Formations superficielles et sols. Dans des régions sans couverture végétale, la surface du sol, autrement dit le sol lui-même, joue en effet un rôle dans le paysage et son expression cartographique sur une carte géomorphologique présente en outre le double avantage de représenter les relations entre sols et reliefs, particulièrement évidentes en régions arides, et d'augmenter l'utilité pratique de la carte. Sinon les sols squelettiques, du moins les divers types de regs, peuvent être portés sur la carte, puisqu'ils masquent la roche en place. Mais il est non moins utile de représenter les dépressions argileuses, non salées, ou salées du type sebkha qui sont azonales mais très variées, par la qualité de l'argile et, plus encore, des sels et par la teneur en sels. Elles jouent parfois un rôle majeur dans les paysages, au point de mériter une cartographie spéciale, comme en Iran septentrional. D'autres sols sont liés aux conditions bioclimatiques et, par suite, permettent de distinguer les

régions arides, semi-arides et subhumides, sols gris, sierozem, sols bruns steppiques, sols rouges méditerranéens, etc., ainsi que les divers types de croûtes siliceuses, gypseuses ou calcaires. Il ne peut s'agir, dans la cartographie des sols, que de représenter leur répartition actuelle, mais non leur âge, ni leur genèse puisque aussi bien, en région aride, la plupart des sols sont fossiles, qu'ils peuvent être ou privés par l'érosion de leurs horizons superficiels, ou bien développés aux dépens d'un sol ancien, etc.

6. Formes liées à l'hydrologie. Elles sont complémentaires des formes précédentes, mais d'une évidente importance puisque les écoulements en nappe, diffus et concentré sont assurément le processus majeur d'évacuation des débris. Ils jouent aussi un rôle dans la dénudation, par érosion latérale des oueds, décapage horizontal par les écoulements non concentrés ; rôle discuté, évident, au moins localement. En tous cas, l'extraordinaire densité des filets de ruissellement diffus est une des caractéristiques des pays arides les plus frappantes, au sol et, plus encore, sur photos aériennes. Les variations de cette densité sont liées aux conditions lithologiques et de pente. Les larges lits alluviaux des oueds ne sont pas moins expressifs, ainsi que leurs divisions diffluentes, leur transformation fréquente vers l'aval en écoulement diffus sur des regs d'épandage alluvial. Si le tracé est d'un intérêt majeur, l'encaissement l'est également, aussi bien celui des ravines dans les Bad Lands, par exemple, que celui des oueds entre les terrasses. Enfin, il n'est pas sans intérêt de joindre à la cartographie des types d'écoulement quelques données hydrologiques, puits et profondeurs, nappes superficielles, trous d'eau, du type guelta et mares. On peut même tenter d'exprimer le rythme et la fréquence des crues d'oueds puisque, si l'oued n'est qu'une forme héritée en région aride ou coule exceptionnellement comme tombe la pluie, on peut admettre qu'une des caractéristiques des régions semi-arides est que les oueds ont au moins une crue annuelle, qu'enfin, dans les régions subhumides, l'écoulement est saisonnier et les oueds les mieux alimentés ne s'assèchent pas complètement.

7. Les formes d'érosion éolienne jouent un rôle réduit dans le paysage, en dehors des champs de dunes, trop réduit pour qu'on puisse songer à les représenter. Les formes d'accumulation sont autrement spectaculaires

dans les régions arides, puisqu'elles disparaissent dans les régions semi-arides, du moins comme formes vives. Accumulations de limon, du type loess, si l'on admet qu'elles sont d'origine éolienne dans les régions méditerranéennes ; accumulations sableuses surtout, dont les formes dépendent non seulement des vents, mais aussi de leur granulométrie, calibre et forme. Aussi ces données, si elles pouvaient être représentées, permettraient, comme pour les débris grossiers, de reconnaître leur origine. Quant aux formes, elles sont faciles à représenter quand elles sont simples, épandages de plaines ou de versants, nebkas, dunes accrochées aux versants, rides, crêtes, dos, barkhanes ; elles le sont évidemment d'autant moins qu'elles sont plus complexes.

Ce sont là les principales formes qu'il paraît souhaitable, sinon possible, de représenter sur une carte géomorphologique. On peut certes en prévoir d'autres, parce que la liste ne saurait être exhaustive et qu'aussi bien le choix dépend de l'échelle adoptée et des documents dont on a la disposition. Conçue de la sorte, la carte est descriptive. Il paraît difficile d'exprimer avec précision, sur la carte, les processus. Certes, les formes des versants, les types d'écoulement, de reliefs sableux sont une indication sur les processus. Mais il est souvent malaisé d'isoler les processus actuels des processus passés qui résultaient de paléoclimats plus humides dans les régions arides, plus secs dans les régions subhumides et ont façonné des formes héritées. Or, les formes héritées jouent un rôle d'autant plus grand dans les régions arides que les processus actuels sont moins efficaces. Il est difficile aussi d'exprimer une chronologie précise des formes, soit qu'elle ne soit pas connue, soit que rien dans le relief n'en porte témoignage. Comment dater un versant de roche nue, escarpée, qui, si la roche est peu fissurée surtout, est pratiquement immunisé ? Une datation des formes n'est possible que dans le cas où des glaciés et terrasses sont emboîtés, où les formations de couverture et, en général, des formations de remblaiement, sont datées. Ce sont, en somme, des cas assez exceptionnels.

Du moins, des cartes géomorphologiques de ce type permettraient, à petite échelle, de préciser nos connaissances générales sur les régions arides, à grande échelle, si elles étaient multipliées, d'exprimer les innombrables nuances d'un type de région aride et, par suite, d'en faciliter la mise en valeur.

DISCUSSION

S. ERİNG. I received the impression that Professor Dresch has given much attention to the structure in classifying desert types. As geomorphologists, we should, of course, base ourselves upon the landforms. But it is also true that origin and evolution of landforms depend on processes and drainage type. Processes and drainage, on the other hand, are mainly determined by climatic conditions. Hence the important differences between deserts in the low and middle latitudes, at low and high elevations. We should also take into considera-

tion the location of the desert, since it is of primary importance regarding the role of the traces of climatic changes in the geological past. Therefore I am of the opinion that a classification of deserts should be based upon the following principles: (a) climatic differentiation both in the horizontal and vertical directions; (b) drainage and hydrological conditions which play an important part in the transport of the material; (c) finally location of the desert area under consideration.

CLIMATIC RESOURCES OF ARID ZONES AND THEIR AGRICULTURAL USE IN THE U.S.S.R.

by

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Arid zones are characterized by a combination of different natural components: climate, relief, soil, water régime, vegetation cover and fauna. These components are interrelated. Therefore a change in one involves a change in all the others.

However, during the development of these components in the course of time, changes are not the same for each component and are far from being synchronized. Climate changes more rapidly than the other components, passing from one phase of its natural fluctuation to the next, that is from a warm to a cold phase, from humid to dry, and so on. A few decades suffice for the completion of this process. Changes in relief are the slowest. The time scale for this phenomenon is measured in millenia. After climate, the other natural components change in the following sequence: water régime, flora, fauna, soils, relief. Therefore the most reliable criteria for establishing the degree of aridity under modern conditions are climatic indices. What is meant by "modern conditions" is the accepted period for establishing climatic norms (30 to 50 years).

As shown in Figure 1, during the last century (1838-1960) mean annual precipitation for consecutive decades varied at different periods, e.g. in a flat area of the Altai (Barnaul), from 150 mm. (1858-67) to 540 mm. (1906-15). This means that according to climatic indices there existed in this region, in the 1860s, an arid zone which gradually became more humid. It became a forest zone during the first two decades of this century. In the 1930s and 1940s the latter changed into a southern type of forest steppe (400-450 mm.), and in the 1950s into a typical forest-steppe zone (about 500 mm.). It goes without saying that the natural environment as a whole cannot change as rapidly as the climate. Only a change of land-water régime followed the climatic change. Changes in both these components, however, occurred within such a short time (only a few decades) that they had little influence upon natural flora, fauna, soil and especially relief. However, even with short-term climatic changes and changes in land-water régime,

a different set of farm crops and their varieties and also different cultivation methods are required. If agriculture does not show flexibility and is not adapted to the changed natural conditions crop yields per unit area will decrease.

A similar fluctuation in the normal annual precipitation, though less distinctly shown, was observed in the north-western regions of the U.S.S.R., for example in Leningrad.

The migration of geographical zones (more precisely: zones of leading components) is most distinctly shown



FIG. 1. Secular variation of the precipitation by running decades: (1) Leningrad; (2) Barnaul.

where different natural zones are contiguous, as in the Altai.

Fluctuation in decennial precipitation (as well as in temperature) is not the same in distribution for different agricultural regions (see Fig. 1).

On the basis of data obtained from various investigators, H. L. Schantz (1956) comes to the conclusion that at present the estimated area of arid lands is 43 per cent of the earth's surface if based on soils data, 36 per cent if based on climatic data and approximately the same percentage according to interior drainage, 35 per cent if based on the distribution of natural vegetation cover. It seems more likely that the differences in percentage can be explained by the above-mentioned inter-relation of different natural components, rather than by differences between the aridity criteria used.

CLIMATIC INDICES OF ARID ZONE

The most important arid zone climatic index is the heat and moisture ratio.

Various coefficients exist for the quantitative expression of this ratio. In the U.S.S.R. the hydrothermic coefficient suggested in 1928 by G. T. Selyaninov (1930) is widely used:

$$C = \frac{\Sigma P}{0.10 \cdot \Sigma \Theta}$$

where ΣP is the total amount of precipitation for the period with an average daily temperature above 10° , and $\Sigma \Theta$ is the accumulated temperatures for the same period. An isoline of this coefficient with the value of 0.5 coincides with desert boundaries: 1.0 goes along the border between steppe and forest steppe; 0.7 marks the boundary between dry steppe areas and typical steppe zones.

Widely distributed farming without irrigation is extremely difficult in regions characterized by hydrothermic coefficients lower than 0.7. In such regions the cultivated lands are restricted to lower altitude areas where moisture is obtained at the expense of local surface run-off, to river valleys or to plots of land where the underground water level is high. Annual precipitation at the border of widely distributed agriculture areas in the U.S.S.R. is 250 mm. or even less.

There is good correlation between Selyaninov's hydrothermic coefficient and the radiation index of dryness $\frac{R}{L \cdot r}$ suggested by M. I. Budyko (1956) where

R is the radiation balance, L the latent heat of evaporation, and r the amount of precipitation.

The merit of the first-mentioned coefficient is its simplicity. Temperature and precipitation observations are made everywhere, even where only the simplest forms of meteorological stations are set up. This coefficient can therefore be used for investigating any region,

especially those areas which have been scantily studied from the geographical point of view.

FEATURES OF ARID ZONES

The most important arid zone features are: profusion of light and heat; insufficient amount of moisture although unproductive evaporation is reduced to a minimum and all available moisture is used to produce organic mass; and high fertility of the soil. With such a combination of favourable conditions ploughing in arid and semi-arid lands can be carried out on a very large scale.

From the total arable lands covering about 210 million hectares in the U.S.S.R. approximately 90 per cent are concentrated in the steppe and forest-steppe regions, where wheat alone is sown on more than 60 million hectares. The most valuable cereals—durum and resistant wheat—are grown only in the steppe zones. In the deserts, and also partly in the steppes, irrigation is widely used for growing cotton, rice, melons, fruit crops, grapes and maize. The total area of land in which there are permanent irrigation systems and water catchments is now 13 million hectares.

By controlling precipitation, evaporation and surface run-off processes and by redistributing water from streams in the arid and semi-arid regions the absolute values of temperature and humidity and especially their ratio can be changed appreciably. A large amount of direct radiation at low relative humidity of the air, together with great differences in temperature within 24 hours create the best conditions for the assimilating activity of most agricultural plants and at the same time prevent pests and diseases from spreading.

By regulating soil moisture alone, plants can be given the best conditions for growth and development. It is more difficult—and in many cases even impossible—to counter excessive humidity (particularly air humidity) and heat deficiency. In humid climates soils are not as fertile as in arid areas because precipitations constantly wash out nutrients from the soil.

Arid lands, however, are not only characterized by positive but also by negative features, the most significant of which are the periodically repeated droughts which very often greatly reduce agricultural productivity.

The role of agriculture is to reinforce the positive properties of the arid lands' climate and to reduce the after-effects of negative factors.

DROUGHTS AND DROUGHT CONTROL

Drought is here defined as the condition under which a sharp discrepancy sets in, for a long enough period, between moisture entering through the root system, moisture movement within the plant's conducting tissue

and possible evaporation through transpiration. Such a discrepancy may be brought about by prolonged dryness, lack of water for plant nutrition or by these combined factors at quite high temperatures. Sometimes droughts are also observed when there is optimal water supply of the root system but these occur at excessively high temperatures and excessive air dryness when the conducting tissue has not had time to bring water to the leaves.

The discrepancy between incoming moisture and moisture consumption sometimes occurs at relatively low dry-air temperatures and takes the form of a so-called cold drought. At high relative humidity of air the occurrence of droughts is a rarer phenomenon. The plant's resistance to drought and the agrotechniques used are very important factors. Under identical weather conditions and with the same degree of soil moisture, droughts may or may not occur depending on the plant's properties and the means of improvement applied to its environment. From the definition given above it follows that the concept of drought cannot be restricted to atmospheric processes alone, as some meteorologists tend to consider. Droughts originate in macroscale atmospheric processes leading to great heat and to moisture deficiency, to insufficient water régime of soils, and poor resistance of the plant to these combined environmental conditions. Drought is sometimes aggravated by the use of farming methods not adapted to arid conditions. The consequences are not the same under different natural conditions but are observed everywhere droughts occur. The average annual frequency of normal and of severe droughts in the forest-steppe and steppe zones of the U.S.S.R. ranges from 0 per cent at the forest-steppe and forest-zone boundary to 60 per cent at the border of steppe and semi-desert. This does not imply that there are no droughts in the forest zone. In principle, droughts may occur anywhere during relatively short periods of plant growth because the mean annual evaporation from the soil is always less than the average potential evaporation. At some definite periods of plant growth (sowing seedlings, tilling seedlings, etc.) the difference between these two factors can reach a critical value for one crop or another.

There are two ways to overcome droughts: one is to influence the generating causes and the other is to adapt the economy so that there is no great decrease in yield—the ultimate consequence of drought. In the first instance direct methods are used and in the second indirect ones.

Direct methods of drought control used extensively in the U.S.S.R. include: fallowing, afforestation to protect the fields, snow retention, retention of thawed snow, irrigation and use of water catchments. It is well established that fallowing gives the best results in forest steppes and typical steppes.

By autumn in these areas the moisture reserve in a soil layer 1 metre deep is greater under fallow than under

summer crops, the difference being 50-100 mm. (Davitaya, 1959).

In dry steppe and in forest zones, in a soil layer 1 metre deep the difference between the moisture reserve under summer crops and under fallow is less than 50 mm.

Fallow has an even smaller effect in deserts where total precipitation is less than 150 mm., while evaporation exceeds 1,200 mm.

Field-protecting forest strips combined with modern agrotechnical methods increase the reserve of efficient moisture in soils possessing agronomically valuable structures.

In a 1 metre deep layer of soil under summer cereal crops the moisture increase ranges from 60 mm. in the south to 100 mm. in the north, within the European part of the U.S.S.R., an area where soil moisture is insufficient.

By the time sowing begins, replenishment of soil moisture is brought about by retaining snow and thawed snow with maximal effectiveness in the typical steppes and in the southern part of the forest steppe. Retaining snow and thawed snow is less effective in areas where moisture is sufficient and where the natural soil moisture reserves are, by the time sowing begins, close to the soil's water capacity. The same applies to those arid areas where the snow cover is thin and surface run-off poor in the spring season. Despite the significance of the above-mentioned direct methods of drought control they are not yet in general use, although they are being increasingly applied over many millions of hectares in the U.S.S.R.

Therefore, at present, in the steppe and forest-steppe zone of the U.S.S.R. where annual precipitation amounts to 400 mm. about 200 mm. is lost in unproductive evaporation during the warm part of the year alone.

Were it possible to turn this loss into productive evaporation and to make the total precipitation biologically effective, droughts would never occur in the areas of insufficient moisture although the amount of precipitation would differ very little on the average.

With the advancement of science and improved agricultural practices, unproductive evaporation will in due course be reduced to a minimum (apparently it is not possible to use all the precipitation for the crops). Considerable progress in this direction has now been achieved and future generations will not tolerate losses such as an annual waste of 200 cubic metres of water per hectare of cultivated land.

Irrigation is a radical method to overcome droughts. However, we must bear in mind that in the case of cereal and other crops, irrigation does not always pay because the yields may reach unjustifiably high cost prices.

Overhead expenses in this case should be estimated not only on the basis of expenditure for irrigation, as is usually done, but also by taking into account the additional measures adopted to cultivate the soil and to combat secondary salinization—these sometimes require

greater efforts than irrigation itself. Moreover, the probability of favourable years in the steppes is about 50 per cent and additional irrigation in these years has a minimal effect whilst maintenance expenditure of inoperative irrigation systems and the cost of suppressing negative effects of irrigation are automatically included in the cost of production.

Such is the unavoidable law of contradiction following from the analysis of natural conditions in semi-arid zones. This contradiction, however, does not characterize desert areas where irrigation is also expensive but highly effective, as shown in annual records; the beneficial effects of irrigation are on the average more than twice increased.

Water catchment in arid zones (building ponds, canals and water tanks) is very important for cattle raising especially in remote pastures, developing fisheries, breeding water fowl, supplying water for domestic and industrial uses as well as for irrigation. Investigations have shown, however, that water catchments in arid regions have a very restricted climatic influence extending over narrow coastal strips only and they do not create the favourable conditions which are essential to agriculture. Water is brought in this manner to about 150 million hectares of pastures in the U.S.S.R. (Askochensky, 1961).

The concepts stated above as to the origin of drought show that the breeding of drought-resistant varieties by using selective genetic methods should be considered as a direct method of drought control.

However, changing a plant's physiological properties in respect to environment seems to be a more difficult problem than improving the plant's economic characteristics such as precocity, yield capacity, quality, etc.

Among the indirect methods of drought control and of ensuring yield stability in a semi-arid zone there is the method of geographically disconnected sowing. The fact is that droughts do not usually spread over an extensive region where moisture is insufficient and variable; they only affect separate component areas of the region. These areas always border a region in which precipitation exceeds the standard norms, an excess which may be twofold, threefold or even more. This occurs because the anticyclone activity of the atmosphere which originates drought in some areas is necessarily connected with a cyclone system in neighbouring areas. The yield shortage of the land affected by drought is therefore compensated by rich harvests in contiguous areas.

In the southern part of the steppe zone of the U.S.S.R. starting from 1954 and within a short period, 42 million hectares of virgin soil and unused lands were developed for the cultivation of spring cereal crops, mainly wheat.

Droughts developing simultaneously in the Ukraine and in north Kazakhstan, for example, are an extremely rare phenomenon. Usually, a drought in Kazakhstan coincides with increased moisture in the Ukraine and vice versa. During the period 1888-1950, twenty-six

droughts were observed in the south of the Ukraine and twenty-nine in the Orenburg region. During the same period, however, droughts occurred simultaneously only three times (1888, 1889, 1923) between sowing and the time the wheat reached golden ripeness.

The virgin soils and unused lands within the boundaries of Kazakhstan alone produce yearly about 1.5 milliard *poods*¹ of additional grain of all cereal crops (especially wheat and maize) as well as beans.

An important fact in neutralizing the consequences of drought is that with geographically disconnected sowing the decisive phase in plant development does not occur simultaneously all over the vast arid zone. Since spring wheat is sown at different times, there is a difference of one month in the dates when a crucial phase such as ear formation is reached within the arid zone (the Ukraine, the Urals, western Siberia). If droughts should develop simultaneously over the whole belt (an extremely rare occurrence) the plants are affected quite differently in each region.

With a sufficient water reserve after the autumn-winter precipitations and under the influence of high temperatures and dry air, plants grow well in some areas while in other areas where plant growth is a month ahead the harmful effects of drought are already apparent.

The second geographical factor which reduces the harmful consequences of drought is distributed sowing—a most advisable process from the ecological point of view. The main crops which determine the yield outcome in various regions are plants belonging to different ecological groups. Winter wheat is the leading grain for bread in the steppes of the Ukraine and in the northern Caucasus, winter rye in the forest steppes of the central Volga area, spring wheat in the steppes of the lower Volga area, the near Urals and western Siberia, etc.

SOIL EROSION AND ITS CONTROL

The problem of drought in arid and semi-arid zones is closely connected with soil erosion, especially wind and water-caused erosion. A small amount of annual precipitation favours water erosion of the upper soil layer which is not protected by a sufficiently rigorous vegetation cover; the torrential run-off in the spring and the subsequent shower rains which are typical of these regions crown the destructive work of water erosion. Dry winds and blown dust usually observed in the spring and summer also bring about soil deflation. In the U.S.S.R. a whole system of measures against water and wind erosion has been developed and are regularly applied. It is a complex system and includes agro-technical, forest-reclamation and hydrotechnical measures, which are applied simultaneously and play a decisive role in drought control.

1. One *pood* equals 16 kilograms.

CO-ORDINATION OF SCIENTIFIC EFFORTS

The possibility of yields compensating each other in an extended zone owing to the peculiarity of atmospheric processes was explained above. Owing to this peculiarity steady yields are obtained year after year and co-ordinated mutual exchanges of agricultural produce can

be developed. Measures for improvement are especially effective when they are applied over extensive areas under a common plan, using the most rational methods.

The task of improving the nature of arid lands as well as increasing their productivity is so important and the results expected are so alluring for the well-being of the people that—here more than elsewhere—a full-scale co-ordination of scientific efforts is called for.

DISCUSSION

K. S. AHMAD. The curve of the decennial average of rainfall 1838-1847 to 1951-1960 shows a very interesting feature. There is a steady rise in the average towards the middle of the period; then the average remains steady for a certain number of years, followed by a continuous decrease till the present time. Could Professor Davitaya explain this?

F. F. DAVITAYA. Precipitation increase and decrease are a result of fluctuation (non-directed change) of climate. These fluctuations lack strict periodicity and their causes are not clear, unfortunately.

E. TÜMERTEKIN. (1) Is there any study on frequency of drought in the Soviet Union? (2) Statistical methods may be used for such calculations. Have such methods been employed?

F. F. DAVITAYA. (1) Many works are devoted to this problem. The most comprehensive among them are the following: *Zasukhi v SSSR, ikh Proiskhozhdenije, Povtorjaemost' i Vlijanie na Urozhai* (Droughts in the U.S.S.R., their origin, frequency and influence on crops) Leningrad, 1959; Davitaya, F. F., "Zasukhi v SSSR i nauchnye obosnovaniya mer borby s nimi po prirodnym zonam", *Voprosy Zemledelija i Borby s Eroziiej pochv v Stepanykh i Lesostepnykh Rajonakh SSSR* (Droughts in the U.S.S.R. and the scientific bases of control measures against them according to different natural zones. In: Problems of Agriculture and Struggle against Soil Erosion in the Steppe and Forest-steppe Regions of the U.S.S.R.) Vol. 1, Saratov, 1959. (2) Yes.

P. MEIGS. Your graph shows a decline in precipitation during the last few decades in the Altai. Is there a similar trend in other parts of the Soviet Union, or is the situation limited to the Altai area?

F. F. DAVITAYA. There are few very long-term records, but the situation in Leningrad, for example, is quite different.

S. ERINÇ. I quite agree with Professor Davitaya as to the causes of drought. Indeed, droughts are a result of large-scale variations in atmospheric circulation, resulting in changes in precipitation and temperature. Thus it is clear that we cannot prevent the occurrence of drought. What we can do is to take steps to avoid its harmful effects. There is only one point that, I think, needs to be clarified. Professor Davitaya says that frequency of occurrence of normal and severe droughts in forest-steppe and steppe areas of the U.S.S.R. is 0 per cent.

I think this figure is far from the reality. I am sure that it must be much higher. Indeed, droughts also occur within the forest area.

F. F. DAVITAYA. This idea of mine is not precisely understood by S. Erinç: (1) Droughts are a result not only of atmospheric circulation but also of water régime of soil, ecological properties of plants and wrong agrotechnics of their cultivation. Out of these causes it is only the atmospheric circulation that cannot be influenced as yet; the rest can be changed for the better. So it is possible to control droughts by means within the reach of man. (2) Normal annual frequency of normal and severe droughts varies from 0 per cent in a forest zone to 60 per cent in a steppe zone. During the comparatively short periods of plant growth (sowing - seedlings, seedlings - tilling, etc.) droughts occur of course, in a forest zone too.

Y. KARMON. (1) The suggestion made in the paper, not to apply irrigation to semi-arid steppe-lands, is feasible only in areas of low population pressure and extensive agriculture, while in the Mediterranean regions, with their high population densities, an intensification of agriculture is to be aimed at. (2) The geographical spreading of the cultivated land as a means of indirect drought control is practicable only in countries of continental size; in areas of political fragmentation it will not work, until a system of mutual aid is adopted.

F. F. DAVITAYA. (1) I agree. Other things being equal, however, the effectiveness of irrigation in steppes is certainly less than in deserts. (2) I agree. That is why a system of international co-operation must be worked out.

D. CHRISTODOULOU. I found the diagram showing the trend in precipitation very interesting. However, before we try to deduce too much from this graph, we must make sure that the data of the pre-scientific age of the nineteenth century are both valid and comparable to data collected later and especially in the last three decades or so.

I would like to inquire from the speaker what checks have been applied to ensure that all data are both valid and comparable.

F. F. DAVITAYA. Instruments and methods of precipitation measurement in the meteorological network all over the world have changed very little in principle during the last two hundred years. Therefore, precipitation data, after being climatologically handled, may be regarded as reliable enough

as well as comparable in time. We may assume that in the nineteenth century the amount of precipitation was diminished, but nevertheless it does not change the main conclusion, because the precipitation in the twentieth century has also changed greatly.

J. DESPOIS. A propos de cette première communication, je crois utile de faire une remarque préliminaire sur la différence qui sépare, dans presque tous les domaines, les pays à précipitations d'été (et à hiver accentué) et les pays méditerranéens aux précipitations de saison fraîche (automne, hiver, printemps) et aux étés à la fois chauds et secs.

F. F. DAVITAYA. I have no remarks.

L. EMBERGER. La remarque de S. Erinc s'applique à tous les climats de transition. Les investigations auxquelles j'ai procédé ont montré que le climat méditerranéen est pur dans le Proche-Orient (Liban, Syrie, Irak, etc.) et que, vers ses limites, il se dégrade, présentant les irrégularités signalées. Déjà à Perpignan, qui est réputé avoir un climat typiquement méditerranéen, il y a, tous les vingt ans, une courbe pluviométrique convexe, c'est-à-dire non méditerranéenne. Ces années deviennent de plus en plus nombreuses vers les limites, ce qui est exprimé par l'irrégularité des régimes signalée par notre collègue pour Istanbul.

C'est par ces phénomènes que s'effectue la transition entre le climat méditerranéen et les climats voisins.

F. F. DAVITAYA. I have no remarks.

D. H. K. AMIRAN. (1) One basic problem in alleviating the effect of climatic fluctuations in semi-arid areas is the absence of periodicity in such fluctuations. This is one point which clearly emerged from the Unesco-WMO Symposium on Changes of Climate, held in Rome in October 1961. (2) It is the purpose of irrigation to remove the element of drought from arid climates. This is always expensive, especially for agricultural products which bear only a low cost-level. It can therefore be applied to small areas only and always has to be used for limited areas as compact as possible. (3) Consequently I would not envisage irrigation primarily for growing cereals except for those which are employed in a second stage of processing, for instance fodder crops. For cereals to be consumed as such the prospects will brighten only if new techniques such as man-induced rainfall become practical. In the meantime irrigation is applicable mainly to high-price speciality crops, such as vegetables, fruit and especially out-of-season crops. Even here preference should be given to methods as economic as possible in the application of water, as for instance subterranean irrigation. (4) The positive side of arid zone agriculture is the limitation of rainfall to specified seasons. This makes possible, far more than in humid areas, the programming of agricultural production for certain dates, fitted to the most advantageous situation of the market. (5) In all arid zone agriculture unproductive evaporation should be restricted to a minimum. In this respect the recent controversy over the relative benefit of afforestation should be given very serious consideration.

F. F. DAVITAYA. I fully agree with the remarks of Professor D. H. K. Amiran.

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THE AVAILABILITY OF WATER IN SEMI-ARID LANDS: POSSIBILITIES AND LIMITATIONS

by

F. DIXEY

INTRODUCTION

Water, particularly ground water, is the prime necessity of life in the arid zones, and knowledge of its occurrence, replenishment and recovery is basic to the development of these regions. Surface waters, except when brought in by rivers from more humid terrains elsewhere, are normally scarce or absent, and ground waters accordingly assume special importance.

Unesco, through its Arid Zone Research Programme, has devoted special attention in recent years to the hydrological problems of arid lands, in the course of which it has organized reviews of research, symposia, and other activities. In 1952 it published *Reviews of Research on Arid Zone Hydrology*, which was discussed in 1952 at the Ankara Symposium on Arid Zone Hydrology, with special reference to hydrogeology. In 1955, jointly with the South-Western Division of the American Association for the Advancement of Science, it held a symposium on the Future of Arid Lands, and at Teheran in 1958, jointly with the Iran Government, it held another on Salinity Problems in the Arid Zone, of which the first section was concerned with hydrology and salinity. In 1959 Unesco published *Arid Zone Hydrology—Recent Developments*. It convened a General Symposium on Arid Zone Problems at Paris in 1960, at which were presented, *inter alia*, review papers on research on Arid Zone Hydrology and Hydrogeology, and, jointly with the International Association of Scientific Hydrology, it held at Helsinki in 1960 a symposium on Hydrogeological Maps. At the same meeting fifteen papers were presented in the section devoted to methods of evaluation of ground-water resources, two of them describing the analysis of ground-water problems with electronic computers. Also, at Athens in 1961, Unesco, in collaboration with the International Association of Scientific Hydrology (IASH), held a symposium on the evaluation of ground-water resources, with emphasis on arid zone problems; papers were submitted on hydrogeological observations

in the search for underground water, hydrodynamic studies of the principles underlying the control of yield from wells and galleries, the mutual interference of wells, the intake of aquifers and artificial recharge, and the forecasting of water-table fluctuations. In addition, FAO has issued numerous reports on the investigation, development, and conservation of surface waters and ground waters in many arid countries. All these reviews and proceedings of symposia are of special interest in relation to the subject of this paper.

The investigation, assessment and development of the water supplies of the arid and semi-arid lands is of special importance at the present time in relation to the need to provide greatly increased supplies of food and other products for the rapidly growing world population, for given adequate water supplies these lands can very considerably increase their yield of meat, hides and skins, and of cereals, fruit and other agricultural products, and provide for industrial expansion. These developments are being encouraged by various forms of international technical aid.

Although there is satisfactory general understanding of what constitutes the "arid zones", including the semi-arid, there appears to be no simple or generally accepted definition. There is fair agreement that the semi-arid regions are those with an average annual precipitation of 250 or 300 to 500 mm., but the term "average" has little practical meaning in view of the prevalent wide areal and annual fluctuations from the mean; the factors of distribution of the rainfall, whether winter, summer or general, temperatures, and "potential evapotranspiration" have also to be taken into account. The "arid" regions are sometimes divided into the "extremely arid" or "desert" areas, with practically no rainfall, and the "arid", with an average annual precipitation of 50 to 300 mm. In the semi-arid regions water is deficient for normal crop growth, although these regions are of great significance as natural grasslands, and they include the great "steppes" of the world. When water is available for irrigation

these regions can be of considerable agricultural importance.

The water supplies of the semi-arid regions are characterized by their seasonal but highly fluctuating nature, both in space and time, and by their localized occurrence, frequently only in small amount; moreover, their usefulness is still further limited by the fact that they are usually more or less saline.

The questions of the availability, possibilities, and limitations of these water supplies are closely bound up with considerations of their use, conservation and quality, as well as by social customs and economics.

SURFACE WATERS

INVESTIGATIONS

Surface water is well known to be a fluctuating and variable resource, both in space and time, and since its variability increases with aridity, this characteristic is most marked in the arid zones. In any attempt to assess the value of surface waters for development purposes it is necessary to carry out certain basic investigations. The first requirements for study are adequate meteorological and hydrological data, and also air photographs and the topographic maps produced from them, when these do not already exist; from this information, and from field observations, basic hydrological maps can be produced. Yet, in spite of their essential importance, records of precipitation, in amount and in intensity, of evaporation and evapotranspiration, of stream flow, in duration and amount, and storm flows, are notably deficient in arid areas, owing to the common low stage of development, the paucity of population, the occurrence of widely scattered storms, the difficulties of transport, etc.; accordingly, in any long-term plan for the assessment and development of the water supplies of such areas, it is of the greatest importance that the collection of such data should be put in hand.

Records of precipitation are of special importance for "dry" farming, as highly developed for example in the semi-arid regions of the U.S.S.R. (Askochensky, 1962) for flash or flood irrigation, as practised for example in Algeria (Drouhin, 1962), and Morocco and the U.S.S.R., for the design and use of excavated tanks, or *hafirs*, and for many other purposes.

Hydrological maps provide information on the nature, occurrence, quality, etc. of the water supplies of a region, and where these might best be developed. They indicate also something of the hydrological régimes of the past, as of lesser aridity, and of former greater utilization of the supplies, as by the Romans in North Africa. Many excellent examples of such maps are now available, as was demonstrated in the exhibition of hydrogeological maps at the Helsinki meeting of the International Association of Scientific Hydrology in 1960. Further examples are to be found in more recent

publications, as by Margat (1960) and by Archambault (1960) for West Africa.

STREAM FLOW

The streams of the semi-arid regions include local and ephemeral streams arising from local storms, those that flow seasonally from surrounding uplands for longer or shorter periods before becoming lost by evaporation and by absorption into their channels, and, rarely, perennial rivers from distant humid areas that flow across the arid lands and support permanent agricultural and nomadic populations.

In many countries the waters of the first two categories could be used much more extensively than they are at present. Thus, the dry Pacific coast of South America and scattered basins in North Africa are susceptible to expansion of irrigated acreage and municipal water supplies by construction of storage reservoirs and the management of ephemeral streams. Again, it is estimated by FAO engineers that in an average year the Wadi Jizan, a drainage area of 1,090 sq. km. on the Red Sea coast of Saudi Arabia, yields flood water sufficient to irrigate 50,000 acres of suitable soil, only part of which is already under rough cultivation; but in order to permit optimum use of supplies that could be made available by retarding works the existing systems of land ownership and water use would require adjustment (G. White, 1962).

In Algeria, flood-spreading is extensively practised, although it is impossible to anticipate reliable yields every year owing to the extreme irregularity of the floods, which may be inadequate in some years and ill-timed in others (Drouhin, 1962). In the U.S.S.R. flood irrigation is extensively employed as a basis for animal husbandry (Askochensky, 1962), and in Israel the run-off from limited hill-side areas was formerly much used to irrigate relatively small terraced areas in the valleys. Locally in the Red Sea area of the Republic of the Sudan flood irrigation is successfully employed.

In the U.S.S.R. a very large amount of irrigation has been achieved in recent years by the construction of canals of great length that bring the waters of permanent rivers into the arid lands; thus the Great Fergansky canal is 350 km. long, and the first section only of the Karakum canal, 400 km. (Askochensky, 1962).

In many countries excavated tanks, or *hafirs*, are extensively employed to store the waters of ephemeral streams; they are particularly developed in the Sudan for agricultural and pastoral use, and their numbers are increasing year by year (Lebon, 1956).

DAMS

Dams are of course extensively used in arid lands to store surplus water, but they have the great disadvantages as compared with those of more humid climates of being exposed to greater evaporation, greater sedi-

mentation, and greater uncertainty of supply. There is an economical limit to their size owing to a general increase of evaporation losses as compared with water stored. It is sometimes necessary, as in Israel for example, to store as much as three times the amount of water actually required, and consequently stress is laid there on the importance of ground water and the possibilities of recharge. In some countries efforts are made to store water equivalent to several times the mean annual flow in deep reservoirs, but the economic and physical success of many river engineering projects will depend upon the ability to predict sedimentary movement and deposition. Moreover, full utilization of a fluctuating supply can rarely be achieved, but it is sometimes possible to provide for a minimum regular demand and to plan limited use of the remaining fluctuating supply. Langbein has summarized the position as follows:

"Surface water is a fluctuating resource: although reservoir storage can stabilize the supply, it can be shown that 100 per cent stabilization and utilization is not attainable. As reservoir capacity is increased to achieve greater control and utilization, evaporation losses also increase, and indeed evaporation imposes a ceiling on river regulation in an arid climate. However, greater utilization, if not regulation, of the fluctuating water supply can be achieved, by fitting the demand pattern to the supply pattern. It appears possible to increase the total utilization of the fluctuating resources by evolving schemes for a perennial or firm supply, supplemented by a planned arrangement for the use of the fluctuating portion on a probability basis. By this principle, reservoir development would be planned not to average out the fluctuations in run-off, but for firming up a basal component to only that degree sufficient to maximize the total utilization of the supply recognizing that in some years, forecastable on a probability basis if not on a specific year basis, there will be deficiency in part of the supply. Once the hydrologic and statistical principles are understood, there still remains the problem of adjusting economic and social patterns of the society which will use the water resources. The latter is indeed a difficult task but without a sound hydrologic basis nothing permanent can be accomplished."

CONSERVATION

In considering the water possibilities of arid lands, conservation and proper use of existing supplies and the prevention of waste are often as important as the provision of new supplies, although in practice it may sometimes be simpler or even more economical to provide a new supply than to try to persuade users to economise on the old, even where this is technically feasible.

Water falling sporadically on arid areas is often best used as soil moisture to grow vegetation or to support

stock on or near where the precipitation falls. In such areas evaporation losses tend to be high and transmission losses important, so that the storage of such moisture in surface reservoirs tends to be inefficient. In the semi-arid areas of the U.S.S.R. it is regarded as a fundamental law of agriculture that as much water as possible should be collected and stored in the soil and that atmospheric moisture should be used economically, and all types of agricultural activity are governed by this law. Thus the so-called "dry" agriculture in this zone, assisted by effective scientific and technical methods and drought-resistant agricultural plant breeds, is able to withstand drought and other very critical periods with a minimum of loss.

In the western United States it is estimated that as much water is consumed in a year by phreatophytes growing in and along streams and irrigation canals as is consumed by the irrigated crops. This is a condition which applies generally where water is conveyed long distances from exogenous sources or from localized exogenous supplies, and in some irrigation projects transpiration losses are well known to account for as much as 40-60 per cent of all water diversions (G. White, 1962). Studies to date indicate that the replacement of the phreatophytes with desirable vegetation of high economic value after the initial clearing is an effective maintenance procedure.

Large quantities of water are lost also by seepage along the irrigation channels, and much research is being undertaken with a view to discovering inexpensive means or preventing such losses, as by chemical methods and by grouting, and by thermal and biochemical methods. In the U.S.S.R. considerable success has been attained by various ways of compacting clayey and loamy soils in place without the need of imported materials (Askochensky, 1962).

In certain of the semi-arid areas of the United States and the U.S.S.R., where the depth to ground water is great and the wells uncertain, stock owners have constructed large numbers of small dams which may dot the landscape at one-mile intervals, and studies have been made of the effect of this proliferation of ponds on water supplies available downstream for irrigation and power production. The results show that the losses by evaporation and by seepage, often not recoverable as ground water, represent a direct loss to the water economy of the region. In the arid Cheyenne River basin of the United States, where stock-water ponds average about one per square mile and about half the flow in the region is intercepted by ponds, about 20 per cent of the total flow of the river is lost through evaporation, and about 20 per cent more by seepage (Langbein, 1962).

The effect of vegetal management on water supply, sediment yield, and water chemistry is a subject of long standing and still poses many unresolved questions in the arid zones, and much further research is required regarding the extent to which vegetal management

can improve water yield in dry countries. The large-scale manipulation of native vegetation may endanger soil stability, and give rise to sedimentation and flooding in downstream channels, and it is as yet unknown whether an artificial plant association introduced by man under particular circumstances can, over a long period of time, continue both stable and productive (Leopold, 1962).

A more economical use of the irrigation water available now and in the future is a matter of immense importance to the arid lands. In the Iraqi section of the basin of the Tigris-Euphrates, one of the great exogenous surface supplies, the mean annual losses of water in the irrigation enterprises is of the order of five or six times the amount which possibly could be utilized by the cultivated crops in their annual growth. This low physical efficiency can be attributed in part to the abundance of water provided by the new system of multiple-purpose dams, and in part to the conditions of land tenure and water allocation which encourage irresponsible applications.

A recent estimate for the western United States is that if no increase were made in the efficiency of application and transmission of irrigation water, an additional 56 million acre-feet will be required in the year 2000 to meet crop and pasture requirements. However, with "reasonable efficiency in the transmission and use of irrigation water, the same production levels could be reached with only 4 million additional acre-feet" (G. White, 1962).

In arid regions the loss of water by evaporation from reservoirs sets a definite limit to the effectiveness of storage, and consequently in many countries much research and experiment has been devoted to the prevention of such losses, mainly by the use of monomolecular films (ICID, 1960). In the arid regions of the United States, for example, the net losses by evaporation total about 13 million acre-feet. The results of a wide range of investigations carried out in that country on the application of monomolecular films indicate that the retardation of evaporation appears to decrease with area of the water body. Observations on pans show reductions of the order of 40 or 50 per cent, on small lakes (say 1 to 100 acres), of the order of 20 to 40 per cent, and on large lakes or reservoirs, of the order of 10 per cent. Experiments on the 2,500 acre Lake Hefner showed that the water savings by evaporation reduction were accomplished at a total cost for labour and hexadecanol approximately equal to the total value of the untreated water saved to the Oklahoma City supply (Langbein, 1962).

In semi-arid regions it is sometimes necessary to consider to what use the available sparse surface waters can best be put, and to take the necessary steps to achieve this end. Where the maximum amount of moisture is retained in the soil for agricultural purposes

there will be less run-off to *hafirs* required for stock use, and if both these purposes are well provided for there will be diminished stream flow for the replenishment of wells needed later in the dry season. In more developed areas the competing needs of irrigation, power, recreation and industry have all to be taken into account.

The conservation of water by induced recharge and by water spreading can be of importance in semi-arid lands, but, except where surplus water from springs can be used, it has to contend with the great difficulty that the flood waters available are normally silt-laden, and that sedimentation basins have to be constructed to render them fit for recharge purposes. In suitable localities flood water can be stored in river sands and gravels, by means of sub-surface dams which offer the great advantage of protection from evaporation.

SALINITY OF SURFACE WATERS

In spite of occasional rain the surface waters of semi-arid lands are more or less saline as a result of constant evaporation, and this greatly limits their use. In Algeria, for example, all too often both the soil and the water are saline, which considerably complicates the questions of supplying eventual industrial and immediate human and even animal needs, and of practising irrigation (Drouhin). In Morocco numerous springs, streams and lakes are saline, as shown on the hydrological map recently published by Margat and even the waters of fresh springs frequently give rise to saline lakes as a result of evaporation. At the 1956 Unesco/Iran Symposium on Salinity Problems in the Arid Zones much attention was devoted to the salinity of surface waters and to problems of irrigation with brackish water and on saline soils.

RELATIONS BETWEEN SURFACE WATERS AND GROUND WATERS

Questions of the inter-relations of surface and ground waters, and of the water balance generally, are of great importance in arid lands. Surface water at one time and place may be a source of ground water, and at other times and places ground water is a source of surface water. The management of water resources can be improved by profiting by this relation, as by using as a joint resource the water of a stream and that in hydraulic continuity with it within the adjacent alluvium. The relationships of the salinities of surface and ground waters are also of considerable interest (Tison, 1955).

The joint use of surface and ground-water resources is a problem of increasing importance, as for example in the use of ground-water reserves as a buffer to tide over dry periods when a deficiency of surface water occurs.

GROUND WATERS

The occurrence, investigation and development of ground waters in arid lands have already been amply described elsewhere, and here it is necessary only to emphasize some aspects of their availability. These waters normally occur either as phreatic, or free, ground waters or as artesian, or confined, waters; the former lie within a zone of saturation at moderate depths beneath the surface depending upon geological conditions, and yield water to wells and bore-holes, while the latter occur usually at greater depths, in porous beds confined between impermeable beds above and below, and are under pressure owing to the higher level of the water intake in distant uplands. When confined water is struck in a bore-hole it rises to a level below, at, or above the surface of the ground.

With some rare and doubtful exceptions all ground waters depend ultimately upon atmospheric precipitation, and consequently they may be expected to be of rare and sporadic occurrence in arid lands, except where they are due to infiltration from rivers entering from more humid regions, or are brought in as artesian flows.

The occurrence of ground water depends upon the topographical, hydrological, and geological conditions of the area concerned, and accordingly in order to determine to what extent ground water exists and is recoverable by means of wells and bore-holes a well-established series of investigations has to be carried out. In the first place, where not already available, air photographs have to be taken and topographical maps prepared from them; then a hydrological examination is made, with special reference to areas of recharge and discharge of ground waters, together with a geological survey, whereby the nature, structure and water-bearing capacities of the underlying rocks are determined. On the basis of these surveys a hydrogeological map of the area is built up, and from this the general prospects of the availability of ground water can be ascertained, and whether or not artesian conditions are likely to be present.

There follows a more detailed examination of the more promising areas, involving geophysical surveys where necessary, and the sinking of trial bore-holes and the determination of their yield, as well as the permeability, transmissibility and other constants of the rocks concerned, by means of pumping tests, geophysical examinations, and other observations. From these and similar data it is possible to estimate the amount of ground water available and the annual recharge, which normally represents the amount that may be withdrawn by pumping without progressive diminution of the supply. Should the annual replenishment be exceeded by withdrawals the water level will gradually fall until ultimately the supply is greatly reduced or even exhausted, as has in fact occurred in many areas with disastrous results to the economy. Similarly, if an artesian water body is overdrawn the pressure head

will be lowered and the yield of bore-holes correspondingly reduced.

Important artesian systems are well known to occur in a number of arid lands, as in large parts of Australia, North Africa and the U.S.S.R.; but as already indicated such systems occur only under special geological conditions, and there are numerous and extensive arid lands in which it is clear from geological examination that artesian conditions do not exist, and where accordingly ground water supplies are to be sought only from small, scattered, and often saline bodies of "free" ground water, at depths of 50 to 100 m. or rarely more.

In general, the development of artesian supplies demands deep and costly drilling, frequently to depths of 1,000 to 2,000 m. or more, as in the Sahara and in Australia—and in places the supplies lie at such depths that the limitation to use is not lack of water but high costs; but as cheap power becomes available, as in parts of the Sahara, large new areas can be opened up for development. Locally, however, the aquifers lie at shallow depths, as in some of the older cases of Morocco and Algeria; many of the older wells in such aquifers urgently need maintenance and repair, since their waters are escaping through corroded linings and becoming lost in the saline ground waters near the surface. In Libya, artesian bore-holes 250 to 400 m. in depth constructed for the Italian settlers in 1939 are still in good condition and show undiminished yields (Desio, 1957). In general, throughout northern Africa there has been a vast increase in the development of ground-water resources during the past two decades.

In most of the artesian basins of the arid lands there is room for an even greater increase in the number of bore-holes and for a corresponding improvement in the economic prospects of these areas; in Algeria, for example, the aquifers are capable of providing safely more than twenty times as much as at present (Drouhin, 1953), and those in Morocco, Libya and elsewhere could also yield greater supplies. Such additional development must however be carried out under proper control, so as to avoid waste and depletion of the resources available.

In North Africa, in addition to the great Albian artesian system that has become so important in the Sahara, there are older and younger systems that could yield new supplies that would be of great economic and social benefit to the countries concerned, and for this reason Unesco is proposing to form an international commission to study these artesian systems as a whole and to recommend plans for their comprehensive development and control.

A factor that greatly limits the use of the normally sparse ground-water supplies of arid lands is the fact that when found they are frequently highly saline. Yet saline and fresh waters may sometimes occur in close proximity, usually as a result of local flushing or replenishment of ground water from seasonal storms.

The various methods of desalination are accordingly

likely to have in the near future considerable bearing on the availability of usable waters in arid lands, especially for domestic purposes and for stock. In Algeria, for example, solar stills are used for very small communities, and resin ion-exchangers, in their modern form of resin-packed polythene containers regenerated on reaching good water, are used by mobile teams forced to supply themselves from brackish wells and springs for limited periods; but the only procedure at present practicable on any scale is that of selective membrane electrolysis. When, in the near future, cheap power becomes available, it is likely that demineralization of local saline waters will cost no more than long-distance pumping from outside sources (Drouhin, 1953). In South Africa experiments are being made with a view to the conversion of small local supplies, as from bore-holes, required for stock and other purposes.

Some of the ground waters of semi-arid regions represent bodies that accumulated in an earlier, more humid period and are no longer subject to annual replenishment; they are accordingly termed fossil ground waters, and they are sometimes highly saline. It is possible in some cases to determine their age by radio-carbon methods (Munnich and Vogel, 1960). While they are of little value for long-term development since they are exhaustible, they can sometimes be "mined" with advantage for short-term purposes, or kept in reserve to supplement surface supplies in time of drought. In the arid south-western United States some home sites are self-supplied with wells that tap ground waters emplaced during late Pleistocene times and for which recharge is now negligible. In many places water is used with little concern for some future time when the pumping lift increases beyond the limit of economic feasibility or when the supply might be exhausted (Leopold, 1962).

AVAILABILITY OF WATERS; SOCIAL AND ECONOMIC ASPECTS

Questions of the availability of water in arid countries cannot be considered apart from such matters as the quality of the water and certain social and economic factors (G. White, 1962). For example, some communities become accustomed to water with a degree of salinity that would be unacceptable to others; local rights and customs in water may affect its proper use and its fair distribution, and thus prevent the adoption of urgently needed new techniques; the cost of recovering water supplies at depth may be too high for some uses, but not for others, while these costs may vary with new equipment and cheaper power; water may be in short supply not because it is lacking at source but because it is wastefully and improperly used, and it may be easier to find or build a new source, such as a reservoir, than to change local methods of use. Furthermore, when supplies are limited a choice has to be made,

after domestic demands are satisfied, as between power, irrigation, agriculture, animal husbandry, recreation, etc., and the water has often to be employed in such a way as to bring in the best economic return to those concerned. In the San Juan basin of Colorado, for example, tentative estimates indicated a monetary value of an acre-foot of water in irrigation of \$14-18 as compared with \$200-300 if used for recreational purposes, and with \$1,200-3,300 when used for municipal and industrial purposes (G. White, 1962); the availability of water in such cases is accordingly related to the price the users are prepared to pay for it, and this applies too to deep artesian waters and to waters brought in from distant sources.

CLIMATIC FLUCTUATIONS

Apart from wide seasonal variations, larger and smaller fluctuations of climate greatly affect the availability of water in semi-arid regions; the question of climatic changes in late geological and early historical times and their significance for water resources and other factors is accordingly one of great importance, and it was the subject of a Unesco/WMO symposium held at Rome in October 1961.

It should be noted that the climatic changes of a given area are frequently due to the advance or recession of the prevalent climatic belts, over distances of as much as 3,000 km., so that in spite of such movements arid belts were maintained throughout the Quaternary, although not continuously in the same latitudes; even some of the minor climatic fluctuations result in shifts of boundaries of 500 to 1,000 km. (Fairbridge, 1961).

Within historic times it is not so much the changes of climate that have been important as the instability, or at most the minor changes, of the climate. In Tunisia, for example, while there appears to have been no climatic change in the last 3,000 years, there have been temporary variations (Tixeront, 1963). In the semi-arid areas a slight negative fluctuation of 100 mm. of precipitation would be critical, whereas elsewhere it would not be important (Amiran, 1963). Also, as far as agriculture is concerned, because methods of husbandry depend largely on the experience of past weather in any locality, the most potentially serious effect of climate is one which occurs in a critical manner following some twenty or thirty years free from such an occurrence (Smith, 1963). Changes of distribution of precipitation, without affecting the amount, can also be important, as in failure in the planting season.

Insufficient rainfall has a double effect in that it not only leads to a reduction in crops, but also to a delayed reduction of ground water. In such circumstances farmers are apt to withdraw ground water beyond the safe replacement limit; this might lead in certain cases to an increasing salination of the ground water resource,

causing permanent damage which does not pass as the dry spell gives way to better and wetter years.

In the semi-arid areas a sound agricultural industry can often be based only on irrigation, for man is then less sensible to fluctuations of climate—provided the volume and extent of irrigation agriculture has been properly planned in relation to average minimum values (Amiran, 1963).

There are accordingly two aspects of climatic fluctuations within historical times, i.e., those of relatively long term, as of 500 or 600 years, affecting, for example, the cultivable lands of Greenland and Iceland, to which man can gradually adapt himself without special hardship, and those of short duration, such as cycles of about eleven years or changes of weather pattern after about thirty years (Smith, 1963), which can bring swift disaster on established agricultural communities.

In the development of semi-arid areas it is therefore necessary to maintain a balanced view of minor climatic variations of a few years' duration, which do certainly take place even if in many cases they are of irregular occurrence; hence too much importance should not be attached to a short run of relatively dry years, since wetter years will certainly follow. The effect of such variations can often be countered by major works, but sometimes records are not sufficiently long to cover extreme variations, as in the case of the larger American dams referred to below, or that of the Zambezi River, which was subject to wholly unprecedented floods, as far as records go, during the building of the Kariba dam. But for lesser works, as in widespread small dams and bore-hole construction, it is still necessary to take climatic variations into account, and in stock raising for example, to plan for the drier periods rather than the wetter.

Butzer (1958), has recently traced numerous climatic changes in the Near East in the Quaternary and to the present day, and has described a climatic deterioration in the elevated plateaux of the Libyan desert since 1900 which has been destructive to life in marginal pastures.

In the arid zone of the United States, for example, some large reservoirs have been the victims of seemingly abrupt downward shifts in the run-off, and it is suspected that many of the newer multi-purpose reservoirs designed for long-term stabilization of flow even on the basis of long periods of record will have to face serious tests in the future (Langbein, 1962).

In the United States and elsewhere in a decade of relatively high precipitation there has sometimes been a great expansion of agriculture and of animal husbandry which could not be maintained in the succeeding period of low precipitation which necessarily followed, leading to great economic and social distress, and particularly to the evils of soil erosion by wind; in the steppes of Algeria a livestock population of 8 million head, built in a succession of good years, was reduced in a few dry years to less than 2 million, as in 1945 (Drouhin, 1962). Such disasters point to the importance of restricting agricultural and pastoral development as far as possible to the level appropriate for the long-term "average" hydrological conditions rather than to expand overconfidently in the better years.

Accordingly, the study of the larger and minor climatic changes within the last few thousand years is a matter of great importance for the semi-arid regions, since it may lead to a basis for the prediction of such changes, to which meteorologists are giving much attention. Wallén (1963) has recorded that although there is certainly some kind of quasi-periodicity in climatic fluctuations, no simple periods have been found to exist. The modern approach of studying, instead of statistical periods, the physical implications of changes in the general circulation and the heat balance on climatic and weather fluctuations seems to give much more hope. The circulation conditions of the atmosphere also indicate that we shall have the best prospects with this approach both as regards explanation of climatic fluctuations and long-range forecasting in the tropics and subtropics, which is an important conclusion for the arid and semi-arid regions.

DISCUSSION

P. MEIGS. One point that might be added to the very complete list of disadvantages of reservoir storage of water is the matter of the filling of the reservoirs with silt. Some engineers, when confronted with this problem, say "What does it matter if the reservoir becomes filled with silt in fifty years? After fifty years the dam will have paid for itself anyhow." Such a short-sighted view does not help the people who will need water after fifty years, when their reservoir, in effect, will no longer exist.

F. DIXEY. Of course I recognized the great importance of sedimentation problems and the disastrous results of sedimen-

tation when the only available reservoir site has been used and then filled with sediment.

D. CHRISTODOULOU. I wish to underline a point made by Dr. Dixey, namely the fundamental importance of land tenure and the general institutional framework of the efficient use of water resources. In the Mediterranean and especially in my country, Cyprus, water use is bound by antiquated water rights which lead to considerable misuse of water, while land tenure places serious limits on its efficient use. In FAO accumulating experience indicates the significance of these factors

in the proper use of resources. The institutional aspects of the problem may prove far more difficult to solve than engineering and technological aspects.

L. D. STAMP. Would Dr. Dixey as a geologist not agree that geological erosion (if not soil erosion) is an inevitable natural process and that one of the greatest tasks awaiting solution is to use the eroded material to build up alluvial flood plains acknowledged as being the most fertile agricultural lands in existence. Surely it should be possible to allow silt-laden waters to spread over suitable areas, deposit the silt and thus draw off clear water—an old process in Egypt and a modern one in the Punjab.

F. DIXEY. Geological erosion certainly leads to streams becoming laden with silt which is of value in building up alluvial plains and in flood irrigation as in Morocco, the Red Sea plains, and elsewhere. But in soil erosion, owing to misuse of land not only are the finer constituents removed but the coarser too, which in many cases are spread over the alluvial lands and destroy them. It is more important to conserve usable soil in its place than to use only a small part of it after deposition downstream.

H. NIEDERBÖSTER. In addition to the remark of Dr. Christodoulou on the importance of land tenure I should like to stress the lack of education and professional training in many countries. Due to this lack the full application and results achieved in the experimental stations will lag behind for quite a time. This is one of the biggest problems and Unesco has begun to grapple with it vigorously.

Y. KARMON. The utilization of all water resources, mentioned by Dr. Dixey, necessitates a central control of all water developments, lest the development of one resource should detract from other resources. In Israel the development of bore-holes in the upper water level interfered severely in some places with the flow of springs in the plains, and it became necessary to revise theories on the flow of underground water in those regions.

L. EMBERGER. Je voudrais donner un point de vue des écologistes pour l'utilisation intégrale des ressources en eau, dont les diverses méthodes nous ont été exposées par le Dr Dixey. Les écologistes ont montré par des mesures que la végétation de beaucoup de régions arides ne consomme pas la quantité

d'eau de pluie à leur disposition et que la dispersion des individus végétaux n'est pas nécessairement le fait du manque d'eau. Une grande partie de l'eau est évaporée en pure perte. C'est ainsi que sur les hauts plateaux algériens, la végétation existante ne consomme qu'une part relativement faible, autour de 50 % au moins, de l'eau qui tombe du ciel. Au lieu de laisser s'évaporer cette eau en pure perte, on pourrait donc la faire passer par la plante, c'est-à-dire augmenter la densité de la végétation, afin que celle-ci consomme toute l'eau qu'elle reçoit par la pluie, sans aucun autre dispositif.

D. H. K. AMIRAN. (a) Is salinity of water resources indeed a feature typical of semi-arid areas and not of arid areas only? (b) The very nature of the occurrence of flood water in many semi-arid regions should make it eventually necessary to develop practical methods for underground storage of flood water. Water stored in surface reservoirs has the great disadvantage of necessitating use at the wrong time, i.e. very soon after its accumulation from rainfall. At this time the land to be irrigated has had the benefit of rainfall as well, whereas later on when irrigation water really is required, most of it is no longer available as it has been lost by evaporation. For this reason too shallow reservoirs are often useless. Reservoirs of medium size often lend themselves advantageously to annual cleaning-out by bulldozers in order to remove sediments, which does not impair their storage capacity.

F. DIXEY. Salinity of water resources is a feature of semi-arid as of arid lands, although to a lesser degree.

Surface water storage in semi-arid regions has many serious disadvantages as pointed out by several speakers, and certainly the smaller storage works, to be of any real value, should be of a depth at least two or three times that of the annual evaporation.

The difficulty in storing flood water underground is firstly to get the water there and secondly into a structure from which it can subsequently be recovered by wells or bore-holes. In general, silt-laden water soon clogs up the absorption surface, so that the water has first to be run into a settling basin to deposit its silt before being spread over the absorption area. While this treatment of the water is often impracticable it can sometimes be achieved, as in California and elsewhere.

Dr. Dixey thanked the remaining speakers for their part in the discussion and for the interesting points they had raised.

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ECONOMIC ASPECTS OF DECISION-MAKING ON WATER USE IN SEMI-ARID AND ARID LANDS

by

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In semi-arid and arid lands, and others as well, successful economic development depends upon the efficient use of the various available resources. In semi-arid and arid lands, the resource which is the major limiting factor to further development is water. In such areas, careful and judicious use of this important foundation stone of economic growth is required if the area is to be developed to its highest economic potential.

To develop a region intelligently requires decisions as to what the people of the region, or those likely to migrate to it, consider to be their important objectives. In other words, it should be decided whether it is desirable to develop an economy which will produce the highest possible *per capita* income, or one which will support the largest possible number of residents, or one which will fulfil some other aspiration, such as a desire for a pastoral or agricultural economy. These questions are something on which the scientist can only assist and advise by making available the factual data showing the relative costs of the possible choices.

In a world where the population is growing at a rate of 1.7 per cent per annum or more—up to 3 or 4 per cent in some areas—it seems likely that the arid and semi-arid lands will be under increasing population pressure, not only from their own natural increase but also from net in-migration. As the population increases, it becomes necessary in most cases to adjust the economy to a more productive type of resource use in order to support the growing numbers. Sometimes this means the substituting of one set of resources for another as the main reliance of the economy. In some cases it may mean a reallocation of priorities for consumptive use of one particular resource, such as water. It may necessitate a change in objectives by the people of the region, if disaster is to be avoided.

In this paper it will be assumed that the population of an arid or semi-arid area is increasing, that the people wish to choose the resource uses that will yield a high average real income for an increasing number of residents. The examination of the problem will be limited

to the choices relating to the alternative uses of water, a resource which is relatively scarce. The question is, then: what are the most efficient uses of water in such an expanding economy? How does one measure the value to the community of the conflicting demands for the limited supply of water?

METHODS OF SMALL AREA ECONOMIC ANALYSIS

Of the seven to ten types of small area or regional economic analysis that have been developed in the past decade or so, two seem to be well adapted to judging the most economic use of water supplies. The economic base study is the simpler of the two, but is essentially static in its approach. The other, inter-regional input-output analysis, is more difficult both in the gathering of data and in the complexity of its mathematical concepts, but is dynamic rather than static. Either method, when used in connexion with detailed water consumption figures, will provide a reasonably reliable guide for economic decision-making in water use, although the two methods vary somewhat in their results.

Both of these research methods are seriously limited because of the difficulty of obtaining adequate data. Census materials are usually not detailed enough to provide the figures needed. Furthermore, the secrecy and ignorance of business entrepreneurs regarding the facts needed about their businesses make an accurate special collection of data discouraging. However, by carefully searching, estimating, and cross checking, it is possible to arrive at something which is relatively meaningful.

THE ECONOMIC BASE STUDY

The theory behind the economic base analysis is that every community and region in the modern, interdependent world lacks the wherewithal to be self-sufficient,

and that it must import many of the goods and services it needs if its economy is not to shrink nearly to the level of bare subsistence. For two populations of similar size and with a similar resource base, the one which is able to trade more, i.e., to sell more to the outside world and buy more from it, is likely to have a higher real income than the other which trades less. Therefore, it is meaningful to isolate the sectors of the economy (called "basic") which are exporting goods and services in exchange for purchasing power which may be used to buy imports. Except to the extent that a growing home market makes it possible to produce additional products at home economically, an increasing population calls for increasing "basic" employment and income because the "non-basic" (or local service) elements of the economy cannot purchase the needed flow of imports. The non-basic portions of the economy merely circulate goods and services within the community or region. In general, the growth of the latter, without loss of efficiency, depends on growth of the basic portions.¹

In arid and semi-arid lands, the important scarce factor in the resource base is water. Therefore the use of water by the basic industries gives an indication of the efficiency with which they use water as a resource in producing basic employment and personal income.

Perhaps this can be shown best by using two studies, each made by the author within the past decade, of the basic economic supports of two cities of the southwestern United States of America: Tucson and Albuquerque (Wilson, 1955a, 1955b, 1958). In Table 1 is shown the basic employment, income, and water consumption by industries for the Tucson area (Wilson, 1955a, p. 204; Schwalen and Shaw, 1961). In Table 2 are basic employment, income and water consumption data for Albuquerque (Wilson, 1958; Bjorklund and Maxwell, 1961). One difficulty is that in neither city are the water consumption figures available in the detail one would wish for in this type of study, a situation which shows the need for an additional class of water data for the study of water use in and for arid and semi-arid lands.

In evaluating Tables 1 and 2, some will be more interested in basic employment, some in the income figures. For the community as a whole, the income figures carry more weight. The general hypothesis to be employed in analysing these data is that the industry group that produces the most income per acre-foot of water should be encouraged and promoted the most, that which produces the second highest income per acre-foot will receive the next highest developmental effort, and so forth. At the other end of the scale, the industries which produce the least income per acre-foot of water consumed should be discouraged, perhaps even limited. If the region is a national State and the products of these low-efficiency water-using industries are protected by import tariffs, these should be reduced or removed to encourage competing imports. Of course,

this should be done only as the more water-efficient industries expand and are able to contribute purchasing power to import the products whose production is to be limited.

In the Tucson situation, shown in Table 1, it is apparent that agriculture is not contributing much to basic income (only 7.2 per cent) while consuming through irrigation water 46.1 per cent of all the water used. On the other hand, mining produces 5.0 per cent of total basic income with only 1.8 per cent of water used in Tucson, and manufacturing 13.7 per cent of income with only 5.8 per cent of the water. Government is one of the best bargains with 25.7 per cent of income with 3.6 per cent of water consumed. Some 22.5 per cent of income is produced by miscellaneous income groups with 42.7 per cent of water consumed—apparently including all home use too. Government, mining, and manufacturing all should be promoted as far as efficiency of water-use is concerned.

In Table 2, it can be seen that the situation is much easier in Albuquerque, which is on the banks of the Rio Grande, an almost perennial stream. Here agriculture produces 0.9 per cent of basic employment and only 0.2 per cent of total basic income. To produce this requires some 18 per cent of the water consumed. On the other hand, income from manufacturing, 21.3 per cent of the total, was produced with only 10.2 per cent of the water. The remaining 71.9 per cent of the water consumed, including household use, produced 60.9 per cent of the income. Some of this should be allocated, perhaps, to manufacturing as representing use of manufacturing employees at home. Nevertheless, it is clear that manufacturing should be encouraged on the present programme.

Nevertheless, the problems of water consumption are not as serious in Albuquerque as they are in Tucson, because the water recharge is at least as great as the water consumption. In Tucson, water recharge is only about 51 per cent of water consumption. From this, one might seriously recommend curtailment of further use of water for irrigation as soon as possible (Wilson, 1960).

INTER-REGIONAL INPUT-OUTPUT ANALYSIS

Inter-regional input-output analysis, the second type of analysis to be examined, is a method of visualizing the effects of changes in one sector of an economic system on other sectors. It is thus an excellent means of discovering which industries may act as "seed" industries in industrial development. Of course, these "seed" industries, as well as others, should be selected not only

1. A full discussion of the methodology and limitations of this type of analysis can be found in Alexander (1954), Blumenfeld (1955) and Isard (1960).

TABLE 1. Basic employment and income payments to individuals for Tucson, 1952, with water consumption combined Tucson Metropolitan and Sahuarita Districts, Arizona, 1956-1960 inclusive

	Basic employment	Per cent of total basic employment	Basic income (thousands of dollars)	Per cent of total basic income	Water consumption by industry groups (thousands of acre-feet)	Per cent water used in Tucson
Employment and earned income payments:						
Agriculture	2 850	9.6	9 647	7.2	45.6	46.1
Mining	1 600	5.4	6 693	5.0	1.8	1.8
Contract construction	800	2.7	4 675	3.5		
Manufacturing	5 780	19.4	18 267	13.7	5.7	5.8
Transport and utilities	3 050	10.3	9 973	7.5		
Trade	1 340	4.5	5 141	3.9		
Finance	100	0.3	357	0.3	42.2 ¹	42.7
Services	3 700	12.4	9 714	7.3		
Government	10 550	35.4	35 216	25.7	3.6	3.6
Total employment and earned income	29 770	100.0	98 683	74.1		
Unearned income payments:						
Miscellaneous income			1 680	1.3		
Property income			14 405	10.8		
Other income			18 456	13.8		
TOTAL			133 224	100.0	98.9	100.0
Water recharge, average annual					50.4	51.0

Sources: Wilson (1955b) and Schwalen and Shaw (1961).

1. Includes all other uses and losses, including natural losses and contract construction.

TABLE 2. Basic employment and income payments to individuals in Albuquerque, 1956 and water consumption for Albuquerque, 1959

	Basic employment, Albuquerque	Per cent of total basic employment	Basic income, Albuquerque (thousands of dollars)	Per cent of total basic income	Water consumption by industry groups, 1959 (million gallons/day)	Water used, 1959 (%)
Employment and earned income payments:						
Agriculture	358	0.9	441	0.2	10.0	17.9
Mining	150	0.4	826	0.4		
Contract construction	1 819	4.7	12 331	5.5		
Manufacturing	8 425	21.6	47 992	21.3	5.7	10.2
Transport and utilities	2 643	6.8	11 892	5.3		
Trade	4 443	11.4	22 851	10.1		
Finance	646	1.6	3 168	1.4	40.2 ¹	71.9
Services	2 364	6.1	9 962	4.4		
Government	18 122	46.5	76 031	33.8		
Total employment and earned income	38 970	100.0	185 494	82.4		
Unearned income payments:						
Miscellaneous income			22 992	10.2		
Property income			16 650	7.4		
Other income						
TOTAL			225 136	100.0	55.9	100.0
Water recharge, average annual, in thousands of cubic feet					?	100.0

Sources: Wilson (1958) and Bjorklund (1961).

1. Includes mining and construction.

in terms of employment and income which they might stimulate, but also in terms of water consumption.

The essential idea in this method is to discover the sources of goods purchased and the market for goods sold for each sector of the economy. Through an input-output matrix, the dynamic processes of change can thus be isolated, their effect on employment and income spotlighted, and their pressure on water supply determined.

Unfortunately, the author does not know of a study of this type for a semi-arid or arid area where water consumption data are available. Suffice it to say that a more dynamic understanding of semi-arid and arid land economies might be obtained with the inter-regional input-output type of economic analysis.¹

CONCLUSIONS

This paper attempts to show how certain research methodologies which have been developed for the study of the economies of small areas might be adapted, by the adding of water consumption data, to the determination of priorities in the use of water in semi-arid or arid lands. Because data are now so limited, there appears to be room for additional research in this field. It is to be hoped that some detailed studies will soon be made.

1. See Isard (1960), Chapter 8, for details of this methodology.

DISCUSSION

G. A. STEWART. As agriculture is much less productive per unit of water, will not economic competition for the limited water rapidly force out agricultural use? Do you think that any regulatory action is desirable to hasten that change?

A. W. WILSON. It is true that agriculture will eventually be priced out of the use of water if present trends continue, but by that time the water table will be so low that there will be a permanent increase in the cost of water to the more efficient users. Therefore, regulatory action may well be necessary if we hope to make the most efficient use of this limited resource. If this sort of regulatory action were taken in Tucson at once it might stop for a time at least further depletion of the underground water resources, for the present overdraft is approximately equal to agricultural use.

L. D. STAMP. How were the figures for water consumption per industry obtained? Were there any figures for *per capita* consumption? It was well known that *per capita* consumption might range from 2 gallons a day where water had to be fetched a distance to 30 gallons and more where it was laid on to the houses. As it would seem that the future developments of arid lands as areas of human settlement would depend more and more on air-conditioning, was the water used in air-conditioning an important factor?

A. W. WILSON. Estimates of industrial water use were made by the Department of Agricultural Engineering of the University of Arizona on the basis of well pumpage records. As for *per capita* consumption figures, I checked with the City of Tucson Water Department early in 1962 and found that *per capita* consumption for all uses within the city was slightly over 180 gallons per day. A small part of this was used for evaporative coolers, but with recirculation of water in these consumptive use is really quite small. As far as refrigeration is concerned, most of these today use no water at all. They dissipate heat directly into the air.

Y. KARMON. (1) In any regional geography the most limiting

resource-factor is recognized as the determining factor. In Israeli agriculture we have begun to judge the different branches according to output per cubic metre of water consumed. (2) In areas of very limited water supply priority should be given to urban development. Thus the development of the Negev is based on towns and not on agriculture. (3) A very important factor in arid zone development is tourism, which should get every encouragement.

A. W. WILSON. I agree with Dr. Karmon's statements. It is my impression that the decision by Israel to develop the Negev by towns rather than agriculture represents a change of view from earlier intentions. If so, I think it represents a change in the right direction.

Tourism is very important in the arid and semi-arid lands of the south-western United States. It is estimated that tourism is a greater source of income than either livestock or crops in the State of Arizona.

D. CHRISTODOULOU. The question of increase of population and industrialization in semi-arid areas merits further consideration. It has been said that industry is moving in to some arid areas and further that population is increasing because people like to live there. The question is whether population and industry are increasing because water supplies are available already, or alternatively whether they move in in the expectation that their presence will stimulate the provision of water to them? This is a problem for the planner or the controlling authority: should an increase be allowed if water is not likely to be found easily?

There is also a question of definition: if water is provided to the inhabitants on a generous scale, can it still be said that they are living in an arid (or even semi-arid) land? Is this not a case of redistribution of aridity, at least at the consumption end?

A. W. WILSON. This raises a fundamental question of political control. In the United States there is precedent and procedure for limiting the use of water, but not the movements of people.

As far as the motivation of people moving into an arid or semi-arid area is concerned, the experience of Los Angeles would indicate that people come with the expectation of water (and employment) being provided because this is where, as a result of the amenities available, they wish to live. As long as Los Angeles remains an attraction to immigrants, it seems that water will be brought in: witness the amazing new Feather River project being started by the State of California to bring water over 500 miles from the northern part of the State.

To some degree a redistribution of aridity does take place. The Owens Valley of California was converted from a beautiful oasis of farms and orchards into a marginal area of limited development by the diversion of water from the Owens River into the Los Angeles Aqueduct in the first decade of this century.

Settlement in arid lands, and *per capita* consumption of water therein, may be reduced, perhaps, by economic controls, such as increasing the unit cost of water with increasing consumption. Yet the cost of water is so minor a charge that I fear it would take a great price increase to greatly influence consumption patterns, at least in the United States.

P. MEIGS. Thank you for bringing this very practical analysis to us. I hope some day there will be an opportunity for you to bring to our attention the very interesting work you are doing in Arizona on land-use and water planning for small communities in your arid and semi-arid lands.

A quick rough mental calculation based upon Professor Wilson's estimate of 250,000 people in Tucson, suggests that if Tucson were to use the Middle Eastern type of toilet instead of the flush-type toilet (developed by humid lands inventors), there would be a daily saving of at least 5 million litres of water. This problem may be quite significant in arid areas where the increase in tourism brings with it European-type hotels with the extravagant water-consuming plumbing fixtures expected by most European and American tourists.

A. W. WILSON. Thank you very much, Dr. Meigs, for those kind expressions of confidence in us. Your comments on the problems of saving water used for sanitary purposes brings to mind the exhibit at the Arizona-Sonora Living Desert Museum near Tucson. This shows a modern flush toilet beside an outdoor privy (or "outhouse") and compares the water consumption of the two. Personally, I have some reservations about the sanitary effectiveness of the Middle East type of toilet, but have no real evidence to back up my doubts.

I would like to point out that a new technological development of a closed circuit sanitary system for homes may

alleviate this type of water loss in the near future. This is a device which uses a small sewage treatment system in the basement of the home and recirculates the purified liquid effluent thereof back through the toilet again. I expect such a system will not be adopted widely, however, without either legal or economic pressures.

D. H. K. AMIRAN. (1) I should not rate recreational use of arid lands as an alternative to their use for mining, services, along trade routes, etc., but rather try to define an order of priority for the various uses for any given area. (2) In water use, supply certainly creates consumption. (3) The great advantage of the method of input-output analysis as presented by Professor Wilson is its quick applicability. It does not need averages of the length required for climatological data. (4) Finally, a point I would like to put forward for your consideration without being able to offer any definite conclusion on it: Is the use of fossil water supplies and in particular mining of water justified? In particular are we permitted to commit future generations by exhausting existing water resources?

A. W. WILSON. May I comment on these points one at a time, please? (1) I agree that there should be a priority of use for water designed for each particular area of arid lands. One possible methodology for this I have tried to suggest today. On the other hand, I think we should keep in mind the possibilities of multiple-use of water supplies so that more than one use is made of the same units of water, as when a municipal or irrigation reservoir is also used for recreation. (2) While it is true that supply creates consumption, it may be true also that education, economic pressures, and new technologies may reduce consumption, at least on a *per capita* basis. Dr. Gilbert White has been particularly clear in pointing up this possibility. (3) This is a good point, but I should also point out that the method of analysis that I illustrated was the basic/non-basic approach, while I simply described briefly the input-output method. (4) This is a problem that has been discussed at length, with, I believe, generally the same lack of conclusion. In the cotton areas of Western Texas in the United States there seems to be a deliberate mining of the ground water with the idea that it is of no value in the ground, just as one might view copper ore. Recently a court allowed a deduction from income taxes for a depletion allowance on mining water in this area, the same as is allowed for mining petroleum. Yet, in my own mind, I am not convinced that this is an acceptable approach. I suppose that it is really a moral question.

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SECTION II

REGIONAL STUDIES

ÉTUDES RÉGIONALES

SOVIET TRANSCAUCASIA-BALKAN PENINSULA

Soil geographical analogies in the Mediterranean regions and its reflection in land use

by

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According to the well-known expression of V. Dokuchayev, founder of soil science, "the soil is the focus or mirror of the natural geographical landscape". All the most important properties of soils, those that condition their external characteristics and potential natural fertility, are formed as a result of a complex interaction of geological, biological, climatic and geomorphological factors which are together the most important components of natural geographical landscapes. The close functional connexion between the character of the soil and the complex of all the aforementioned factors of soil formation is so regular that it permits reliable forecasts to be made of the peculiarities of climate, vegetation, composition of the parent rock and general relief conditions on the basis of the genetic properties of the soils. These properties are also of the greatest importance for the cultivation of various crops. Thus, the genetic studies and comparison of the soils of different countries and regions not only make it possible to draw far-reaching geographical inferences of theoretical value, but can also serve as the scientific basis for fruitful analysis of practical land use.

This can be demonstrated by a comparison of soil composition and physiogeographic indices and their reflection in the land use of Soviet Transcaucasia on the one hand, and the countries of the Balkan Peninsula on the other.

The general geographic reasons for such a comparison are numerous. Both territories are in the vast Mediterranean region, are located in almost the same geographic latitudes (44° - 38° and 36° N.) and are parts of a continent surrounded or fringed by internal seas. The greater part of the area of the territories compared is covered by mountain elevations with a steep slope; between the elevations there are depressions, plains, and lowlands of different sizes. Some of the elevations are of the nature of highland plateaux; some of them are young volcanic formations.

The general soil composition of both territories is very similar. The highest parts of the elevations of the

Major and Minor Caucasus, the Balkans, the Rhodopes (Rila, Pirin) and the highland regions of Macedonia and the Pindus Mountains are covered with mountain-meadow soils under alpine and subalpine meadows. The vast expanses of the medium and low mountains are covered with brown forest soils under broadleaves and mixed, coniferous and deciduous forests separated from the mountain-meadow soils by a narrow belt of mountain-podzol (in the Caucasus) and dark podzolized soils (Rhodopes) under purely coniferous plantations. On the northern slope of the Major Caucasus, in the foothill plains, the brown forest soils are replaced by grey forest and, further, North Caucasus steppe chernozems. A perfectly analogous change occurs in the transitions from the mountains of the Balkan Peninsula to the plains of the Vojvodina and the Danube lowland. Within the limits of the latter there are, as is well known, the basic chernozem regions of Yugoslavia and Bulgaria. This type of soil and geographic vertical zonality is thus characteristic of the European slopes of the Caucasian and Balkan mountains. An entirely different change of soil types is observed in Soviet Transcaucasia, on the territory of South Macedonia and Bulgaria, as well as in Greece. The brown forest soils of the mountain belt of deciduous forests are replaced here by cinnamon soils of dry forests and shrubs, which are the most widespread and, perhaps, the most typical soils of the Mediterranean region.

It is interesting to note that the idea of the genetic independence of the Mediterranean cinnamon soils and of the necessity of decisively separating them from the chestnut soils of the dry steppes was first expressed in 1924 by S. Zakharov, a well-known student of Caucasian soils. I also developed this idea at first for the same region of the eastern part of Georgia (Mtskheta) and later confirmed and substantiated it by studies of the soils in the southern part of Bulgaria conducted jointly with Bulgarian geographers and soil scientists (1948, 1954, 1959). "Les sols marrons—le type principal génétique des régions méditerranéennes", an article

dealing with the general characteristic of brown soils and their geographical distribution, was published in the second issue of the journal *Méditerranée* in 1961.

In the central regions of Soviet Transcaucasia cinnamon soils of dry forests and shrubs cover territories generally referred to as dry or arid subtropics. Their climatic indices are as follows: annual atmospheric precipitation, 400-800 mm.; snow cover, unstable; mean January temperature, close to 0° C.; mean June temperature, close to 24-25° C. It is easy to see that many typical Mediterranean regions of the Balkan Peninsula are characterized by analogous climatic indices.

The cinnamon soils of the dry forests and shrubs in Soviet Transcaucasia are a favourable substrate for cultivating the grapevine. Today the main grades of Georgian table wines which are considered the best Soviet wines of this type are produced in the regions of development of typical cinnamon soils (for example, in Kakhetia, etc.). At the same time vine-growing and wine-making are as old in these parts as they are in Greece. It is well known, for example, that, according to Herodotus and other scholars of ancient Hellas, grapes, wheat, nuts, etc., were cultivated in the countries east of the ancient Greek colonies of Phasis, Dioscurias, Pityus, etc. On the other hand, the excellent historical museum of Armenia (Yerevan) has among the plentiful remains of material culture of the Urartu kingdom (ninth to seventh centuries B.C.) enormous ceramic wine vessels (Karasy, the combined capacity of which amounts to several thousand gallons). Thus, the cinnamon soils under discussion were used on Mediterranean territories in antiquity, as they are also used today, for special agricultural purposes connected primarily with vine-growing.

Despite the general similarities in the structure of the soil cover of Transcaucasia, on the one hand, and the Mediterranean regions of the Balkan Peninsula, on the other, there are also essential local differences between these territories. Owing to the great contrasts in the climatic conditions, sharper dissection of the relief and other geographical peculiarities, the soil cover of Soviet Transcaucasia shows greater variety than that of the Balkans. In addition to the more extensive development of the belt of mountain-meadow (alpine and subalpine) soil, some modifications of soil-geographic conditions which are clearly defined on the territory of Soviet Transcaucasia are much less pronounced in the Balkans. This implies: (a) formation of the most humid soils of a subtropical nature—red soils (krasnozem) and yellow soils (geltozem); (b) formation of the most arid (extra-arid) structures represented by grey cinnamon and grey (siewzem) soils; (c) the presence of peculiar dark-coloured soils called mountain chernozems.

As is well known, red soils¹ (krasnozem) and yellow soils (geltozem) form in Soviet Transcaucasia in the most humid (up to 2,400-3,000 mm. of precipitation per annum) and warmest (July temperature, +22-23° C., January temperature, 5-6° C.) southern region of the Black Sea Coast (Abkhazia and Adzharia). Here the natural vegetation is represented by evergreen humid subtropical forests. The particularly important agricultural crops are tea and citrus fruit.

A somewhat cooler variety of the same type of region is to be found in the humid subtropical region of the Caspian Coast in Azerbaijan (Talysh) with its yellow soils (geltozem) and the northern region of the Black Sea Coast (Sochi) with its yellow-brown soils under deciduous forests with certain evergreen plants in the underwood. An almost exact soil and geographical analogue of the latter region on the Balkan Peninsula is the southern part of the Bulgarian Black Sea Coast.

The extra-arid regions of Soviet Transcaucasia with a predominance of grey-cinnamon soils (partly grey soils) (sieroze) are the lowland regions of Azerbaijan (Kura Lowland, Apsheron Peninsula, Nakhiche Van Depression) and the Ararat Plain in Armenia. Here the amount of atmospheric precipitation decreases to 200-400 mm. per annum, the mean July temperature reaches +25° C. and the mean January temperature goes down to between 0 and -5° C. The natural vegetation is represented by semi-desert formations; cotton (irrigated) is a very important agricultural crop.

The dark-coloured "pitch"-type soils (smolniza) developed on volcanic rock and Pliocene lake deposits in Bulgaria, Yugoslavia and other Balkan countries are possibly an analogue of the mountain chernozems of Soviet Transcaucasia. However, the geographic conditions for the development of these soils are very different (except the country rock of volcanic origin). The mountain chernozems of Transcaucasia are apparently intermediate formations between the alpine mountain-meadow soils and the dark-coloured blended soils on mountain rock of the basic composition developed in the plain regions with a semi-arid subtropical climate. For example, the Armenian chernozems have developed under conditions of a moderately warm mountain climate (mean June temperature, +19-20° C.; January temperature, between -3 and 5° C.; annual sum of atmospheric precipitation, 500-800 mm.) under meadow steppes. Grain growing is the main branch of agriculture on these soils.

The following table compiled from reference books contains quantitative data showing the features of similarity and differences in the composition of the soils and the land use of the territories compared.

1. These zonal soils must be sharply distinguished from the azonal *terra rossa* type soils formed on limestone.

Comparison of the composition of soils and land use

Territory	Area (million hectares)	Population (millions)	Composition of soils used in agriculture	Arable lands (%)	Orchards and vineyards (%)	Pastures and haymaking (%)	Forests and shrubs (%)	Predominant agricultural crops
Soviet Transcaucasia:								
Georgia	7.3	4.0	Cinnamon, humus-carbonate, red soils, yellow soils, brown forest, etc.	15.4	3.4	22.3	39.2	Cereals, grapes, fruit, tea, citrus fruit, sugar beets, tobacco, etc.
Armenia	2.9	1.8	Mountain chernozems, humus-carbonate, cinnamon and grey cinnamon, etc.	21.5	1.2	33.3	11.5	Cereals, grapes, fruit, cotton, tobacco, etc.
Azerbaijan	8.7	3.7	Grey cinnamon and grey soils, cinnamon humus-carbonate, yellow soils, etc.	19.5	1.3	28.1	14.5	Cereals, cotton, grapes, fruit, tobacco, tea, citrus fruit, etc.
Greece	13.5	8.2	Cinnamon and grey cinnamon humus-carbonate, chernozems, "pitch" yellow-brown forest soils, etc.	18.8	3.7	40	15	Cereals, grapes, fruit, olives, tobacco, cotton, citrus fruit, etc.

LES RÉGIONS SEMI-ARIDES DE LA GRÈCE¹

par

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La subdivision des différentes régions en zones climatiques présente un grand intérêt, scientifique aussi bien que pratique, notamment en ce qui concerne l'utilisation des ressources agricoles et énergétiques. Ainsi la productivité agricole dépend surtout des variations (pendant l'année et d'une année à l'autre) et en général des conditions de température et de pluie, éléments dont l'action combinée détermine le taux de croissance des plantes locales, surtout de celles qui sont cultivées sans irrigation. C'est pour cette raison que la plupart des classifications climatiques proposées auparavant étaient basées sur ces deux éléments.

En ce qui concerne la Grèce, Enginitis (1908a, b) a classé l'Attique parmi les régions à climat semi-aride selon la température et la pluie. Mariolopoulos (1938) a classé dans la même catégorie le sud-est de l'Attique, la plupart des Cyclades et le sud-est de l'île de Crète, d'après les quantités et la distribution annuelle des pluies et la température de l'air avec ses variations.

Cependant, il s'est avéré difficile de distinguer entre les différents types de climats établis selon les données pluviométriques et thermiques étudiées séparément. Plusieurs chercheurs (Köppen, Lang, de Martonne, Thornthwaite, Emberger, Geslin et autres) ont donc proposé l'emploi d'indices climatiques basés sur les combinaisons de ces deux éléments.

La question du degré d'aridité dans les différentes parties de la Grèce n'a été abordée pour la première fois qu'un peu avant la deuxième guerre mondiale (Mistardis, 1938). En comparant la carte établie alors avec celles des autres pays méditerranéens, on constate que la Grèce est moins aride que l'Espagne orientale ou l'Asie Mineure, mais plus aride que l'Italie péninsulaire. Cette carte fut dressée en tenant compte d'indices d'aridité calculés selon deux formules : P/t' , où P représente les moyennes annuelles des pluies et t' les températures moyennes du mois le plus chaud (juillet) ; et $P/(T + 10)$, où T représente les moyennes annuelles de température.

Les régions au climat le plus sec (indices 10 à 15) n'occupent en Grèce qu'une partie extrêmement faible du pays, tandis qu'en Espagne orientale elles couvrent des étendues très considérables. Même les régions les moins sèches (indices 15 à 20) ne correspondent qu'à un dixième à peu près de la superficie totale du territoire grec.

Toutes ces régions, qu'on pourrait caractériser de semi-arides (indices 10 à 20), se trouvent en Grèce orientale. Dans la moitié septentrionale de cette partie du pays, seules la région de Salonique et une partie de la Thessalie orientale présentent des indices supérieurs à 20. Par contre, dans sa moitié méridionale, les régions à indices d'aridité inférieurs à 20 sont plus nombreuses : ce sont surtout l'extrême sud-est de la Grèce moyenne, une partie du Péloponnèse oriental, la moitié orientale de la Crète et presque toutes les Cyclades.

Dans une communication plus récente, Mistardis (1960, 1962) a étudié plus en détail les rapports entre le degré de l'aridité et la végétation, soulignant les différences très sensibles entre les diverses parties d'une région aussi peu étendue que l'île d'Andros, une des Cyclades septentrionales.

Tout récemment, E. Mariolopoulos, analysant le degré d'aridité des différentes régions de la Grèce, a dressé une carte selon la formule d'Emberger $Q = P.100 (M^2 - m^2)$, où P représente la moyenne annuelle des précipitations en millimètres, M la moyenne des températures maximales du mois le plus chaud et m la moyenne des températures minimales du mois le plus froid de l'année. Cette carte accorde un climat semi-aride aux régions suivantes : l'Attique et spécialement sa partie sud-est, l'Argolide et une petite partie du Péloponnèse du Sud-Est, la partie orientale de la Crète, les Cyclades et les autres petites îles de la mer Égée, la partie méridionale de l'Eubée, les plaines de

1. En ce qui concerne la discussion relative à cet article, voir p. 67.

la Thessalie, de la Macédoine centrale et de la Thrace occidentale. Il faut remarquer que, dans quelques grandes îles et autres régions reconnues comme semi-arides, certaines parties ont un climat plus humide.

Utilisant les données concernant la pluie et la température réunies par 39 stations météorologiques de la Grèce, Carapiperis (1962) divise le pays en zones climatiques selon l'indice d'efficacité de la pluie calculé d'après la formule de Thornthwaite :

$$I = P/E = \sum 115 \left(\frac{P}{T-10} \right)^{10-9}$$

où P représente les précipitations en pouces anglais et T la température en degrés Fahrenheit. La carte établie par cet auteur démontre que l'Attique, le Troïzène du Sud-Est, les Cyclades méridionales et la Crète orientale possèdent un climat semi-aride; la Grèce ne présente nulle part un climat aride, du point de vue de l'efficacité de la pluie.

Tenant compte des travaux mentionnés plus haut et en se basant sur certains traits du paysage naturel et sur des indices calculés selon la formule suivante : $(P/T + 4p'''/t''')/2$, où P est la moyenne annuelle des pluies, T la température moyenne annuelle, p''' la moyenne des pluies du trimestre juin-juillet-août et t''' la température moyenne du même trimestre, G. Mistrardis a dressé une carte de la Grèce orientale. Seules les régions qui, en dehors de certaines caractéristiques de leur paysage naturel, possèdent des conditions climatiques générales telles qu'on ne peut les qualifier ni d'arides ni de non arides y sont représentées. Ce serait donc des régions semi-arides, mais dans un sens plus large, car quelques-unes d'entre elles n'entreraient pas dans cette catégorie si l'on se servait uniquement de la formule de Thornthwaite — elles dépassent en effet la limite du climat semi-aride fixé par ce dernier à 30. La carte de Mistrardis fait état de trois types principaux : a) semi-aridité extrêmement faible ou périodique : région de Salonique et une partie de la Thessalie orientale; b) semi-aridité modérée: ici on distingue entre une semi-aridité plus faible (la partie occidentale de l'Eubée centrale et méridionale, la Béotie orientale, la plus grande partie de l'Argolide, une partie des Cyclades, etc.) et plus accusée (une grande partie de l'Attique, la Corinthe orientale, une partie de l'île de

Crète centrale, plusieurs des Cyclades, etc.); c) semi-aridité accentuée : l'extrémité orientale de la Crète, une partie des Cyclades méridionales, quelques îles du golfe Saronique.

Bien entendu, à l'intérieur de toutes ces régions, le degré de semi-aridité n'est pas uniforme et dans plusieurs d'entre elles il existe des îlots qui ne sont pas semi-arides.

En ce qui concerne les sols qui prédominent dans les zones plus ou moins sèches ou semi-arides de la Grèce, D. Catacoussinos donne le tableau suivant des types d'association des sols : a) sols squelettiques et des Rendzines; b) sols squelettiques et rouges méditerranéens; c) terres rouges méditerranéennes transportées; d) sols alluviaux avec ou sans CaCO_3 ; e) sols hydromorphes ou semi-hydromorphes ordinairement riches en matière organique et plus rarement de constitution tourbeuse à une profondeur assez considérable au-dessous de la surface du sol; f) sols salins-alcalins, riches en sels solubles dans l'eau et en sodium échangeable.

La plupart des sols agricoles de la Grèce ne sont pas assez pourvus en matières organiques. Ils sont relativement riches en K_2O assimilable et en calcaire actif. Quant à leur pH, il oscille généralement entre 7,0 et 8,5 et présente rarement une réaction supéralcalinée (pH supérieur à 8,6) allant seulement dans quelques cas jusqu'à 9,5.

La productivité des sols dans les zones à climat aride ou semi-aride en Grèce est élevée — surtout si l'on peut les irriguer — quand il s'agit de formations alluviales et de sols rouges méditerranéens transportés qui possèdent généralement une faible pente de surface et une ample profondeur active. La productivité est également élevée pour les sols hydromorphes dont le drainage est réglé. Les types des sols mentionnés (alluviaux, hydromorphes et rouges méditerranéens) sont propres à la culture de plusieurs espèces à grand semis des agrumes, des arbres fruitiers, du coton, du maïs, du trèfle, du riz, des légumes, etc.

Les régions semi-arides de la Grèce sont loin de correspondre aux divisions administratives pour lesquelles seules nous avons des données statistiques. Les départements (*nones*) qui figurent dans le tableau statistique ci-joint peuvent être caractérisés comme semi-arides dans la majeure partie de leur superficie.

	Attique ^a	Corinthie ^b	Argolide ^c	Cyclades ^d	Crète ^e
	%	%	%	%	%
Forêts	22,9	29,9	13,0	0,5	2,8
Surfaces partiellement couvertes de forêts	25,6	17,1	51,5	52,9	15,4
Lacs et marais	0,6	0,5	0,3	0,2	0,1
Sols rocheux	15,9	1,4	4,4	3,7	0,7
Sols agricoles	33,6	31,6	31,5	19,9	30,7
<i>Espèces forestières</i>					
Pins	59,8	84,4	21,7	4,2	48,2
Sapins	11,5	12,4	7,9	—	—
A larges feuilles persistantes	27,5	0,8	69,4	95,1	35,3
Autres espèces	1,2	2,0	1,05	0,7	16,5
<i>Sols agricoles</i>					
Vignobles	19,0	19,7	1,7	11,3	10,7
Agrumes	6,2	2,2	8,7	7,1	2,6
Plantes fourragères	12,7	9,5	6,7	4,2	3,9
Céréales	26,0	35,4	31,5	45,1	21,1
Plantes industrielles	0,9	0,5	8,2	0,3	0,4
Oliviers	3,9	5,0	8,8	3,2	21,7
Cultures irriguées	6,0	15,0	19,0	8,5	9,5

a. Superficie, 3 776 km²; population, 2 057 974 habitants; agriculteurs, 6,6 %; non agriculteurs, 93,4 %.
 b. Superficie, 2 292 km²; population, 112 505 habitants; agriculteurs, 64,6 %; non agriculteurs, 35,4 %.
 c. Superficie, 2 117 km²; population, 90 145 habitants; agriculteurs, 64,4 %; non agriculteurs, 35,4 %.
 d. Superficie, 2 577 km²; population, 99 159 habitants; agriculteurs, 40,6 %; non agriculteurs, 59,4 %.
 e. Superficie, 8 335 km²; population, 433 258 habitants; agriculteurs, 60,9 %; non agriculteurs, 39,1 %.

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LAND USE IN THE SEMI-ARID ZONE OF GREECE

by

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GENERAL DESCRIPTION OF THE AREA

The accurate delineation of climatic zones in Greece is not easy for there are few meteorological stations and the mountainous terrain causes complex variations in the local climates. Climatic zones in Greece can therefore only be approximately defined.

The closest approximation one can make of the area of the semi-arid zone, on the basis of the "indice d'aridité" of de Martonne (Mariolopoulos, 1960) and "indice pluviométrique" of Emberger,¹ is 5 to 10 per cent of the total area of Greece.

The typical natural vegetation of the zone consists of pine forests (*Pinus halepensis*) and of chaparral shrubs and trees of varying density and composition.

The semi-arid zone occupies large portions of the following provinces:

1. Attica and the nearby small islands. Most of the agricultural land, the pine forests and the chaparral forests are in the semi-arid zone.
2. Argolis-Corinthia. Most of the agricultural lands, the pine forests and the chaparral forests.
3. Cyclades Islands and the nearby islands of the Aegean Sea. The entire area of the islands belongs to the semi-arid zone.
4. South-eastern Crete. The semi-arid zone includes a large portion of the agricultural lands and the pine and chaparral forests.

Isolated areas along the eastern and south-eastern shoreline of Greece also belong to the semi-arid zone. There are a few inland stations, like Serres and Larissa, in which the values of the indices are at the upper limits (subhumid) of the zone. However, the general appearance of the natural vegetation and the climatic conditions of the surrounding areas resemble those of the subhumid zone. The above four provinces are the most representative of the semi-arid zone, and only these will be studied in this paper.

The geological formations of the semi-arid zone

consist of: (a) recent alluvium; (b) Tertiary marl, clays, sands, and conglomerates; (c) Cretaceous shales and limestones; (d) Paleozoic marbles, mica schists and phyllites.

Land use studies and recommendations should be based on detailed soil maps. Such maps are not available at present and detailed soil units are not known. The only presently known units are the great soil groups.

The soils of the zone have been strongly influenced by erosion induced by man's activities over a period of several centuries. These soils at their present stage of development can be classified as follows:

Group A. Lithosols (Lithic Orthustents) and associated Red Mediterranean soils (Orthic Rhodustalfs), brown soils developed on schists, shales and sandstones (Typustalfs) and Rendzinas (Rendolls). The Lithosols are eroded phases of soils that had developed under pine and chaparral forests on the sedimentary and metamorphic rocks of the area. They occupy the sloping sides of the mountains and hills. There are some small areas, however, where the orthic rhodustalf profile has been preserved.

Group B. Alluvial and colluvial soils. They can be characterized as regosols (Orthustents). The soils consist of mixtures of erosion products of Group A soils. They contain much clay and various amounts of gravel and rock fragments. Their reactions commonly range from neutral to moderately alkaline. The calcium carbonate content ranges from 0 to 70 per cent. A very small portion of these soils are saline and/or saline-alkali soils containing harmful quantities of soluble salts.

Group C. Rock outcrops. A considerable area of the mountains and hills remains as barren rocks, because the soil has been completely washed away by erosion.

Lack of moisture during the summer is the major limitation of the soils of the semi-arid zone. Under permanent vegetation the soils commonly develop a

1. G. Plaisance, *Dictionnaire des sols*, p. 418.

moderately high organic matter content. However, cultivated and eroded soils have very low organic matter and nitrogen contents. The phosphorus, available to plants, is also low because of its fixation due to the presence of calcium carbonate. The relatively high *pH* of the soils induces iron, zinc and other minor element deficiencies. The extent and importance of these lime-induced deficiencies in Greek soils are not known as yet. Thus, in spite of their high base contents, the soils of the semi-arid zone are lacking in water and in available forms of important macro- and micro-nutrients. Therefore, they tend to be somewhat less productive than the soils of the subhumid zone.

POPULATION AND ECONOMY

The distribution of the population in the semi-arid zone of Greece is shown in Table 1. Attica is the most important of the provinces in the table, since it includes Athens, the capital, and Piraeus, the main port of Greece. Attica has about 24 per cent of the total population and the bulk of the industrial development of the country, but represents only about 2.8 per cent of the total area of Greece.

TABLE 1. Population distribution in the semi-arid zone of Greece

Province	Total population	Farm population (%)	Urban population (%)
Attica	2 058 000	6.6	93.4
Argolis-Corinthia	202 000	64.6	35.5
Cyclades Islands	100 000	40.6	59.4
South-east Crete	150 000	61.0	39.0
Greece	8 500 000	62.0	38.0

The influx of industry and population to Athens and Piraeus is due mainly to the following factors: (a) highly centralized forms of government, which existed in Greece until a few years ago; (b) favourable location and good harbour facilities; (c) feelings of insecurity developed among the rural population during the wars and foreign occupation of the country.

Excluding Athens and Piraeus, the population of the rest of Attica is 58 per cent rural and 42 per cent urban. The Athens-Piraeus complex is the financial, trade, industrial and transportation centre of Greece. Located favourably, it has become the marketing centre for the agricultural products of the zone; thus the semi-arid zone has a distinct trade advantage over other areas of the country.

In the other three provinces agriculture is the main source of income of the local population. In the Cyclades Islands and the nearby islands of the Aegean Sea,

merchant shipping is also an important source of income.

LAND USE

The figures in the following tables have been taken from the 1950 census (Statist. nat. de la Grèce, 1950). They may differ from the 1961 census which will be published in a few months. Table 2 shows the approximate distribution of the different forms of land use in the semi-arid zone. Land use is closely related to soils.

TABLE 2. Percent distribution of major forms of land use in the semi-arid zone of Greece

Land use	Province			
	Attica	Argolis-Corinthia	Cyclades Islands	South-eastern Crete
Agricultural	39.5	32.6	20.0	30.0
Forests	18.4	20.0	0.5	2.0
Partially forested and grazed	20.6	37.0	63.0	
Marshes and lakes	0.5	0.4	0.2	
Idle rock outcrops	15.0	3.0	15.0	
Residential, industrial and other	6.0 ¹	7.0	1.3	

1. The residential and industrial land in Attica is approximately 6 per cent of the total area. However, it is insignificant in the other provinces.

The alluvial soils (Orthustents) of Group B are largely used for the production of agricultural crops. However, some moderately sloping soils of Group A are also cultivated. The soils of the forest and partially forested and grazed lands commonly are Lithic Orthustents and associated Orthic Rhodustals and Rendolls. The slopes of these soils are usually steep and this makes their agricultural use impractical. Group C soils are idle and no use is made of them, except for a few quarries located near the population centres.

USE OF THE AGRICULTURAL LANDS

Table 3 shows that the annual plants, vines and olive trees are the main agricultural crops in the semi-arid zone. Disputed lands in Table 3 include partially forested areas with moderate slopes, usually less than 20 per cent. These lands are claimed for forest use by the foresters and for crop production by the agronomists. The authors feel that they should be distinctly separated into forest and agricultural lands and be managed according to their productivity. However, the majority of them should be planted with fast-growing forest trees.

TABLE 3. Crop distribution in the semi-arid zone of Greece

Crop	Percentage of total agricultural land			
	Attica	Argolis-Corinthia	Cyclades Islands	South-eastern Crete
Annual plants	64.0	68.0	66.0	54.0
Vineyards	18.0	11.0	12.0	13.0
Olive trees	4.0	7.0	3.0	21.0
Citrus trees	0.5	1.5	1.0	0.5
Lowland pastures	3.0	3.0	16.0	7.0
Disputed lands	9.5	9.5	2.0	4.5
Total agricultural land (in thousand hectares)	115.4	135.3	43.1	160

Table 4 shows that the predominant farm crops in the semi-arid zone are the cereal grains: wheat, barley and oats. Among the grain crops, barley is the most abundant in the Cyclades Islands and wheat in the other three provinces. Small grains usually grow on relatively infertile and dry soils. The vegetable crops are grown on the best soils and are usually irrigated. Due to the early harvest in this area as compared with the other areas of Greece, and to the closeness of the principal markets of the country, vegetables are very significant cash crops in the semi-arid zone, especially in the Cyclades Islands.

TABLE 4. Distribution of annual crops in the semi-arid zone of Greece

Crop	Percentage of the total agricultural land used for annual plants			
	Attica	Argolis-Corinthia	Cyclades Islands	South-eastern Crete
Wheat	37	48	10	27
Barley	17	12	38	15
Oats	3	3	1	14
Vegetables	10	7	19	11
Legumes	3	3	12	8
Forage crops	25	11	1	8
Industrial crops	0.5	9	1	1
Other	4.5	7	18	16

Vineyards are the next most important form of agricultural land use of the zone. They grow on rather productive soils. About 24 per cent of the vineyards of Greece are confined to the semi-arid zone. Almost all the vineyards of Attica and of the Cyclades Islands are used for the production of grapes and wine. In Argolis-Corinthia and in Crete, however, about 60 per cent of vineyards are used for the production of raisins and

about 40 per cent for the production of grapes and wine.

The semi-arid zone includes about 9 per cent of the total olive plantation of the country. Olive trees usually grow on dry and relatively unproductive soils. In many cases they grow on Lithosols with steep slopes and on gravelly colluvial and alluvial deposits.

About 17 per cent of the total citrus fruit plantations are located in the semi-arid zone. They usually occupy productive soils in the valleys. Many of the plantations are irrigated.

The lowland pastures are of poor quality and severely overgrazed. They commonly occupy dry unproductive and eroded soils. Many of these areas once supported productive forests.

TABLE 5. Average production of certain agricultural crops in the semi-arid zone

Province	Wheat (kg./hect.)	Barley (kg./hect.)	Oats (kg./hect.)	Citrus fruits (tons/ 1,000 trees)
Cyclades Islands	700	1 260	673	26.4
South-eastern Crete	460	885	620	18.4
Greece (average)	1 100	1 400	1 155	20.0

Table 5 shows that the wheat production per hectare is quite low and the returns to wheat farming in this area are much lower than in other parts of the country. Considering the surplus of wheat in Greece, its production in the semi-arid zone is rather unprofitable. The other agricultural crops occupy relatively productive soil sites and are commonly grown in their natural environment.

The productivity of the soils in the area can generally be improved by irrigating and fertilizing them. At present, irrigated agricultural land amounts to about 6 per cent in Attica, 17 per cent in Argolis-Corinthia and 8.5 per cent in the Cyclades Islands.

The average size of the family farm in the semi-arid zone is about 2.8 hectares, compared with 3.1 hectares in the entire country. Each farm, however, consists on the average of seven isolated pieces. These figures show that a drastic reduction in the farm population of Greece and proper soil management are urgently needed.

FOREST LANDS

There are two kinds of forests in the semi-arid zone: pine forests and chaparral forests. The pine forests (*Pinus halepensis*) are the more important of the two in the economy of the area. However, owing to grazing, forest fires, poor management and man's other destructive activities, the majority of the stands are understocked and of poor quality. Therefore, timber production is very low. The economic importance of the

pine forests lies in the production of turpentine, which provides an additional income to the local rural population (Table 6).

Table 7 shows that private ownership of the pine forests is preferable to public ownership.

TABLE 6. Relative distribution of forest species in the semi-arid zone

Province	Percentage of the total forest land		
	Pine	Chaparral species	Other species
Attica	67	31	2
Argolis-Corinthia	74	24	2
Cyclades Islands	4	95	1
South-eastern Crete ¹	48	35	17

1. The values are for the whole island of Crete.

TABLE 7. Average timber stock in cubic metres per hectare

Province	Pine forest		Chaparral forest	
	Public	Private	Public	Private
Attica	29	48	1.3	1.9
Cyclades	2.5	36	1.0	1.0

PARTIALLY FORESTED AND GRAZED LANDS

Partially forested and grazed lands make up the less intensively used and less productive part of the zone excluding the areas of barren rocks. The soils of these lands are mainly Group A and the eroded, unproductive, dry, gravelly soils of Group B. The forest vegetation is so sparse that it is of little economic value. Due to overgrazing, soil erosion and general low productivity, the grazing capacity of the area is quite low. The area is grazed mainly by sheep and goats. Numbers of sheep and goats in each of the provinces are as follows:

	Sheep	Goats
Attica	158 000	86 000
Argolis-Corinthia	187 000	175 000
Cyclades Islands	58 000	61 000
South-eastern Crete	129 000	100 000

Plantations of *Ceratonia siliqua* (carob tree) mixed with pines are common in these lands in Crete.

This low-income form of land use is extensive in the semi-arid zone and especially in the Cyclades Islands, where it includes about 63 per cent of the total land area. Productivity of the land can be increased to some extent by reduction of grazing and increased reforestation and by more systematic cultivation of the carob tree.

INDUSTRIAL AND RESIDENTIAL LANDS

Industrial and residential use of land is important only in the vicinity of Athens and Piraeus. The size of these two cities is rapidly increasing. The increase will continue as more people arrive from the rural areas and the number of privately owned cars increases.

CONCLUSIONS

The semi-arid zone of Greece is very important to the general economy of the country. It includes the principal industrial trade and population centres of the country.

The vineyards, olive groves and citrus plantations of the zone produce a significant fraction of the total agricultural production in the country. Large areas of the zone include idle barren rocks and partially forested and grazed lands of low productivity. The farm population is quite dense, and therefore the average farm is small. Decrease of the rural population and improvement in the management and use of land is urgently needed.

Wheat production must be reduced in favour of forage crops. The productive and relatively level soils of the partially forested lands should be reclaimed and used for the production of agricultural crops. Extensive reforestation is recommended for most of the partially forested and grazed lands. The introduction of carob trees in these lands must also be stimulated. Unproductive and severely eroded soils, at present used for the production of grains, should be reforested. Goats should be gradually eliminated from areas where productive forests could grow.

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DISCUSSION

H. M. GAUSSEN. La carte bioclimatique de l'Unesco-FAO montre une répartition de l'aridité très analogue à celle qui vient d'être présentée. La carte bioclimatique est établie d'après le nombre de jours biologiquement secs. Les parties les plus arides sont en Crète, aux îles Cyclades, en Attique. Puis les îles Zante et Cephalonie, Larissa, Salonique, Kayal.

N. J. YASSOGLOU. I agree with Professor Gausсен except for the islands of Zante and Cephalonia which belong to the subhumid zone.

The meteorological stations of Thessaloniki and Larissa are located in the transitional zone between the subhumid and the semi-arid zones.

P. MEIGS. Dr. Yassoglou has given us a valuable picture of the distribution and character of the semi-arid zone of Greece.

I should like to ask him, in what sense does he use the term "chaparral", which in California refers to a brushy vegetation, rather than a true forest.

N. J. YASSOGLOU. The term "chaparral" refers to a brushy vegetation similar to that of California. However, it must be pointed out that this vegetation is not limited to the semi-arid zone of Greece but also extends to the subhumid zone.

H. NIEDERBÖSTER. What is the reason for the high percentage of barley in the Cyclades Islands and that of forage crops in Attica? Which are the forage crops grown? Which rotation systems are used? In view of the high percentage of forage crops the low yield of wheat is astonishing. I should therefore like to know something about the farming systems, rotation, the use of fertilizers and perhaps about irrigation if employed in farming systems with a high percentage of forage crops.

N. J. YASSOGLOU. The high percentage of barley in the Cyclades Islands is due to severe soil limitations such as dryness, stoniness and shallowness which make the growth of other crops unprofitable. There are also traditional reasons for the high acreage of barley.

Forage crops which are grown on the dry soils of the semi-arid zone are mainly oats and barley. These crops are harvested when green. Legumes are grown on irrigated soils. Therefore forage crops do not aid in the fertility of the dry soils of the semi-arid zone.

Fertilization practices have not been systematized as yet. A tremendous amount of research work is presently needed for a scientific formulation of the proper fertilization of our soils.

P. MONBEIG. Je désirerais savoir sur quels critères se pose la définition de « population urbaine » dans la communication de MM. Yassoglou, Catacousinos et Kouskolekas. Il est essentiel de savoir très exactement ce que l'on entend par « ville ». D'autre part le phénomène urbain a en Attique une importance telle qu'il est difficile de comparer cette région avec les autres contrées de la Grèce semi-aride.

N. J. YASSOGLOU. We have distinguished the rural from the urban population according to the 1950 census of Greece as follows:

Rural population includes the farmers and rangers and all those who live with the owner of the farm and work on it. Farm workers who do not belong to a farm family are not included in the rural population. The rest of the population of the country is characterized as urban.

The high percentage of the urban population in Attica is self-explanatory because of the presence of the Athens-Piraeus complex.

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L'UTILISATION DU SOL DANS LES MONTAGNES DE L'ATLAS

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LES CONDITIONS NATURELLES ET HUMAINES

Les montagnes de l'Atlas, qui accidentent la plus grande partie de l'Afrique du Nord ou Maghreb, ont des conditions physiques si variées que leur utilisation par les hommes est elle-même très diverse. Des facteurs historiques interviennent pour accroître encore cette diversité.

Du détroit de Gibraltar au détroit de Sicile, les chaînes du Rif et de l'Atlas tellien bordent la Méditerranée sur plus de 1 500 kilomètres, à une latitude variant de 35° à 37°, avec des altitudes de 1 000 à 2 400 mètres. Le Haut Atlas marocain, dont quelques sommets atteignent 4 000 mètres, est sensiblement plus méridional; il se prolonge par l'Atlas saharien d'Algérie qui culmine dans l'Aurès à 2 331 mètres; les chaînes de cet Atlas saharien viennent rejoindre les chaînes du Tell dans le nord-ouest de la Tunisie et couvrir l'ensemble de ce dernier pays. La latitude de ce deuxième alignement de montagnes est comprise entre le 31° parallèle sur les bords de l'Atlantique et le 37° parallèle sur le détroit de Sicile. Le Moyen-Atlas et les monts du Hodna relient les deux grands alignements montagneux que séparent ailleurs la Meseta marocaine et les hautes plaines algéro-marocaines. L'Anti-Atlas, au Maroc, dépasse 2 000 mètres et atteint le 29° parallèle, tandis qu'à l'est l'arc montagneux tuniso-tripolitain domine modestement les plaines du golfe de Gabès sur le 32° parallèle.

Il résulte des différences d'exposition, de latitude et d'altitude que l'Afrique du Nord comprend :

1. Des montagnes humides ou sub-humides recevant plus de 600 mm de pluies annuelles (Rif occidental et central, Moyen-Atlas et Massif central marocains, Atlas tellien depuis les monts de l'Ouarsenis et de Miliana jusqu'à Bizerte).
2. Des montagnes semi-arides arrosées par 400 à 600 mm de pluie (Haut-Atlas, Atlas tabulaire d'Oranie, Aurès, dorsale tunisienne).

3. Des montagnes arides recevant de 150 à 400 mm de pluie (Anti-Atlas, Haut-Atlas oriental, Atlas saharien, arc tuniso-tripolitain). Seules les parties méridionales de ce dernier et l'Anti-Atlas atteignent la zone aride désertique.

La structure et le relief introduisent d'autres différences. L'Atlas tellien et le Rif forment un ensemble complexe de terrains sédimentaires épais et fortement plissés, avec des débris du socle primaire et des nappes d'écoulement vers le sud. L'érosion, accélérée par la proximité du niveau de base méditerranéen et des pluies souvent abondantes, a profondément découpé les masses d'argiles, de marnes et de flysch, laissant en relief des bancs de grès et surtout de calcaires que les oueds recoupent en gorges escarpées. La circulation est partout difficile sauf dans quelques dépressions longitudinales comme le sillon qui se creuse de Bougie à Médéa ou la vallée du Chélif inférieure.

Le Haut-Atlas occidental résulte d'un pli de fond récent qui a porté le soubassement primaire fait de roches cassantes à plus de 4 000 mètres. Ce soubassement s'enfonce vers le nord-est sous les plis de surface des sédiments jurassiques et crétacés du Haut-Atlas oriental, du Moyen-Atlas et de l'Atlas saharien. Aux approches de l'Aurès, dans l'Aurès et dans le Tell tunisien les plis ont affecté une grande épaisseur de sédiments qui vont du trias au miocène. Tandis que le relief du Haut-Atlas occidental se résout principalement en crêtes et en vallées profondes, avec des cols élevés, les formes structurales, souvent très évoluées, l'emportent dans le Haut-Atlas oriental et l'Atlas saharien : les montagnes, calcaires ou gréseuses, sont séparées par de larges glacis d'érosion et des plaines de remblaiement qui rendent presque partout la circulation aisée.

Quant à l'Anti-Atlas, très massif, et à l'arc tuniso-tripolitain, bien plus modeste, ils appartiennent à la plate-forme saharienne. Celle-ci est portée à plus de 2 000 mètres dans l'Anti-Atlas et elle reste masquée, dans le Sud tunisien, par des terrains sédimentaires que découpe une longue cuesta en arc de cercle.

Les conditions climatiques et structurales, si variées soient-elles, font des montagnes de l'Atlas des montagnes pauvres et fragiles avec, surtout au nord, des versants exposés aux ravinements d'oueds torrentiels, aux glissements de terrain et aux éboulements. Fragiles aussi, hors de la zone humide, sont les forêts, parce qu'elles sont exposées à la sécheresse et, depuis des millénaires, aux déprédations des animaux et des hommes. Plus fragiles encore sont les sols, sols squelettiques tout au plus, qui rendent la culture ingrate et peu productive.

Et pourtant les montagnes ont l'avantage d'avoir des ressources variées et d'offrir aux hommes, selon l'altitude, toute une gamme de possibilités : cultures d'arbres (des palmiers aux noyers en passant par les arbres méditerranéens types comme l'olivier et le figuier, l'abricotier également) ; cultures, sans doute médiocres, de céréales (céréales d'hiver mais aussi, avec l'irrigation, céréales d'été et légumes) ; maquis étendus et variés et aussi gazons des hautes montagnes propices à l'élevage ; forêts qui offrent aussi bien des pâturages que du bois de feu et du bois d'œuvre pour les instruments de travail et les habitations. De plus les montagnes sont plus arrosées que les plaines, souvent steppiques sinon désertiques, qu'elles dominent et l'irrigation s'y trouve favorisée. Les températures d'été sont adoucies tandis qu'elles sont parfois torrides dans le bas. Les hivers sont rudes, il est vrai, avec d'abondantes chutes de neige au-dessus de 2 000 mètres ; mais le climat est sain, ignorant la tiède moiteur des régions littorales et le paludisme, du reste en recul, des basses plaines.

Aussi ne faut-il pas s'étonner que les montagnes atlasiques aient toujours eu une population relativement dense. Mais l'histoire a introduit dans le classement des montagnes une nouvelle diversité.

Les montagnes les plus massives sont pour la plupart restées à l'écart des dominations étrangères et même des États locaux ; elles ont évité les invasions, les conquêtes et les transferts de tribus. Elles sont restées plus ou moins indépendantes. Repliées dans leurs vallées et sur leurs crêtes, leurs habitants sont restés fidèles à une vieille vie villageoise et à une économie fondée en grande partie sur l'arboriculture, sèche ou irriguée, sur un élevage plus ou moins transhumant et sur une céréaliculture faite surtout au pied des montagnes. Car c'est un caractère original des sociétés montagnardes de l'Atlas que de déborder souvent sur le piedmont de leurs massifs qui sert également de pâturage d'hiver pour une partie du bétail. Ces sociétés montagnardes ont assimilé les groupes venus de l'extérieur : conquérants, réfugiés ou familles maraboutiques. Ils sont presque tous restés berbérophones et fidèles à certaines coutumes qui ne doivent rien à l'islam ni à l'arabisation. Leur densité est forte et la propriété très morcelée. La colonisation européenne n'a pu pénétrer que dans quelques vallées et bassins. Tels sont : les Chleuh de l'Anti-Atlas et du Haut-Atlas occidental ; les habitants de la chaîne rifaine, dont cependant les Djebala sont

arabisés ; les Beni Snassen et les Trara ; les Aurasiens et les Kabyles, bien que les Kabyles de l'Est soient arabisés.

Il est, par contre, des régions montagneuses qui ont été conquises ou submergées lentement par des étrangers, presque toujours par des tribus nomades venues du sud, arabisées ou non. Ces tribus n'ont pas pu pénétrer les montagnes massives défendues par leur relief jeune, mais seulement celles que leurs formes protégeaient mal : plateaux de l'Atlas tabulaire orano-marocain et arc tuniso-tripolitain où subsistent cependant de petits noyaux berbérophones ; Haut-Atlas oriental, où les dépressions élargies par des glaciais ouvraient des couloirs d'invasions, et Moyen-Atlas aux larges synclinaux et aux vastes plateaux porteurs de beaux pâturages ; Atlas saharien d'Algérie, sauf l'Aurès, dont les chaînes sont isolées par des glaciais et de larges dépressions et qui a été presque totalement arabisé. Dans toutes ces régions la vie agricole, autrefois moins réduite, a reculé devant la vie pastorale et le nomadisme.

Mais les conditions naturelles nuancent cette opposition entre montagnes villageoises et agricoles et montagnes pastorales : l'élevage est une ressource pour les villageois et les pasteurs n'ignorent pas l'agriculture.

IMPORTANCE DE L'AGRICULTURE

La latitude déjà fortement méridionale des montagnes de l'Atlas, en particulier de celles du sud, permet à la culture de s'élever parfois très haut et de couvrir les surfaces relativement grandes. L'olivier croît jusqu'à 1 000 mètres dans la Kabylie du Djurdjura et jusqu'à 1 500 mètres dans le Haut-Atlas de l'Ouest ; dans celui-ci les noyers poussent jusqu'à 2 200 mètres et l'on cultive l'orge jusqu'à 2 800 mètres. L'agriculture paraît s'être parfois d'autant plus développée dans certaines montagnes qu'elle reculait dans les plaines devant les invasions, les guerres ou une insécurité larvée.

La pauvreté et la minceur des sols, la pente, mais aussi une bonne pluviosité ou des possibilités d'irrigation, font des montagnes des milieux plus favorables à l'arboriculture qu'aux céréales ; d'autant plus que les arbres méditerranéens (oliviers et figuiers principalement, mais aussi abricotiers, amandiers et noyers) produisent des fruits beaucoup plus importants pour l'alimentation des hommes que les arbres fruitiers des régions tempérées atlantiques.

L'olivier est notamment l'arbre de la Kabylie occidentale : son huile est presque le seul corps gras utilisé et le principal produit d'échange. Mais le Rif (en particulier les Djebala), le Haut-Atlas de l'Ouest et les Trara lui consacrent également d'importantes surfaces. Le figuier est l'arbre nourricier par excellence des Kabyles de l'Ouest qui manquent de grain ; on le retrouve dans toutes les montagnes. L'amandier est particulièrement répandu dans le Rif oriental, déjà aride, et dans l'Anti-Atlas. L'abricotier, très rustique

mais le plus souvent arrosé, se multiplie dans les jardins des altitudes moyennes : ceux de l'Atlas saharien, notamment ceux de l'Aurès ; ses fruits séchés servent de condiment. Quant au noyer, il est l'arbre des hautes vallées du Haut-Atlas et de l'Aurès. Les grenadiers, très résistants, les pêchers, la vigne et, en altitude, de médiocres pommiers et des poiriers jouent un rôle beaucoup plus faible dans l'alimentation des montagnards.

La plupart de ces arbres (les oliviers, les figuiers et les amandiers en particulier) ne sont pas irrigués dans le Tell et le Rif. Mais, contrairement à bien d'autres contrées méditerranéennes, les habitants de ces montagnes ignorent, pour la culture sèche, les champs en terrasses ; malgré les précautions parfois prises, par les Kabyles de l'Ouest en particulier, les vergers des versants sont de médiocre rapport et exposés à l'érosion.

Il n'existe de champs en terrasses que pour les cultures irriguées. Et celles-ci ne sont étendues que dans les régions où l'irrigation est nécessaire et où la terre végétale, rare, doit être retenue par des murettes de pierres sèches, c'est-à-dire dans les montagnes pré-sahariennes. Les plus belles terrasses s'observent dans le Haut-Atlas occidental où elles montent à l'assaut des versants ; celles de l'Aurès, dans des vallées souvent plus évasées, s'éloignent moins des fonds. Un peu partout les eaux de source descendent sur un éventail de terrasses étagées. Celles du Sud tunisien retiennent les rares eaux de ruissellement en même temps que la terre. Dans le Rif et le Tell seuls les jardins irrigués sont des pentes construites en terrasses au pied des sources les plus importantes, à Chaouen comme à Taza, à Tlemcen aussi bien qu'à Miliana, au Kef et à Teboursoek.

Partout l'irrigation sert également à d'autres cultures, notamment à des cultures maraîchères d'hiver et d'été : pommes de terre, carottes, navets et oignons, cucurbitacées, tomates et piments.

Les céréales — les céréales d'hiver surtout qui sont de beaucoup les plus étendues puisque, sauf exception, les céréales d'été ont besoin d'être arrosées — sont médiocrement adaptées aux sols pauvres et minces qui ne retiennent pas l'eau et où elles s'enracinent peu. Les labours, qui sont un simple grattage à l'araire, ne favorisent heureusement pas trop l'érosion.

L'orge, plus encore que le blé dur auquel on réserve les meilleurs terrains, est la céréale des montagnes ; le seigle n'est cultivé que dans les régions les plus élevées du Haut-Atlas. Le blé tendre et l'avoine, introduits par les Européens, n'ont pas gagné les montagnes. Les céréales d'hiver ne sont presque jamais irriguées dans le Tell et le Rif central et occidental ; elles ne le sont pas toujours dans les montagnes du Sud comme le Haut-Atlas et le versant nord de l'Aurès. Dans les montagnes méridionales on leur consacre généralement le surplus hivernal des eaux d'irrigation qu'on réserve jalousement en été au maïs, au sorgho, aux légumes et aux arbres. Du reste les champs de blé et d'orge ne s'étalent vraiment qu'au pied des montagnes où l'on dérive une

partie du débit des oueds : ainsi le Sous et le Dir au Maroc, le Charâ et le Sahara pour l'Aurès.

Les légumineuses telles que les fèves et, dans le Haut-Atlas, les lentilles, sont cultivées en sec dans le nord et dans des jardins irrigués dans le Sud.

Partout les surfaces cultivées s'étendent aussi bien dans les montagnes pastorales que dans les vieilles régions agricoles.

L'ÉLEVAGE ET LES MONTAGNES PASTORALES

Les possibilités qu'ont les agriculteurs d'étendre leurs champs ou leurs plantations sur les hauteurs restreignent parfois singulièrement les surfaces disponibles pour le bétail. C'est ainsi que les Kabyles de l'Ouest, dont la montagne est presque totalement cultivée à l'exception des grès couverts de forêts, ne peuvent avoir que très peu de petit bétail ; les paires de bœufs nécessaires aux labours sont ordinairement achetés avant les semailles et revendus ensuite, à moins qu'ils ne soient simplement loués. Certains arbres comme les frênes surtout, les micocouliers, les ormes et même les figuiers sont effeuillés pour nourrir le bétail. Seuls les villages voisins des crêtes calcaires ou des forêts ont quelques petits troupeaux.

L'élevage est moins réduit chez les Kabyles de l'Est et chez les habitants des clairières forestières des environs de Bône et de Krourimie, car si les cultures sont concurrencées par la forêt, celle-ci est utilisée par le bétail. Il en est de même dans l'Ouarsenis.

L'élevage prend plus d'importance chez les Chleuh du Haut-Atlas et chez les Chaouia de l'Aurès ; c'est parfois leur principale ressource. Chez les Chleuh, notamment, la richesse des gens se juge à leur tas de fumier, fumier indispensable par ailleurs aux cultures irriguées. Dans le Haut-Atlas occidental les chèvres restent aux environs des villages, de même que les brebis, tout au moins dans les basses et moyennes vallées où la stabulation est pratiquée. Mais les ovins des villages de montagne descendent en automne, sous la conduite de bergers, dans les plaines du Sous et du Haouz. Cette transhumance d'hiver, descendante, est doublée d'une transhumance d'été, ascendante, sur les tichka, hauts pâturages où les moutons rencontrent les bovins. Ceux-ci, nourris à l'étable de foin et de feuilles tant qu'il y a de la neige, estivent sur les tichka avec une partie des familles : il y a donc là une forme atténuée de semi-nomadisme.

Le semi-nomadisme était un peu plus répandu dans l'Aurès avant la rébellion de 1944. Les Chaouia connaissent aussi la transhumance descendante de l'automne, mais les familles des villages des hautes vallées accompagnaient leurs troupeaux de moutons et de chèvres au pied de l'Aurès : au Charâ au nord et au Sahara au sud. Par contre, la transhumance ascendante de l'été n'était accompagnée que par les bergers

et quelques familles. Le semi-nomadisme était plus répandu que chez les Chleuh tout en n'intéressant qu'une minorité de la population.

Les Djebala (montagnards) du Sud tunisien et de Tripolitaine suivent en partie leur petit bétail dans ses modestes déplacements entre la plaine de la Djeffara et le plateau appelé Dahar, de part et d'autre des vallons du Djebel où se concentrent les cultures et les villages.

L'élevage et la vie pastorale deviennent prépondérants dans les montagnes qui ont été occupées par des tribus nomades du Sahara. La vie agricole et villageoise, avec un élevage plus ou moins important, a reculé devant la vie nomade et pastorale. Dans le Haut-Atlas calcaire les troupeaux hivernent dans les vallées et les dépressions où se localisent les cultures irriguées et transhumant en été, avec les familles, sur les pâturages de haute montagne que fréquentent également les Sahariens Ait Atta et leur petit bétail.

Le Moyen-Atlas, montagne humide beaucoup plus riche en pâturages et en eau, a été, jusqu'aux premières années du siècle, la plus belle montagne pastorale du Maghreb. Il connaissait une transhumance descendante d'automne assez générale vers les plaines et les dépressions qui l'entourent, et une transhumance ascendante d'été plus limitée. Les populations pratiquaient un semi-nomadisme lié à la descente des troupeaux et à la culture d'été en montagne; les bergers étaient le plus souvent seuls à accompagner les troupeaux sur les alpages. Les bovins, nombreux ici, participaient à la double transhumance et les gens chargeaient leurs tentes et leur matériel sur des bœufs porteurs. Depuis trente à quarante ans les déplacements des troupeaux se sont restreints et le semi-nomadisme fait place peu à peu à la simple transhumance.

Des abris sont construits pour le bétail, les cultures de céréales s'étendent en montagne et bien des tentes sont remplacées par des habitations fixes. L'évolution est, et a été, semblable dans le massif central voisin.

C'est dans l'Atlas saharien, série de massifs arides, sauf l'Aurès, que l'emprise des nomades a été la plus forte. Si quelques villages (ksour, sing, ksar) subsistent auprès de jardins irrigués, la vie se résume essentiellement en un lent va-et-vient des troupeaux et des hommes, des pâturages sahariens où ils hivernent aux hauteurs de l'Atlas où ils passent de quatre à six mois. Ainsi vivent les Ouled Sidi Cheikh, les Ouled Nail du Sud et, plus loin vers l'est, les Nememcha. Les Amour sont plutôt des éleveurs de montagne qui hivernent avec leur bétail sur la frange saharienne. Mais, presque partout, les cultures de céréales s'étendent en montagne, et plus d'un pasteur confie maintenant ses bêtes à un berger. Depuis 1956, transhumance et nomadisme sont gênés par la rébellion et la répression.

LES FORÊTS

Tandis que, pour les uns, l'agriculture est la principale ressource et que, pour d'autres, c'est l'élevage, et tandis

que pour certains ces deux ressources s'équilibrent, les forêts, sans être une richesse comparable, sont un mode partiel mais non négligeable de l'utilisation du sol, principalement dans les massifs voisins de la Méditerranée. Elles occupent, Sahara exclu, 16 % de la surface du Maroc, 12,5 % en Algérie et 9,5 % en Tunisie. Le faible taux de boisement s'explique davantage par le très ancien peuplement du Maghreb et par l'augmentation récente et rapide de sa population que par les conditions naturelles.

Comme dans bien des pays méditerranéens les forêts sont d'abord un pâturage et cela aussi explique leur dégradation. On peut estimer grossièrement qu'un tiers du cheptel au Maroc, un quart en Algérie et un huitième en Tunisie vit en presque totalité ou, plus souvent, partiellement de la forêt. Or il n'existe pas de porcs pour utiliser les glands des nombreuses forêts de chênes; ce sont des bêtes impures aux yeux des musulmans. Et les chèvres, qui les remplacent en partie, sont les pires ennemis des forêts dont elles sont théoriquement exclues.

Pas de châtaigniers non plus, pas de cet arbre nourricier important au point de donner son nom à des régions de montagnes méditerranéennes. Les hommes des forêts de l'Afrique du Nord se contentent de greffer les oliviers sauvages là où ils existent, et les plus misérables mêlent à de la farine d'orge l'indigeste farine faite de gland grillé et écrasé.

Bien entendu la forêt est productrice de bois, mais d'un bois de faible valeur qui, pour les deux tiers, est utilisé comme combustible. Le pin fournit des poteaux de mines, des charpentes de faible portée, des traverses de chemins de fer, et est aussi utilisé pour la fabrication de caisses; seuls les chênes à feuilles caduques, peu nombreux, les cèdres et les thuyas sont de bons bois d'œuvre et de menuiserie.

La forêt fournit aussi un peu de tan et de résine (Ouarsenis), mais son seul produit de valeur est le liège, qu'on exploite dans les forêts qui s'étendent de la Kabylie occidentale à Bizerte et dans le Maroc du Nord. Elles couvrent 923 000 hectares, soit une surface plus grande que les forêts espagnoles et portugaises réunies. Par contre, l'alfa des montagnes sèches n'est pas exploité.

LES DIFFÉRENTS TYPES DE MONTAGNES

La diversité de l'utilisation du sol par la culture, l'élevage et la forêt nous permettent de préciser quatre types de montagnes.

1. Montagnes d'agriculteurs sédentaires et villageois faisant une place importante à l'arboriculture et diverse à l'élevage. Elles abritent des sociétés fortement organisées et presque toutes restées berbérophones; le peuplement est dense et l'émigration forte. En font partie: a) la Kabylie de l'Ouest qui vit

- presque exclusivement d'une arboriculture sèche pratiquée sans terrasses, mais dont la principale ressource est souvent l'émigration dans les villes ou en France; s'en rapprochent l'Atlas mitidjian, les monts de Miliana et les Trara; b) la chaîne rifaine dont l'économie est plus équilibrée, sauf dans l'Est, trop sec, avec une arboriculture sèche et quelquefois irriguée, un élevage bovin et ovin et des forêts; c) l'Anti-Atlas et le Haut-Atlas occidental qui ont diverses cultures irriguées sur terrasses et un élevage important, difficile dans l'Anti-Atlas, trop sec, mais avec les possibilités d'une double transhumance dans le Haut-Atlas; les Chleuh émigrent beaucoup vers le Maroc atlantique et surtout vers les villes.
2. Montagnes forestières à économie agropastorale de clairières. L'élevage du petit bétail l'emporte dans l'Atlas tabulaire orano-marocain et dans l'Ouarsenis; chez les Kabyles de l'Est et leurs voisins orientaux, l'activité se partage entre l'élevage bovin, la culture de l'orge, du sorgho et de quelques oliviers et le travail en forêt; partout la population, arabisée,

est peu cohérente et pauvre et se disperse en hameaux; l'émigration est importante.

3. Montagnes d'agriculteurs villageois chez qui l'élevage entraîne des déplacements partiels de la population. En font partie: a) l'Aurès, dont les habitants, les Chaouia, vivent un peu comme les Chleuh du Haut-Atlas, mais avec un semi-nomadisme partiel doublant la transhumance d'hiver, normalement très importante dans les hautes vallées; b) l'arc tuniso-tripolitain dont les villageois suivent souvent leurs troupeaux dans leurs faibles déplacements et qui émigrent à Tunis.
4. Montagnes pastorales où l'élevage transhumant est la principale ressource et s'accompagne de nomadisme. Ce sont: a) le Moyen-Atlas et le Massif central marocains, où la vie pastorale et nomade est en recul devant l'extension des cultures et de l'élevage sur place; b) le Haut-Atlas oriental et l'Atlas saharien (l'Aurès excepté) où, malgré le progrès des cultures, la vie reste rythmée par le va-et-vient des troupeaux et des nomades entre le piedmont saharien et la montagne; l'émigration est faible.

DISCUSSION

H. M. GAUSSEN. La question de la spontanéité du châtaignier est encore mal connue des botanistes. Les grandes régions de châtaigniers sont, en France, par exemple, surtout autour des régions viticoles, car les taillis de cet arbre donnent le bois utilisé pour la « vaisselle vinaire »: tonneaux, comportes, etc. Elles sont dans des montagnes siliceuses assez humides, Cévennes, Corse où le fruit a longtemps été la base de l'alimentation. Il y a actuellement une nette décroissance dans la consommation des châtaignes. En Afrique du Nord seule la région de l'Edough comporte beaucoup de châtaigniers. L'absence d'élevage du porc est peut-être à considérer pour des pays musulmans.

L'action de l'homme sur la forêt est fondamentale mais parfois on l'accuse à tort. Certains creux dépourvus de cèdres ne sont pas dus au déboisement mais à la présence de « creux à gel », comme l'a montré M. Pujos au Maroc.

H. AWAD. La dégradation de la forêt peut être également la conséquence de certaines orientations peu favorables à la conservation d'un manteau colluvial d'âge quaternaire. C'est le cas notamment de la cédraie du Moyen-Atlas.

D. K. H. AMIRAN. The presentation of Professor Despois showed the overriding importance of mountain areas in semi-arid agricultural economy. This is very typical of most semi-arid areas.

Are fruit trees on untterraced mountain land grown on specific soils or on every type of soil?

Is there in the Atlas Mountains a process of transition from the nomadic way of life to a non-nomadic, especially urban, way of life?

J. DESPOIS. Les cultures arbustives sont caractéristiques de toutes les montagnes de l'Afrique du Nord, sauf celles qui ont été gagnées par la vie pastorale et nomade au cours des huit derniers siècles (exemple: le Moyen-Atlas).

L'absence de terrasses de culture pourrait localement s'expliquer par la nature du sol (pour l'argile par exemple). Mais, en fait, il n'y a de terrasses de culture que lorsqu'il y a irrigation proprement dite ou utilisation des eaux de ruissellement: petits jardins des montagnes humides du Tell — cultures irriguées, les seules qui existent, dans les montagnes présahariennes arides. Les exemples sont très rares et alors récents de terrasses pour la culture sèche (collines à l'est de Bizerte en Tunisie).

Dans les montagnes arides gagnées par la vie pastorale et nomade, les cultures arbustives sur les terrasses irriguées ont reculé et ne se sont maintenues qu'en petits îlots auprès des villages (ksour) qui ont survécu. Elles sont beaucoup plus répandues dans les massifs les moins accessibles où les populations villageoises ont résisté aux nomades (Aurès, Haut-Atlas de l'Ouest).

Il n'y a pas de villes dans les montagnes nord-africaines sinon, parfois, sur leur bordure (exemple: le dir du Maroc). Les modes de culture qui les entourent diffèrent peu de ceux des villages.

P. MONBEIG. Je voudrais simplement dire l'importance de la communication de M. Despois dans l'ensemble de nos travaux. L'utilisation du sol ne dépend pas seulement des conditions naturelles et peut-être les exposés que nous avons entendus jusqu'à maintenant l'ont-ils trop négligé. Il est heureux que M. Despois nous rappelle que l'utilisation du sol dépend aussi des civilisations et des économies actuelles.

X. DE PLANHOL. A propos de la culture en terrasses, je pense qu'une explication assez générale de leur présence ou de leur absence doit être cherchée dans l'origine des populations montagnardes. Technique savante, liée aux nécessités d'irrigation à l'origine, elle est certainement née dans les steppes semi-arides et n'a été appliquée que par la suite aux montagnes

humides ou sub-humides. Sa présence dans le Liban s'explique par l'origine des Maronites en Syrie intérieure. Son absence dans la plus grande partie des montagnes telliennes d'Afrique du Nord peut être due à l'origine locale des populations qui les habitent.

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L'UTILISATION DU SOL DANS LA RÉGION SEMI-ARIDE DE L'ESPAGNE

par

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Pour la délimitation des régions aride et semi-aride, nous avons suivi la classification du climat de Thornthwaite, appliquée à l'Espagne par C. Tamès (fig. 1). Cette classification, bien que très utile, ne peut cependant pas représenter toute la complexité des faits climatologiques et de leurs répercussions sur l'agriculture des régions qui nous intéressent ici. Il faut, en parlant de l'aridité, examiner attentivement la précipitation moyenne annuelle et sa distribution saisonnière.

Précipitation. L'absence de pluie n'est pas une cause déterminante de l'aridité en Espagne car 1,5 % seulement de la superficie du pays (y compris les îles proches) reçoit moins de 300 mm par an, tandis que 36,5 % de cette même superficie recueillent jusqu'à 500 mm de pluie, 78 % jusqu'à 800 mm et 15 % plus de 1 000 mm par an. Donc, dans un tiers du pays, l'aridité imposera le choix des cultures et les assolements seront très limités si l'irrigation artificielle ne peut s'y implanter.

Il faut noter par ailleurs que les zones semi-arides comprennent la partie la plus plate du pays, tandis que les régions humides, la côte nord et nord-ouest et les montagnes, sont mieux adaptées aux pâturages et aux forêts qu'aux cultures de céréales, d'oliviers ou de vignobles.

Précipitation et température. La figure 1 représente les précipitations et températures moyennes mensuelles relevées pour chaque région dans plusieurs stations météorologiques.

On constate que dans toute la péninsule la pluie est distribuée entre deux maximums, l'un en automne et l'autre au printemps. Le minimum d'été est bien marqué : très réduit dans le Sud, avec beaucoup d'années sèches en juillet et en août, il est plus élevé dans le Nord, avec près de 50 mm de pluie par mois sur la côte septentrionale.

La température atteint son maximum en même temps que la pluie arrive à son minimum, ce qui rend difficile non seulement le développement, mais encore la vie

des plantes. Une des raisons de la grande superficie en jachère et de l'expansion de l'olivier et du vignoble dans la région semi-aride se trouve certainement dans cette opposition des conditions d'humidité et de chaleur pendant l'été. D'autre part, ce fait explique partout le succès de l'irrigation.

Indice d'humidité. La région aride espagnole (indice de Thornthwaite inférieur à -40) est située dans le sud-est de la péninsule (fig. 1) et comprend 3 % de la superficie nationale.

La région semi-aride (indice -40 à -20) couvre 61 % de la superficie totale, créant l'impression que l'aridité est générale en Espagne. Seulement 15 % de la superficie correspondent au climat sec subhumide (indice -20 à 0) et il ne reste que 21 % pour les climats humides (indice au-dessus de 0).

Sols. La figure 2, réduite et simplifiée, montre la distribution des sols d'après C. Tamès, suivant la classification américaine des Great Groups of Soils. Toute la région aride est occupée par le sierozem, car dans sa lithologie les terrains calcaires prédominent.

Il en est de même pour toute la moitié orientale de la région semi-aride où il y a cependant d'amples représentations des sols bruns ou burosem dans les contrées les plus humides ou tempérées, en accord avec le climat. Par contre, dans la moitié occidentale on ne trouve que des terres brunes méridionales ou bien la variété méridionale acide, ainsi que des terres rouges non calcaires méditerranéennes. Cette distribution est très importante pour les cultures sans irrigation, car ces derniers sols empêchent de cultiver certaines plantes avec succès.

Les sols alluviaux se trouvent tout au long des fleuves et des rivières et c'est là que prend place, de préférence, l'irrigation, en dehors des grandes installations hydrau-

1. L'auteur n'ayant pu présenter sa communication, seul le titre a été mentionné.

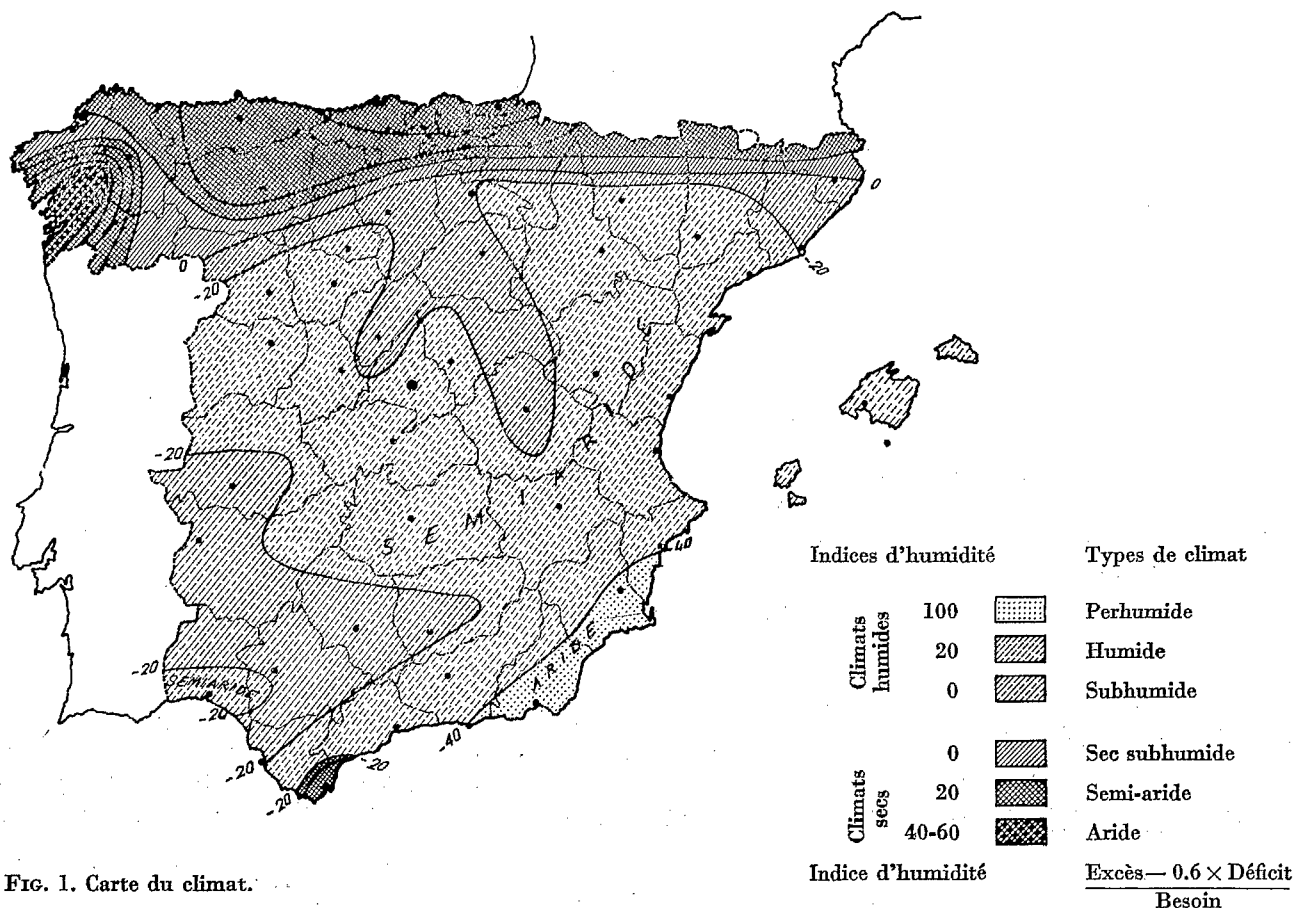


FIG. 1. Carte du climat.

liques qui arrivent à amener l'eau jusqu'aux sols développés sur les roches-mères autochtones des fonds de vallée.

Les sols salins, très fréquents dans les régions aride et semi-aride, sont distribués en taches isolées, en général dans le bassin de l'Èbre et dans le Sud-Est. On peut les classer comme solonchaks, car la solonetzisation est beaucoup moins répandue.

Les sols de montagne et les lithosols se trouvent partout, le facteur orographique étant présent presque dans toute la région considérée.

Le problème de l'érosion se pose absolument partout où le terrain n'est pas assez plat pour empêcher le ruissellement. Pendant des siècles l'érosion causée par la pluie a ravagé les terres et, en conséquence, la fertilité naturelle s'en trouve très diminuée. Souvent le fermier laboure le sous-sol, parce que le vrai sol a disparu, emporté par l'érosion. Le besoin urgent d'une solution pousse à employer non seulement les moyens traditionnels (vieilles terrasses, conduction de l'eau des « oueds »), mais encore des techniques agricoles modernes de la conservation du sol. La tâche à accomplir est énorme.

PROBLÈMES DE L'UTILISATION DE L'EAU

Nous nous bornerons ici à exposer l'emploi de l'eau pour l'irrigation ; les deux paragraphes suivants traiteront des précipitations par rapport aux cultures.

Origine de l'eau. En 1960, en Espagne, la superficie totale irriguée était de 1 851 000 hectares, dont 500 000 hectares recevant des eaux de provenance souterraine. On prévoit qu'au cours des quinze prochaines années ce total sera augmenté de 300 000 hectares.

Ce sont les cours d'eau naturels qui, pour la plupart, alimentent et alimenteront l'irrigation actuelle et future. Donc, le problème principal est la mise en valeur des cours d'eau, grâce aux grands barrages (plusieurs de plus d'un milliard de mètres cubes, et un système, le plus grand d'Europe, de plus de deux milliards de mètres cubes).

Malheureusement, les fleuves les mieux dotés en eau (l'Èbre, le Guadalquivir, le Douro et le Tage) ne permettent pas toujours d'irriguer les contrées les plus

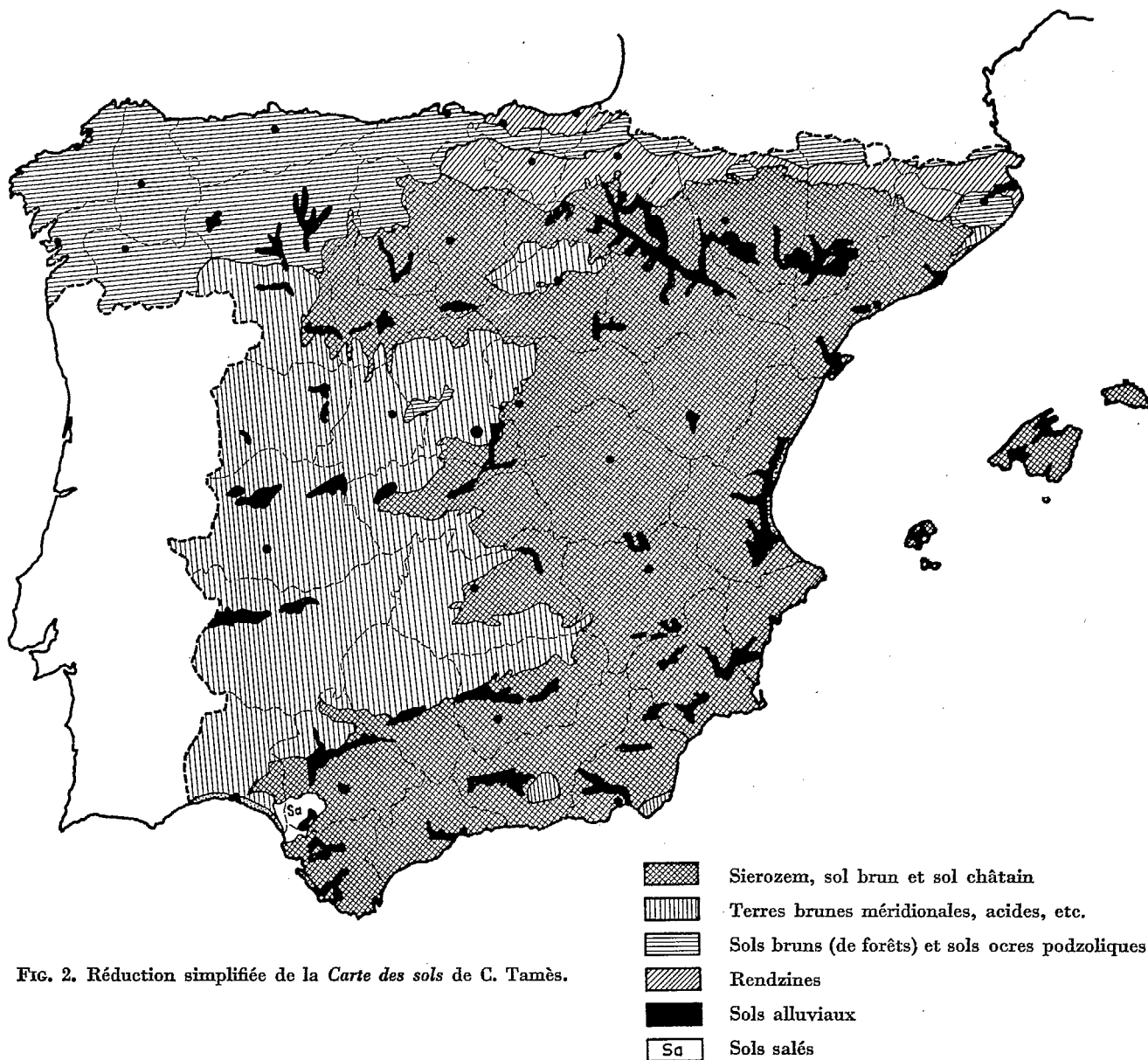


FIG. 2. Réduction simplifiée de la Carte des sols de C. Tamès.

intéressantes par leur climat et leur sol. Il y a plusieurs projets d'amener l'eau de l'Èbre et du Tage jusqu'à la côte, entre Tarragone et Almería, car les cours d'eau locaux ne suffisent pas pour l'irrigation des terres le long de la Méditerranée.

Un autre problème pressant qui se pose pour la côte dont nous venons de parler, et pour beaucoup de bassins intérieurs, est le danger qui menace les barrages : ils peuvent être rendus inutilisables à cause de la sédimentation des terres attaquées par l'érosion et amenées par les rivières jusqu'aux lacs artificiels. Cela empêche la construction de ces coûteux ouvrages dans les régions les

plus arides et peut-être les plus intéressantes en ce qui concerne la production des fruits et les cultures maraîchères. Les cours d'eau sans barrages ne peuvent servir qu'à l'irrigation occasionnelle ou temporaire, laquelle ne peut se faire que pendant le ruissellement produit par la pluie intense, lorsqu'on dirige l'eau et le sol en suspension vers les terres aménagées préalablement.

Les eaux salines ne sont pas fréquentes dans les rivières ; par contre, dans les puits des régions arides, il est facile de trouver des concentrations salines dépassant 2 à 3 grammes par litre et qui sont néanmoins employées pour l'irrigation, quelquefois avec succès.

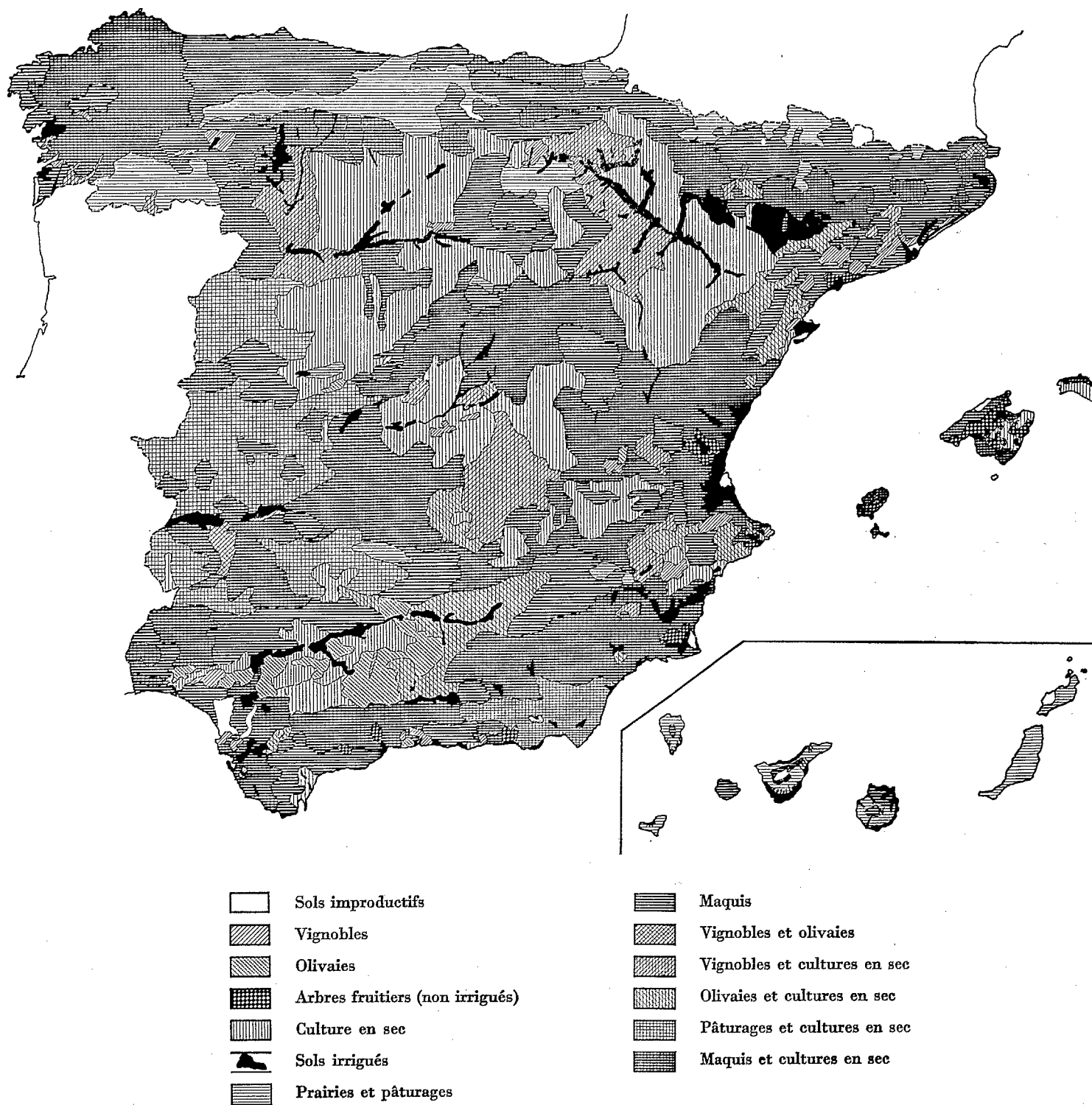


FIG. 3. Reproduction simplifiée de la carte des cultures et aménagements des sols cultivés d'Espagne.

Économie de l'eau et formation des agriculteurs. Les terres irriguées depuis longtemps apportent un bon profit aux agriculteurs.

Après un demi-siècle d'expérience, il s'est révélé absolument nécessaire que l'État organise les travaux et avance l'argent pour la construction des barrages et grands canaux, tout au moins lorsqu'il s'agit de grands ouvrages d'irrigation. Les coopératives d'agriculteurs n'arriveront jamais à les terminer. Les travaux secondaires et la préparation de la terre peuvent être effectués par les propriétaires, mais en général il est préférable qu'ils soient entrepris par les services officiels qui disposent de fonds suffisants et de machines appropriées.

La sélection des futurs fermiers et l'enseignement qui leur est donné déterminent parfois l'échec ou le succès de tous les efforts accomplis pour installer la nouvelle irrigation. Nous n'arriverons jamais à accorder toute l'attention que mérite ce point important, car il est très difficile de faire une sélection juste et efficace.

UTILISATION DU SOL DANS LA PARTIE LA PLUS SÈCHE DE LA RÉGION

Les terres classées comme « arides » reçoivent si peu de pluie que l'agriculture n'y est pas possible sans irrigation, ne serait-ce que de l'irrigation occasionnelle ou temporaire dont nous avons parlé. Une grande partie de la terre labourée bénéficie de l'eau provenant des *ramblas* (oueds) et qui est conduite pendant l'orage jusqu'au pied des amandiers ou quelquefois jusqu'au blé semé dans cet espoir. Cette méthode est si développée en Espagne que M. Hugh H. Bennett, le « père » de la conservation du sol, n'a pas caché son étonnement pendant sa visite aux environs d'Almería et de Murcie, en 1956, lorsqu'il a parcouru des milliers d'hectares parfaitement disposés à cette fin.

Il n'y a pas de problème quand on dispose d'eau pour l'irrigation permanente, car la température ne descend presque jamais au-dessous du zéro sur la côte où se trouvent les terres plates plantées d'agrumes, de riz, de canne à sucre et de beaucoup d'autres cultures printanières. La salinité est redoutable, mais on a eu des succès dans quelques travaux de récupération, grâce à l'eau de bonne qualité (par exemple, à Albatera et à Alicante). Depuis dix ans, la culture sous sable au grand air obtient un grand succès et son développement est extraordinaire, car, en limitant l'évaporation du sol, on réduit la quantité d'eau employée et, par là-même, le danger de salinisation diminue (la qualité de l'eau n'est pas toujours bonne), le sol devient plus chaud et la plante croît plus rapidement.

Les terres sans irrigation sont de vrais déserts et seul l'alfa peut s'y développer. La chèvre est le seul animal qui puisse vivre dans de telles conditions, mais sa contribution à l'épuisement de la végétation est redoutable.

L'érosion travaille très activement et la défense du sol est rendue difficile par l'intensité des pluies et la pente des terrains.

UTILISATION DU SOL DANS LA PARTIE LA PLUS HUMIDE DE LA RÉGION

Le manque de précipitations et d'azote, nécessaires pour une culture continue, oblige à laisser en jachère une énorme superficie (environ 4 millions d'hectares dans les régions aride et semi-aride). Cette jachère devient en général superflue dans les régions sèches subhumides où la pluie est plus abondante (Andalousie, occidentale) et là où l'évapotranspiration diminue (au nord de la Vieille-Castille et dans les montagnes Ibériques [voir fig. 1]).

Assolements semi-arides. En région aride on ne peut pas parler d'assolement sans irrigation. Par contre en région semi-aride les assolements reflètent avec fidélité les conditions du milieu agricole (voir fig. 4). En premier lieu vient l'assolement biennal appelé traditionnellement *año y vez*, c'est-à-dire une année de culture d'hiver suivie d'une année de jachère complète. Les cultures peuvent être seulement : blé et orge (très répandus) ou bien seigle et avoine (dans la moitié occidentale, sur les sols acides), légumineuses, fève, pois, lentille et d'autres espèces fourragères telles que *Vicia*, *Ervum*, *Lathyrus*, etc. ; le lin ne peut pousser qu'exceptionnellement sans irrigation.

Vient ensuite la culture triennale, malheureusement pas très commune : céréale d'hiver - légumineuse d'hiver - jachère. On en arrive ainsi à la culture pluriennale qu'on appelle *dehesa*, typique pour les grandes fermes de l'Ouest et qui comporte une année de culture, puis quatre, cinq, six années ou davantage, pour profiter de la pâture naturelle qui pousse après le chaume, et finalement une année de jachère pour préparer la nouvelle récolte de céréale. Le sol impose cet assolement par sa pauvreté, son manque d'épaisseur et de pouvoir de rétention, etc.

Jusqu'à présent nous n'avons pas parlé de culture d'été, car la sécheresse ne la permet que dans les contrées les plus humides ou les plus fraîches (mais pas froides) ou bien sur les sols de meilleure qualité. Là où ces conditions existent, on trouve un autre assolement biennal : céréale d'hiver et chaume - courte jachère et pois chiche et jachère. Le pois chiche (*Cicer arietinum*) est devenu une légumineuse très importante pour la nourriture humaine, occupant plus de cent mille hectares dans la région semi-aride.

Enfin mentionnons l'assolement triennal dit « au tiers » qui est une prolongation du biennal avec une dernière année de pâturage.

Tous ces assolements dépendent étroitement des disponibilités en eau pour les plantes. Il s'avère que

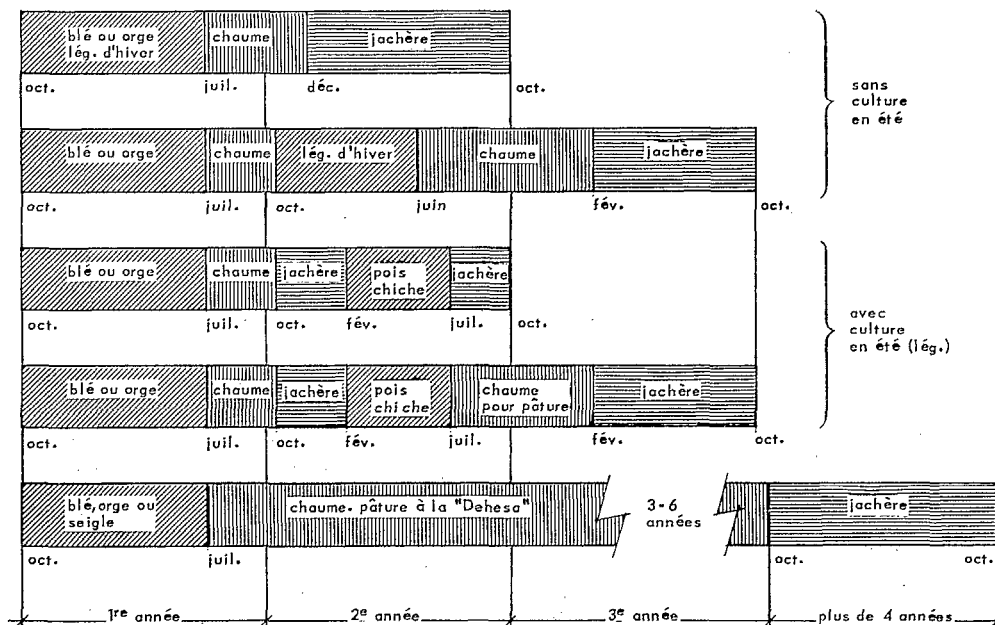


FIG. 4. Principaux assolements dans la région semi-aride.

la conservation du sol liée à l'emploi de l'eau de pluie est le meilleur moyen de relever l'agriculture typiquement semi-aride.

Irrigation dans la région semi-aride. Les cultures irriguées ont des limitations imposées par la température : le coton, l'oranger et surtout la canne à sucre et les fruits subtropicaux ne peuvent pas se développer partout à cause des gelées printanières ou tardives.

La betterave sucrière, la pomme de terre, le lin, le maïs, la luzerne et d'autres espèces fourragères supportent les contrées froides, tandis que le chanvre, le tabac, le tournesol et l'oignon exigent au contraire des conditions plus chaudes.

Vignoble, olivier et arbres fruitiers. Le vignoble règne dans toute la région semi-aride grâce à ses profondes racines et seulement les gelées tardives lui nuisent. Du point de vue du sol, ce sont les calcaires qui lui conviennent le mieux (voir fig. 2) et nombre de vins renommés sont produits dans la moitié orientale de la région.

L'olivier, qui exige une température plus élevée, ne pousse pas au nord des montagnes du Sistema Central, sauf dans la vallée de l'Èbre. Il a également besoin de plus d'humidité, ce qui limite son expansion au sud. Il préfère les sols calcaires, mais donne, de même que la vigne, des produits très fins quoique en petite quantité, dans les sols sablonneux.

Les arbres fruitiers, sauf le figuier et l'amandier, demandent des terres irriguées.

Bétail. Les mulets sont employés traditionnellement pour les labours, tandis que les vaches et les bœufs, moins nombreux, le sont pour les tâches plus lourdes.

Les chèvres sont remplacées dans la région semi-aride par les moutons, bien adaptés au milieu et d'un bon revenu malgré leur nourriture frugale.

CARTOGRAPHIE DE L'UTILISATION DU SOL

On vient de publier la *Carte des cultures de l'Espagne* à l'échelle de 1/1 000 000 établie par l'Office du Mapa Agronómico Nacional du Ministère de l'Agriculture. Elle tient compte de 23 catégories de cultures et de superficies de plus de 500 hectares.

Cette carte a été dressée selon les données du service cartographique de l'Instituto Geográfico y Catastral (échelles 1/50 000 et 1/200 000), et avec l'aide de photos aériennes pour certaines régions et d'informations directes des bureaux locaux de la Dirección General de Agricultura. Dans la notice qui l'accompagne, la classification choisie est comparée avec celle de l'Union géographique internationale et celle du *World atlas of agriculture*; des tableaux indiquent les superficies d'après ces dernières classifications. La figure 3 (Cultures prédominantes) en est une réduction simplifiée.

Il existe aussi 30 cartes de cultures à l'échelle de 1/50 000 éditées par le Mapa Agronómico Nacional, avec les notices explicatives correspondantes, mais l'édition a été suspendue et sera probablement remplacée par des cartes provinciales à 1/200 000.

L'UTILISATION DU SOL EN CORSE : SUR LA DÉCADENCE D'UN TERROIR INSULAIRE

par

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L'étude du terroir agricole de la Corse relève plutôt du domaine de la géographie historique ; en effet, le terme d'« agriculture » en Corse n'évoque plus qu'une réalité amère, celle d'un terroir abandonné aujourd'hui dans sa presque totalité au maquis. Cette situation traduit un des aspects majeurs du problème de l'intégration économique de l'« île de Beauté » à la France.

L'intégration a brisé un mode de vie traditionnel, basé autrefois sur une économie de subsistance : « pays insulaire, voué à une défensive perpétuelle et ne pouvant pas compter sur un ravitaillement par l'extérieur, la Corse était obligée de se suffire à elle-même et par suite de porter tout son effort vers des modes d'exploitation donnant les produits essentiels, le pain et la viande » (Blanchard). D'où l'importance attribuée à la culture des céréales, autrefois : sur les 30 % du terroir utile à la fin du XVIII^e siècle (tableau 1), plus de 50 % étaient emblavés. La culture extensive de céréales (blé, seigle et orge), à faibles rendements (4-5 quintaux à l'hectare) et à longues alternances de jachère, s'accompagnait d'une arboriculture encore à ses premiers pas : la vigne (1,4 %), l'olivier (0,4 %) et l'arbre nourricier par excellence, le châtaignier (3,2 % du terroir). L'association d'une polyculture typiquement méditerranéenne et de l'élevage (transhumance inverse) convenait à la persistance d'une société foncièrement rurale (90 % de la population) retranchée dans la montagne, en opposition avec les villes-forteresses du littoral, de fondation génoise.

Petite île rattachée depuis 1769 au pays le plus riche et le plus évolué du bassin Méditerranéen, la Corse doit faire face au problème capital de l'adaptation économique. En fait, les activités agricoles et pastorales traditionnelles s'y maintinrent jusqu'au début du XX^e siècle : l'avènement des moyens de transport modernes facilita la pénétration de denrées importées (de meilleure qualité et à prix de revient inférieur), ce qui accéléra la décadence de l'agriculture. L'élevage s'avéra à nouveau comme la branche la plus fructueuse, ne demandant presque pas de soins pour le troupeau (6 vétérinaires en

1960 pour plus de 400 000 têtes de bétail), et pas du tout pour les terrains de pacage, tout en procurant des revenus substantiels (vente du lait de brebis aux laiteries de Roquefort). A part quelques exploitations agricoles de fondation récente, utilisant des méthodes de culture modernes à des fins de production pour le marché national (vignobles, primeurs), et des cultures maraîchères à proximité des villes importantes, le terroir agricole mis en valeur aujourd'hui se compose de minuscules jardins potagers (auxquels s'ajoutent quelques arpents de vignes et d'arbres fruitiers) cultivés par les retraités qui peuplent désormais les villages (tableau 2).

La destruction de l'économie insulaire traditionnelle s'allie à l'effondrement de la classe paysanne : le paysan jaloux de son bien et ancré dans ses habitudes ancestrales se prêtait fort mal aux tentatives de rénovation engagées par l'administration depuis le XIX^e siècle. L'échec de certaines cultures nouvelles (mûrier, cédratier, coton, etc.) ne fit qu'augmenter sa méfiance instinctive. Son exploitation garda les caractères rustiques d'autrefois : outillage rudimentaire, emploi d'engrais dans la seule parcelle aux légumes, méthodes défectueuses de culture, écobuage précédant les labours, entretien précaire des arbres fruitiers, absence de moyens de stockage, etc. L'habitat groupé en villages perchés loin des champs et des points d'eau et l'extrême morcellement du terroir rendent l'exploitation particulièrement difficile. D'autre part, la classe paysanne, dont les ressources se trouvent coupées par la concurrence des denrées importées, fut décimée par la guerre de 1914-1918. Elle trouva cependant un appui dans le fait qu'elle appartient à un pays riche, alors maître d'un vaste empire colonial ; d'où un puissant courant d'émigration qui videra l'île de sa substance humaine. Le Corse, hier pasteur et cultivateur, est devenu aujourd'hui le symbole du fonctionnaire français, et sa terre natale n'est plus dans son ensemble que le lieu de résidence de retraités (18 000 relevant du seul secteur public, sur une population estimée à 160 000 habitants en 1960)

TABLEAU 1. L'utilisation du sol à l'époque du plan terrier (fin du XVIII^e siècle).

VALEUR DES TERRES	ÉTAT DE LA PROPRIÉTÉ		
Bonnes (9,7 %).	Citoyens (58,7 %).		
Médiocres (47,9 %).	Commune (30,0 %).		
Mauvaises (24,0 %).	Nation (11,3 %).		
Eaux et rochers (18,4 %).			
ÉTAT DES CULTURES			
Nature des cultures	En deçà des monts ¹ (%)	Au-delà des monts ² (%)	Total pour la Corse (%)
<i>Terroir cultivé</i>			
Cultures annuelles	11,54	5,05	16,59
Vignes	1,12	0,25	1,37
Oliviers	0,32	0,04	0,36
Châtaigniers	2,93	0,24	3,17
Prés	—	0,02	0,02
Bois	3,79	5,05	8,84
	19,70	10,65	30,35
<i>Inculte et cultivable,</i>			
<i>bon en pâture</i>	14,44	15,33	29,77
<i>Non cultivable</i>	18,74	21,14	39,88
	52,88	47,12	100,00
Total général	52,88	47,12	100,00

LISTE DES OCCUPATIONS (d'après l'occupation principale par communautés)

	Nombre de communautés (communes)	Pourcentage
Pasteurs	6	1,6
Cultivateurs	30	7,9
Pasteurs et cultivateurs	289	75,5
Cultivateurs et artisans	14	3,6
Pasteurs, cultivateurs et commerçants	40	10,5
Artisans et commerçants	1	0,9
Total	380	100,0

1. Arrondissements de Bastia, Calvi et Corte.

2. Arrondissements d'Ajaccio, de Vico et de Sartène.

vivant pour l'essentiel sur les pensions payées par l'État. La fonction actuelle de l'île s'illustre par cette boutade quelque peu cynique, entendue à Ajaccio : « La Corse exporte des fonctionnaires et importe des retraités ». Devenue zone de recrutement d'employés d'État, la Corse ne vit désormais que sur des apports monétaires extra-insulaires : pensions, salaires et frais de l'administration servant à combler le déficit de la balance commerciale, l'île important non seulement des farines, mais encore des légumes et des fruits, des produits laitiers, des huiles, de la viande. Le Corse, réduit autrefois à subsister des maigres produits de son terroir, voit

aujourd'hui sur sa table des tomates du Maroc, des pommes de terre venues d'Espagne, des oignons d'Égypte, des carottes et des oranges d'Algérie, des pommes d'Italie, des pamplemousses d'Israël et de l'Arizona, de l'huile d'olive de Tunisie, du lait et des œufs de Normandie, des farines de la Beauce, etc. Si l'on ajoute que bon nombre de « paysans » viennent en ville pour s'approvisionner de ces denrées, que seulement 3 à 5 % du terroir est mis en culture, que 65,6 % des chefs d'exploitation ont dépassé cinquante-cinq ans, on saisira l'ampleur de l'effondrement de l'ancienne structure rurale en Corse.

Pendant le dernier demi-siècle, la Corse a perdu quelque 40 % de son effectif humain ; sur ce chiffre global, la population rurale, qui constituait à la fin du XVIII^e siècle près de 90 % de la population totale, ne dépasse plus aujourd'hui 55 à 60 %. Or, s'il y a un siècle et demi la population rurale (et même une partie importante de la population urbaine) était foncièrement paysanne, de nos jours le terme « rural » n'indique plus forcément une activité primaire.

Cette déperdition critique jure avec la progression continue du peuplement observée dans les îles voisines (tableau 3).

La régression démographique ne s'explique qu'en partie par des conditions naturelles défavorables ; certes, le relief de l'île est par trop accidenté, et nous n'y trouvons rien de comparable à certaines terres volcaniques de Sicile ou de Sardaigne, ni aux richesses minières de ces îles. Cependant l'état lamentable du terroir actuel est surtout la conséquence d'une mise en valeur défectueuse ; l'abandon est accentué encore par le fait subjectif (mais d'une importance capitale sur le plan économique) que la Corse appartient à un pays qui possède des terres fertiles comme la Beauce et la Normandie, pays trop riche pour s'offrir le luxe de mettre en valeur ses régions agricoles les plus déshéritées.

LES CONTRAINTES DU CADRE PHYSIQUE

Les caractéristiques du cadre insulaire se résument dans la dénomination donnée par Ratzel : « pays de montagnes dans la mer », avec la précision climatique de Bénévent — « dans une mer méditerranéenne ». La quatrième par sa superficie, la Corse est la première par son altitude moyenne : 568 m (Sicile, 441 m ; Sardaigne, 344 m). Une puissante chaîne dorsale, de direction N.N.O.-S.S.E., qui culmine au mont Cinto (2 170 m), partage l'île en deux versants. Le versant sud-ouest, « L'au-delà des monts » (48 %), comprend un ancien bloc de roches cristallines ; basculé lors des plissements alpins, il a été affouillé par plusieurs cycles d'érosion en une série de vallées compartimentées qui se terminent par de minuscules plaines alluviales de quelques centaines d'hectares. C'est le versant essentiellement pastoral et forestier, en opposition avec le versant nord-est, « L'en deçà des monts » (52 %), où

TABLEAU 2. Évolution du terroir (8 722 km²)¹.

				1959	
	Fin du xviii ^e siècle (%)	1910 (%)	1959 (%)	Sud-est de la France (%)	Total pour la France (%)
UTILISATION DU SOL					
Terres labourables	16,6	29,7	1,5	9,5	34,2
Cultures maraîchères		0,3	0,5	1,2	1,0
Vignes	1,4	1,5	1,1	5,8	2,6
Cultures fruitières (châ- taigniers y compris)	3,6	4,5	4,5	3,1	0,9
Bois	8,8	15,2	20,7	30,3	20,9
Surfaces en herbe	29,7	21,4	42,9	24,6	23,9
Landes et sols	39,9	27,6	29,0	25,5	16,5
Total	100,0	100,0	100,0	100,0	100,0

CHEPTTEL (en milliers de têtes de bétail)

	1787	1872	1929/30	1958
Bovins	38,2	44,4	40,9	40,6
Ovins	86,9	255,3	339,3	196,0
Caprins	121,0	190,9	46,1	107,0
Porcins	31,7	71,8	140,0	45,1
Chevaux	10,9	9,5	4,6	1,2
Mulets	3,2	12,1	6,9	2,3
Anes	5,3	8,3	23,3	14,0

1. L'évolution du terroir se traduit en premier lieu par la disparition des céréales, remplacées par des herbages de valeurs diverses. La progression forestière est factice, car la statistique comprend désormais dans cette rubrique des futaies clairsemées. La forte proportion de cultures arbustives est due à l'inclusion de la châtaigneraie dans cette rubrique : progression des essences fruitières proprement dites, régression continue de l'olivier et du châtaignier.

En règle générale, les statistiques agricoles sont plus que sujettes à caution : si l'on se rappelle qu'en Corse les recensements démographiques donnent lieu à des majorations de 50 à 100 %, on ne s'étonnera plus des chiffres fantaisistes sur l'état des cultures et l'effectif du cheptel ; l'incertitude des données interdit toute analyse valable.

TABLEAU 3. Progression démographique de certaines îles par rapport à la Corse.

	Superficie km ²	Population ¹		Densité ²	
		1900-1901	1954-1956	1900-1901	1954-1956
Sicile	25 701	3 529	4 681	137	184
Sardaigne	24 089	789	1 365	33	57
Chypre	9 251	237	536	26	58
Corse	8 722	275	170	32	20
Crète	8 379	304	462	36	55
Baléares	5 014	307	430	61	86

1. En milliers d'habitants.

2. Nombre d'habitants au kilomètre carré.

l'agriculture s'est mieux implantée. Le Nord-Est, à prédominance de roches métamorphiques (schistes lustrés — nappes de charriage replissées au miocène) offre des aspects morphologiques plus diversifiés : le massif de la Castagniccia (« Châtaigneraie »), séparé de la Corse granitique par le sillon central ; la seule plaine de quelque importance sur la côte orientale (12 500 ha), et enfin le cap Corse, unique région de la Corse qui ait vu se développer autrefois une vie proprement maritime.

Sols¹. D'origine cristalline ou métamorphique les sols sont superficiels et perméables. L'altération du granite donne des sols constitués de sables grossiers ; comme les sols schisteux (ces derniers toutefois moins secs, et souvent plus profonds), ils sont d'une pauvreté extrême en azote, phosphore, chaux et potasse, et manquent d'humus ; l'acidité des sols est renforcée par la décomposition de la végétation du maquis. Les alluvions anciennes forment des sols riches en graviers et cailloux grossiers ; la couche superficielle est à nette tendance argileuse (15-35 %) ; en profondeur les horizons sont lourds et compacts, peu filtrants. Par ailleurs, ces sols sont d'une extrême hétérogénéité, en relation avec les divagations des lits torrentiels.

Les alluvions récentes sont formées d'éléments sablo-limoneux, à caractère neutre ou alcalin. Elles se rencontrent dans les basses vallées et les lits actuels. Ces sols conviennent parfaitement aux cultures maraîchères et arboricoles ; cependant la présence d'horizons argileux en profondeur peut interdire la culture des agrumes, à laquelle la douceur du climat les prédispose.

Climat. Le climat insulaire est influencé par deux facteurs : a) de par sa position méditerranéenne l'île subit l'alternance des vents d'ouest en hiver (avec un premier maximum de précipitations en novembre, et un second en mars), puis celle de la transgression désertique estivale ; b) l'altitude provoque des précipitations orographiques : alors que le littoral est brûlé par la canicule de juin à août, la haute montagne reçoit quelque 90 mm de pluie. La moyenne annuelle des précipitations en altitude dépasse 1 500 mm ; elle a permis la formation des magnifiques forêts à prédominance de résineux (pin laricio), principale richesse de l'île et qui lui a donné d'ailleurs son nom actuel². Ces fortes pluies entretiennent d'autre part les pâturages alpestres, évalués à près de 80 000 hectares. La moyenne annuelle va diminuant vers le littoral, seule région de l'île pouvant être considérée comme semi-humide, avec des précipitations annuelles moyennes de 500-700 mm. Le littoral et les premiers contreforts qui le surplombent, uniques régions de l'île propres à une large mise en culture, subissent

1. Répartition des formations géologiques principales : roches cristallines, à base de granites et granulites (68,6 %) ; schistes lustrés et serpentines (20,8 %) ; calcaires tertiaires (4,1 %) ; alluvions, anciennes et récentes (6,5 %).

2. Corse (Corsica), de Korsai ou Khorsai, mot à racine sémitique qui signifie bois, forêts.

directement les contraintes du climat méditerranéen : divorce entre la chaleur et l'humidité, irrégularité des précipitations, avec des inondations hivernales (d'où érosion intense, accélérée par la raideur des pentes et le déboisement, la formation de marécages et la propagation de la malaria) et une sécheresse estivale absolue qui interdit les cultures en sec.

LA RÉPARTITION ALTIMÉTRIQUE DES ZONES DE CULTURES

Plus importante sur la plan agricole que la répartition initiale en deux versants opposés, apparaît la division en zones climato-phytologiques naturelles. L'altitude a provoqué une variété climatique qui se traduit par des cultures étagées de natures diverses, et qui ont suscité à l'origine des modes de vie différents et complémentaires.

1. Littoral (0-100 m) : 1 658 km² (19,0 %), 22 communes.
2. Région méditerranéenne (100-600 m) : 3 723 km² (42,8 %), 238 communes.
3. Région subalpine (600-1 200 m) : 2 299 km² (26,5 %), 104 communes.
4. Région alpine (+1 200 m) : 1 032 km² (11,8 %).

Du point de vue de l'habitat, la Corse rurale commence avec les premières hauteurs, pour monter jusque dans les hautes vallées (altitude maximum de 1 100 m à Calasima, dans le Niolo). Le paludisme et l'insécurité ont longtemps fait du littoral un lieu de répulsion à l'habitat permanent, exception faite de l'implantation urbaine d'origine étrangère. Sur les 22 communes situées entre 0 et 100 m d'altitude, 7 sont urbaines, comprenant 35 % de la population totale actuelle, et 90 % de la population urbaine. Aujourd'hui, malgré la tranquillité revenue, l'éviction du paludisme, l'implantation du tourisme balnéaire et surtout la concentration urbaine, on note encore l'absence d'un genre de vie associé à la mer : la pêche locale, artisanale et archaïque, occupait en 1959 seulement 603 pêcheurs, montés sur 263 embarcations jaugeant en tout 613 tonnes.

Littoral. La plupart des communes rurales situées sur le littoral sont de fondation récente, avec l'installation permanente des pasteurs de la montagne sur les terres de parcours. Ainsi Monacia est issue d'Aullène, Bastelicaccia de Bastelica, Ghisonaccia de Ghisoni, Figari de Levie, etc. Implantation saisonnière à ses débuts, la garde des troupeaux s'accompagnait de la culture de céréales d'hiver (alternance d'une année de labour avec deux ou trois années de jachère), du démasclage des chênes-lièges, et de la préparation de charbon de bois à base de chênes verts. De nos jours, le berger a abandonné la cérélculture, ce qui a eu pour conséquence de perturber le renouvellement de la prairie, livrée

désormais à la végétation du maquis et aux abus de pacage. Dans certaines terres alluviales, comme les basses vallées du Taravo et du Liamone (sud-ouest), on pratique encore une rotation triennale routinière (maïs, blé, pâturage). Il n'est fait usage de fumier naturel que dans les jardins potagers et les exploitations maraîchères ; les engrais chimiques sont surtout employés dans les vignobles, en particulier dans les grandes exploitations. Dans le reste de l'île, la propriété est extrêmement morcelée par les successions, ce qui a une influence néfaste sur la mise en culture : la relation entre parcelles de cultures et parcelles de propriété s'établit en général de 1 à 7, et dans les meilleurs cas, de 1 à 5. Les exploitations d'un seul tenant sont rares ; ce n'est que dans la plaine orientale que nous trouvons de vastes exploitations dépassant 50 hectares et dont certaines appartiennent à des citadins bastiais. Aussi la taille moyenne de l'exploitation agricole du littoral, qui s'élève à 11,15 hectares, est supérieure de 50 % à la moyenne insulaire.

Les meilleures terres alluviales sont consacrées aux cultures maraîchères ; la douceur du climat hivernal et la proximité des villes permettent de produire et d'écouler deux à trois récoltes annuelles. On y cultive de même la vigne, les arbres fruitiers, les agrumes (cédrats), le tabac, le maïs, les fourrages et les céréales.

Bien que le littoral ne réunisse que 22,5 % du terroir cultivé et 18 % des actifs agricoles (1955), on peut considérer qu'il comprend l'essentiel de l'agriculture proprement dite de l'île. On remarquera (tableau 4) la forte proportion des moyennes et grandes exploitations, le plus fort pourcentage de salariés (8,3 %), l'âge moyen légèrement plus jeune des chefs d'exploitation. Possédant les meilleures terres et les plus faciles à cultiver, c'est aussi la région qui produit l'essentiel des denrées agricoles commercialisées : vins, primeurs (artichauts), agrumes, tabacs ; là également a lieu la transformation des denrées venues de l'intérieur : pâtes de fromage (Roquefort), bois sciés, préparation du liège, d'ébauchons de pipes (racines de bruyère), etc.

Région méditerranéenne (100-600 m). Dénommée aussi « coteaux corses », cette région réunit la majorité de l'habitat rural (238 communes sur 364). C'est l'ancien domaine de la polyculture du type méditerranéen, qui comprenait la culture des céréales dans les parties basses ou les moins accidentées, des cultures arbustives sur les versants bien exposés (vigne et olivier surtout) et des jardins potagers près des points d'eau. Aujourd'hui encore, une grande partie des terres du littoral est mise en valeur par des paysans résidant dans les villages haut perchés qui dominent la plaine ; rares (et récentes) sont les fermes isolées, à l'exception des plaines de Lucciana, de San Nicolao, d'Aleri et de Ghisonaccia. Alors que la vigne est en nette régression dans l'ensemble du Cap et se maintient dans la Balagne et le Sartenais, elle est en progression constante dans le Nebbio (Patri-monio), dans la plaine orientale et sur les coteaux qui

TABLEAU 4. Structures des exploitations (recensement agricole de 1955)

Répartition des exploitations¹ selon leur superficie totale, bois non compris (en pourcentage du nombre total d'exploitations)

Surface de l'exploitation	Ensemble de la Corse (%)	Sud-est de la France (%)	Total pour la France (%)
Moins de 1 ha	18,7	16,1	6,7
1 ha à 4 ha 99	49,6	43,0	28,3
5 ha à 9 ha 99	15,6	18,7	20,8
10 ha à 19 ha 99	8,4	12,8	23,5
20 ha à 49 ha 99	5,5	6,9	16,5
50 ha et plus	2,2	2,5	4,2
Nombre total d'exploitations	12 279	139 157	2 267 701

Répartition des exploitations selon les régions agricoles en Corse

Région agricole	Ensemble des exploitations			Exploitations de plus de 20 ha	
	Nombre et pourcentage (%)	Superficie et pourcentage (ha) (%)	Taille moyenne (ha)	Nombre (%)	Superficie (%)
Littoral	1 880 (15,3)	20 966 (22,5)	11,15	12,6	63,7
Coteaux	4 999 (40,7)	46 717 (50,0)	9,35	9,6	61,2
Montagne	5 400 (44,0)	25 680 (27,5)	4,76	4,1	29,9
Ensemble de la Corse	12 279 (100)	93 363 (100)	7,60	7,7	53,2

Répartition des actifs agricoles (population active agricole)

Région agricole	Actifs agricoles		Pourcentage des salariés	Pourcentage des chefs d'exploitation de plus de 55 ans	Nombre de tracteurs ²	Nombre d'actifs ²
	Nombre	Pourcentage				
Littoral	4 345	18,0	8,3	62,7	0,5	20,7
Coteaux	9 776	40,4	5,3	66,9	0,1	20,9
Montagne	10 029	41,6	2,3	65,3	0,03	39,1
Ensemble	24 150	100,0	4,6	65,6	0,2	25,8

1. Exploitation agricole : ensemble de terres (bois non compris) mises en valeur à des fins de production animale ou végétale sous la direction d'une personne exerçant la profession d'agriculteur, de maraîcher, d'arboriculteur.

Ensemble de terres (bois non compris) de 1 ha ou plus en polyculture, de 20 ha ou plus en culture spécialisée (culture maraîchère, potagère, arboricole fruitière, florale, viticole).

2. Pour 100 hectares.

la dominant (Casinca, Cervione). Par contre l'olivier (prospère autrefois surtout en Balagne) subit une nette régression, causée par la concurrence des huiles importées, les maladies, le manque de soins et de main-d'œuvre.

L'abandon des labours dans la région méditerranéenne et le sillon central a provoqué un repli sur les minuscules terrasses irriguées à proximité des sources et des villages. Ces jardins potagers, fumés intensivement et travaillés à la bêche, procurent aux retraités qui les exploitent des légumes, des pommes de terre et du maïs. Ces denrées, consommées en général sur place, ne rentrent que fort rarement dans le circuit de distri-

bution ; on observe ainsi un repli vers une autarcie d'un nouveau genre, complément d'une pension d'État.

Région subalpine (ou montagnes et hautes vallées habitées : 600-1 200 m). Cette région comprend les hautes vallées du Niolo, d'Asco, du Taravo et du Rizzanese, le Fium' Orbo, etc., et englobe l'essentiel de l'habitat pastoral permanent, situé entre les hauts pâturages alpestres et les « plages » du littoral (terres de parcours, souvent biens communaux indivis appartenant aux communes de la montagne). Le mouvement de transhumance inverse (*muntana-piagha*) emprunte des voies de parcours bien définies (10-25 km, maximum de

45 km). De nos jours les routes traditionnelles de la transhumance sont moins fréquentées ; certains bergers transportent leurs troupeaux par camion. Le lait est transformé dans les bergeries en fromages de type local (sartenais, venacais, niolin, etc.) et en « bruceiu » (fromage blanc à base de lait de brebis et de chèvre), consommés sur place ou écoulés vers les villes. Cependant la commercialisation principale s'effectue par l'entremise des nombreuses laiteries de Roquefort disséminées dans l'île, qui achètent le lait de brebis et le transforment en pâte (installations à Bastia, Ajaccio et l'île Rousse) avant de l'acheminer pour son conditionnement définitif vers les caves de Roquefort. La vente du lait à Roquefort a fortifié la vocation pastorale de l'île ; par ailleurs, le pasteur s'est libéré depuis la guerre de 1914-1918 des anciennes conditions de louage des terrains (partage par moitié du fruit et du croît), similaires à celles du métayage d'autrefois. Aujourd'hui, le berger loue les pacages à un prix déterminé, ce qui lui permet, à force d'économies et tout en gardant un mode de vie extrêmement fruste, de devenir à son tour acquéreur de terres. Ainsi l'élevage, forme passive de l'utilisation du sol, a supplanté l'agriculture ; ce processus est activé par le fait que de nombreux propriétaires (absents ou non) préfèrent louer leurs terres plutôt que de les mettre en valeur. Le berger pour sa part se contente de payer les droits de pacage, et n'apporte aux pâturages aucune amélioration. L'absentéisme, le morcellement infini à la faveur des successions, les abus de pacage, sont autant de facteurs qui, s'ajoutant à la résistance instinctive du paysan à la vente, aboutissent en fin de compte à un regroupement du terroir dans le maquis. En conséquence, les dernières cultures vivrières (céréales : seigle, méteil, etc.) ont été abandonnées, au profit des jardins potagers et de la prairie.

Les caractéristiques de l'exploitation agricole en montagne sont : a) domaine de la petite propriété privée, dans un ensemble à prépondérance de vastes terres communales ; b) faire-valoir direct ; c) élevage extensif de bovins et d'ovins (les cultures fourragères, la protection du bétail contre les intempéries et les épizooties sont inconnues) ; le troupeau (race ovine locale, rustique et vigoureuse, à lait riche en matières grasses, mais à viande coriace) se trouve toujours en plein champ ; on le parque le soir dans un enclos entouré de branchages et de murettes, à proximité de la cabane du berger.

En résumé, l'élevage, tel qu'il est pratiqué en Corse, se trouve complètement à la merci de la nature et ne subsiste que de ce que celle-ci veut bien lui procurer. Cette économie pastorale, qui n'a dépassé le stade de l'élevage primaire que par la vente à Roquefort, met en relief le caractère commun de l'agriculture insulaire, soit de la production (et souvent de produits laitiers de premier choix) par la destruction du terroir.

La même constatation vaut pour l'économie forestière ; la forêt corse, évaluée à 167 000 hectares (28 % de bois domaniaux, 54 % de bois communaux, 18 % non

soumis au régime forestier), souffre non seulement d'une exploitation à outrance (production de traverses, bois en grumes, etc.), mais surtout des déprédations causées par les incendies (volontaires ou involontaires). Les terrains de pacage dégagés par le feu sont soumis à la dent des troupeaux, ce qui interdit le renouvellement naturel des essences forestières.

La montagne a également suscité un genre de vie original, du type dit de la « Castagniccia » (châtaigneraie), dans la région située dans le massif schisteux compris entre le Golo et le Tavignano. Les villages se trouvent à l'altitude optimale du châtaignier (500-700 m). Autrefois la subsistance de cette région était assurée par la cueillette des châtaignes et leur préparation (farines et dérivés, élevage de porcins), complétée par quelques cultures dans les « solane » bien exposées, par l'élevage caprin, et enfin par un artisanat rudimentaire. Il s'y ajoutait un système d'échanges, le paysan troquant ses châtaignes et les produits de l'artisanat local contre le blé, l'huile et le vin des régions méditerranéennes, le bétail et les produits laitiers des hautes vallées. D'où une prospérité relative de cette région, qui supportait encore au début du ^{xx}e siècle une densité rurale de 80 habitants par kilomètre carré.

Aujourd'hui, l'arbre nourricier a perdu son importance d'antan : la farine de châtaignes s'est effacée devant celle de froment (importée), et le châtaignier, rongé par la maladie de l'encre, le feu, la chèvre et les coupes effrénées (utilisation du bois aux fins de production d'extraits tannants), ne couvre plus dans l'île qu'une surface de 30 000 hectares. Les minuscules villages semés sous les frondaisons de la Castagniccia, n'abritent plus que quelques familles de retraités.

LES PROJETS DE MISE EN VALEUR

Au cours du demi-siècle dernier s'est précisé le phénomène connu sous le nom de « problème corse », et dont les signes frappants sont le vide humain, le terroir inculte et la production insignifiante. Faisant désormais part de cette inquiétante entité qu'est le « désert français », la Corse se trouve dans une situation particulière du fait de son isolement géographique et de son dépeuplement exceptionnel parmi les îles méditerranéennes. Ce contraste est le premier à être reconnu dans le Programme d'action régionale pour la Corse du 2 avril 1957. Ce programme souligne les efforts accomplis par l'Italie dans l'île voisine, puis propose les mesures à appliquer en vue de rendre à la Corse des activités productives ; il se résume en trois thèmes : « l'aire du tourisme le levier de la renaissance corse » ; « Utiliser rationnellement le potentiel agricole et forestier » ; « Réduire les frais de transport entre l'île et le continent ».

A cet effet, deux sociétés d'économie mixte ont été créées en 1957 (formule d'association de capitaux

publics et semi-publics, conciliant les vertus de l'initiative privée avec la nécessité d'une orientation gouvernementale), avec un capital de 100 millions d'anciens francs chacune :

La Société pour l'équipement touristique de la Corse (Setco), dont l'activité principale est dirigée vers le développement de l'infrastructure hôtelière dans l'« île de Beauté ». La Corse possède en effet un ensemble incomparable de montagnes, mer et forêts, et 800 km de plages magnifiques et presque vides. La progression spectaculaire du mouvement touristique (de 43 000 touristes en 1953 à 115 000 en 1959), les multiples investissements (construction d'hôtels, de camps de vacances et d'ensembles résidentiels, ainsi que la spéculation sur les terres de parcours devenues plages) permettent d'escompter une large participation de l'industrie touristique au renouveau de l'île. Il est à noter cependant qu'il ne s'agit que d'un tourisme saisonnier, limité aux trois mois de l'été; d'où la nécessité de rechercher d'autres activités substantielles.

La Société pour la mise en valeur agricole de la Corse (Somivac) a pour but de créer et d'équiper des séries d'unités agricoles complètes, de 40 hectares chacune. Pour l'instant, l'action de la Somivac se concentre sur la plaine orientale, et plus précisément aux périmètres de Ghisonnaccia et de Linguizetta, soit sur une superficie de près de 10 000 hectares. Ce terroir comprend un ensemble hétérogène de terres alluviales (anciennes et récentes), biens indivis de communes de la montagne d'une part, de citadins et de propriétaires ruraux d'autre part. Les terrains sont achetés par la Somivac, ou pris en bail pour cinquante ans, ou encore mis en valeur sans en déposséder leurs propriétaires. L'accesseur est tenu d'acquitter les annuités des frais de mise en valeur (déduction faite des subventions de l'État, qui comprennent, outre l'aménagement du terrain (démaquillage, défoncement et amendement), la clôture et l'irrigation (par aspersion), la voirie et l'électricité, une maison de 80 m², un hangar (200 m²), un magasin et un logement d'ouvrier (80 m²). L'exploitation comprendra 80 % de cultures irriguées, équilibrées sur le maraîchage, les cultures fruitières et agrumes (25 %), le maïs et la prairie. Les forages dans la plaine s'étant montrés décevants, le problème de l'eau ne sera résolu qu'avec l'installation d'une conduite à partir d'un barrage-réservoir sur le Fium' Orbo.

En fin juillet 1959, la Somivac avait attribué un premier lot de 18 exploitations totalisant 870 hectares; cette action a par ailleurs stimulé l'initiative privée dans la région, en particulier l'implantation de vastes vignobles (plusieurs centaines d'hectares d'un seul tenants), exploités par d'anciens colons d'Afrique du Nord.

L'action de la Somivac étant encore au stade préliminaire (études de terrain et essais de culture), il est

malaisé d'apporter une appréciation définitive sur les travaux entrepris. Il s'avère cependant que le plan initial de 20 000 hectares (1957-1961) subit un retard important, 2 000 à 3 000 hectares seulement ayant été mis en valeur jusqu'en 1961. La volonté d'aboutir à des exploitations rentables a dirigé la Somivac vers la création de grandes exploitations (40 hectares à 80 % irrigables), basées sur un outillage motorisé et une main-d'œuvre salariée (ouvriers italiens), exigeant du candidat éventuel non seulement des connaissances agricoles mais encore d'importantes disponibilités financières. Or, cela interdit à l'exploitant local l'accès à ces installations modèles, car son avoir financier est presque toujours insignifiant. En voulant à tout prix assurer la réussite de l'expérience, la Somivac s'est écartée du véritable problème agricole corse, qui consiste à remodeler une structure agraire archaïque, basée sur le faire-valoir direct par de petits exploitants. On voit mal pourquoi on s'est efforcé de créer de grosses fermes modèles, alors que des exploitations plus modestes (de 5 à 10 hectares de terres irriguées [maraîchage et arbres fruitiers], ou, dans les terres moins riches, 40 à 50 hectares en polyculture [élevage intensif, fourrages et blé dur, verger et petit vignoble]), auraient été susceptibles d'atteindre des couches plus vastes du paysannat insulaire. Par ailleurs, la question de la commercialisation est loin d'être résolue et, malgré le développement touristique, le marché local sera vite saturé. Les frais d'approche causés par l'insularité ne permettent d'écouler que des denrées de haute valeur, concurrencées par celles du Midi et de l'Italie. D'autre part, les conditions climatiques (printemps frais) ne semblent pas favoriser des productions plus précoces, mais plutôt celles d'arrière-saison. Un élément envisagé paraît être l'agrumiculture, la Corse étant le seul département de la métropole où cette culture soit possible. Aujourd'hui, seule la vigne est susceptible d'offrir un revenu spéculatif sur une petite ou moyenne exploitation cultivée en sec. Toutefois, et bien que des crus de qualité manquent rarement d'acquéreurs, il serait dangereux de miser sur la viticulture dont la France est plus que surchargée.

A notre avis, une mise en valeur rationnelle du potentiel agricole doit porter la même sollicitude aux deux régions complémentaires de l'île : la montagne et la plaine. Le développement unilatéral des seules plaines du littoral ne peut en aucun cas améliorer la condition du paysannat corse, concentré dans sa majorité (80 %) à l'intérieur; il active au contraire l'exode rural, au profit des villes du littoral et du continent. Il faut, en premier lieu, préserver la forêt des incendies et des coupes déraisonnées, qui sont à la source de la dégradation du terroir. La protection et l'utilisation dirigée de la forêt, alliées à l'amélioration sélective des pâturages en montagne et à la création de pâturages artificiels dans les plaines, sont susceptibles d'aboutir à la constitution d'une économie sylvo-pastorale évoluée, adaptée à une région à faible peuplement. Il semble que le

renouveau agricole de la Corse, sans exclure les cultures intensives dans les terres les plus riches, doit en premier lieu s'inspirer de ces deux activités conjuguées : la forêt et l'élevage. En effet, et alors que les cultures fruitières et légumières demandent des investissements onéreux, et s'adressent à un marché local négligeable et à une forte concurrence extérieure, le troupeau ovin est à même de fournir des quantités intéressantes de

fromages du type de Roquefort, dont la qualité assure un écoulement illimité.

Cependant, l'immobilisme du milieu économique et social (renforcé par l'âge avancé de la classe paysanne) met en doute la réalisation de tout programme qui viserait à améliorer la situation actuelle de l'agriculture insulaire. Comme le dit fort justement R. Dumont, l'avenir de l'agriculture corse « repose presque en entier sur une redoutable inconnue ».

DISCUSSION

C. TROLL. The term "désert français" may refer to the low density of population or to the declining population in southern Corsica. Are there really semi-arid regions on the island, and if so, what are the semi-arid features of soil, vegetation, agriculture, etc.? The aspect of the limestone region in the south depends perhaps only on edaphic factors. Climatically it is semi-humid.

Y. KOLODNY. Le terme « désert français » ne s'applique pas uniquement au sud de la Corse ; il comprend, en plus de l'île entière, toutes les régions rurales françaises en voie de dépeuplement. Cette expression met surtout en relief le vide humain de la campagne en contraste avec l'agglomération monstre de la capitale, Paris, qui accapare une part toujours plus grande, disproportionnée, de la population et des activités de la France. Il va sans dire que l'influence des conditions climatiques sur cet état de choses n'est que très indirecte.

Les régions semi-désertiques (du point de vue du peuplement) — sur la côte occidentale le « désert » des Agriates, la « Balagne déserte » et l'extrême sud de l'île — ne sont pas, sur le plan du climat, semi-arides, puisque les précipitations moyennes annuelles y atteignent ou dépassent 500 mm. Toutefois la nature des roches (granites, granulites, rhyolites, calcaires karstiques), le relief accidenté, l'absence du sol et la répartition inadéquate des maigres précipitations, en font des lieux de répulsion à l'habitat permanent (terrains de pacage).

Ce n'est qu'à Bonifacio que l'on trouvait autrefois une véritable agriculture (vignoble, olivettes, arbres fruitiers, cultures irriguées) dans les cuvettes et les fonds de vallée ; il s'agit d'un véritable exploit de mise en valeur par les colons génois, avec adduction d'eau et construction de murettes de protection contre le « libeccio ». Ici encore, l'exploitation était motivée par les besoins stratégiques extra-insulaires ; ce qui explique cette implantation sur un terrain particulièrement ingrat.

Y. KARMON. All the Mediterranean islands are less developed than their mainlands, but certainly Corsica is the least developed of them. Is this because it became part of the most highly developed country of the Mediterranean? It seems that the contrast with the mainland is so great that it was much easier to emigrate to continental France and retire in old age, than to develop the island.

Y. KOLODNY. La situation particulière de la Corse est étroitement liée au fait que cette petite île aux ressources médiocres fait partie, depuis deux siècles, du pays le plus riche et le plus évolué de la Méditerranée. De ce contraste qui ne fait qu'empirer avec le temps est né le rapport qui caractérisait et caractérise encore l'île : la Corse fournissait les hommes, tandis que la France offrait aux Corses des débouchés bien supérieurs à ceux proposés aux habitants des îles voisines par leurs propres gouvernements. Toutefois, pour obtenir ces avantages, il valait mieux aller à leur rencontre et partir pour le « continent », en Afrique du Nord ou dans les colonies. Aujourd'hui, la dissolution de l'empire colonial a singulièrement rétréci le champ d'action des insulaires ; le repli sur le territoire métropolitain permet cependant d'escompter un mouvement accentué de mise en valeur de l'île, grâce au rapatriement d'anciens colons.

Sur le plan de la productivité, la Corse est certainement la plus attardée des îles méditerranéennes. Mais le bilan négatif des activités insulaires, bien qu'il implique un niveau de vie inférieur à la moyenne française, ne traduit pas en entier la situation, car la Corse, en tant que département français, possède une infrastructure de services développée et jouit des lois sociales que lui procure cette qualité. Certes, la pauvreté n'y est pas absente, mais, à l'encontre d'autres îles, la misère noire a disparu, il n'y a plus d'illettrés, les opportunités d'avancement social ne manquent pas et une condition décente est assurée à chacun. Le contraste entre une productivité en baisse et un niveau de vie qui s'améliore constitue un des aspects les plus frappants de ce qu'on appelle le « problème corse ».

D. CHRISTODOULOU. There is a minor correction I should like to make to the general statement made by Dr. Karmon on the contrast between the Mediterranean islands and their mainlands, namely, that Sicily does not present such a contrast in its degree of development with the south of Italy.

L. D. STAMP. Corsica affords a magnificent example of changing geographical values. Its early attraction was that of a natural rocky fortress from which the mainland could be controlled ; Corsicans pointed to the fact that the island had given birth to Napoleon and they continued to exercise world power beyond their number. The "villages" were for the most part small, compact fortified towns. There was perhaps no area anywhere more in need of a detailed land use survey which

would pose the many questions calling for an answer. Historical factors were surely dominant and the current attitude seemed to be why bother about agriculture when there are tourists as a source of income.

Y. KOLODNY. On peut formuler quelques objections au sujet de la « puissance mondiale » des Corses dont l'exemple illustre serait celui de Napoléon. L'influence actuelle d'éléments d'origine corse provient du fait que l'île est devenue une zone de recrutement de fonctionnaires d'État (comme d'ailleurs le « Mezzogiorno » en Italie) et qu'à tous les échelons de l'administration et de l'armée françaises on trouve des Corses dans une proportion plus forte que les originaires des autres départements. Ce qui est encore loin d'impliquer une mainmise des Corses sur les affaires nationales ou internationales.

Il me paraît inexact de décrire la plupart des villages corses comme petites villes compactes et fortifiées. Certes, la maison-bloc en hauteur se retrouve dans les moindres agglomérations rurales (et même en rase campagne) et donne à quelques gros bourgs tassés un semblant de paysage urbain. Par ailleurs, le village type en Corse (par exemple : Levie et Bastelica, parmi les plus importants) est formé de plusieurs hameaux plus ou moins resserrés (signe de dispersion par familles ou clans plutôt que de mouvement d'agglomération). Le cas de villages fortifiés est très rare ; par contre, la maison-forteresse est plus courante. En règle générale, la défense est assurée par l'inaccessibilité du site caché à la vue de l'ennemi plutôt que par des ouvrages d'art.

Du point de vue des genres de vie, la ville est un phénomène social qui tire ses origines de l'extérieur (implantation génoise). La Corse offre un des rares exemples en pays méditerranéen de l'absence d'une civilisation urbaine propre. Ainsi Corte,

capitale de la Corse indépendante et siège d'une université à la fin du XVIII^e siècle, n'était qu'une bourgade (non fortifiée) de moins de deux mille habitants, pour la plupart agriculteurs ou bergers. Aujourd'hui, il est difficile d'établir la différence entre la ville et le village insulaires, puisque d'une part un genre de vie rurale active est en voie de disparition et que, d'autre part, on vit en ville des mêmes ressources qu'à la campagne (pensions d'État).

Dans la conjoncture actuelle, le tourisme n'est pas la panacée qui mettra fin aux maux dont souffre la Corse. Ne pouvant combiner une saison de sports d'hiver avec une saison estivale, le mouvement touristique est limité aux trois mois de l'été et il en sera ainsi tant que les congés payés ne seront pas étalés sur toute l'année au lieu de correspondre exactement à l'époque des vacances scolaires. N'étant qu'en faible partie le fruit d'investissements locaux, employant un personnel recruté souvent de l'extérieur, consommant des denrées importées, l'activité touristique, jusqu'ici, n'a pas fait bénéficier la population insulaire de tous les avantages que l'on aurait pu escompter. Il va sans dire que le tourisme peut et doit apporter des atouts de premier ordre au renouveau de l'île, mais il ne peut répondre à tous ses besoins, si l'on ne veut pas laisser la Corse à son triste sort de colonie de vacances vide neuf mois sur douze. C'est pourquoi il ne faut pas dédaigner la mise en valeur des terres du littoral, non plus que le reboisement et l'amélioration des pâturages en montagne, la motorisation de la pêche, ou encore l'exploitation de certaines richesses minières (comme la mine d'amiante de Canari, dans le Cap, qui a permis la fixation de la population locale), l'installation d'industries de transformation (produits forestiers, laitages, fruits et légumes) et le renouveau d'un artisanat local (vente aux touristes).

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LAND USE IN TURKEY

by

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Agriculture is the foundation of the Turkish economy. A very large proportion of the population (more than 80 per cent) is occupied in farming while national income (70 per cent) and a preponderance of exports (90 per cent) are based upon agricultural products.

However, for a country dependent on agriculture, Turkey actually is poorly endowed. Only 25 per cent of Turkey's entire area is devoted to agriculture. This situation is essentially the result of natural conditions. In fact most of the country receives insufficient rainfall, of great annual variability, and drought is periodic. In addition to these climatic limitations, agriculture is handicapped by large mountainous areas with steep slopes and resultant soil erosion, and long, severe winters.

Since climatic and physiographic conditions of the country play a dominant part on land use in Turkey we can study the above facts under three headings: arid, mountainous, and humid regions.

LAND USE IN ARID REGIONS

South-eastern Anatolia, the Mediterranean and Aegean coastal areas, interior Anatolia, Thrace and the East Anatolian depression are the main arid regions of Turkey. Although its duration and intensity differ, drought is a predominant feature in the climates of these areas. There are common features and similarities between the agricultural activities in these areas, which resemble one another closely as regards climate.

It can easily be seen that there are three types of activities in the arid regions of Turkey, as there are in almost all the arid regions of the world. First, irrigated agriculture in valley bottoms and some flat areas where industrial plants and fruits are the chief products (especially Mediterranean Aegean coastal areas); second, cereal growing (limited to the lands outside the irrigated areas), and third, extensive livestock grazing.

Arid regions can be divided into: (a) continental

arid areas in which dry farming is predominant, (b) Mediterranean arid areas in which dry farming is predominant.

CONTINENTAL ARID REGIONS

In continental arid regions, cereal growing is the most extensive and dominant type of agricultural activity, especially in south-eastern and interior Anatolia and Thrace. Of the total cultivated area, 87 per cent is under cereals but in certain regions the percentage reaches more than 95.

In these parts of Turkey, cereal growing is practised on the fallow-cereal system. This system is an outcome of geographical conditions which necessitate field growing without any irrigation in these dry steppes, and it has been used in the inhabited arid areas from the earliest periods of history up to the present.

TABLE 1. Contribution of the arid areas to cereal growing in Turkey

Kind of cereal	Over-all production in Turkey (tons)	Production in arid areas (tons)	Percentage of the arid areas
Wheat	5 127 423	3 244 598	63.28
Barley	2 616 746	1 466 052	56.02
Rye	558 171	354 757	63.55
Oats	334 088	181 100	54.21

This system certainly has a varying degree of application and importance in various periods and nations, and after being taken as a subject for scientific investigation it has acquired the name "dry farming". In some parts of interior and southern Anatolia and Thrace, livestock growing has superseded agriculture. But livestock grazing in these dry steppes is limited to the methods

of an extensive stock raising which is most suitable to the poor feeding conditions. Agricultural administration and settlement have special characteristics in these dry steppes where severe drought conditions exist. For example, the fields of a farmer who has a field coverage of 300 *dönüm* (1/4 acre) are divided into at least eight or ten parts, at considerable distances from one another. The sheep are the dominant livestock. In the agricultural economy of these regions cattle are not raised for meat or other products but rather as draft animals. The peasants meet their limited needs with this subsistence economy.

LAND USE IN MEDITERRANEAN REGIONS

Agricultural economy in the Mediterranean and Aegean coastal areas, which are also among the arid areas of Turkey, is different in character from that of the other arid areas, although cereals form the basis.

The most outstanding characteristic of the agriculture in the Mediterranean regions is its diversity. If we exclude the high plateau, which calls to mind the conditions in interior Anatolia, and the mountain sides which surround these plateaux in the Aegean region, then the agricultural activities show a great variety such as citrus, olive plantations, vineyards and industrial crops. Apart from the activities in which irrigation is the basic factor, the cereal fields which cover half of the total cultivated area contribute in a way to this variety. As in most Mediterranean climates, much land which cannot be irrigated is better for grain than for anything else.

Although the cereal fields cover 50-60 per cent of the cultivated area, in the Aegean coastal areas the industrial crops form the most developed activity. Each valley opening on to the Aegean Sea, with a groove-like shape and flowing rivers, has its own particular product. The following crops grow best in these areas: grapes and tobacco in the Gediz valley, figs especially in the Büyük Menderes valley, tobacco in the Bakircay, sesame, poppy and cotton in the Gediz and Büyük Menderes and Küçük Menderes valleys. Another economic activity in this region is extensive livestock ranching.

As has been mentioned before, the climatic factor in Turkey gives special emphasis to irrigation. Irrigation is necessary both for increasing yields on existing cropland (e.g. cotton) and for bringing new areas into continuous production. Turkey's "water problem" varies according to local conditions, but it is most severe in those areas where there is never enough precipitation and also where the precipitation régime includes both seasonal surpluses and deficiencies. In spite of the importance of irrigation in Turkey only a very small proportion of the land (6.5 per cent of all cropland) is thus farmed. Approximately three-quarters of the irrigated land is concentrated in such areas as Konya in interior Anatolia and in the Aegean region and

in Çukurova. The Çukurova is the best-developed agricultural area in Turkey. Here the chief crop is cotton, but production of early fruits and vegetables is increasing as a result of improvements in transport.

LAND USE IN MOUNTAINOUS REGIONS

Turkey's mountainous regions lie mainly in the eastern half of the country, called eastern Anatolia, which is a country of rugged mountains, high plateaux and some small tectonic depressions. In this mountainous region the great altitude is the governing factor in agriculture. As a matter of fact, east Anatolia comprises the smallest part of Turkish agriculture. Only 5 to 10 per cent of the total area is cultivated, and in many districts the proportion is no higher than 1 per cent. Tectonic depressions are the only places with adequate soils. But agriculture is handicapped not only by land-forms, but also drought. Thus irrigation has a vital importance in these eastern depressions too. Some call eastern Anatolia a land of cereal production. But its economy is mainly based on stock-raising for which the wide expanses of meadow and pasture are well suited. Both beef and cattle are raised, of better quality than in other parts of Turkey.

LAND USE IN HUMID REGIONS (BLACK SEA REGION)

These areas lie mainly on the narrow strip along the Anatolian and Thracian coast of the Black Sea and the northern slopes of the North Anatolian ranges (Pontic Mountains). Precipitation is heavy but decreases to the west. Winter temperatures are higher than in the interior, largely owing to the regulating effect of the Black Sea. The annual temperature range is about the same as on the Mediterranean coast. The climate enables the area to support natural forest. Severe dissection and intense topsoil erosion limit the amount of arable land, yet the coastal belt has the highest rural population density in the country (more than 100 per square kilometre; in 1960, 112); in the east, in some parts, the density is more than 500 per square kilometre. The inclination of the slopes, in many places reaching 40 degrees, makes the use of the plough impossible, and an intensive hoe cultivation is characteristic.¹ Corn (maize) is the principal crop and staple food. Tea, citrus fruits, fine tobacco and hazel nuts are cash crops. Hazel nuts become a monoculture crop in some areas, though the plantations and trade are centred

1. Until the end of World War II, animals and men provided most of the energy for the Turkish "ox-plough" system of agriculture. In 1949, there were only 3,200 tractors in Turkey, and of these only 2,000 were in working condition. In the following years the number of tractors increased to 43,219. At present there is one tractor for every 308 hectares of cultivated land, which is a reasonably high figure when compared with other such ratios throughout the world. It may be said that, considering topography, the fragmentation of holdings, the type of ownership, and the nature of the economic system that an adequate number of tractors are now in use in Turkey. The problem at present is how to provide an adequate spare parts service for the existing tractors.

around Giresun and Ordu. Tobacco is mainly grown in the surroundings of Samsun and Bafra on the coast and the plain of Tasova. Tobacco also covers a large

area in the vicinity of Trabzon. Tea plantations and tangerine groving are the most important activities around Rize.

DISCUSSION

X. DE PLANHOL. (1) Je voudrais souligner, à propos du très clair résumé de M. Erol Tümertekin, ce qui fait à mon sens l'originalité de la Turquie dans la gamme des pays que nous étudions. Alors que l'utilisation du sol dans les régions méditerranéennes, pontiques ou arides de la Turquie est dans l'ensemble conforme aux exigences et aux possibilités naturelles, toute l'Anatolie orientale, soit le tiers du pays, est, pour des raisons historiques, pratiquement inutilisée. Le problème fondamental de la Turquie est d'y développer des noyaux d'agriculture intensive et stable. (2) Je souligne la nécessité absolue de développer la technique des terrasses en Turquie, où elle est presque inconnue (sauf dans la région d'Akseki dans le Taurus), comme procédé essentiel de lutte contre l'érosion des sols.

D. H. K. AMIRAN. Commenting on Professor de Planhol's remark, I consider the problem of semi-arid inner Anatolia

to be the adaptation of a pre-existing rural, and urban, economy to modern standards of agriculture and rural living.

To what extent is the economy of the farmer of inner Anatolia stabilized by government subsidies in bad crop years?

Is available land the limitation to cultivation in the valleys of the Aegean slope, or are there limitations of water as well?

E. TÜMERTEKIN. Soil is the sole limitation.

H. NIEDERBÖSTER. (1) Apart from inner Anatolia, where the dry farming system cannot be substituted, there are regions where forage crops could be introduced. Perhaps 400 mm. of precipitation is the limit of dry farming. (2) In the plains and valleys of southern and western Turkey a rotation system with livestock raising should be substituted for the often practised monoculture of cotton.

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TRAITS GÉNÉRAUX DE L'UTILISATION DU SOL EN PERSE

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LES CONDITIONS HISTORIQUES ET LA MISE EN PLACE DES TYPES D'UTILISATION DU SOL

L'utilisation du sol en Perse est dominée par l'opposition du nomadisme et de la vie sédentaire¹. Les conditions écologiques susceptibles d'expliquer ce contraste sont bien connues dans leurs grandes lignes par les travaux fondamentaux de H. Bobek (1951a, 1952a, b). La répartition des régions où la culture pluviale est possible a pu être notablement délimitée de façon relativement précise (Bobek, 1951b). La distribution et les itinéraires précis des grands groupes nomades sont par contre beaucoup moins bien connus et il faut encore se référer essentiellement à la vaste compilation de H. Field (1939), inventaire commode mais dont les renseignements géographiques restent très incomplets. La comparaison de ces deux ordres de données suggère néanmoins des conclusions remarquables. Si dans les régions cultivables humides du nord du pays ou de l'Azerbaïdjan montagneux les nomades sont effectivement en très petit nombre, si leur importance dans le Baloutchistan cadre bien de même avec l'aridité du pays², ils sont par contre peu nombreux dans les grands déserts de l'Iran centro-oriental tandis que les grandes confédérations nomades des Qachqai, des Khamseh et des Bakhtyari dominent la vie du Zagros, qui appartient pourtant dans sa presque totalité au domaine de la culture pluviale et de la vie sédentaire.

Cette répartition apparaît tout à fait anormale et contraire aux exigences du milieu naturel. Il n'en a cependant pas toujours été ainsi. Dans l'antiquité achéménide les rares données que nous possédons, sur la répartition des tribus iraniennes, et notamment celles d'Hérodote, nous montrent les vrais nomades en petit nombre. Dans l'armée de Xerxès ils ne forment qu'un dixième des effectifs de la cavalerie et leur principale tribu, celle des Sagartiens, la seule qui compte véritablement, occupe le désert iranien, là où est sa vraie place, tandis que les régions de vie sédentaire

ne connaissent comme nomades que de misérables résidus, à noms péjoratifs, chasseurs plutôt qu'éleveurs, éléments marginaux et impurs très comparables à certaines « tribus » actuelles de l'Inde péninsulaire. Les montagnes du Zagros étaient sans doute occupées à cette époque par des populations semi-nomades à courtes migrations le long des vallées montagnardes, vivant une partie de l'année dans des villages et l'été sur des hauteurs assez proches, dont le modèle actuel est abondamment représenté en pays Lour, notamment par les Papis étudiés récemment par l'ethnologue danois C. G. Feilberg (1952). Ces tribus ne constituaient pas une menace pour la tranquillité de l'empire achéménide bien que certaines d'entre elles eussent gardé leur indépendance nominale et fissent même payer tribu au grand roi (Bobek, 1953-1954, p. 38). La route de Persépolis à Ecbatane filait au plus court à travers les vallées longitudinales de la montagne, dans un pays pacifié (Gabriel, 1952, p. 9).

Ce sont essentiellement les grandes invasions médiévales turco-mongoles, et spécialement l'invasion mongole avec la ruine de la vie sédentaire qu'elle a entraînée, qui sont responsables de la « bédouinisation » du Zagros, et de la formation progressive, dans un contexte de grand nomadisme guerrier, des vastes confédérations actuelles (de Planhol, 1962), et les textes ne manquent pas pour nous décrire cette régression de la vie paysanne (voir par exemple Marco Polo, XXXV; Muntahab al-tavarih-i Mu'ini, ed. J. Aubin, Téhéran, 1957, p. 44). Des arguments tirés de la technologie de la tente, dont certaines formes, centrées dans le Baloutchistan, semblent bien dériver directement de huttes à arceaux de paysans semi-nomades (Ferdinand, 1960, 1961), vont dans le même sens. On observe par ailleurs un peu

1. Le nombre ridiculement faible de 247 000 nomades donné par le recensement de 1956, qui par exemple ne mentionne pas de nomades en Baloutchistan (Bobek, 1961), ne doit pas faire illusion. Les nomades vrais ne doivent pas être loin d'atteindre le million. Les semi-nomades sous une forme ou sous une autre sont certainement plusieurs millions.
2. Voir de bonnes notations sur la géographie humaine du Baloutchistan dans Castiglioni (1960).

partout des vestiges de terroirs agricoles abandonnés (voir par exemple Feilberg, 1952, p. 85; Herzfeld, 1907, p. 60) et la généralisation de certaines mauvaises herbes comme *Phlomis persica* dans de vastes étendues montagneuses du Zagros entre 1 500 et 2 500 mètres semble bien liée à l'ancienne extension de la culture (Pabot, 1960).

Cette coupure majeure permet ainsi de distinguer deux grandes catégories de modes d'utilisation du sol; ceux qui découlent directement de l'ancienne vie sédentaire iranienne, des montagnes et des oasis, et qui ont pu persister à travers les bouleversements médiévaux et modernes; ceux au contraire qui se sont organisés en fonction des conditions politiques et sociales nouvelles et sont fondés sur le grand nomadisme.

LES TYPES D'UTILISATION DU SOL

Culture irriguée des oasis de l'Iran aride. La culture irriguée est le type le plus perfectionné des modes traditionnels d'utilisation du sol. On connaît la minutie et l'ancienneté des techniques de l'eau, qanats sans doute antérieurs à l'arrivée des Indo-Européens, et dont le débit total est évalué à 600-700 m³/sec., barrages-poids dès l'époque achéménide, barrages-voutes peut-être dès l'époque mongole (Goblot, 1961). Nous manquons d'analyses précises sur la proportion de terres restant en jachère dans les grands complexes irrigués comme celui d'Ispahan, sur la limitation de la culture permanente par l'insuffisance des ressources en eau ou par la rareté de la fumure animale. Il est en tout cas certain que les rendements sont élevés, de l'ordre de 35-50 quintaux à l'hectare par exemple pour le blé dans la zone d'irrigation du Zayandeh Roud (Zahedi et al., 1954), et que la densité humaine est forte, pouvant atteindre 200 à 500 au kilomètre carré.

Les vieux noyaux sédentaires des vallées montagneuses. Ayant pu résister aux bédouinisations médiévales et modernes, ils constituent d'autre part des centres de population dense et d'agriculture perfectionnée, fondée sur l'association de terroirs de culture permanente irrigués par barrages de dérivation, façonnés en terrasses, intensément arrosés et fumés, grâce à l'engrais fourni par un gros bétail stabulant que permettent d'entretenir des cultures fourragères (luzerne), et d'un domaine périphérique d'exploitation beaucoup plus lâche, voué à la vie pastorale ou à la culture pluviale (de Planhol, 1958, 1959, 1960a, b, 1961). Les rendements des céréales peuvent être élevés dans le terroir en culture permanente, atteignant par exemple 30 quintaux à l'hectare en moyenne dans la haute vallée du Hérás, dans l'Elbourz (de Planhol, 1961), beaucoup plus faibles naturellement en culture pluviale — 10 quintaux à l'hectare encore en moyenne en culture fumée dans des terres proches du village (de Planhol, 1963), 5 quintaux

à l'hectare en moyenne dans l'ensemble de l'Iran (Wolkenstein, 1960). La densité humaine qui correspond à ce type de vie est éminemment variable, suivant la part respective des noyaux agricoles et des espaces pastoraux périphériques. Elle peut atteindre 30 au kilomètre carré, peut-être même davantage, dans les vallées abritées, restées à peu près intactes (haute vallée du Hérás par exemple dans l'Elbourz, Sahend en Azerbaïdjan). Elle tombe beaucoup plus bas dans des cas de types régressifs, à agriculture partiellement ruinée, fortement influencés par l'atmosphère environnante et ayant allongé leurs migrations et la part de la vie pastorale semi-nomade aux dépens de la vie sédentaire [Papis du Louristan où la densité ne doit guère dépasser 5 au kilomètre carré (Feilberg, 1951, p. 38)].

Le grand nomadisme et ses dérivés. Ils restent mal connus. Les travaux récents de F. Barth (1959-1960, 1961) viennent d'apporter les premières données précises, montrant notamment le calendrier savamment dosé qui assure, à l'échelle régionale, la succession dans le temps sur un espace considéré de divers groupes tribaux qui se remplacent en maintenant toujours une stratification altitudinale rigoureuse. Ce système complexe, qui assure une utilisation totale du pâturage, ôte toute signification à la notion de territoire tribal, celui-ci ne pouvant se définir sur la carte mais comme la somme de droits sur des espaces différents pour les diverses périodes de l'année, et rend à peu près impossible le calcul de la densité de population. En tout cas les Basseri étudiés par F. Barth semblent posséder un bétail assez abondant (près de 100 têtes en moyenne par tente de 5 à 6 personnes), jouir d'un niveau de vie relativement élevé pour une population nomade (le revenu étant évalué à près de 200 livres sterling par an et par tente en 1958, sauf cas d'épizootie ou de pertes de bétail) et d'une démographie de longue date particulièrement saine, qui vaut aux nomades d'être à l'origine de la plus grande partie de la population actuellement fixée dans le Fars. Il semble bien ainsi que ce soit une agriculture dérivée de la sédentarisation de nomades qui soit dans de vastes régions iraniennes le mode caractéristique d'utilisation du sol. Nous ne possédons malheureusement aucune donnée comparative précise sur cette agriculture de nomades fixés, sur ses techniques, ses méthodes, ses rendements. Une des tâches les plus urgentes consisterait à les confronter à celle des vieux paysans, des oasis ou des noyaux de résistance montagnards, et à déterminer dans quelle mesure les nomades fixés se sont purement et simplement assimilés peu à peu à des centres sédentaires préexistants, et à leur organisation savante du travail du sol, ou dans quelle mesure leur agriculture reste plus rudimentaire. Il semble bien que l'agriculture spontanément dérivée du grand nomadisme reste, dans la plupart des cas, strictement pluviale, avec jachère, et sans enrichissement du sol autre qu'un pacage extensif d'hiver sur jachère, donnant des rendements très faibles qui doivent

rester de l'ordre de 5 quintaux à l'hectare¹. Établir la carte des « résistances sédentaires », donc des systèmes supérieurs d'occupation du sol, dans toutes les montagnes de l'arc méridional, apparaît le prélude nécessaire à toute politique raisonnée d'aménagement de cette région.

Le dynamisme respectif des divers modes d'utilisation du sol. Il apparaît actuellement très inégal. Le rôle des conditions sociales est ici capital. Un inventaire détaillé en a été donné dans le livre fondamental de A. K. S. Lambton (1953). Des estimations chiffrées ont été fournies récemment par H. Bobek (1961, p. 115). La très grande propriété, par villages entiers, doit couvrir à peu près le tiers du pays, les propriétés d'État un dixième, la moyenne et la petite propriété un peu plus de la moitié. Mais on sait que la grande propriété domine dans les régions irriguées, et la petite propriété dans les régions de montagne et d'agriculture pluviale, pour laquelle la part du paysan dans la récolte est notablement plus forte. Les grands propriétaires favorisent surtout le progrès par irrigation (qui régularise leurs ressources et les accroît considérablement par augmentation de leur part dans la récolte, beaucoup plus élevée quand ils fournissent l'eau) et par mécanisation (qui conduit à une élimination des métayers, des ouvriers agricoles faiblement rémunérés demeurant seuls), sans aucune modification majeure des méthodes culturales et sans s'attacher à intensifier l'association de l'agriculture et de l'élevage (Wolkenstein, 1960). Les petits propriétaires des zones montagneuses, sans capitaux et sans moyens d'action permettant l'extension des terres irriguées, défrichent des terres de plus en plus marginales, accroissent leur petit bétail, et de toute façon augmentent considérablement le déséquilibre entre le milieu naturel et l'action humaine.

La dégradation du milieu. Elle apparaît en effet de plus en plus comme la conséquence flagrante des deux derniers types d'utilisation du sol. La proportion des climax naturels encore existante a pu être évaluée récemment à un neuvième pour la forêt basse caspienne, à 50 % pour la forêt caspienne d'altitude, à 15-20 % pour la chênaie du Zagros, à 5 % au plus pour les forêts de genévriers de l'Elbourz et du Khorassan (Bobek, 1958), tandis que le surpâturage favorise dans les hautes montagnes subarides l'extension des formations à coussinets épineux, à *Acantholimon*, *Astragalus* et *Acantholophyllum*, aux dépens du tapis végétal naturel de graminées vivaces (Pabot, 1960).

PROBLÈMES D'AMÉNAGEMENT

Quels remèdes peuvent donc être apportés à ces imperfections et dans quel sens peut-on réaménager les rapports entre l'homme et le milieu ? On s'efforcera au moins de résumer ici quelques directions fondamentales.

En ce qui concerne les zones irriguées, de modestes améliorations techniques entraîneraient, sans grandes difficultés, un sensible accroissement des rendements. On a pu expérimenter que la substitution de la technique de l'irrigation par sillons à celle de l'irrigation par bassins se marquait dans le Fars par une augmentation de rendement de 70 % en moyenne (de 4,5 à 150 % suivant les cas) pour le coton (Anderson, 1954). L'extension des surfaces irrigables, qui reste naturellement un objectif essentiel, devra se faire aussi bien dans le cadre des méthodes traditionnelles que dans celui des grands travaux modernes. Les calculs de P. Beckett (1953) ont montré que la rentabilité de la construction de nouveaux qanats (de 7 à 25 % dans la région de Kirman) est actuellement encore comparable à celle qu'apportent les grands barrages-réservoirs [25 % pour le barrage du Séfid-Roud d'après M^{me} F. Bémont (1961), mais la rentabilité de certains travaux à l'étude, comme le barrage d'Abassabad près de Qoum, semble en année sèche devoir à peine dépasser celle des puits].

La recolonisation agricole des zones dégradées par le nomadisme pose, quant à elle, de redoutables problèmes. On sait les catastrophes qu'a entraînées la politique inconsiderée de fixation menée sous le gouvernement de Riza Chah, qui s'est d'ailleurs soldée par un retour rapide aux grandes migrations antérieures. Une fixation brutale, soit en sardsir soit en garmsir, doit entraîner des pertes de bétail allant jusqu'à 70-80 % de l'effectif (F. Barth, 1961, p. 6). Le semi-nomadisme, avec un développement progressif de l'intérêt du nomade pour la culture, peu à peu intégrée dans le cycle migratoire annuel, nous semble une étape absolument indispensable. Il convient avant tout d'encourager la tendance spontanée qui se fait jour actuellement chez les nomades vers le développement de l'agriculture, de façon à ramener peu à peu le problème au cas suivant.

En effet quel traitement apporter aux zones d'agriculture montagnarde associée au semi-nomadisme où à la vie pastorale à courte distance ? Les terres agricoles semblent dans bien des cas avoir atteint la limite de leur expansion (de Planhol, 1958, 1960a, b). L'effort d'aménagement ne pourra porter que sur le sort des parties périphériques, d'étendue considérable, de plus en plus menacées par l'érosion des sols et la diminution des couverts végétaux naturels, en un mot, la désertification. Les remèdes de première urgence consistent certes en des plantations arborescentes mais aussi, et surtout, afin d'assurer aux pasteurs existants le maintien ou l'accroissement de la base de subsistance du bétail, en la régénération parallèle des pâturages naturels par l'extension de graminées à prolifération rapide sélectionnées dans la flore indigène (Pabot, 1960).

L'exploitation des zones forestières enfin pose un

1. Voir pour ce contraste la comparaison instructive entre l'agriculture tadjik et celle des Moghols et des Taimannis faite par H. F. Schurzmann, 1962, *The Mongols of Afghanistan, Central Asiatic studies*, IV, 's-Gravenhage.

problème particulier. La carbonisation est actuellement la principale responsable de leur dévastation. La simple distribution aux charbonniers d'un outillage métallique adéquat permettrait le débitage de troncs actuellement inutilisés et qui pourrissent sur place, en augmentant considérablement le rendement. La substitution aux fours locaux, de rendement moyen voisin de 10 %, de fours métalliques (rendement voisin de 20 %), permettrait de limiter à une zone de 800 000 hectares prise dans les forêts du Nord, la zone affectée à la carbonisation pour les besoins de tout l'Iran (Uhart, 1952) et d'aborder la régénération des forêts du Zagros.

SUGGESTIONS CARTOGRAPHIQUES

Cet exposé suffit à montrer au moins l'extrême complexité du problème cartographique. Il est en particulier impossible d'utiliser les photographies aériennes. La simple représentation des catégories de culture et du paysage agraire est tout à fait insuffisante pour donner une idée de l'intensité réelle de l'utilisation du sol. Toute classification doit être résolument génétique, et s'attacher en premier lieu à exprimer les rendements et la densité de la population, qui peuvent varier considérablement dans le seul cadre de l'agriculture céréalière pluviale par exemple.

DISCUSSION

J. H. G. LEBON. What is the effect of the present policy of breaking up the large estates in the agricultural areas and creating a new class of peasant-proprietors, particularly upon the yields shown in the table on the blackboard? (2) Has the government yet formulated a rational policy towards the pastoral nomads? The speaker has told us about the consequences of an forced sedentarization; also, of the results of over-grazing and of « spontaneous cultivation ». Has the government begun to apply a sound policy towards the nomads?

X. DE PLANHOL. (1) Les expériences de création d'une classe nouvelle de paysans propriétaires, faites surtout sur les terres de la couronne, sont encore trop fragmentaires pour qu'un jugement puisse être apporté. (2) La politique de sédentarisation forcée, qui a repris dans le Zagros depuis 1957, ne peut avoir que des conséquences désastreuses, dans les conditions définies par M. Barth en ce qui concerne les pertes en bétail.

J. DRESCH. (1) De nombreuses enquêtes faites par des sociétés privées italiennes, françaises et anglaises permettraient, pour discutables qu'en soient souvent les résultats, de compléter certaines lacunes de nos connaissances. Il serait souhaitable qu'elles soient consultables et publiées. (2) Signalons l'apparition de types de culture moderne irriguée par barrages ou pompage, ou en culture sèche mécanisée. Il serait intéressant de comparer leurs rendements.

X. DE PLANHOL. Je suis tout à fait d'accord avec M. Dresch sur l'urgence de cette publication. Les résultats des travaux

italiens sur le Baloutchistan, au moins, sont déjà accessibles grâce au travail publié par le professeur Castiglioni, de Padoue, dans la *Rivista geografica italiana* de 1960. (2) Les types d'agriculture moderne ont été volontairement négligés. Je renvoie seulement aux études de P. Beckett signalées dans le texte, pour le rendement comparé de la construction de nouveaux qanats et des barrages modernes.

Y. KARMON. Do the conditions described in the paper apply also to the littoral areas of the Caspian Sea and Shott-el-Arab?

X. DE PLANHOL. Le littoral caspien en Iran est véritablement un autre monde. Une communication sur cette région devait être présentée par M. Bobek et je ne peux que renvoyer à ses travaux dont j'espère la publication prochaine.

I. KOBORI. I visited Iran immediately before the symposium, after the disastrous earthquake of 1 September 1962. It appears that modernization of *qanats* is an urgent necessity. One village depending on *qanats* and modern deep wells retained a good water supply as no modern deep well was damaged by the earthquake. The enormous amount of money and labour required for *qanat* construction still remains the primary problem to be solved in the future.

X. DE PLANHOL. L'irrigation par puits est certainement bien préférable à l'irrigation par qanats, mais elle n'est généralement possible que dans une zone limitée et l'objet des qanats est précisément d'amener l'eau dans des zones où la nappe est plus difficilement accessible.

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LAND USE IN ISRAEL

by

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A review of land use in Israel is perhaps of particular interest as here a variety of geographic factors, both physical and human, are placed in sharp focus, creating a range of conditions not often found in so small an area or so short a span of time.

THE GEOGRAPHICAL BACKGROUND

As far as physical geography is concerned, this review is mainly restricted to the area of Mediterranean-type climate (Köppen's Csa) which is both Israel's most important agricultural region and covers the largest part of the densely inhabited area of the country.¹ This includes mountains typical of the Mediterranean region rising to a maximum of 1,200 metres. Most of these consist of limestone, some of chalk; in addition, there are the basalt plateaus of Eastern Galilee. Apart from the uplands there is a coastal plain of varying width, intermontane basins and the long and narrow rift valley, most of which has a pronounced arid climate and is, therefore, outside the scope of this paper. Soils comprise terra rossa, rendzina, heavy basaltic clay soils, heavy and medium-heavy alluvial soils, light sandy soils in the coastal plain—Israel's premier citrus soil—and loess at the fringe of the arid region.

As for the population involved, there are considerable differences in type and agrotechnical and economic standards. These range from the backward, tradition-bound fellaheen of the last century over beduin of variously advanced shades of sedentarization to the Jewish farmer with a high standard of modern education, and his present-day Arab colleague who in Israel more and more adapts himself to the standard set by intensive Jewish farming and marketing methods.

Agriculture ranges all the way from dry farming with near-famine conditions in years of crop failure or successions of such years, to nearly complete irrigation farming, where the selection of crops is closely geared

to market conditions with a sophisticated use of out-of-season crops in particular areas.

As regards area, agriculture is the pre-eminent land use, but non-agricultural uses increase steadily in importance in Israel, which has the doubtful privilege of being the world's third-ranking country for rate of urbanization.² This results in tough competition for and between agriculture and urban uses.

TRADITIONAL ARAB DRY FARMING

GEOGRAPHIC CONTROLS

The traditional type of rural land use practised by the Arab farmers, the fellaheen, has cereals as its basic element with tree-crops, livestock, and often vegetables as additional branches of the agricultural economy. In nearly all instances, both of region and time, cereals are the first-ranking crop, at least in area and often no less in importance to the farm economy. The actual composition and relative importance of the other crops depends both on the region concerned and on marketing demands and conditions. Topography, soils and the state of public security determined the extent and location of land cultivated in the various villages. In the coastal plain, soil and drainage conditions were the major controls determining the extent of cultivated land. On the heavy alluvial soils most of the cereals were grown. The light sandy soils were uncultivable as long as dry farming methods only were employed.

1. The population density of predominantly rural districts in the central coastal plain rose from 60 per square kilometre in 1922 to 327 in 1961. When dealing with Israel, and Palestine before it, it is a good thing to remember two sets of basic figures which illustrate the very small size of the country. The following figures refer to Israel and Palestine north of the Negev only, as the Negev is largely arid and by 1961 had a population of less than 100,000 (density 7.6 per square kilometre). Palestine, 1922: area 11,039 sq.km., density 61; Israel, 1961: area 7,420 sq.km., density 279. (Total area, including the Negev: Palestine, 1922: 25,256 sq.km., Israel, 1961: 20,700 sq.km.)
2. In 1961, 77.9 per cent. The two top-ranking countries are the United Kingdom and Australia (cf. *United Nations, Demographic Yearbook, 1960.*)

On extensive parts of these soils oak forests, a most singular feature of Israel's landscape in the nineteenth century, were preserved until the First World War. But once irrigation was introduced these well-aerated soils soon turned into the prime citrus soils on which the famous Jaffa oranges were grown. This change in technology brought about a very considerable increase in the total cultivated area.¹ Least used were the unconsolidated sands of the coastal dunes on which grapes and certain fruit trees, e.g. figs, were grown at low densities of cultivation.

It is rather difficult to give valid values for the average size of land units cultivated by peasant families. In common with many countries, pre-1948 Palestine exhibited vast contrasts in size of land holdings. Arabs ranged from landless share-croppers to rich feudal families, the cream of Arab society. A small number of them owned 10,000 hectares and more per family. According to a well-informed estimate, 250 families owned a total of 414,300 hectares of landed property in Palestine, nearly equivalent to the total area cultivated by all farmers of Palestine at the time.² Furthermore, much land, including some of the largest holdings, was the property of the Moslem religious domain, the *waqf*.

But it is not size of land holdings that interests us here but the average size of land cultivated per farmer, irrespective of whether it is owned by him or not. Lacking such data we shall use as a substitute the ratio of total area of land to the number of occupied houses for a given village or, for short, the "land-house ratio". This ratio gives the average amount of land in hectares available per farmer family in the village. The figures thus obtained certainly are higher than the actual area of land cultivated by the "average farmer", as apart from the built-up land of the village itself it includes much uncultivated land, part of which was uncultivable at prevailing levels of agricultural technology and economy. According to the official *Village Statistics* of the British mandatory administration, in certain villages the amount of land classified as uncultivable reached three-quarters of the total area. But this in a way is only the expression of a low level of agricultural technology and a low-gear economy in general.

Taking then the land-house ratio³ as an inflated measure we obtain values of 5-8 hectares in the coastal plain. Values in most of the mountains are considerably higher, averaging between 8 and 15 with occasional values even higher than that.

In the hills and mountains, topography and resulting soil conditions determine to a considerable degree extent and type of cultivation. Intermontane basins, characteristic especially of Lower Galilee and Samaria, are focal areas of cultivation, notwithstanding the disadvantage that seasonal flooding or at least increasingly marshy conditions as the winter rainy season advances often prevent the growing of a winter crop. The large

Beth Netofah Basin, in part of which water would sometimes stand through June and into early July, is a case in point.

Where intermontane basins or broad valley bottoms are not to be found, man had no choice but to cultivate the slopes of valleys, some of them with gradients of 20-30 degrees. This obviously was possible only by terracing. Consequently, Judea—both for want of more suitable types of topography and for the antiquity of intensive land occupation—shows the most pronounced degree of ancient terracing. According to a recent, yet unpublished, sample study by Z. Ron the over-all amount of terraced land to the west of Jerusalem amounted to 56 per cent of the total surface area. This certainly is extremely high. It does not imply that all these terraces were cultivated at the same time. But one might be justified in assuming that at least at the time Judea prospered most,⁴ most of these terraces were cultivated simultaneously. The preparation of these terraces was relatively easy, as in Judea near-horizontal stratification of its well-bedded limestone is characteristic. It requires, therefore, only a clearing of the head of the stratum, the construction of a retaining wall and some stone clearance to prepare a terrace. Nevertheless, the amount of labour invested in these ancient terraces and their maintenance was tremendous, an investment possible only when labour was a cheap commodity and when the crops grown on these terraces commanded a good price in a stable market. As these conditions did not persist with the deterioration of the Palestinian landscape during most of the second millennium A.D., it is little wonder that the area of terraced land under cultivation declined sharply. By the nineteenth century no more than an estimated 10 per cent of the ancient terraces were actually cultivated, the rest was abandoned land in various stages of terrace deterioration. This is one of the most outstanding cases of regression in land use in the Mediterranean area.

For two reasons the extent of cultivated land in Judea in various periods is restricted and has fluctuated considerably. First, the high cost of preparing land for cultivation in terraces. This results in a rather small area being cultivated and at the same time in frequent double cultivation, the most frequent combination being cereals grown underneath olive trees on the same terrace. In the centre of the Judean Mountains the

1. Cf. *Atlas of Israel*, sheets VIII/2 and VIII/3.

2. The foremost source on land holding in Palestine: types, sizes and legal status, is A. Granott, *The Land System in Palestine: History and Structure* (London, Eyre and Spottiswoode, 1952). The estimate referred to is by M. Smilansky, cited by Granott, p. 39.

3. All figures for the land-house ratio given here refer to 1931, for which year the number of houses occupied is given in the census returns.

4. Apparently first century B.C. to fourth century A.D. Compare: A. Reifenberg, *The Struggle Between the Desert and the Sown: Rise and Fall of Agriculture in the Levant* (Jerusalem, Jewish Agency, 1955, especially Chapter VI; and R. O. Whyte, "Evolution of land use in South-western Asia", in: L. D. Stamp (ed.), *A History of Land Use in Arid Regions* (Paris, Unesco, 1961), p. 57-118, especially p. 98-100.

For an account of quite similar terraces and their construction in a neighbouring area where terrace cultivation persisted, cf. N. N. Lewis, "Lebanon—the Mountain and its Terraces", *Geographical Review*, vol. 43, no. 1, 1953, p. 1-14.

land-house ratio, therefore, goes down to 5-6 hectares. The second factor limiting cultivated areas is deterioration of national security, which was the fate of Palestine for much of the time between the *pax Romana* and the *pax Britannica*. This affected most of all the frontier region of settlement, the more so as the semi-arid frontier was not only a climatic and consequently agricultural frontier, but the frontier of the area controlled by Bedouin as well. Here it was unsafe to settle in villages too small to defend themselves effectively against Bedouin raids. Equally, it was unsafe not to return for the night to the village from cultivating distant fields. Consequently, a limited part of the village lands only, those nearest to the village, were cultivated and the land-house ratio rose in these areas to its highest value: 15-40.

AGRICULTURAL PRACTICES

Traditional Arab dry farming employs a system of crop rotation extending over $1\frac{1}{2}$ to 2 years, in which the following sequence is adhered to: winter crop (wheat or barley); summer crop (durrha, maize or sesame); fallow (not always observed). Very little manure is applied except for that obtained by pasturing sheep and goats as well as cattle on the field after harvest. In this traditional farm economy hardly any chemical fertilizer was applied.

Next to cereals in importance in the traditional farm economy are fruit growing and tree-crops. Both provide essential supplies for the farmer's own consumption as

well as cash products sold locally and on the export market. The most important of these crops was originally the olive which mainly as oil but as pickled fruit as well—formed the most important source of fat for the Arab kitchen. Olive oil and its derivatives, e.g. soap, were in certain periods the first-ranking export commodity of Palestine. The olive grown without irrigation produces alternating yields: a heavy crop one year, followed by a very small one the next year. Additional fruit and tree-crops are: grapes, figs, apricots and plums, and a large number of less important ones, such as pomegranates.

Part of the vegetables grown and a small amount of fruit, including some grapes, were cultivated under irrigation. Those irrigated plots were mostly located close to the small springs of the mountain area, partly in the bottoms of valleys and partly on terraces.

The ascendancy of citrus is closely linked to the improvement of shipping which only late in the nineteenth century permitted the export of this perishable crop to European markets. By 1880 nearly all of the citrus acreage was near Jaffa, amounting to no more than 2,900 hectares as late as 1920. There was a steep increase to 30,000 hectares by 1938. The greater part of this acreage was owned by commercial operators rather than by farmers, both in the Arab and the Jewish sector of economy.

The prevailing system of land tenure had great influence on agricultural economy and its development as well as on agricultural land itself. Apart from rather small areas held as definite private property (*mulk*),

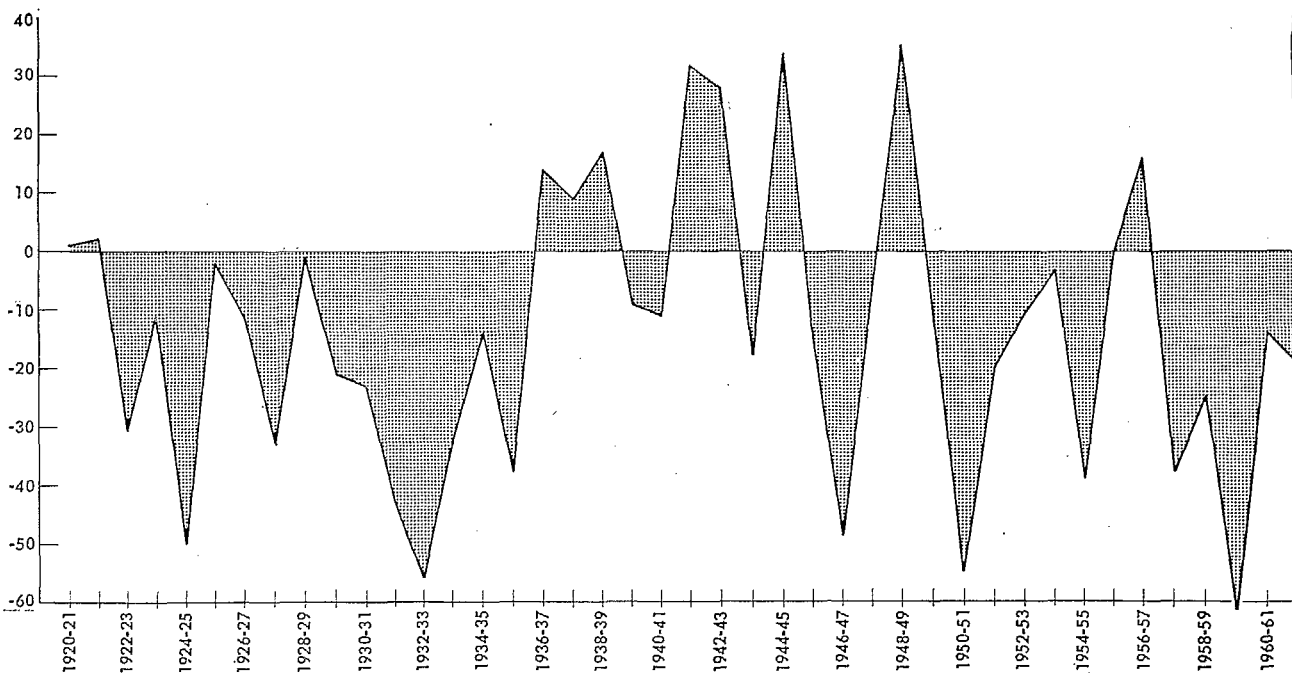


FIG. 1. Jerusalem. Rainfall. Percentage deviation from average.

most of the agricultural land was *mesh'a* (i.e., land held as joint and undivided property, generally of all the families or clans of a village). The parcels of *mesh'a* land were distributed by lot between all joint owners at regular intervals, generally 1-3 years. Needless to say such a system of tenure had a most deleterious effect on the land, discouraging any permanent improvement. Excessive parcellation by division between subsequent generations of heirs was another negative factor.

CHARACTERISTICS OF LAND USE

Field crops, over 90 per cent cereals, occupied the first place in the traditional farm acreage. They were the highest contributor to the income of the non-commercial farmer. Only citrus contributed a higher share by value to the national income derived from agriculture (43 per cent as against 29 for field crops in 1935). Field crops had first call on agricultural labour. All this irrespective of their low unit value and the extensive nature of their cultivation. Most of the crop was grown for local consumption and often did not satisfy demands. Only the southern coastal plain produced exportable surpluses of barley in good crop years which were shipped through the roadstead of Gaza. The contribution to the national farm economy by vegetables and fruit other than citrus was less than the share of field crops.

In this economy the most important commodity for production is land; the more land available to the farmer, the better his chances to grow large crops. Labour was cheap and ample. The critical and uncontrollable element is climate, specifically rainfall, its amount and distribution, and to a lesser degree evapotranspiration. The sub-humid to semi-arid climate of Israel involves considerable fluctuations of climate and its elements. A dry year in a series of more or less normal years or of wet ones rarely has serious consequences for the farm economy. But Israel, like all other semi-arid countries, is distinguished by prolonged series of sub-normal rainfall years. These do not always repeat the grim biblical story of seven lean years, but three consecutive lean years, each with a negative deviation of 30 per cent or more from average values are unfortunately part of the experience of every farmer.¹ Whereas a farmer can weather a single dry year, a series of such years spells want. And near-famine conditions are in the memory of all who have experienced the type of farm economy mentioned above.

MODERN JEWISH IRRIGATION FARMING

Agricultural land use as practised by Jewish farmers has undergone considerable development. It started at the end of the nineteenth century as dry farming with methods similar to the traditional way of the Arab

TABLE 1. Percentage deviations from average rainfall in Jerusalem for two subnormal periods

Period	1920/21-1937/38		1944/45-1961/62	
	Total amount of deviation	No. of years of occurrence	Total amount of deviation	No. of years of occurrence
Number of years		18		18
Positive deviations	26	4	85.4	4
Negative deviations	365	14	369	14
Positive deviations of 30 per cent or more	0	0	79	2
Negative deviations of 30 per cent or more	283	7	243	5
Negative deviations of 50 per cent or more	106	2	117	2

Sources: (a) N. Rosenan, "One hundred years of rainfall in Jerusalem", *Israel Exploration Journal*, Vol. 5, No. 3, 1955, p. 151. (b) Israel Meteorological Service.

farmer and requiring land units of a similar order of magnitude. It suffered from the same disadvantages of a two- or three-crop economy in which cereals outweighed the rest. And it was at the mercy of climate and good or bad crop years just as the Arab farmer was.

THE TRANSITION PERIOD OF MIXED FARMING

Three major changes were gradually introduced into Jewish agriculture to make it less vulnerable and more resistant to annual changes of yield. First, *mixed farming*, resulting in a great diversity in land use. Each farm would engage in all or several of the following operations: cereals as a winter crop, cereals as an irrigated summer crop, mainly for fodder, vegetables, fruit, commercial poultry farming, dairy cattle—nearly all stall-fed on fodder crops grown by irrigation, and various specialty crops. This type of mixed farming permitted a much denser crop rotation on the land, getting higher yields from the same acreage. This was made possible by advanced methods of cultivation and full-scale application of fertilizer. It permitted too a maximum utilization of the small labour force—the farmer and his family being employed all year round with very few slack seasons. It involved rather small but intensively cultivated parcels of land. These had to be carefully prepared—levelled, cleared of stones—and cultivated. Investment of labour per unit of land, therefore, became much more intensive.

1. Cf. N. Rosenan, "One hundred years of rainfall in Jerusalem", *Israel Exploration Journal*, vol. 5, no. 3, 1955, p. 137-153, and supplementary data kindly provided by the Israel Meteorological Service. From the data published there, Figure 1 and Table 1 were prepared. The eighteen-year series 1920/21-1937/38 contained 14 consecutive years with such deviations exceeding 20 per cent. A shorter but no less extreme period of negative deviation occurred recently, beginning in 1957/58; negative deviations at Jerusalem were: 38, 25, 63, 14, 19 and 59 per cent.

TABLE 2. Israel: cultivated area

Year	Total cultivated area		Non-irrigated area		Irrigated area		
	In hectares	As percentage of 1944/45 total	In hectares	As percentage of 1944/45 non-irrigated area	In hectares	As percentage of 1944/45 irrigated area	As percentage of total cultivated area
1944/45 ¹	57 100	100	53 100	100	4 000	100	7.0
1954/55	35 900	62.9	27 000	50.8	8 900	222.5	24.8
1960/61	42 850	75.0	28 850	54.4	14 000	350.0	32.7

Sources: (a) *Statistical Abstract of Israel (1961)*, Vol. 12, p. 172. (b) E. L. Levie and Z. Raz, in: *Atlas of Israel (1959)*, sheet XII/2, table A.

1. Figures for 1944/45 refer to the area now in the state of Israel only.

The second feature of this intermediate period of Jewish farming was the *co-operation* of effort to farm the land in more efficient larger units, spreading both investment and risk. This led to a number of types of agricultural co-operation culminating in the well-known communal village, the kibbutz, which became the prevalent type of village organization characteristic of this period. It is obvious that this organization of farming is more efficient both because plots of land cultivated are larger and because the whole village operates as one management unit, permitting the full and most efficient utilization of agricultural machinery and of manpower, and specialist manpower in particular. The considerable acreage devoted to a given crop in a kibbutz and the size of a given branch of agriculture in kibbutz economy brought about the emergence of a group of highly qualified specialists in various branches of agriculture in communal villages.

In physical appearance there is, therefore, a striking difference between land cultivated by a kibbutz (a communal village) and that held in other forms of ownership or management. Furthermore, the increasing mechanization and higher labour intensity not only permit, but demand, higher output per unit of land and make this advanced type of agriculture more selective as to the land cultivated. Much land of marginal quality which is cultivated by the traditional farmer is retired here.

The third major change in Jewish agriculture is an advanced rate of *investment* of capital to permit the mechanization referred to and no less to develop *irrigation* as a major item of agricultural technique. The gradual increase of this trend brought about a number of major changes in farm economy, and consequently in land use. Basic investment in preparing land for cultivation became more expensive. The same applies to labour, either because more labour was employed per unit of land, or because this had to be more expert farm labour, i.e. requiring higher wages. As a result, production per unit of land became more expensive. Consequently, the land had to yield more and higher returns per unit. As far as land use is concerned, this

involved a definite change from cereals as the mainstay of traditional farming to high-value, market-oriented crops.

The development outlined above was characteristic of a transitional period of Jewish agriculture roughly between 1920 and 1950. One additional characteristic of this period has still to be mentioned: the great expansion of citrus cultivation, entirely under irrigation. A considerable area of land amounting to about 30,000 hectares in 1938 was put under citrus cultivation. This involved a considerable acreage of Red Sandy Soils, the weathering product of a Quaternary sandstone in the coastal plain, which because of its permeability could not be cultivated before the introduction of irrigation. Most of this was used for orange growing. Much of the grapefruit was grown on heavy alluvial or clayey soils in the intermontane basins and on the basaltic soils of Eastern Galilee.

Citrus cultivation, which reached its peak during the period referred to, played an important part in advancing agricultural organization in Israel towards the present stage. By being fully market-oriented it introduced strict standards of quality and handling, and centralized, co-operative organization of marketing which are standard features of modern agricultural organization in Israel.

SPECIALIZED IRRIGATION AGRICULTURE

Present-day agriculture in Israel then is characterized by a high degree of specialization in both crops and manpower, maximum returns per unit of land obtained by an often nearly complete transition to irrigation and by a pronounced orientation towards the market. This is a long way from traditional farming, which mainly catered for the needs of the farmer's own family with but a small amount of produce available for marketing.

AGRICULTURAL CONTROLS

The decisive agricultural commodity no longer is land, which is in relatively ample supply, nor mechanical

equipment, the availability of which is taken for granted at the prevailing level of capital investment. Their place has been taken by water as the controlling physical commodity and the price of labour as the economic one. Preference is, therefore, given to those crops which will give the highest return per cubic metre of water and per work day. The latter gives automatic preference to crops which permit of mechanized cultivation and discriminates against those which do not permit this. One of the reasons for the popularity of cotton in Israel (grown on about 10,000 hectares in 1959-1960) is that all cultivation, including picking, can be done by mechanical equipment, including pest control by dusting from aircraft. The same economic considerations brought about a sharp decline in the importance of so time-honoured and well established a crop as olives. The medium margin of profit of the olive, irrespective of the good price commanded by olive oil, makes it less and less attractive to farmers, who have to cultivate it entirely by manual labour, including picking. The high price of olive oil necessitated by its manual cultivation brings about a shift of consumer preference in its disfavour. They gradually shift to the use of other edible fats, as margarine, soya-, groundnut- or other oils, restricting the use of olive oil to a few special purposes only.¹ This has not yet brought about a restriction of the area of olive groves, but some of them are already very poorly maintained.

That price and mechanization are the decisive factors in determining priorities of land use is shown by another crop demanding a high amount of manual labour, namely citrus. Picking still has to be done by hand. Sorting and packing has been mechanized to a considerable degree. Cultivation is almost entirely mechanized. To make this possible, a considerable number of groves have been replanted² to achieve wider spacing of trees and permit thereby cultivation by tractor-drawn equipment. Irrigation is applied by sprinkling instead of the earlier practice, where the farm labourer had to direct a certain amount of water by pipe or channel into a bowl-shaped excavation around each tree. These excavations were one of the largest items in demand for labour. Pest control too is mechanized, nearly all by aircraft dusting.

The high-quality seedless Jaffa orange has a great appeal both to the local and the foreign markets. This, together with the mechanization of most stages of cultivation save picking, permits it not only to hold its ground but to enlarge its area. We thus have here a first typical specimen of a specialty crop which as a group is gaining ever-greater ascendancy in the land-use pattern of Israel.

WATER

The most stringent control determining land use is without doubt availability and price of water. In a

planned agricultural economy like that of Israel this expresses itself in many ways. To make maximum use of available rainfall a considerable acreage of the plains and plateaux in the north, is used in dry farming.³ Parallel with this, the average over-all allotment of irrigation water per unit of land is smaller in the north than in the south, and highest in the semi-arid areas of the east, in the Jordan Valley.⁴ The *Atlas of Israel* (sheet XII/3) shows for six selected crops the amount of water required for irrigation. This increases steadily towards the east and the south but decreases beyond the southern coastal plain on the fine-grained loess soils of the northern Negev. These maps, therefore, express increasing costs to produce the same yield. In planning the addition of irrigated acreage preference will be given to the loess type soils of the south (the western Beer-sheba Basin) where less water is required to produce standard yields.⁵

The cost of water becomes a limiting factor where it has to be pumped to considerable altitudes, as in general this is much more expensive than delivering it—by pipeline—to a greater distance. In some areas of Upper Galilee the cost price of water is more than ten times that of the water in the Huleh Basin nearby, but 750 metres lower. This would prevent agricultural use of water in the mountains without lowering the consumer price by subsidy.

In general, the over-all amount of water available,⁶ and more specifically that part of it allotted to agriculture determines the amount of land which can be irrigated. In view of the strictly limited availability of this basic commodity the use of water is subject to

1. In part this shift is due to the change in food habits brought about by population changes. People of European origin generally use little olive oil. By mid-1962, retail prices for various popular oils were the following percentages of the price of olive oil: soya, 39; sunflower, 46; groundnut, 49; corn, 57.
2. This is relatively easy with citrus trees which come into production after seven years and have a useful life span of not much more than thirty-five years. It would be much more difficult with olives which live and produce for many hundreds of years. The realignment of citrus groves was easy too as many of the groves had to be replanted after 1950. Being entirely market-oriented the maintenance of many groves was discontinued during the Second World War when the unavailability of shipping made exports impossible. The dislocation of labour during the Arab-Israel War of 1948-49 brought about another interruption in cultivation.
3. Cf. *Atlas of Israel*, sheet XII/2, map G. It is interesting to note that villages which practise dry farming in the southern coastal plain, near the border of aridity, consistently give preference in cultivation to their northern lands over their southern ones. The advantage thus gained is not only a few millimetres of rainfall but no less taking a lesser chance with annual fluctuations of rainfall which increase as the average amount of rainfall decreases.
4. *Atlas of Israel*, sheet XII/3, map C: northern coastal plain and Lower Galilee, 400-500 cubic metres per dunam; central coastal plain, 500-550; southern coastal plain, 550-600; eastern area: Huleh Basin, central Jordan Valley, Beth Shan and Harod Basins, 600-1400 (1 dunam = 0.1 ha. = 0.247 acre).
5. This will be the case in the Bsor Region, west of Beersheba, now in the planning stage.
6. To allow for annual fluctuations in rainfall and in groundwater recharge and more specifically for series of under-average years it is necessary to plan average withdrawal rates on mean minimum recharge values and not on average ones. One should note that, as far as ground water recharge is concerned, over-average years often do not balance deficient ones. If, as often occurs, high-rainfall years are characterized by a high concentration of rainfall, most of this will be lost as storm water run-off into the sea with but a small percentage recharging the groundwater. Total rainfall in a given year and ground-water recharge are, therefore, not directly comparable. The distribution of rainfall is an important factor in determining recharge.

an authorization from the Water Commissioner. This authorization specifies the exact amount every village may use and even specifies the rates for individual months. As most of the water is supplied by a central public utility corporation, the Mekoroth Water Company, Ltd., supervision is easy. The divisional controller will discontinue or restrict the supply to any customer village which consumes more water than the amount allotted to it. This has even happened to the city of Tel Aviv.

Notwithstanding the severe limitations on water the farmer of Israel, in common with nearly all his colleagues in other countries employing irrigation, uses considerably more water than he should or plans to use. Sometimes the discrepancy is quite considerable. Over-irrigation, delay in switching off the water at the proper time, irrigation around midday, continuing irrigation during strong rains in winter, leakages in the pipes, all contribute to this. If the Jewish farmer uses too much water in irrigating, his Arab colleagues who is a newcomer in irrigating with pipe-borne water is even more wasteful with this precious resource. Especially in the initial stages of irrigation farming he often believes that the more water he applies to his crop the higher will be the yield. It takes him some time before he reduces his water consumption to the correct rates.¹

To sum up, the present extent of the irrigated area is mainly controlled by the amount of water available. An increase in supply would permit the extension of irrigation to other lands without difficulty; this includes both land dry-farmed at present and land not cultivated at all.

Water and labour costs are the major controls of agricultural production, and therefore of land use, but by no means the only ones. Transportation distance and cost are also very obvious ones.

PRESENT TYPES OF LAND USE

The limited availability of water, the relatively small units of land cultivated per farmer, and the necessity of gaining high returns for labour in an economy which is distinguished by a rather high standard of living, has brought about the emergence of a number of well-defined land use types. Every one of these specializes in a limited number of crops, often particularly fitted to the area concerned, or fitting within an over-all national plan balancing production with marketing possibilities. These land use types are a distinct departure from the over-all tendency towards mixed farming characteristic of the preceding period. Although unirrigated crops, mainly cereals, are still grown on an extensive area and in certain land use types form an important component, they nowhere form the backbone of farming, but are considered a sideline on which the farmer takes his chances. Occasionally he

gets a bonus out of them, sometimes they just pay the labour invested, and sometimes he loses heavily—that is unless the government pays him compensation for losses sustained by drought.²

LAND USE TYPES OF THE PLAINS

Obviously, there will be a difference between the major land use types in the plains and the mountains. In the plains the most common combinations are the following: cereals and dairying;³ vegetables, poultry, with or without dairy farming; fruits and vegetables; industrial crops, i.e. cotton, sugar beet, groundnuts.⁴ Among the fruits (apart from citrus), bananas are often of particular importance to farmers, giving high returns.⁵

Industrial crops as the mainstay of the economy of new villages were introduced into the land use pattern about 1955 when the market for food products became saturated. Another reason for introducing them was the desire to substitute locally produced raw materials for imports. The major region devoted to industrial crops is located in the southern coastal plain. A considerable acreage of citrus and bananas, and a certain percentage of the industrial crops are grown by communal villages (kibbutzim).

In distinct contrast to the traditional type of farming where nearly all summer crops were grown without irrigation, modern land use is distinguished by large areas of irrigated summer crops including all the important crops grown during that season: fodder

1. In an unpublished recent study of Taibeh, the largest Arab village in Israel, G. Golany cites the following figures on water applied in irrigating selected vegetables and fruits (in cubic metres per hectare):

Crop	Taibeh		Jewish villages in comparable conditions
	1954/55	1960	
Tomatoes	8 000	4 000- 6 000	5 100-5 900
Cucumbers	6 000	4 400- 5 000	3 500-5 800
Citrus	—	7 000- 8 000	7 000
Guavas	—	8 000-12 000	8 000

2. Cereal farming in Israel today has turned to a considerable degree into a game of chance between reasonable or good harvests on the one hand and government compensation for either drought or flood damage on the other. The more pronounced the semi-arid character of the region concerned, the more frequently such damage occurs. Small wonder, therefore, that the semi-sedentary beduin of the Beersheba Basin have become most adept in handling compensation. Consequently their main sources of income are today, in this order of priority: wage labour in agriculture or construction, smuggling, compensation for damage to crops, sale of goats and camels for slaughtering.
3. Wherever dairy farming is a branch of the farm economy a considerable area is used for growing irrigated fodder crops. In 1959/60 out of a total of 130,000 hectares cultivated under irrigation 27,188 (or 21 per cent) were devoted to fodder crops, and this in addition to 47,738 hectares on which fodder crops were grown without irrigation (20 per cent of the non-irrigated field crop area).
- Fodder crops are heavy consumers of water, alfalfa getting as much as 10,000 cubic metres per hectare. In some villages which concentrate on dairy farming the annual yield of milk in litres is roughly equal to the annual consumption of water in cubic metres. Average annual yields of good average cows are 4,500-5,500 litres, top yields up to 12,000.
4. These three major "industrial crops" commanded in 1959/60 an area of 19,364 hectares.
5. Banana, mainly a summer crop in Israel, requires great amounts of water, up to 40,000 cubic metres per hectare. This would make the soil waterlogged. To prevent this, banana is generally planted once only in a six to ten-year rotation. It is followed by alfalfa or other heavy water consumers which are then grown with very little additional irrigation at first.

TABLE 3. Israel: agricultural land use¹

	1935				1943				1956/57				1959/60				Changes, 1935-1959/60	
	Area		Value		Area		Value		Area		Value		Area		Value		Area	Value
	ha.	%	£ (I) 1,000	%	ha.	%	£ (I) 1,000	%	ha.	%	£ (I) 1,000	%	ha.	%	£ (I) 1,000	%		
Total cultivated area	797 169	100	5 421	100	624 397	100	22 240	100	382 000	100	579 391	100	407 000	100	748 867	100		
Non-irrigated area	...		...						272 000	71.2			277 000	68.1				
Irrigated area	...		...						110 000	28.8			130 000	31.9				
Field crops	653 503	82.0	1 597	29.4	456 825	73.1	4 860	21.7	272 632	71.4			285 000	70.0			-12.0	
Wheat	225 102	28.5	861	15.9	175 485	28.1	1 779	7.9	57 288	15.0	19 180	3.3	59 328	14.6	8 960	1.2	-13.9	-13.2
Barley	262 794	32.8	294	5.4	147 796	23.7	1 149	5.1	51 914	13.6	14 062	2.4	59 631	14.7	4 599	0.6	-18.1	-4.2
Fodder crops ²	135 791	17.0	...		90 475	14.5	960	4.5	106 348	27.8	55 658	9.6	85 158	20.9	44 812	6.0	+3.9	...
Cultivated fallow	...		...		...		...		19 778	5.2			39 898	9.8				
Industrial crops	—		—		—		—		23 159	6.1	30 183	5.2	26 019	6.4	53 413	7.2		
Cotton	—		—		—		—		4 825	1.3	10 096	1.7	10 500	2.6	24 782	3.3		
Sugar beet	—		—		—		—		1 338	0.4	3 073	0.5	3 799	0.9	8 851	1.2		
Groundnuts	—		—		—		—		5 460	1.4	9 205	1.6	5 055	1.2	9 836	1.3		
Tobacco	2 231	0.3	93	1.7	2 759	0.4	447	2.0	3 133	0.8	2 653	0.5	3 814	0.9	2 795	0.4	+0.6	-1.3
Vegetables	11 854	1.5	366	6.7	27 587	4.4	7 159	32.3	16 938	4.4	45 077	7.8	17 638	4.3	48 810	6.5	+2.8	-0.2
Tomatoes	3 225	0.4	118	2.2	8 084	1.3	1 904	8.5	3 563	0.9	12 709	2.2	3 311	0.7	18 095	2.4	+0.3	+0.2
Fruits	117 581	14.8	3 365	62.0	137 227	22.0	9 775	43.9	59 800	15.7	130 480	23.3	72 200	17.7	187 420	25.2	+2.9	-36.8
do. irrigated	...		...		...		...		49 300	12.9			36 500	9.0				
Citrus	27 800	3.5	2 344	43.2	27 200	4.4	1 160	5.2 ³	24 600	6.4	87 654	15.1	32 800	8.1	108 637	14.5	+4.6	-28.7
Grapes	14 945	1.9	156	2.9	17 495	2.8	1 626	7.3	10 900	2.9	14 728	2.6	11 500	2.8	18 112	2.4	+0.9	-0.5
Bananas	...		...		708	0.1	630	2.8	1 700	0.4	10 562	1.8	2 100	0.5	14 325	1.9		
Olives	47 447	5.9	474	8.7	59 239	9.5	3 735	16.8	13 000	3.4	2 833	0.5	12 300	3.0	4 163	0.6	-2.9	-8.1
Pond fish	—		—		420	0.07	182	0.8	4 100	1.1	10 418	1.8	4 800	1.2	13 267	1.8		

Source: (a) *Statistical Abstract of Palestine, 1937-38, 1944-45*. (b) *Statistical Abstract of Israel, 1957/58, 1961*.

Note. ... = not available; — nil.

1. Cf. note 1 (page 101) on areas of Palestine and Israel respectively. Rainfall was about average in 1935, above average in 1943 and 1956/57, whereas 1959/60 was one of the most deficient rainfall years on record.

2. In 1935, 6.6 per cent of the acreage of fodder crops was irrigated; by 1959/60 this had increased to 33.3 per cent.

3. Due to the war citrus cultivation in 1943 represents abnormal conditions.

plants, cotton, sugar beet, banana, other fruits, vegetables, groundnuts.

At first this departure from age-old agricultural practice brought a striking unbalance of natural conditions in some areas. The soil no longer dries out in summer, developing deep cracks. The microfauna, including various plant pests, are no longer destroyed—or rendered dormant at least—by summer drought. Their continued activity at the time of optimal conditions due to high temperatures required suitable adaptation of control and cultivation methods before yields could reach the desired standards.

As a result of basing land use to a great extent on irrigation and making irrigated crops the secure basis of a farm economy no longer dependent on climatic and other variations from year to year, the size of the standard land unit has been reduced considerably. Farm units based entirely on irrigation have standards of 2.25 to 6 hectares, the most frequent values being 3 to 5. Farm units in the mountains are similar in size, tending more to the lower limit of this scale.

Every one of the land use combinations mentioned above may have one or more sidelines in specialty crops. Of special importance amongst these is pond fishery, a most desirable type of land use to the farmer of Israel as no other agricultural product gives such high returns per unit of labour. Introduced originally in order to permit the utilization of swampy and saline soil or slightly saline water, or both, fish ponds have transformed the agricultural landscape in many parts of Israel. They are particularly to be found in the Huleh Basin (Lake Huleh itself has been drained), the Beth Shan and Harod plains and in parts of the coastal plain between Acco and the northern Sharon. In 1961, 5,345 hectares were used as fish ponds, giving a total yield of 8,865 tons, valued close to 14 million Israel pounds. The great majority of the fish bred in ponds is carp, a standard item on the Sabbath table. As fish ponds lose large amounts of water by evaporation, the tendency at present is either to restrict them to those places where they can use water too saline for other agricultural uses or to fill them solely with storm-water which otherwise would run off into the sea.

LAND USE IN THE MOUNTAINS

In the mountains fruit growing normally forms one standard element in land use combinations. Grapes, plums, apples, apricots, pears, peaches are the main fruit grown. Additional elements may be vegetables, poultry farming, sheep or beef cattle, or even dairying. Two of these types of land use are of particular interest. Farmers producing certain vegetables and fruit, especially tomatoes and table grapes, make use of local climatic conditions in order to market them either very early or very late in the season. This even permits them to use or to prepare for use land which otherwise could not be cultivated profitably. An outstanding example

is the tomato cultivation around Lake Tiberias. The high temperatures on the slopes around this rift valley lake permit the marketing of tomatoes four to six weeks ahead of the main season. The lake itself is a cheap and ample source of irrigation water. Early in the nineteen-fifties enterprising farmers started growing tomatoes on the lowest parts of the slopes along the main highway, lifting water from the lake by means of small diesel pumps. Gradually tomato fields climbed up the slopes. By 1962 the highest tomato fields were 180 metres above the lake at its south-west corner and 220 metres above it on the north side. Even when water has to be pumped from the lake to these altitudes, tomato growing is still a very profitable business. A similar and even more extreme case is that of the oasis of Ein Gedi on the western shore of the Dead Sea. Here both tomatoes and grapes ripen well before the onset of the season. Tomatoes from Ein Gedi are not only marketed two to four weeks ahead of those grown in any other region, beginning early in March, but produce yields as much as a third above the average. Notwithstanding the considerable distance from the market, the village is making a handsome profit by selling to high-class hotels and other selected customers. Another limited, though profitable, branch of the very specialized economy of Ein Gedi is rose growing. Flowering between December and April, the roses of Ein Gedi find no competition on the market.¹

Whereas the rift valley (Lake Tiberias and Ein Gedi) concentrates on off-season agriculture and horticulture producing very early crops, the mountain region tries to do the same by aiming at the late part of the season, a time when no other producer has any more products to market. Grapes from the mountains reach the market as late as September and even early October and so do tomatoes.² The village of Eilon in Upper Galilee finds it profitable to specialize in late tomatoes grown under irrigation on terraces prepared for this purpose.

1. It is a measure of the pace of agricultural development in Israel that since the above was written early in 1962, the farmers of Ein Gedi have introduced certain significant changes into their village economy and decided on even more far-reaching ones. The improvement of agricultural techniques in the Lake Tiberias area, especially the extensive use of plastic cover by tomato growers, leaves Ein Gedi an advantage of not more than ten days over the Tiberias area in marketing tomatoes. So close a marketing gap makes tomato growing at Ein Gedi marginal, in view of transportation costs. As from the 1963/64 season, therefore, Ein Gedi will concentrate on the following agricultural products in this order of economic importance: onions, cucumbers, egg-plant (aubergine), roses, grapes. Ein Gedi has been included in this discussion to exemplify an extreme case of land use which is possible only by cultivating crops out of season. Ein Gedi can do so because it is not located in the Mediterranean climate area of Israel but in its arid region. This case, therefore, is strictly speaking outside the region discussed in this paper.

Mention must be made in this connexion of a successful early effort at off-season vegetable growing in the lowest part of the Jordan Valley, north of the Dead Sea. Beth ha-Arava, a village which was located 3 kilometres north of the Dead Sea on marly soil of excessive salinity, succeeded in growing especially juicy tomatoes and other vegetables and marketing them at about the same season that crops from Ein Gedi reach the market today. This was done by flushing the soil and irrigating with great amounts of Jordan water, itself rather saline. As the site of Beth ha-Arava is now in Jordan, the village had to be abandoned in 1948.

2. A parallel case well remembered by Jerusalemites is that of the region around Hebron, south of Jerusalem and now in the Kingdom of Jordan, at 800-900 metres elevation. This area is famous for its delicious late grapes.

Whereas all off-season marketing is profitable,¹ the greatest price difference between mid-season and extreme off-season for a product marketed in considerable volume (excluding flowers, etc.) is fetched by tomatoes, the ratio reaching 1 : 8.

Irrigation farming obviously requires level land, i.e. terracing. Mechanized farming requires that these terraces be of sufficient width and connected by ramps, thus permitting the movement of equipment from one terrace to another. There is, therefore, a significant difference between the often narrow ancient terraces and the carefully levelled, broad modern ones, connected by ramps. For the reasons stated, ancient terraces cannot be used for modern mechanized irrigation farming. It is only high price crops that make the expensive investment in terracing worth while. In extreme cases the cost of land reclamation in the mountains reaches 4,000 Israeli pounds per hectare and more. But for the mountain area the choice is often between no cultivation and cultivation based on expensive land reclamation. Without it the mountain farmer will have no chance to earn a living at a standard acceptable to him. If he is unable to achieve this he will join the universal move from rural to city life. As stated before, the achievement of this standard requires expensive investment in land reclamation, making mountain farming from the outset more expensive than that of the plains. Therefore only crops giving a high return will find a place in the mountain economy, and specialty crops play a foremost part in this.

Another source of income for the mountain farmer is playing an increasing part in land use as the general standard of living of the country rises. This is the resort industry. A resort hotel or guest house operating throughout the long summer months is an increasingly common feature in the mountain villages of Israel. Sometimes it is located close to but outside the village in a nearby forest. A large number of week-end guests having at least a meal there provide an additional bonus.

A number of villages close to cities engage in a different type of resort operation. They maintain a swimming pool catering for the population of the nearby city a pleasant rural environment. Most of the water needed in the pool is not lost but used later on in irrigation. Shores, a co-operative village in the Judean hills, maintains a swimming pool and country club patronized by the inhabitants of Jerusalem.

Both types of resort industry enjoy the additional advantage of selling a certain amount of fresh produce to retail customers at prices which are considerably above wholesale prices but still much cheaper than retail levels.

The rural resort industry is better suited to communal villages than to private or co-operative ones. The individual farmer will find it difficult to maintain and staff any resort enterprise larger than renting a room to summer guests. In the centrally operated communal

village, however, the resort enterprise is just another branch of the local economy. Most rural resorts are therefore found in kibbutzim.

LAND USE COMBINATIONS OF MOUNTAINS AND PLAINS

Despite the booster effect of specialty land uses on the economy of mountain villages, the latter rarely reach the standard of rentability of the plains villages. Higher prices for water, smaller units of cultivation and sometimes higher transportation costs (both due to the mountain topography), as well as the more restricted variety of crops that can be grown, are the reasons for this.²

It is not surprising, therefore, that a number of mountain villages try to combine the advantages of cultivating land in both areas and have acquired rights to land in the plains in addition to their regular village lands in the mountains. Again it is the communal villages that lead in this respect. A number of villages in Galilee own and operate fish ponds in the Huleh Basin of the Haifa Plain. And villages near Jerusalem provide the fodder for their dairy herds from fields in the coastal plain at road distances of 25 to 35 kilometres. Every morning a truck goes from the mountain village to the detached village lands in the plains and returns with a full load of fresh fodder—alfalfa, clover or some other crop—in the afternoon. The price of transportation over the short distances involved in Israel is by no means prohibitive. First, the main item of cost and time is loading and unloading the truck. Whether the truck then has to be driven 4 or 25 kilometres is of relatively minor importance. Second, the dairy cattle kept in the fresh mountain air are often in a better state of health and tend to produce high yields, which compensate for the longer supply distances for green fodder. The fringe benefit for the farmer himself is his living in the mountains, climatically preferable to the plains with their sometimes strenuous summer heat, often aggravated nearer the coast by the high moisture content of the air.

The tendency to combine residence in the cooler mountains with cultivation of the more fertile plains is especially prominent in villages of Eastern Upper Galilee. They supplement their sometimes mediocre local conditions by cultivating additional land in the nearby Huleh Basin, 400-600 metres below, with its rich soils and ample and especially cheap water supply. The extreme case is that of the village of Alumot above Lake Tiberias. Most of its cultivated lands are down in the heat of the Jordan Valley, cultivated under full

1. One could well make the opposite statement, i.e., that beyond a certain level of agricultural supply crops which have to be marketed at the peak of their respective seasons give a rather marginal profit, and not infrequently are unprofitable.
2. This does not even take into account the initial cost of land reclamation. In Israel this is not charged against the village but borne as reclamation investment by the Jewish National Fund.

irrigation, whereas the village itself is located 230 metres higher on the rim of the slope overlooking the valley, enjoying fresh breezes. The travel time from the village to the fields is only twenty minutes, a very slight inconvenience compared with the climatic advantage of the village site. On the whole, this is a modern form of a time-honoured pattern of land occupation of the Mediterranean region where villages in the mountains farm lands in the plain.

LAND USE OF ARAB FARMERS TODAY

The Arab farmer in Israel is at present undergoing an accelerated process of acculturation to Jewish techniques and standards of land use. Therefore, all stages of agriculture are to be found in Arab villages, ranging from traditional dry farming with fruit growing and livestock raising to entirely market-oriented irrigation farming.¹ Each year sees an increase in the more advanced land use types and a corresponding decrease in traditional farming. In the most advanced stage of Arab rural economy, as in Jewish agriculture, the crops to be grown are selected according to production allotments by the various agricultural producer organizations. Farmers' co-operatives too are found in numerous Arab villages. With the increasing use of mechanized equipment a considerable number of the traditional labour force of the village have become redundant, and hence available for work outside the village in industry and construction or agriculture. The wages they earn are a bonus to the village economy.

Arab mountain villages still retain a considerable acreage in cereals and keep low-quality livestock; the all-devouring black goat especially makes extensive use—or rather misuse—of bushes and dwarf vegetation. The Arab farmer devotes a considerable acreage to the crop that permits the most intensive land use without irrigation: tobacco. This is grown mainly on rendzina-type soils. As tobacco has to be hand picked it is well suited to the Arab rural economy, which prices its own labour lower than the Jewish farmer does.² By contrast, even for the Arab farmer the olive is gradually becoming a marginal crop.

It is not only the sedentary fellahen that have adopted themselves to modern agricultural technology; even the Bedouin are well on the way to doing so. (It should be noted here that the true nomadic Bedouin, disdaining any agriculture, have not been found in Israel for well over a hundred years.) Not only has the nomad and his flocks no place in a modern rural economy, not only are his movements more and more restricted, but the mechanization of transport has made the main items of the Bedouin economy—pack animals and handling of caravans—obsolete. The Bedouin, therefore, have had to look for other sources of income and they too at present earn most of their regular

income as wage labourers. The money thus earned serves partly to mechanize Bedouin agriculture, and the tractor with disc attachment is now a common tool of the Bedouin farmer.

This is a doubtful blessing: the Bedouin farmer lacks the tradition of conservation farming and with his powerful new tools is apt to initiate dangerous soil erosion. The tractor has brought a revolution in land use to the northern Negev where Bedouin are still an important part of the rural landscape. In the past a large area was cultivated by the Bedouin in a kind of long-term rotation, an individual plot of land being ploughed only once in a good many years. Today the total area is not much bigger but a great part of it is ploughed year after year.

TRENDS IN LAND USE AND RURAL ECONOMY

The above survey shows a definite shift from subsistence farming to commercialized farming. Table 2 shows not only a $3\frac{1}{2}$ times increase of the irrigated acreage—which rose from 7 per cent of the total cultivated area in 1944/1945 to one-third of it in 1960-1961—but a significant decrease in the total cultivated area. The concentration on irrigation farming brings about the retirement of much marginal land. It should be noted that from the increase of the total cultivated area between 1954/1955 and 1960/1961 (an increase of 17.8 per cent) only 26.6 per cent was contributed by non-irrigated land whilst irrigated land contributed 73.4 per cent to the total increase. This trend becomes the more significant if we remember that out of a total increase of the non-irrigated area in the years 1954-1955 to 1960-1961 of 1,850 hectares, some 1,200 hectares are accounted for by the expansion of extensive mechanized dry farming by Bedouin farmers in the northern Negev.

The reliance on irrigation stabilizes yields and the rural economy as a whole and forms an essential counter-balance to rural depopulation. The following considerations determine the rural economy and therefore the use of land: maximum prices on the market, giving a premium to specialty uses and out-of-season crops; minimum production cost, i.e. highest returns for water and labour invested and a preference for the use of low-priced water. All these considerations discriminate basically against mountain agriculture with its higher costs of water delivery and smaller parcels of land and are in favour of land use in plains. Here land use is water intensive and soil selective and irrigation enforces its concentration in limited areas. All this is in distinct contrast to the time-honoured traditional pattern of

1. Cf. note 1, page 107 above on frequent excessive use of water by Arab farmers.

2. As the Arab wage labourer working outside his village is earning standard wages, his real income is high, often higher than that of his Jewish counterpart.

land use, which by employing large amounts of labour and very little irrigation tended to favour mountain areas.

The increasing efficiency of agriculture as measured by manpower makes an increasing part of the rural labour force redundant. Today, this balance is in most countries absorbed by the world-wide process of rural depopulation. Israel tries to retain part of it in villages or rural towns by the planned dispersal of industry into these areas.

RURAL-URBAN COMPETITION FOR LAND

Although in Israel as in other Mediterranean countries an expanding population nowadays no longer requires a corresponding expansion of the agricultural area but is taken care of by more intensive cultivation methods, this does not ease the keen competition of urban and industrial users with agriculture for the use of the land. Very often this competition is the keener in that for

a variety of reasons, partly historical, cities are located on the best agricultural land and therefore continue to expand onto it. For obvious economic reasons, unless government exercises planned interference, agriculture will be the loser in this contest, which is unequal both economically and in its attraction to the labour force. If it is a large city the situation will be aggravated by the formation of a belt of waste land on the outskirts of the city evacuated by agriculture in anticipation of urban land uses—and land prices. This can be clearly seen at the northern fringe of Tel Aviv. In Israel this competition for land is especially serious, for on the losing side is some of Israel's economically most important land: citrus plantations.¹

Here, therefore, is a profound challenge to the geographer, the agricultural economist and others to plan the most adequate distribution of land use, and an even greater challenge to governments to see to the implementation of such plans.

1. Cf. *Atlas of Israel*, sheet XII/7, which shows the extent of citrus orchards as against built-up areas for 1922, 1937 and 1956.

DISCUSSION

A. W. WILSON. I wished to hear more about recharge of underground storage with run-off: this is easy in California and difficult in Arizona. How easy is it to recharge in Israel?

Has Israel thought of having cities buy up land for expansion, leasing back farm land until needed, and perhaps isolating certain outstanding agricultural land as a green belt? This would be in the style of Stockholm (starting in 1902 in their case).

D. H. K. AMIRAN. At present only one pilot project for recharging ground water is in progress in Israel. This is being carried out in the dune area along the coast and shows so far encouraging prospects. But it must be given a trial of about ten years before conclusions can be arrived at.

I. KOBORI. I am very impressed by Dr. Amiran's lecture on specialty crops like tomato. Referring to my experience in southern Israel, may I ask whether Ein Gedi, which has a wonderful water supply in the dry Dead Sea area, may be able to reclaim the land economically because of the occurrence of water. In Yotvata, which lies in the true desert of the Aravah Valley, the reclamation of land is very costly. Consequently, the problem will still remain of how to return such a large investment in the conquest of the desert.

D. H. K. AMIRAN. Both Ein Gedi on the Dead Sea and Yotvata in the southern Aravah are located in true desert environments. Both of them are true cases, and natural conditions therefore definitely limit the possibilities for development. In the case of Ein Gedi the limiting factor is soil, in that of Yotvata, which on the whole is more unfavourable, the limiting factor is water.

H. NIEDERBÖSTER. (1) How will the splitting up of the 5 to 6 hectare farms be prevented? (2) How does the farmer with his fixed size of farm adapt himself to the changing economic condition, to a higher income? Is it by constantly improved irrigation together with a shift to industrial and specialty crops?

D. H. K. AMIRAN. We hope to prevent further splitting up of farms by legal means. Land for additional farming families, especially of the second generation, will be made available out of the general land reserve near a given village, or these farmers, in groups or individually, will be diverted to new villages. The new farmer will be able to raise his standard of living by gradually transforming all his land to irrigated cultivation and laying emphasis on crops securing high prices.

LOCAL WATERS OF MIDDLE ASIAN DESERTS WITH MEDITERRANEAN CLIMATIC FEATURES¹

by

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New and apparently more satisfactory definitions have nowadays almost completely ousted the term "Mediterranean type of climate" from Soviet geographical publications. This is nonetheless a very convenient definition for the subject discussed in the present paper because it aptly reflects the important features of the hydrological régime in arid regions.

Roughly, these features can be summed up as follows: the year is subdivided into two very distinct seasons—warm and dry; cool and humid. In the less arid Mediterranean regions the spring season favours vegetation and is pleasant for man, from the point of view of temperature and humidity, and autumn is dry and warm; the "summer" season lasts for the greater part of the year, attracting numerous holiday-makers to the seaside areas which are buried in a wealth of verdure.

As aridity increases, the favourable ratio between heat and humidity changes to more heat and less humidity. Climatic conditions which characterize the southern belt of the Middle Asian deserts originate in the desert regions. It is very hot in April which here is practically a summer month. The warm days last until November and sometimes even occur during the winter months. Daytime air temperatures vary between 40° and 50° C. during the summer months. Winter has a uniform character. Frost and snow are usual, but are not as a rule prolonged. The maximum precipitation occurs in February, March and April, amounting to about 50 per cent of the total and ranging from 200 to 80-100 mm.

A warm and generally humid spring creates favourable conditions for natural vegetation in Mediterranean-type deserts. Ephemeroids blossom in extensive areas thereby providing a huge reserve of green fodder. The heat that sets in quickly withers the grasses among which there are ephemeroids with remarkable properties: they remain in the form of dry grass stand (unmown hay), retaining their high nutritive qualities. Throughout the summer and late into the autumn these plants are readily eaten by cattle and as soon as the

first winter rains begin the ephemeroids grow green again.

The largest areas of the Middle Asian deserts are occupied by sandy deserts with a predominant precipitation of about 100 mm. a year. About 40 mm. occurs in spring, but this apparently is not enough for the development of dense spring grass stand. Hence a great variety of bushes develop here and these also are generally used as fodder.

It is extremely difficult to supply cattle with water in the boundless deserts of Central Asia.

Comprehensive development of artificial irrigation is undoubtedly the most radical solution of this problem. Major successes have been achieved in the U.S.S.R. in this sphere. Suffice it so say that after the October Revolution we nearly doubled the irrigated area, i.e., supplied water to as much land as was irrigated during the entire history of farming, which goes back far beyond the limits of our era. For all that, transit river waters remain the primary source for irrigating the Central Asian deserts. Their utilization is confined to the land bordering the rivers and is more profitable to agriculture than to cattle breeding for which mainly underground and local surface waters are utilized.

We have a fairly good knowledge of the Middle Asian deserts in respect to underground waters and local surface run-off. This enables us to plan further development of cattle breeding in the deserts on the basis of more intensive utilization of these water resources.

The desert plains of Middle Asia are bounded on the south by a system of gigantic mountains. Because of this, the whole of the southern stretch of the desert zone is covered by thick piedmont deposits; elsewhere large parts are covered by predominantly old alluvial

1. The term "Middle Asia" used by Soviet geographers comprises the territories of the Soviet Asiatic republics and the south of Kazakhstan—hence it is part of the generally accepted term "Central Asia".
2. As the author was unable to attend the symposium only the title of this paper was read.

deposits. The vast expanse of such deserts has an extensively developed system of water table aquifers, i.e., with a single free surface over large areas (for example, for Kara-Kum and the adjoining regions the area of such a single basin of ground waters exceeds 300,000 sq. km. and possibly is not less than 400,000 sq. km.). The ground water basins formed under such conditions are of varying thickness: from hundreds of metres to a few metres only.

They are supplied from three sources: (1) infiltration from the beds of rivers running through the deserts or terminating at their extremities; (2) subsurface drainage from the piedmont deposits; (3) direct infiltration of precipitation or infiltration of waters from the local temporary run-off.

In this way, the following system emerges: ground water flows with negligible velocity (due to small gradients and low filtration properties of water-bearing rocks) and moves from the main recharge areas (rivers, irrigated districts, mountains) in conformity with the general orographic slope. Evaporation, including evapotranspiration begins from the first metres of the moving ground-water bodies. As a result of evaporation and interaction with rocks the ground waters, which are only lightly mineralized in the initial stages of movement, become more saline. The greatest salinization is observed in stagnant zones, causing the formation of salt bottoms. For this reason, the maximum mineralization of ground waters is encountered near the water basin which are the bases for the run-off of ground waters (Caspian Sea, Aral Sea, Lake Balkhash) or in large closed depressions (Sarakamysh, etc.). In the majority of cases the initial stages of mineralization are characterized by hydrocarbonated calcic waters, and the final stages by highly mineralized waters of the chloride-sodium and even chloride-calcic type. This general system is complicated by the effect of local factors.

In areas where the ground waters are shallow, surface salt bottoms develop under which the salinization of water reaches high magnitudes, and may even cause the formation of brine. On the other hand, fresh water accumulates where conditions are favourable for the infiltration of surface waters or the condensation of water vapours. Depending on local factors (size and composition of the surface drainage systems, area and thickness of bare blownsands which are the principal points of condensation), the areas and contours of of refreshed waters may range from several square metres to hundreds and thousands of square kilometres. All this creates a great diversity in the amount and types of salinization of desert ground waters which largely depend on the geographical environment. Generally speaking, vast desert areas contain mineralized ground waters. However, since stock breeding practices are adapted to the consumption of mineralized water (7 to 13 gm./l., in different seasons) considerable areas of the deserts are fit for watering purposes; the main

task in such areas is to supply water to man. However, there are extensive regions where underground waters, owing to still higher mineralization, cannot be used either for drinking or watering. In these cases, local supply waters acquire a special importance. They form fresh water lenses floating on salt water. From a genetic point of view, there are two types of lenses: the first is due to the infiltration of the waters of the ephemeral local run-off and is always connected with the presence of surface drainage systems; the other type of lens is not connected with such drainage systems. Ordinarily, these lenses lie under the sands, have no visible recharge and until recently were in many respects a scientific riddle.

Fresh water lenses floating on salt water were artificially built up by shepherds in the Middle Asian deserts from immemorial times. Since they employed very simple implements these structures were highly primitive but their practical importance can hardly be over-estimated. For drainage systems, use was made of clayey plains with takyr soils or lowland landscapes of a badland type. Ephemeral run-off rain waters were channelled into artificial pits or onto natural sandy surfaces. As they filtered through, they reached the saline water table and settled there in the form of floating lenses. Sometimes recharge was carried out by the use of recharge wells. Exploitation was effected by means of simple dug wells. In this manner, the minimum necessary supply of fresh and brackish water was provided on vast sections of deserts with natural surface drainage systems.

Although spring rains typical of the Mediterranean type of climate were considered the main source of supply, all the systems were always kept ready to receive heavy summer showers which for all their rare occurrence were remarkable here for high intensity, giving a considerable instantaneous run-off.

The investigations carried out with a view to improving the methods of water supply used by the local population have established the inter-annual distribution of flow and its dependence on the area of drainage systems and wetting of the surface; they have provided material for the computation of the factors and volumes of run-off under various conditions. The method of artificial formation of fresh water lenses is effective since it requires no outlay on the construction of artificial reservoirs.

Another type of fresh water lens which occurs in Central Asian deserts is of far greater practical interest. It is in no way connected with ephemeral run-off and has, so to speak, no visible source of recharge. Lenses of this type lying under bare blownsands, have been known for a long time. Their connexion with bare sands is an indisputable fact and there is no doubt that they exist thanks to local recharge. With a shallow water table it was easy to assume that such lenses originated from infiltration of surface water. At a greater depth, where levels dried up to the state approximating

maximum hygroscopicity were revealed in the zone of aeration and gravity wetting was almost out of the question, opinions were voiced on the possibility of recharge being originated by condensation. In this case, since it was clear that the penetration of water vapour from the atmosphere into the zone of aeration could be of no essential importance, the mechanism of condensation recharge was regarded as an interground evaporation of the infiltration moisture, its vapour-like distillation downwards with a subsequent condensation and additional recharging of the lens level. We knew only of small lenses of this type which had no reserves worth speaking of but large lenses of this type have been discovered during the last twenty years. The capacities of such fresh water lenses amount to many hundreds of millions of cubic metres or to several cubic kilometres. The thickness of the fresh ground-water layer amounts to several dozen metres and the distance to the water table reaches dozens of metres. In a number of cases we have revealed the presence of ultra-fresh water. In other cases the waters, despite very low mineralization, displayed a chloride-sodium type of salinization usually typical of saline ground waters of deserts. This faced us with an urgent task of elucidating the origin of these fresh waters.

It was obvious that the answer to the riddle of the origin of large lenses was to be sought in the zone of aeration. The investigations which were undertaken for this purpose required special apparatus which could be placed in natural conditions at a depth of dozens of metres to ensure remote reading of the indices and repeated regular boring for the use of the weight

method of humidity determination so as to organize observations over the chemical régimes of waters and the levels which would preclude atmospheric effects, etc.

These were the first investigations of the kind to be conducted regularly in a sand desert and at a depth of dozens of metres. They have confirmed the presence of the zones of interground evaporation, determined the depths and conditions of interground condensation in definite zones, and revealed a vapour-like movement of moisture from the evaporation zones to the zones of condensation and further gravity flow of the moisture recharging the fresh-water lenses. These investigations have helped to explain the great diversity of the chemical composition of the desert ground waters which was until then rather obscure. It has become clear that some conditions favoured evaporation and concentration while under others condensation predominated and this, depending on its intensity and the salinization of the water underlying the lenses, might produce any range of types and degrees of salinization; the latter, incidentally, explained the possibility of the appearance of ultra-fresh waters. Finally, we have established the presence, under certain natural conditions, of a through gravity wetting of the zone of aeration. The results of these investigations not only give us a clue to the understanding of the origin of fresh waters of the above type and provide us with a method to obtain data for calculation but they will also, we hope, show us how to control the accumulation of fresh waters artificially on the basis of the energetic processes which exist in the zone of aeration of the desert.

METHODS OF LAND USE IN AUSTRALIA'S ARID AND SEMI-ARID AREAS

by

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The Australian continent was virtually unknown until the late eighteenth century. The European newcomer was faced with a very sparsely populated, large land mass of nearly three million square miles, spread over a latitudinal range of 30 degrees and with a great variety of climates. About two-thirds of the total area was arid or semi-arid country, and none of it was agriculturally developed.

Thus early land use development was made difficult by the complete absence of indigenous agricultural methods. With the exception of native pasture and fodder plants and forest species, all commercially useful crops, sown pasture species, softwood plantation forest species, and all domestic animals had to be introduced into Australia and adapted to new environments. The initial technical knowledge of plant and animal production had to be copied or modified from practices in far distant countries with quite different conditions, or invented in the face of sheer necessity to meet the needs of the new environment. The present forms of land use are the results of a little more than one hundred years' effort.

THE ARID AND SEMI-ARID ENVIRONMENTS

The broad picture of total annual rainfall in this continent is one of a series of concentric zones with rainfall decreasing inland from the coast (Fig. 1). These zones are displaced westward slightly and the inner zones of low rainfall extend to the western coast of the continent. Superimposed on this picture is a change in seasonal incidence of rainfall from north to south. In the north, rainfall occurs mainly in summer and in the north-west is restricted, for all practical purposes to this season. In the south, rainfall occurs dominantly in winter. The arid and semi-arid areas, in the middle latitudes, are in the transition zone in which rainfall is not only low but is also erratic. Furthermore, long

periods of drought, lasting many months, are common. The range of climatic environments is illustrated by the fact that the following arid homoclimates of Meigs are represented—Sb (34, 33, 24, 23), Sa (23, 13), Sc (23, 13), Ab (24, 23), Aa (24, 23), Ac 23. No part of Australia falls into Meigs's "Extremely Arid" category.

Because of differences in evaporation rates summer and winter rainfalls are not equally effective. Hence the outer margins of the semi-arid zones in the north and south coincide with different isohyets. In the north the margin lies between the 10 and 15 in. isohyets, in the middle latitude in the east, at about the 20 in. isohyet, and in the north at about the 25 in. isohyet.

Associated with the range of climates of inland Australia there is a comparable variety of natural vegetation types, which are further diversified by the local influence of soil, drainage and other land surface features. The broad relationship to climate is evident from Figure 2. Many of the arid vegetation types are useful for pastoral purposes, particularly those which include edible perennial species such as the Mulga, Salt bush, Mitchell and Blue grass communities. However, communities such as the Spinifex grasslands, and desert vegetation types which cover vast areas contain many sclerophyllous species of poor value. The stock-carrying capacity of these areas is so low that it often does not justify the expense of providing water supply points for grazing animals.

The whole of the semi-arid and arid zones of Australia are areas of low relief and there is an absence of the "humid islands" so characteristic of many other arid lands. Furthermore, with the exception of the Murray River system in the south-east, the perennial rivers of Australia are all short streams flowing from coastal ranges to the sea. Inland streams are mostly non-perennial ones associated with inland drainages. This

1. In the absence of Mr. Christian, this paper was presented by Dr. C. A. Stewart.

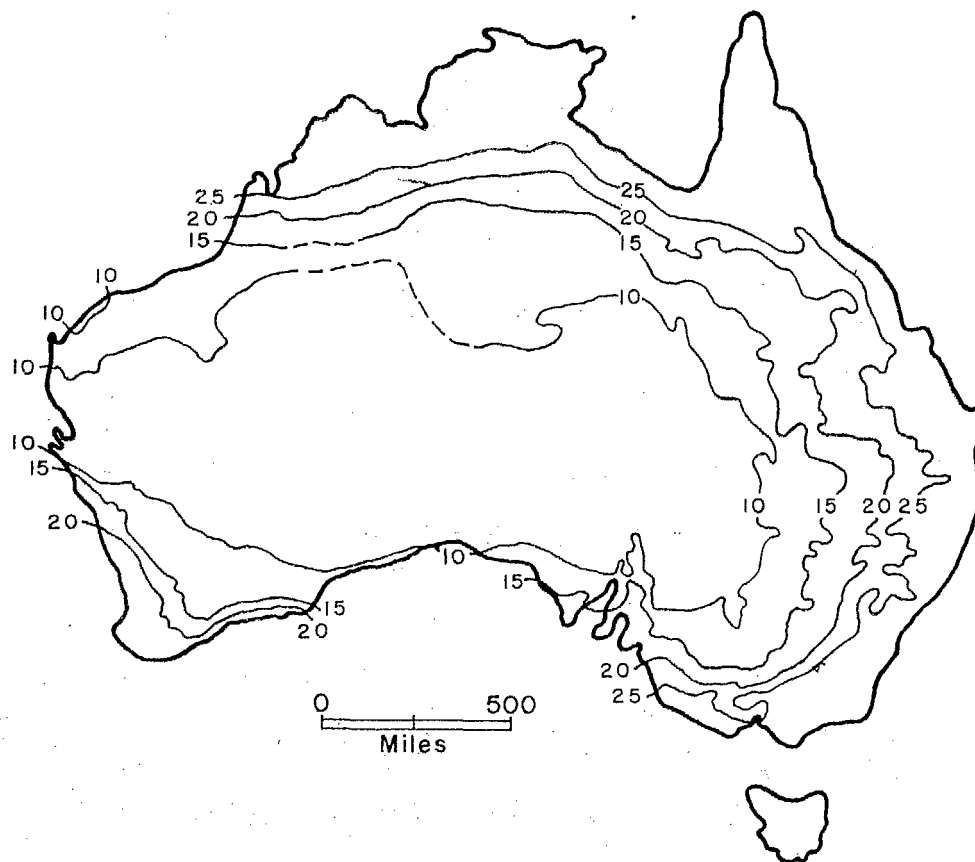


FIG. 1. Average annual rainfall in inches.

restricts major irrigation projects in arid Australia to the south-eastern sector, the scope elsewhere being limited to isolated possibilities of very small potential. It also means that there is very little surface water available for grazing animals. The stock industries have had to depend largely upon artificial storage, and underground water, often at great depth. In common with most arid lands many of these underground and non-flowing surface waters are saline and are unsuitable for irrigation, and even for livestock.

Another environmental feature of great significance is the low fertility of many Australian soils. Although fertile soils do occur in Australia's semi-arid and arid areas, most of them are deficient in phosphorus, are usually low in nitrogen and in some localities are deficient in trace elements.

LAND USE PROBLEMS

The semi-arid and arid areas presented special problems of development. They first had to be explored before they could be utilized. The pioneer settlers were often the explorers. They faced the problems of vast distances,

scarce surface water supplies, lack of communications and transport systems, distant and uncertain markets, shortage of labour, high cost of mechanical operations in remote areas, and the health and social hazards of a new country. A pattern of land use had to be devised which economized on labour, on the use of imported materials, and on capital. For many reasons the grazing industries were the most successful in developing the new areas. They expanded rapidly in the last half of the nineteenth century. These industries were established on an extensive, rather than intensive land use pattern, with large areas of land being operated as single units. Although land reform measures have since led to a considerable degree of intensification, many of the initial disabilities still apply, and much of the original pattern still persists. The products from the arid and semi-arid regions depend largely upon overseas markets and costs of production are of ever-increasing importance. Current economic thought does not favour a high degree of intensification in these areas.

Land is held under various systems of tenure according to the locality and according to State laws. These vary from freehold to various kinds of leases from the Government, for a fixed period of time or

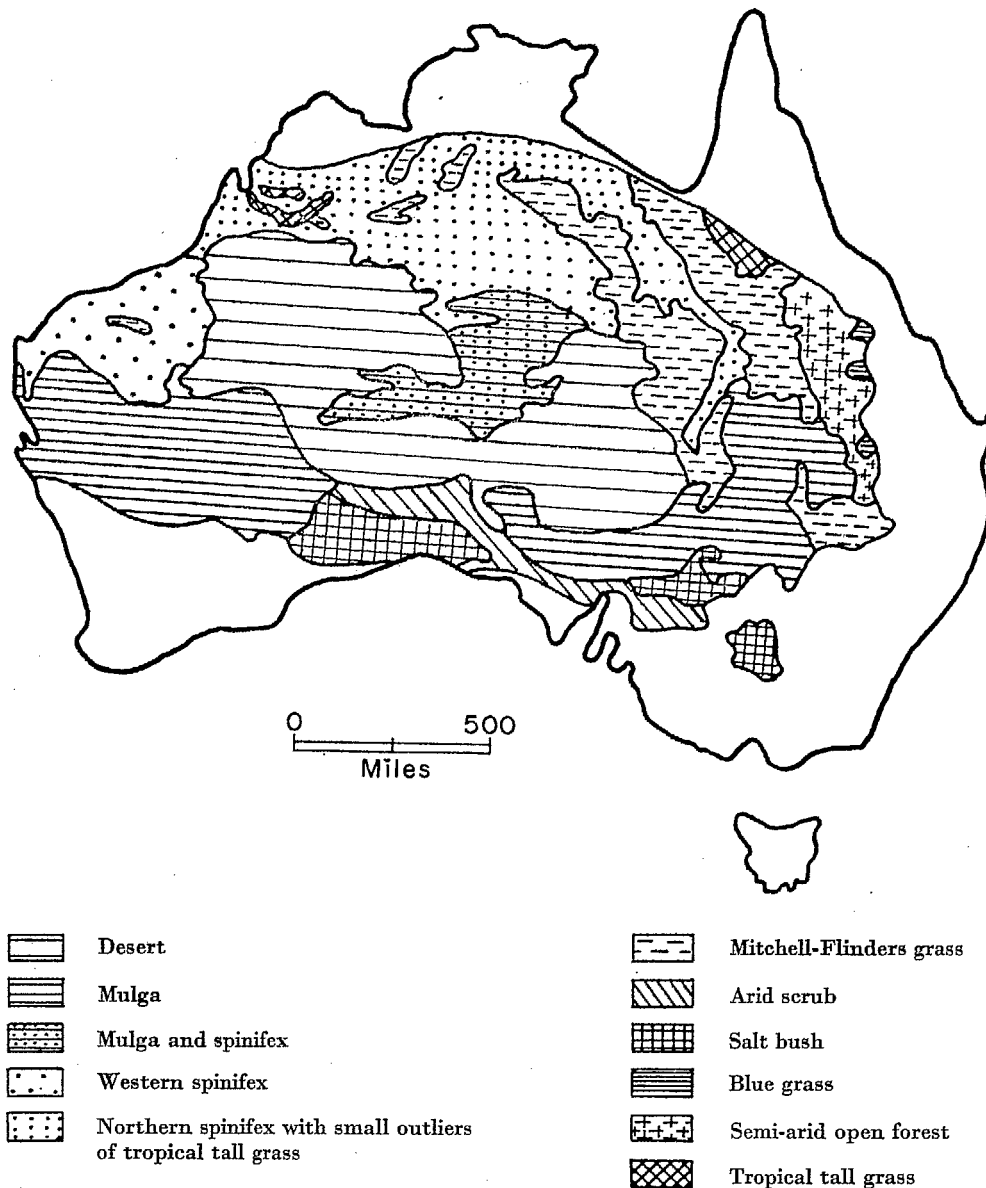


FIG. 2. Variety of natural vegetation.

in perpetuity. In general, agriculture is sedentary in the sense that each landholder carries all his stock and limits his crop production to one area of land referred to as a "station" in the livestock industries, a "farm" in dryland agricultural areas, a "block" in irrigation areas, and generically as a "property". The exception is the holding and joint management of a series of properties by large pastoral companies. The private landholder attempts to maintain his stock entirely on his own land although there is inevitable fluctuation in stock numbers through the year and as animals are sold. The drier, more remote and more difficult regions

are used for stock breeding and store and excess animals are sold to producers in more favoured areas. Nomadic grazing as practised in so many other countries does not exist. There is some sale or movement of stock for agistment to less affected pasture areas during drought periods and the more recent progress in large-scale road transport has assisted this. The movement of stock, particularly cattle, from breeding to fattening areas is often done on foot, and cattle from far northern areas may travel for periods of several months. This is the nearest approach to nomadic grazing. To assist this essential movement special tracts of country are set

aside and declared as stock routes over which the herds or flocks travel. They are provided with bores or other forms of water supply, at distances usually representing one or two days' travel.

The sedentary form of land use imposes two special problems of management on livestock producers. The first is to provide adequate watering points for animals, the second is to handle the problems of fodder shortage during long rainless periods. The ease of providing water may determine whether sheep or cattle are produced, as the latter can forage for greater distances from their water supply, but other factors such as quality of pasturage, density of vegetation, climate, the presence of predators, and distance from markets are also contributing factors. Artificial watering points are usually of a kind that can be established by mechanical means such as the excavation or mounding of large earth "tanks" or boring for underground water. This is partly due to the cost of manual labour and partly a matter of necessity. For instance, in western Queensland and north-western New South Wales substantial supplies of water are available from the Great Artesian Basin but this requires deep boring in much of this area, sometimes to several thousand feet. Where artesian flows do not occur, the lifting of water by pump requires the provision of a windmill or other power units. The establishment and equipment of a watering point costs several thousand pounds, and thus the land developer needs substantial capital resources. In arid country, with a low level of return per unit area, it is necessary to make each watering point serve as large an area and as many animals as possible. Because of this and the consequential concentration of animals around each watering point, there is frequently a degree of pasture deterioration near the water, but there is also incomplete utilization of the pasturage midway between watering points.

Apart from moving stock to other areas, the problems of feed supplies during drought are met in two ways. The first is the reservation of pasture as a form of insurance. In the larger properties of the more arid regions where in the past it has not been practicable to provide sufficient subdivision fences to control the distribution of stock, this may be done by temporarily "closing down" a watering point, thus concentrating stock in other areas where water is available. However, in the more arid areas a prolonged drought is usually accompanied by severe losses in animal numbers. During these climatic crises, there is a two-way stress. Not only does the shortage of feed apply nutritional stress to the animal but the level of stock numbers imposes an increasing stress on the vegetation as the feed supply diminishes. Unless the number of stock is reduced, fortuitously or deliberately, to an extremely low level, there is further severe stress on the vegetation during the initial stages of plant regrowth following the rain which ends the drought period. In general, the probability of drought has led to fairly conservative rates of

stocking. Where this has not been so, serious deterioration of vegetation has served as a grim warning to other landholders.

The second way of meeting feed shortages in drought periods is by supplying supplementary feed, such as hay or grain, or sometimes silage, produced on the property or bought nearby. Where such supplies have to be taken long distances, grain is most commonly used because of the lower transport costs. These practices, combined with the increase in improved pastures have substantially reduced drought losses in the semi-arid areas, but many arid zone properties cannot meet drought stresses in this way. If feed is bought it is reserved for a selected class of stock only.

PRESENT LAND USE SYSTEMS

Four main groups of land use industries occupy most of the Australian arid and semi-arid zone, the production of sheep, and beef cattle, sheep production mixed with arable agriculture, and irrigated intensive agriculture. Large areas of extremely low rainfall with sparse water resources are still not utilized.

THE SHEEP INDUSTRIES

The sheep industry was the major factor in the initial exploration of inland Australia during the last century. It was favoured by the availability of an export market in Great Britain and the obvious adaptability of the Merino sheep to arid conditions. Wool production soon became Australia's major primary industry. The sheep population is densest in the subhumid areas fringing the semi-arid zones, but both the arid and semi-arid zones make a substantial contribution to the total production, carrying about one-quarter of the total sheep population of 155 million. The industry has been raised to a high level of organizational efficiency. Many technical advances in breed adaptation and improvement, disease and pest control (particularly, control of the rabbit), and the mechanization of shearing equipment, have led to a high return per unit of manpower. The Merino sheep, well adapted to stand the stresses of inland Australia, has been much improved, and now several strains have been developed for different districts.

Under low rainfall conditions sheep depend largely upon native pastures but pasture improvement has made rapid advances in southern Australia and this has spread well into the semi-arid zone.

Pasture legumes are sparse in the native vegetation and phosphate deficiency retards the growth of introduced legumes with higher phosphate demands. By removing this deficiency, introduced legumes and their associated nitrogen-fixing root-nodule organisms flourish with a consequent increase in nitrogen available to the grass species. The main method of pasture improve-

ment now used is the top-dressing of native pastures with superphosphate, often by the use of aircraft, and the seeding of subterranean clover. In some localities, deficiencies of trace elements such as molybdenum, zinc, copper, and sulphur also have to be overcome by the addition of appropriate salts of these elements in small quantities. Perennial grasses such as *Phalaris tuberosa* are used in legume-grass mixture in more favoured areas.

The sheep industry is best developed in those areas which have a substantial winter rainfall component and where summer temperatures are not so high that ram fertility is reduced. However, the industry extends northwards in Queensland between the 10 and 15 in. isohyets to about 20° S. latitude and in Western Australia to about 18° S. latitude. In these northern dry tropical climates pasture improvement has made less advance, but in some localities in Queensland the production of animal fodder sorghum for silage provides a fodder reserve for drought periods.

MIXED WHEAT GROWING AND SHEEP PRODUCTION

Wheat growing in the subhumid and less arid portions of the inland expanded in southern Australia once transport systems extended into these areas. Successful production of wheat under Australian conditions depended upon the production of varieties suitable to the environment, the development of machinery permitting the rapid cultivation, sowing, and harvesting of large areas with the minimum of manpower, and the use of superphosphate to remove the major soil deficiency. A later and very important development was that of mixed sheep and wheat farming. Wool, mutton and fat lambs are produced according to circumstances. The sheep feed on the stubble of the wheat crops on the naturally regenerating or sown pastures on cultivated land, and on improved and native pastures of non-arable portions of the farm. This system of rotational land use is now well developed and is a very important aspect of semi-arid agriculture in the southern half of the sheep areas. It benefits both crop and animal and economizes in fertilizer use, and assists the control of aggressive weeds. It has been a significant factor in reducing soil erosion on cultivated lands. The practice does not extend far into the northern sheep areas where there is still a need to develop sub-tropical and tropical semi-arid mixed farming procedures.

THE BEEF CATTLE INDUSTRY

Although the beef cattle industry had to await the advent of refrigeration before overseas markets could be supplied, it played its part in the early exploration and development of Australia. It was most important in the more tropical areas, and the more remote areas of the south, especially where wild dogs and other

predators harassed sheep flocks. The greatest numbers of beef cattle are in the high rainfall coastal and sub-coastal fringes of eastern Australia but, as with the sheep population, about one-quarter of Australia's total occurs in the arid and semi-arid zones. In contrast to sheep, which are mainly concentrated in the southern half of the continent, the beef cattle population occurs mainly in northern areas. This industry has not advanced technically to the same degree as the sheep industry, partly because of less favourable markets, and partly because it has occupied the more difficult and remote country where transport systems are least developed. In many ways the present pattern of the industry is the relic of the early days of exploration when cattlemen took their herds into the north in search of land for breeding, and brought mobs of cattle by road back to fattening areas or to the centres of population for sale. The growth of capital city markets and the establishment of abattoirs for overseas export on the eastern seaboard has tended to maintain this pattern. The arid and semi-arid country is better suited to breeding than fattening, and this is likely to remain its role. In the past the breeding properties of the zone have been notoriously underdeveloped with respect to the establishment of watering points and fences for stock management. In recent years improved marketing conditions have led to a considerable improvement in this direction and there has also been an expansion of research programmes for the beef cattle industry. Road transport developments have aided progress as younger cattle can now be taken to fattening areas than when store cattle had to be walked distances of hundreds of miles. A current programme of building roads more suitable for this kind of transport is an important step towards more effective land use.

One of the disabilities of the industry is the occurrence of contagious pleuropneumonia in some areas, which has placed restrictions on the movement of cattle to free areas. An active programme of eradication is now in progress and in Central Australia the programme has been so successful that from a large area cattle can now be sent south to fattening areas. Previously cattle could only be sent for immediate slaughter. This means that instead of marketing mature cattle of variable quality for killing, younger cattle can now be sold. Such advances are reflected in pronounced changes in stock and property management and in the numbers produced per unit area. Other advances, such as the development of improved pasture for more favoured areas, and the breeding of better adapted cattle, are also likely to lead to changes in the forms of the industry.

IRRIGATED AGRICULTURE

Apart from scattered, very small, private irrigation projects, irrigated agriculture in the Australian arid and semi-arid regions is largely restricted to the Murray River and its tributaries in the south-east of the

continent. Water is supplied either by pumping from the rivers or by gravitational schemes from major storages. The crops grown are vines, citrus, deciduous fruits, rice, other small grains, and pastures and fodder crops. Rising water tables and salting of soils are important problems and drainage schemes are being established or are planned for most areas.

There is scope for an expansion of irrigation. The large hydro-electric power scheme in the Snowy Mountains is providing increased quantities of water for irrigation in the Murray River System. There have been proposals for the redirection inland of some of the river flows in north-east Queensland but these have not stood up to technical examination. There are relatively large quantities of water available for storage in north-west Australia and a small pilot project on the Ord River in the Kimberley Division of Western Australia is an attempt to prove the feasibility of irrigated agriculture in such areas. Economic conditions will govern the rate at which such schemes advance.

FUTURE LAND USE

The development of Australia's arid and semi-arid areas has followed the dictates of economic circumstances and the present degree of development is the product of a very short historical period compared with other arid lands. There have not been any sociological traditions comparable to those of older countries to influence methods of land use, and no overwhelming population

pressure to enforce over-exploitation of land. Land deterioration has been serious in only a small number of localities but no plant ecologist could be satisfied that important changes in native vegetation have not been initiated. As time advances the effect of climatic crises on native vegetation become more significant and research into trends, and into systems of pasture management, to approach full utilization consistent with maintenance, are of increasing importance.

There is unlikely to be any major reorientation of the use of arid lands, but the results of research into animal adaptation, pasture management and utilization, animal health, and water resource assessment and use, will continue to lead to more efficient and more stable methods. However, other factors than research are of equal significance. Of these, inadequacy of transport in the more arid regions remains outstanding. The Australian arid and semi-arid areas form one large continuous region in the interior of a vast continent with only scattered mineral developments as alternatives to agriculture in regional advancement. The absence of any large centres of population within the region has meant that there has not been the intensive to develop intensive transport systems far beyond the more favoured sub-humid regions.

There is evidence, however, that transport problems are slowly being solved. Aircraft have already overcome distance and isolation for human travel and light transport. Large-scale improved road transport is rapidly influencing heavy transport.

DISCUSSION

D. H. K. AMIRAN. (1) What are considered safe ratios of stocking of sheep in semi-arid Australia? (2) There were reports of cattle being raised in north-west Australia and the carcasses being flown into cities for marketing. Is this method of transportation still being employed?

C. A. STEWART. (1) 1 sheep per 4 hectares to 1 sheep per 15-20 hectares. (2) This air transportation is still practised, but only at one place, near Derby, north-western Australia, where the terrain (of the cattle routes) is too rough to have the cattle walking across.

PROFESSOR STAMP, as chairman, called attention to the important work of Dr. Christian on quantitative and qualitative study of vegetation (published in the *Journal of Ecology*). He also pointed out that a land use map should, in such regions as the heart of Australia, become automatically a map stressing the factors of relief, hydrology and vegetation which would condition the use of land at present unused.

Professor Stamp stressed the very great importance of the series of publications on Arid Zone Research issued by Unesco. No worker could afford to be ignorant of the range of material, often available nowhere else, contained in this series.

LAND USE IN THE SEMI-ARID ZONE OF WEST PAKISTAN

by

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Practically the whole of West Pakistan, excluding the southern flanks of the Himalayan axis and the narrow submontane belt, lies in the arid and semi-arid zone. The semi-arid zone, on the basis of Thornthwaite's moisture index, includes the middle section of the Doabs or the Punjab plain and the western bordering mountains, widening out in the hilly lobe of north-east Baluchistan. The Safed Koh in Kohat, a partly sub-humid region, drives a wedge eastward separating the Peshawar plain from that of Bannu. The chief determinants of land use are physiography, soils, climate and water supply, the last-named being the most important in a semi-arid region like the one under study.

PHYSIOGRAPHY

The semi-arid lands consist mainly of an alluvial plain stretching from the Suleimans towards the east and a small mountain region to its west. The plain is very flat, with an average gradient of one foot per mile. Between the Sutlej and the Jhelum, the Ravi and the Chenab divide it into three doabs. The physiographic features of these regions include: (a) Active flood plains (or *bet* lands)—the land lying adjacent to the rivers and inundated in most summers. It is composed of the youngest alluvium. (b) The meander flood plains or recently abandoned active flood plains, exhibiting distinct evidence of river action. They may be adjacent to the flood plains or far from them. (c) The cover flood plains—former meander flood plains which have been subjected to widespread sheet flooding and obscured by a blanket of alluvium. They now form flat, level expanses. (d) Scalloped interfluves (or *bar* uplands)—uniform plain occupying the central parts of the doabs, rising higher than the adjacent flood plains, from which the interfluves are at places separated by sharp river cut bluffs. These consist mostly of old alluvium but part of the deposits may be wind-borne. Between the Jhelum and the Indus, the Sind-Sagar

Doab or Thal is physiographically different. Its northern part included in the semi-arid zone consists of rolling sand plain. The aeolian sand is derived from the alluvium. The surface soils have been reworked to form low dunes. A large part of it has been levelled to be brought under cultivation by the construction of canals.

West of the Indus up to the Suleimans lies the piedmont alluvial plain. It consists of sediments carried down from the mountains by rivers and hill torrents.

Further to the west and north-west lie the Bannu Basin and the Peshawar Vale which consists of alluvial sediments filling the intermont depressions. The Potwar, north of the Salt Range, consists of a dissected basin plain in which gully and sheet erosion is widespread.

The region to the west of the Suleimans in the north-east of Baluchistan consists of mountains and exposed bedrocks intersected by numerous river valleys of varying width and intermont plains. The valleys show similar features and consist of flat plain of alluvial soil in the centre, with a pebbly slope or *daman* of varying length rising on either side to the surrounding mountains. It is from these pebbly beds that the supply of water for irrigation is derived through Karezes.

SOILS

The soils of the plains are generally alluvial, and having been deposited only recently, are mostly immature in pedogenesis. Like other semi-arid parts of the world they have a high calcium carbonate content and are quite productive when irrigated. They are, however, low in organic matter, and nitrogen and phosphate.

The soils of the active flood plains are predominantly coarse in texture, and finely stratified silt forms the largest element. Lenses of silt are often intermingled with strata of sand. The soil is sufficiently permeable and is easily drained of excess water after the floods. Much of this land is cropped during the winter months for Rabi.

The soils of the meander flood plains generally range between medium and coarse, though lenses of fine-textured materials may be found. They are finely stratified and their pattern is exceedingly complex. Areas of like profile are small.

The soils of the cover flood plain differ very much in texture both laterally and vertically. Shallow basins have thick strata of fine-textured soils.

The soils of the scalloped interfluvies are extremely uniform in texture. They vary from moderately coarse to medium texture with a high percentage of sand and silt. There are some coarse-textured materials in the dune areas. Sand is the characteristic soil of the Thal region. The Bannu Basin and the Peshawar Vale consist of mountain outwash material, the coarse-textured material having been deposited at the foot of the mountains and the finer-textured in the central parts.

In the Quetta-Zhob region the river valleys and plains consist to a great extent of fine-grained alluvial silt and clays, especially towards the centre of the flat areas. These deposits graduate into coarser accumulations towards the margins of valleys and plains passing into taluses of boulders skirting the hills.

In the irrigated lands, as a result of percolation from canals, waterlogging and salinity pose a very serious problem. Rechna and Chaj doabs are much affected by waterlogging, poor drainage and salinity.

RAINFALL

The semi-arid zone corresponds fairly well with a rainfall of 10-20 in. In the plains it is concentrated in the summer half of the year, though the winters are not dry. Winter-spring rains become more and more important towards the west and there is secondary maximum in spring or winter. The plain has 40 per cent or more of its precipitation in late summer during the prevalence of monsoons while the highlands in the Quetta-Zhob region have 40 per cent of the precipitation in the cold season. Snowfall is an important element bearing on land use, as the melting snows keep the *karez*s running. South of Safed Koh, the Suleimans and the neighbouring belt of mountains is a zone of evenly distributed precipitation favourable to the growth of grass. North of Safed Koh there is a spring or early summer maximum.

In the region under study the average annual variability of rainfall is 30 to 50 per cent.

TEMPERATURE

The mean minimum temperatures in January vary from 40.1° F. in Lahore to 27.6° F. in Quetta, two stations which are fairly well representative of the plain and hilly sections respectively. The mean maximum tem-

peratures of the hottest month are 105.9° F. and 91.6° F., respectively.

Rainfall and temperature both play an important part in the determination of land use and its several characteristics. The region suffers from lack of adequate rainfall. There is a general water deficiency of 25 to 30 in. There is, therefore, almost complete dependence upon river and torrent resources of water for agriculture. Apart from the amount, the seasonal distribution and reliability of rainfall have an important bearing on agriculture. Though cultivation without irrigation is practised in many areas, it is extremely precarious. Even the irrigated areas are not independent of rainfall, and protection afforded by canals is not complete. High average temperatures in the plains make cultivation possible all the year round. But the great extremes of temperature determine the type of crop to be grown in the two seasons.

LAND USE

The classification of land use has been made according to the categories adopted by the International Geographical Union's Commission on World Land-Use Survey, modified to bring into focus the special features of Pakistan (see Fig. 1).

SETTLEMENTS AND ASSOCIATED NON-AGRICULTURAL LANDS

According to the census of 1961 the urban population of West Pakistan represents 22.5 per cent and the rural population 77.5 per cent of the total. The process of urbanization has been gaining momentum ever since independence, but has been particularly marked during the decade 1951-1961. The process of industrial growth has involved radical shifts in the use of manpower and natural resources. There have been large-scale movements from predominantly rural areas to urban centres of rapid industrial expansion. The social effects of industrialization and improvements in the standard of living have led to an appreciable change in the structure of settlements and the use of land in urban areas. The suburban lands, which were formerly put to intensive farming, have been taken up for the building of residential, commercial and industrial units.

In our semi-arid lands there are five cities, with Lahore, Quetta and Peshawar at the ends and Lyallpur and Sargodha in the centre, each having a population of over 100,000. Their intercensal growth (1951-1961) is given in Table 1.

All these cities have greatly developed industrially and each has satellite residential colonies.

Urban settlements diminish in size and number west of Jhelum-Chenab line. The villages also become more scattered towards the west. In the mountainous west the settlements are almost confined to river valleys and

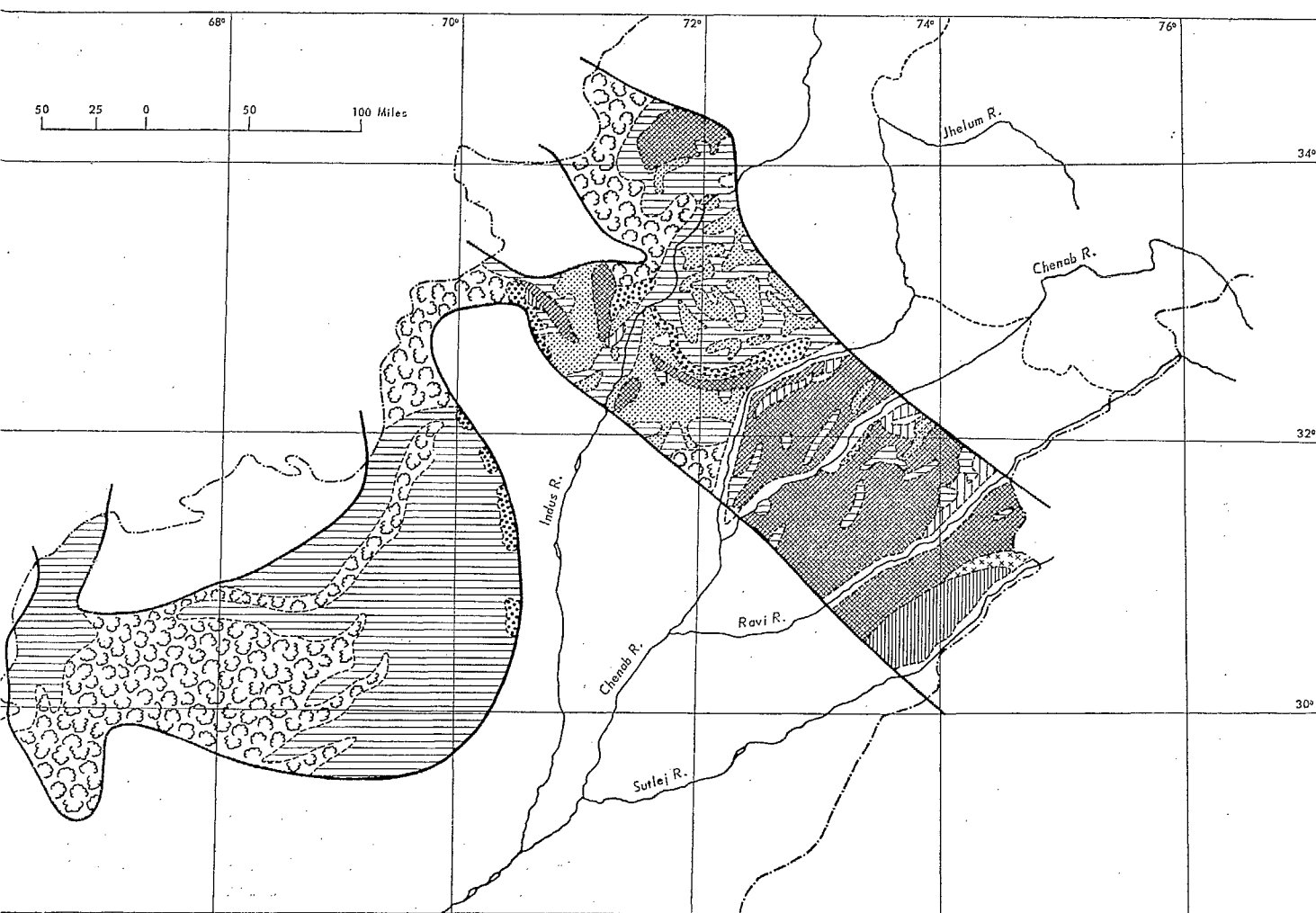


FIG. 1. Land use.

-  Perennially canal-irrigated cropland
-  Seasonally canal-irrigated cropland (considerable well irrigation)
-  Seasonally canal-irrigated cropland (inconsiderable well irrigation)
-  Seasonally flooded cropland
-  Torrent-watered cropland
-  Dry cropped land
-  Unimproved grazing land, grassland, scrubland, semi-desert
-  Unused land (unproductive)

TABLE 1. Population increase, 1951-1961

City	Population		Increase	
	1951	1961	No.	%
Peshawar	1 51 176	1 66 273	66 915	44
Sargodha	78 463	1 29 291	50 862	65
Lyallpur	1 79 144	4 25 248	2 46 104	137
Lahore	8 49 476	12 96 477	4 47 001	53
Quetta	1 06 633	84 343	22 290	26

intermont plains, where water is available, and to the mining areas.

HORTICULTURE

This category includes all intensive cultivation of small fruit and vegetables. Horticulture is practised around almost all urban centres and on a small scale throughout the countryside. But it occupies too small an area to be shown separately and has therefore been included in crop-lands (Fig. 3).

TREE AND OTHER PERENNIAL CROPS

This includes orchards mainly of deciduous and citrus fruits and groves of date-palms and mango trees. They constitute the predominant land use in some areas but the total extent in most of the districts is too small to be shown separately on the map.

CROP-LAND

Arable farming is the most important land use in the plains and its pattern has been mainly determined by water supply and the sources of irrigation. In the canal-irrigated lands the use of land and the crop grown generally depend upon the amount of water available from season to season. As there are no reservoirs, water is supplied to the land by diversion barrages and weirs; water supply is therefore dependent on the seasonal behaviour of rivers and is not constant. Owing to the enormous difference between flood and low water, there are two types of canals: (a) perennial, which run throughout the year, and (b) seasonal, which operate in the flood season only and include (i) non-perennial and (ii) flood canals. The use of land for any particular crop and the intensity of cultivation depend mainly upon the position of the land in relation to these canals and the period and amount of water available from them.

Cultivation under *perennial irrigation* is the predominant use of land in the scalloped interfluvies of the three Punjab doabs and the basin plains of Peshawar and Bannu (Fig. 2). High cropping intensity and a charac-

teristic cropping programme distinguish these areas in land use from those having other types of water supply. In Punjab the intensity is seldom less than 100 per cent while in the Peshawar Vale it is as high as 150 per cent.

There is a predominance of winter crops, wheat being the most important. Paradoxically the season of maximum cropping coincides with the period of deficient flow in rivers. This may be explained by the fact that canal capacities are adjusted more closely to winter river flow than to summer and thus carry not much more water in summer than in winter. And in summer on account of higher evaporation and transpiration the water supply is about one-half as effective as winter supply and cannot mature as large an acreage of crop. Another important characteristic land use in these lands is that assured year-round water supply permits greater variety in food, fodder and cash crops than is possible in other lands. This advantage in addition to high crop intensities makes these perennially irrigated lands the most prosperous in West Pakistan. Cotton is the major Kharif crop of these areas in Punjab and millets are extensively grown for fodder.

The tracts *seasonally irrigated* by non-perennial or flood canals are generally distributed over meander or cover flood plains. They can be given copious summer waterings for raising Kharif crops with high water requirements like rice. Cotton and millets are other chief crops. These canals operate throughout the entire growing season of Kharif crops. The Rabi crops in this area, including wheat, are matured with the help of rains or wells or both. Intensities of cropping on land irrigated by canals and wells combined may be almost as great as those under perennial irrigation.

Seasonal supply of water is given to lands which are rough, saline or otherwise inferior. Crops which require particularly assured supply of water over long periods, such as sugar-cane, are not widely grown. Seasonally irrigated canal lands which have no supplementary water supply from wells are devoted to rice in Kharif and drought-tolerant gram and oilseeds as well as some wheat.

Cultivation based on *river flooding* is the sole or predominant use of ribbon-like belts along the major rivers and in patches along the minor rivers interspersed with small patches or extensive tracts of scrub or unused land.

While wheat is the only crop grown on the active flood plains of the Ravi, Chenab and Jhelum in Rabi, summer or Kharif cropping is often extensive, with millets, pulses and oilseed as the chief crops.

Torrent-watered cropland is dependent on sporadic flood water tapped from torrent beds by irrigation cuts and trained into the embanked fields. These lands are of special significance in the piedmont plain of Dera Ghazi Khan and Dera Ismail Khan. The water must be used as

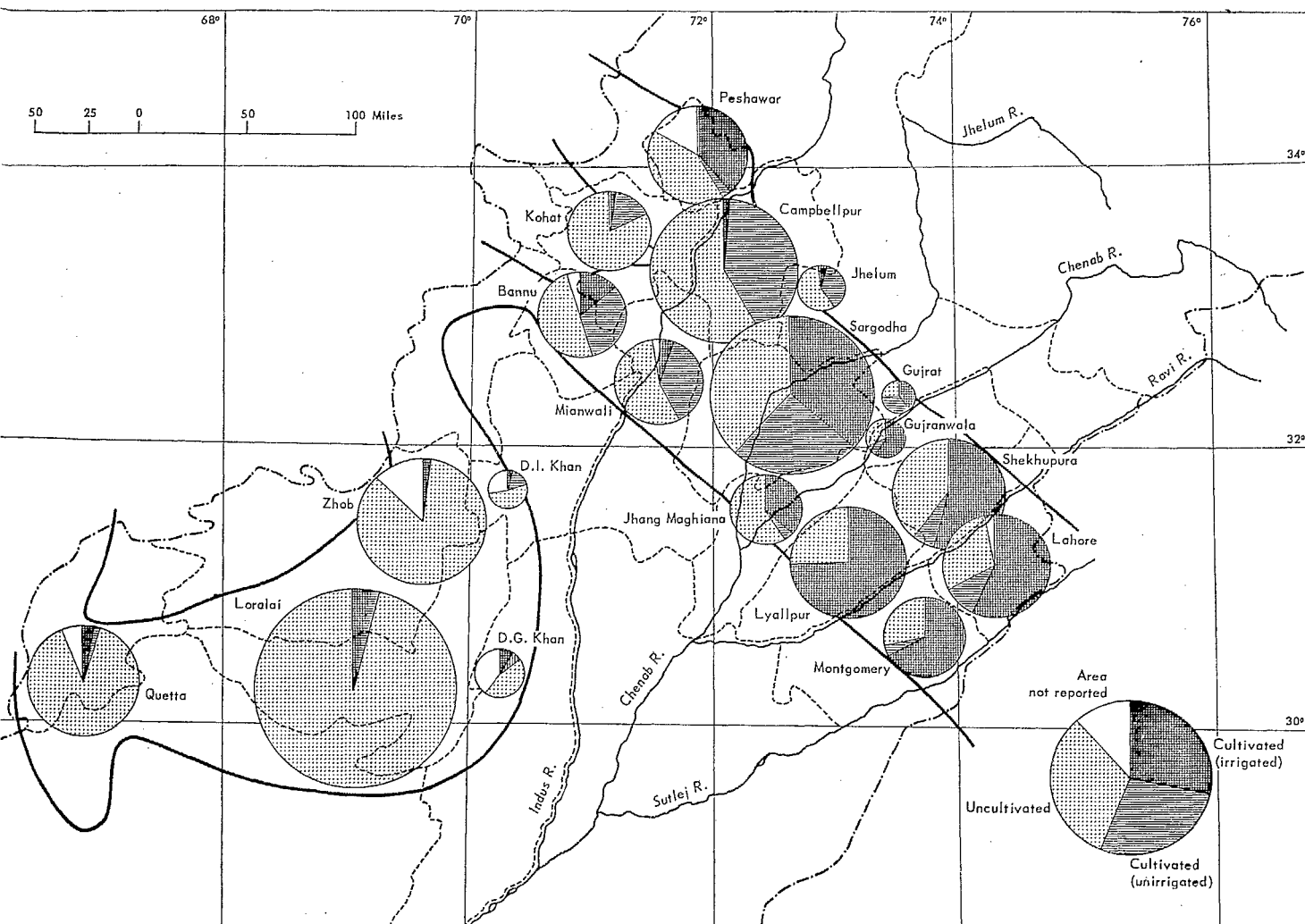


FIG. 2. Cultivated and uncultivated area as percentage.

it comes. Cultivation is precarious and only a limited number of crops can be grown. Crop intensities are generally low, the highest to be found along the torrents. Millets are the only crops grown in Kharif while grain and oilseeds are the main crops of the restricted winter-cropped fields.

Such lands also occur in the Peshawar Vale and Bannu Basin. But here the winter crops are more important as the winter rains are more significant. These rains are also useful for fruits.

Well-irrigated cropland. Land of this category is irrigated with ground water raised by various methods, the commonest being the Persian wheel. Secure from the vagaries of rainfall and involving much labour and expense, these lands are very intensively cultivated. Well irrigation, though widely distributed, is found in concentration in some parts, e.g., the Swabi Tehsil in

Peshawar Vale, where water is used in specialized commercial tobacco production. In well-irrigated lands the intensity of cultivation is in places as high as 200 per cent. Wells and canals are found together in many areas. They supplement the canal supplies to maintain high cropping intensities. Well irrigation is also practised in active flood plains sufficiently high to escape damage from normal floods.

In well-irrigated lands the spring harvest is almost always much larger than the autumn harvest because the intense summer heat lowers the efficiency of the draught animals and increases the rate of water loss through evaporation. Wheat is the most widely grown winter crop. But with an assured and regulated water supply there is a wide range of crops grown.

Dry cropped land. Land of this category is cultivated with the help of rainfall only, without irrigation from

any sources. Crops are, therefore, precarious. Various practices for the conservation and judicious use of water are adopted. These lands are common both outside and inside the area commanded by canals. In the latter case dry cropping is restricted to those lands which are too high or too rough to be watered by any sources. In Potwar the terrain is intricately gullied and the rivers are deeply incised below the general land level. In Peshawar and Bannu, the rolling sandy plains are mainly dry cropped. Here the monsoon rains are supplemented by winter rains from western disturbances. Thus both the Kharif and Rabi crops can be grown, millets and pulses in the former and wheat and gram in the latter season.

In parts where the soil is fine-textured and the water tends to run off, the rainfall conserved in many fields is distributed over a few by the construction of embankments and diversion ditches or drains. Blocks of fields are thus cultivated in rotation from year to year.

IMPROVED PERENNIAL PASTURE

This land use category includes grazing lands which are managed or enclosed. Such lands do not exist in West Pakistan.

UNIMPROVED GRAZING LAND

Lands of this category include all natural grazing grounds. The vegetation consists of grasses, shrubs and scrubs. They are generally confined to lands which are unsuitable for cultivation because of ruggedness of terrain, excessive salinity or waterlogging, inaccessibility to flow from canals or susceptibility to frequent, destructive river flooding. The land use problems in these lands are similar to those found in arid grasslands in many other parts of the world. The life is hard and hazardous. The rainfall being low and erratic, the risk of starvation for flocks and their owners is ever-present. Grazing is abundant only during the rainy season and for the rest of the year the animals subsist on dry grasses and shrubs. Grasslands are commonly found on riverain belts which are subjected to annual inundations and on waterlogged soils, where there is plentiful soil moisture to counteract aridity.

Practically every village has an area called culturable waste which serves as pasture for village cattle. The village common or *shamilat* is a part of it. The stony slopes at the foot of the mountains in north-east Baluchistan are scrub and/or semi-desert and are useful only for grazing.

WOODLAND

These semi-arid lands are deficient in forest resources for want of water. There are a few small areas of Government reserved or protected forests in different parts.

SWAMP AND MARSH

This category includes fresh or salt water areas used for fishing, hunting or grazing. These are too small to be demarcated. Most of them are confined to depressions and abandoned river channels in the meander flood plain or to a smaller extent in the cover flood plain. The moist ground at the edges supports plant growth for grazing.

UNUSED LAND

This land use category includes land which is at present unproductive, i.e., the land which does not fall in any of the categories mentioned above.

Although such lands are scattered over the whole region under study, they are found to a large extent in piedmont plains, Potwar uplands and the hilly area of north-east Baluchistan. These lands could not be used for a variety of reasons in different parts, e.g. extreme aridity, unproductive soils—too stiff, saline, alkaline or waterlogged. Some of these lands could be cultivated if irrigation were extended.

SUB-REGIONAL AND VILLAGE STUDIES (FIGURE 3)

Bari Doab. This region is highly irrigated, predominantly seasonally in its eastern part constituting the Nili Bar and perennially in the west part known as Ganji Bar. There is considerable well irrigation to supplement the seasonal canal irrigation and the soil is very fertile, with the result that the agricultural use of land and the intensity of cultivation are very high. It is almost completely free from waterlogging and salinity. Deficiency of water supply in winter is the main problem. Cotton and millets are the principal crops. Wheat is the chief Rabi crop while oilseeds are also grown in the western parts. This is a part of the area which will be most affected by the loss of the waters of the three eastern rivers to India.

Sanda Kalan and Khurd (Lahore District). The twin village is located in the active flood plain of the River Ravi, two miles south-west of Lahore. The rainfall is under 20 in. The area is irrigated by canals, wells and city drainage; 65 per cent of the area is cultivated, of which 56 per cent is double cropped. The very high percentage of uncultivated land in a village so near Lahore is due to the fact that a large expanse is subjected to too much soil moisture. Irrigation extends over 68.3 per cent of the cultivated area, city drainage accounting for about 45.7 per cent. The rest (31.7 per cent) is seasonally flooded (*sailaba*) by the Ravi. Dry cropped (*barani*) area is negligible. On account of the proximity of Lahore cash crops occupy 75 per cent of the cultivated area. There are several harvests of vegetables, and fodder is necessary for the maintenance of

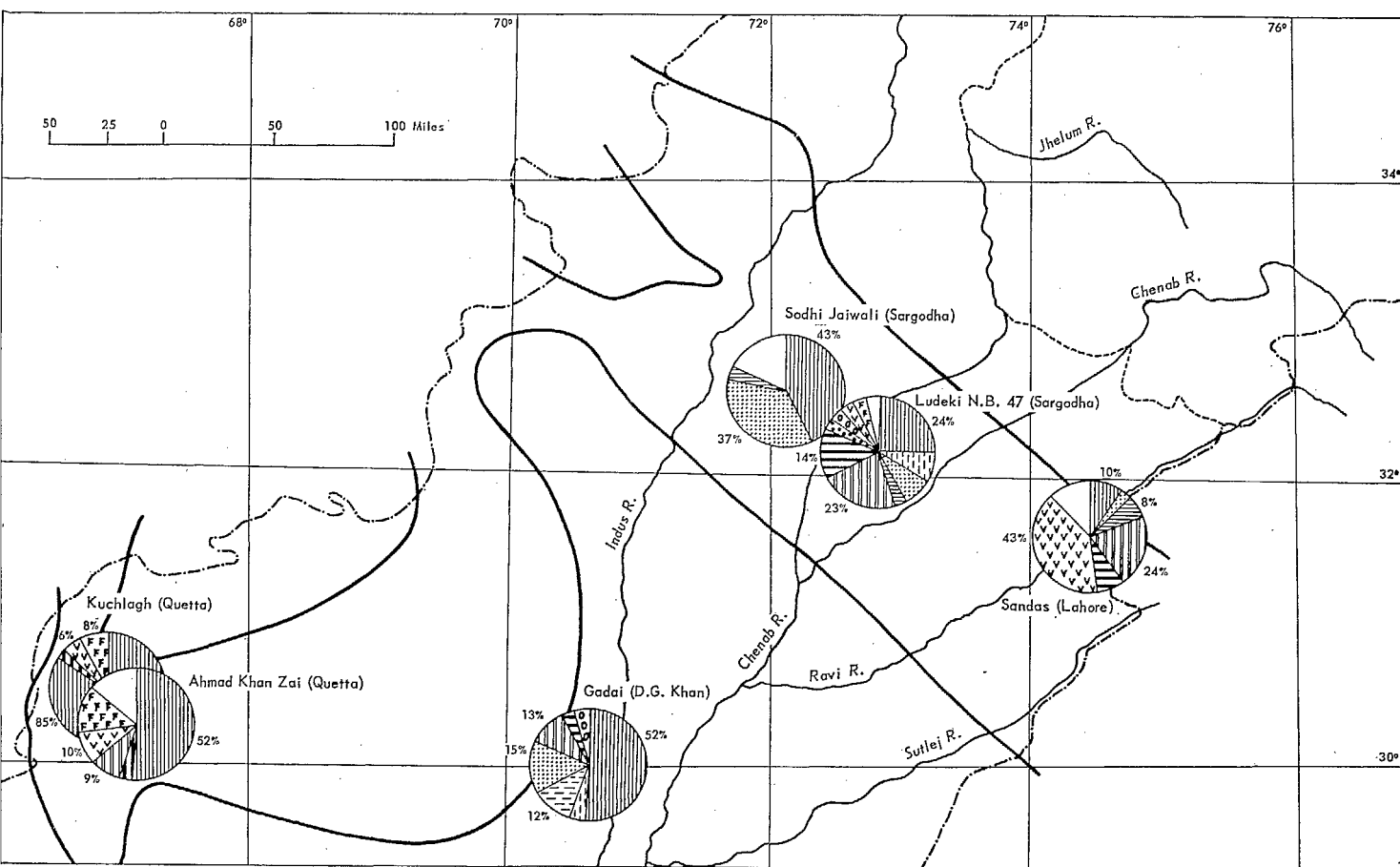
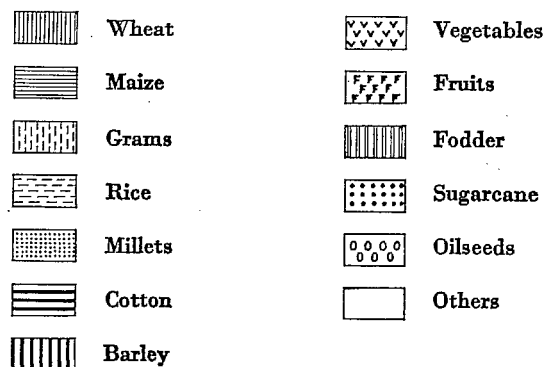


FIG. 3. Area under principal crops as percentage of the total harvested area (some villages).



cattle to supply milk. Wheat and maize are the chief grains (see Fig. 2). The holdings are small but are quite economic on account of the intensity of cultivation.

Rechna Doab. The greater part of the Doab in the semi-arid zone consists of meander or cover flood plains which are greatly waterlogged and highly saline. Large areas of cultivated land, once highly productive, have fallen into disuse. The scalloped interfluvium is however

free from these menaces and is perennially irrigated with cropping intensities as high as 130 per cent. Soils, though complex in pattern, are productive. Wells are widely scattered to help the winter crops. Wheat, maize and fodder are grown in winter and cotton and sugarcane in summer. Rice is the principal crop of the seasonally irrigated land and of the depressed areas, occupying the foremost position in its cultivation in West Pakistan.

Dry cropping is practised in the sandy lands which are too high to be reached by flow from canals. The moisture from the summer rains is conserved for winter grains, wheat or gram or a mixture. The active flood plains are used for flood cultivation (*sailaba*) and grazing. Grazing is the main use of land on the waterlogged parts where water-loving grasses and shrubs grow profusely in areas which are unsuitable for cultivation.

Chaj Doab. Meander flood plain and scalloped interfluvium are the two land forms which cover the bulk of the area, the latter being a part of the Kirana bar. There is no cover flood plain. The perennially irrigated bar uplands constitute one of the most prosperous agricultural lands with wheat as the chief winter and cotton as the summer crop. Rice is grown in the fine-textured soils of the riverain lands.

Dry cropping is practised on the sandy soils of the high river banks and central parts of the meander plain. The active flood plains are used for flood cultivation and grazing. Some areas are waterlogged and saline but to a much lesser extent than in Rechna Doab. Unused lands include some rocky wastes and belts of shifting sand.

Ludeke Village (Sargodha District). The village is located $1\frac{1}{2}$ miles north-west of Sargodha to which it owes its prosperity. The cultivated area is very high (83 per cent) and practically the whole of it is irrigated by canals. The water table is too low for well irrigation. Cash crops occupy 55 per cent, much less than in the case of Sandas of Lahore, an obvious commentary on the difference of the influence of the nearby urban centres. Food crops cover 45 per cent of the area. Rabi has 56 per cent and Kharif 44 per cent of the crops. Wheat and cotton are the main crops. Though fodder occupies about the same position, the acreage under wheat is high and that under vegetables much lower than in the Lahore village. Only 20 per cent of the area is double-cropped.

Northern Thal (Sind Sagar Doab). This is a rolling sand plain. Unlike other doabs it lacks alluvium and consists mainly of wind-blown sand. Sandstorms, excessive permeability and rough land are the main problems of land use in this area. These lands provide a living example of a large-scale transformation of a semi-desert area with a pastoral economy into a prosperous canal colony. The land use in this area is also notably affected by integrated socio-economic development as distinct from other plain areas. There is a long strip of perennially irrigated land in the south of the Salt Range with wheat, gram and fodder as the main crops. The summer crops include sugar-cane and cotton. The rest of the area is dry cropped with gram as the main crop. Waterlogging is developing fast.

In the Salt Range the piedmont and the alluvial fans

are grazed but not cultivated. Further south are found the torrent-watered and dry-cropped land. The most secure lands lie near the *nalas* and are reserved for winter crops.

The Suleiman Piedmont. These lands lie to the west of the Indus and consist of a plain, sloping gradually down from the mountain foot to the river. Numerous torrents have cut deep beds for themselves and the entire submontane belt is dissected into strips or blocks. It is an area marked by great extremes in water supply—from plenty to scarcity. The rainfall within the region is no index of its hydrological resources. Its water supply depends not so much on its own rainfall as that of the bare hills to the west.

The deposits show an orderly sequence in texture from gravel fans and sandy outwash near the mountain to medium and moderately fine materials at the far end. The whole region is monotonously uniform both in physical appearance and land use.

The torrents being the main source of water supply, agriculture depends upon the size of the catchment basin and rainfall it receives. Torrent-watered crop land lies in strips along the mountain base and alongside the large streams. The divides between the torrents are generally waste.

In the northern part where the rainfall is heavier and more evenly distributed dry cropping is also practised. In the south dry cropping is not practicable, and torrent-watered cultivation is confined to the summer season. The Rabi harvest—wheat and gram—is normally greater in the northern part, and Kharif, mainly millets, in the southern. About one-third of the land in Dera Ghazi Khan plain is used for grazing. On account of the great radiation of heat from the mountains, villages are rarely found in the immediate neighbourhood of hills. The deposits against the protective embankments of villages raise the fields higher.

Gadai Village. The village is two miles south of Dera Ghazi Khan, a little outside the semi-arid area. It has two distinct zones: (a) an alluvial plain in the south and east, and (b) a hill-torrent area in the north and west built of coarser material brought by seasonal torrents. Fifty-two per cent of the area is cultivated, entirely by irrigation; 16 per cent of the irrigation is provided by hill torrents and the rest by flood canal and wells. Cash crops are unimportant on account of irregular water supply. The hill-torrent area produces only millets, mainly jowar. Wheat, fodder and rice are important in the canal-irrigated lands.

Bannu Plain. This is a large alluvial basin drained by the River Kurram and its tributaries and practically isolated by a ring of mountains. It possesses a productive central core, aligned along the course of the River Kurram and a surrounding belt of less productive, rolling sand plains and torrent-seamed piedmont plains.

It exhibits the normal depositional sequence, coarse-textured deposits at the foot of the mountains, moderately fine or fine-textured at the centre.

The land use varies in different areas. In the central plain of the Kurram Cambila doab, with perennial irrigation, a large number of crops are grown—wheat, fodders and vegetables in winter and maize, sugar-cane, rice and fodders in summer. As the rainfall is fairly well distributed throughout the year, both Rabi and Kharif crops are almost equally important.

Torrent-watered cropland is restricted to narrow lands along the major *nalas* while the intervening tracts are devoid of cultivation and vegetation. Cultivation is devoted to raising such crops as wheat, gram and millets.

The rolling sand plains in the east and south are precariously dry cropped. Winter crops are more important than summer crops, the former being grown with the help of monsoon rains and matured by winter showers. Desert scrub and wasteland are found in some places.

Peshawar Vale. Situated in the extreme north-west, the Peshawar Vale is hemmed in on three sides by arid mountain ranges. It opens towards the east into the Potwar Uplands. The central part of the vale is a very fertile alluvial plain drained by the River Kabul and its northern tributaries of which the Swat is the most important. Fed by melting snows and rainfall both in summer and winter they carry a plentiful supply of water all the year round. About half of the area is under perennial irrigation with cropping intensities as high as 150 per cent. With a good winter rainfall the area under winter crop exceeds that of the summer crops. Wheat is the most widely raised winter crop, followed by barley and fodders. Maize and sugar-cane are the chief summer crops. Rice is important on the riverain lands. Cotton, which is an important crop in the canal-irrigated lands of the Punjab Plains, is rarely grown.

Well irrigation is concentrated in Swabi, where excellent tobacco is grown.

Dry cropping is confined to a narrow belt along the mountains and Sar. i Maira tract in the south-east. Here the soils are sandy and favourable to dry (*barani*) cultivation. Mostly Rabi crops are grown on such lands. The bordering ranges are clothed with scrub and grass and provide extensive suitable grazing grounds.

Potwar Uplands and the Salt Range. The Potwar Uplands and the Salt Range bordering it in the south are made up mainly of landforms not encountered in other parts of the Indus Plains. The lithology and attitude of bedrock and its depth below the surface together with erosion are the main features determining landforms.

The soil consists of alluvial and residual materials of variable texture.

The summit of the Salt Range is a broad plateau, occupied by a series of shallow basins with several salt

lakes. Most of the land is unused, with patches of dry cropped or torrent-irrigated lands. Coal and salt and some other minerals are mined in various parts.

The Potwar Uplands are greatly affected by gully and sheet erosion. About half of the area is unused and most of the rest is devoted to dry farming. The pressure of human and livestock population on the land is very great. Scarcely a cultivable acre is left untilled and cultivation takes place on the most unlikely spots, such as high uneroded pinnacles of alluvium, flanks of gullies and pockets of alluvial soil in the bare rock plains. Cattle, sheep and goats are put out to graze wherever vegetation grows in gullies along stream courses and mountains. Grazing of these lands makes them even more susceptible to erosion.

In all parts the winter crops are greater than the summer even though the summer rainfall is everywhere greater than that of winter. Wheat is the predominant crop. Rabi crops are grown only on the coarser soils and Kharif crops on the finer textured soils. Millets are grown in summer.

Sodhi Jai Wali Village (Sargodha District). The village is situated in Soan-Sakesar valley in the Salt Range. The rainfall is about 15 in. The summer half is rainier than the winter half. Only one-third of the total area is cultivated, of which only 7.1 per cent is irrigated by the waters of the Jai Wali stream and three wells. The small cultivated acreage is due to the rough topography, and lack of water supply. The water-table is very low. The existing wells lie on the banks of the Jai Wali. Food crops occupy 87 per cent of the harvested area. Of these wheat is the most important, occupying 43 per cent of the total harvested area and 50 per cent of the food crops. Bajra (millet) occupies 34 per cent of the harvested area. Cash crops occupy only 13 per cent of the total harvested area and include oilseeds and tobacco and some fodder for local consumption. Sixty per cent of the total area is used for grazing sheep and goats. It lies along the hill slopes. Holdings are small; only one-quarter of the holdings are larger than 8 acres. Located far in the interior, the economy of the village is primarily based on subsistence farming.

Quetta-Zhob hilly region. This region lying in north-east Baluchistan is different from other regions dealt with so far in the pattern of land use. The two dominant factors are the presence of mountainous tracts incapable of cultivation and the absolute necessity of perennial irrigation to ensure a harvest. More than 90 per cent of the area is unused or unproductive. The cultivated area, only 2.5 per cent, is confined to the river valleys, irrigated by flood water or to the intermont plains, irrigated by *karezes*. For dry crop cultivation the fields are embanked and are filled with rain or flood water in winter and summer.

Wheat is the predominant crop in Rabi and fruits in Kharif. Grapes and apples are the chief fruits. Rabi

crops are rain-fed but almost all the Kharif crops depend upon irrigation. Forest occupies only about 1.5 per cent of the area.

Unimproved grazing lands are found in the valleys and the plains and the lower slopes.

Ahmad Khan Zai and Kuchlagh Villages (Quetta District). Ahmad Khan Zai is located $3\frac{1}{2}$ miles south-west of Quetta, and Kuchlagh $14\frac{1}{2}$ miles north-west of the city. Both the villages have a high ratio of cultivated area, amounting to 78 per cent and 71 per cent respectively, of which 91 per cent and 65 per cent is irrigated. The higher percentage of cultivated land in an otherwise semi-arid and unproductive area is due to the availability of water from *karez*s and springs and due to the proximity of these villages to the urban centre of Quetta.

Cash crops occupy 46 per cent in Ahmad Khan Zai and 14 per cent in Kuchlagh. The difference is due to their relative distance from Quetta. Of the cash crops, fodder, vegetable and fruit are important in the nearer Ahmad Khan Zai. In Kuchlagh only apples and fodder are the chief cash crops. Wheat is the predominant food crop, accounting for as much as 86 per cent in the farther Kuchlagh and 52 per cent in the nearer Ahmad Khan Zai. Crop failures are common, much more so in Kuchlagh with a smaller irrigated area. They are as high as 25 per cent in some years. The failure of crops is generally due to heavy spring frost when the trees are fruiting or to heavy winter rains which

spoil the wheat crops. The double cropped area is negligible.

LAND USE IN PROSPECT

On account of the heavy pressure of population, shortage of food, extension of irrigation and water power, implementation of land reforms and the growth of industry, land use is likely to undergo an appreciable change in the years to come. More and more culturable wastes are being brought into cultivation through mechanized cultivation and tube-well irrigation, which has been made possible by the development of hydro-electric power and the electrification of the rural area. Co-operative farming is being encouraged on government lands commanded by the new barrages.

According to the Land Reforms Commission a ceiling has been fixed for agricultural holdings at 500 acres of irrigated land or 1,000 acres of unirrigated land. The land over and above these limits has been appropriated and the tenants cultivating the appropriated areas have been given the option to buy them on instalments spreading over twenty-five years.

Fragmentation of holdings below the subsistence or economic limit has been restricted. A subsistence holding comprises an area of $12\frac{1}{2}$ to 16 acres and an economic holding 40 to 60 acres depending upon its cultivation. These measures are bound to affect land use pattern in some areas.

DISCUSSION

D. CHRISTODOULOU. I would like to hear the speaker enlarge further on his concluding remarks concerning the influence of land reform on land use. It seems to me that throughout our discussions we have concentrated almost exclusively on the natural factors and have neglected the other important facet of land use, that is, the human factors.

I should appreciate it further if the speaker would give us more information regarding the introduction and operation of co-operative farming, to which he has made rather passing reference.

K. S. AHMAD. Co-operative farming has recently been introduced in West Pakistan in areas which have been brought under cultivation by the construction of new canals as in Thal or in the Ghulam Mohammad Barrage area, where it has proved quite successful.

P. MEIGS. This carefully prepared paper shows in detail the

actual land use conditions in a large region. The paper shows some of the complications that will be faced by our subcommittee in designing a legend for desert land use. The form of application of water is of great importance in distinguishing different types of land use, as Dr. Ahmad has shown. He distinguishes perennial irrigation by canal, seasonal canal irrigation, flood irrigation and torrent irrigation. These are familiar patterns in the desert regions, and the question arises: Should not the form of water use be made a part of any legend of desert land use? Or should crop type be the basis of the legend? Or both? I would like to ask Dr. Ahmad what he means by torrent irrigation. The type of uncontrolled flood irrigation in the Tokar Delta, Sudan, on the margin of the Red Sea, would represent a still different form of water use.

K. S. AHMAD. I described torrent irrigation as irrigation at the base of mountain slopes, where people divert the seasonal floods to the desired land.

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HUMAN GEOGRAPHY OF METHODS OF IRRIGATION IN THE CENTRAL ANDES

by

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The well known irrigation system of the Central Andes may have started in the Mochica period and the techniques of irrigation engineering were highly developed in the pre-Columbian era. Some of them are still used today, but most have disappeared. On this problem, however, few comprehensive studies have been carried out, and consequently much remains to be done in the future.

The hydrogeographic characteristics of the Central Andes will be divided into the following three areas.

Costa. In the Costa region, especially of Peru, about fifty rivers flow down from the Andes, and we have a typical landscape of the arid zone type, with small oases around the rivers. In addition to the permanent rivers, there are many which are dried up in the dry season, and there are to be found permanently dried up *quebradas* similar to the wadis of Western Asia. Methods of irrigation, such as canals or wells, are fairly well developed in farming areas. In profile these rivers follow a steep slope from the Andes and their water balance depends not only upon precipitation, but also upon melting snow from the Andes. The other interesting feature of water use in the Costa is the utilization of underground water for irrigation. Cotton and cane cultivation largely relies on this source. In the neighbourhood of Trujillo, drinking water is available from deep wells.

Sierra. The waters in the Sierra region, especially in the *altiplano*, run through the *puna* or *pampa*. Water from melting glaciers and snow flows into the rivers. Springs (*manantial* in Spanish) are fairly widely used as a source of drinking water by the Indians and their domestic animals. Precipitation is more than in the Costa, but the evaporation rate is also higher, and consequently, glacial lakes called "cochas" are often found in this area, sometimes turning into salt ones.

Selva. Generally speaking, Selva is a drainage of the Amazon and her tributaries. This is a region of heavy rainfall and the rivers are never dried up. That is why

few irrigation methods are found in this region besides the utilization of natural water flow.

The following examples will indicate the typical methods of water utilization in the Costa, Sierra and Selva.

COSTA

PIURA DESERT

The Piura Desert is located between latitude 5° and 6° S. There are few settlements to be seen with the exception of Sechura Village at the mouth of the Piura River. Eolian sand over the bed rock, and both moving and fixed dunes (SSW.-NNE. in direction, similar to the Barchan type) occupy the greater part of the land. River terraces are formed on both banks of the dried-up valley. All this tells of the geomorphological history of the region in the Plio-Pleistocene era.

At Moroppe, a small village at the southern entrance to the Piura Desert, we found an old irrigation canal of 1 to 1.2 metres in width and 70 to 80 centimetres in depth. A sedimented sand layer of 60 centimetres in thickness suggests a fairly old date. On the other hand, to judge from our observation of wells used by the villagers of Moroppe, underground water is reached at a depth of 7 metres from the surface. The water-layer is more than 14 metres in depth. When on the way from Moroppe to Sechura the jeep happened to run into soft sand to a depth of 60 centimetres, salty water began to flow out. The salinity of this water was higher than that of sea water and its electric conductivity amounted to 147.0 mmh./25° C. This may be caused by the infiltration of salt from the surface, or alternatively, the underground water itself may be condensed from alkaline soil in the course of evaporation.

Generally speaking, the fixed dunes are covered with trees or shrubs, which are rather deeply rooted. This phenomenon indicates that the vegetation depends not

only upon dew, arising from the difference in temperature between day and night, but also upon salty underground water. In other words, as the seed of a plant extends its roots into the salty water and becomes fixed in one place, a kind of micro-sand dune may be formed around it, gradually becoming larger. At the foot of some fixed sand dunes we found stone implements and potsherds. It is highly probable that an old settlement was built around a fixed dune with relatively shallow underground water.

Near Bayobar in the north-western part of the Piura Desert, we found some wells utilizing a subterranean stream in an old river bed. The stream runs about 70 centimetres below the river bed. The wells, divided into those for men and those for domesticated animals, have long been familiar to the shepherds in this area. It may be supposed that these wells were originally found by some animals and then used by shepherds who had tracked the animals to their water holes. The discovery of water must have played a most important role in the cultural history of the desert areas.

NAZCA

The general lay-out of Nazca reminds us of the Iranian Plateau. The Nazca River is dried up except in summer (from December to March) and water for irrigation is largely dependent on an old canal called *puquio*. This remarkable method of irrigation is formed of shafts dug at the foot of hills and underground tunnels or open or semi-open canals which carry the water to the fields. Some of the *puquios* derive their water by filtration or from reservoirs close to the fields. The *puquio* is apparently similar to the *kanat* system in Iran and the *foggara* in North Africa. The stone construction of the *puquio* is neatly organized. This method poses several questions. The first problem is how the temperature of water was raised. (The temperature of underground water is low and is liable to damage crops.) The second is the maintenance of the canal, that is, how to prevent it from being buried in sand.

The role of the *puquio* in Andean cultural history should be defined by excavating one particular complete chain as well as by studying comparable methods in Peru and Chile.

SIERRA

INCAIC AQUEDUCT (IN CUMBEMAYO)

The source of the Inca aqueduct in Cumbemayo is on top of a mountain 9,000 feet above sea level, west of the city of Cajamarca and the water is conducted down to the cultivated fields through skilfully made open canals and tunnels of stone. The tunnels are sometimes underground. The stone structures show an exquisite workmanship and some of them are supposed to be

a kind of holy place where llamas and other animals were sacrificed. The aqueduct is still used by the Indians today for cultivating *quinua* and other crops suitable to a cool climate.

The stone-work of the Cumbemayo aqueducts is excellent, just like the stone structures of Machu-Pichu. The technique used in working stone in Cumbemayo was apparently very similar to that of Ollantaytambo, Sacsahuman and other ruins of the Inca civilization. An interesting contrast can be seen between the Roman aqueducts in the Old World and the Inca one. The former were mainly used for drinking purposes while the latter were for irrigation. The study of technology and science in the pre-Columbian age, on which those highly developed engineering projects were based, should prove an important task for future investigators. The complete excavation of an aqueduct will surely throw light on this subject.

LAKE POPO

A complete subterranean drainage system is located at Lake Poopo, about 250 kilometres south of Titicaca. This area is relatively unexplored by geographers or archaeologists. On the western lacustrine plain, a vast pampa covered with Ichu shrubs, are to be found several villages of mostly Aymara Indians. Some of the settlements are occupied by the Chipayani and Uru tribes, whose way of life is still primitive.

The main source of water in this area is subterranean streams. For example, an Aymara village has two wells, both within a depth of 2 metres from the surface. There is no artificial superstructure, only the wells. A Moroto settlement near Andamarca has one hole where we found dirty water containing various plants and the carcasses of birds. Fragments of plainware vessels and an axe-like artefact of obsidian were collected by the author near a certain Moroto village. On the pampa we found some Inca stone works and *chullpas*. It may be concluded that the western lacustrine plain of Lake Poopo has been inhabited from the pre-Incaic period up to the present and the settlement has always been located near an underground water supply.

SELVA

At Iquitos, on the bank of the Amazon, all water supplies are dependent on the river. In a Yagua settlement near Iquitos, water is obtained from a dirty stream running through the village. A striking difference in transparency and chemical content was observed between the Amazon and her one tributary near Iquitos. Floating rice is found in this district, and we have a typical landscape of the humid tropics.

At San Juan, 150 kilometres north of Santa Cruz, Bolivia, there is a Japanese colony of 130 families. Through the virgin forest of this colony runs the Rio

Yapacani, a tributary of the Rio Grande. The lateral erosion by the river is striking and the water is less transparent than the Amazon near Iquitos. The source of water in the colony is a small opaque stream, a tributary of the Yapacani River. As the Yapacani Indians do not obey the government regulations, sanitary conditions in the neighbourhood of the colony are so bad that the construction of wells is an urgent necessity for its people.

Water utilization in the Costa region of Peru and Bolivia of today is very interesting. In the lower reaches

of the river valleys, where fertile oases are found, we have as usual a well-organized irrigation system.

The ownership of water rights is generally in the hands of the *hacendados*, except in cases where there is a *comunidad*. In the middle reaches a system of terrace irrigation is employed, the agricultural crops changing as we get more upstream. Towards the source, usually in the *altiplano*, the available water is derived from glaciers and permanent snow. The pastoral way of life is more general here than in the lower valleys, and water is sometimes used for hydro-electric plants or waterworks.

DISCUSSION

PROFESSOR STAMP referred to the very interesting chapter on early South American irrigation in *The History of Land Use in Arid Regions* (Unesco), especially the system of smoothing or lowering an irregular land surface of suitable light material to conform with the sub-surface water table in such a way that the water became available to plant roots. Professor Stamp suggested that modern machinery, e.g. bulldozers, ought to be efficiently used for a similar purpose.

C. TROLL. To date, we know of three areas in Latin America where the *qanat* system is known: the province of Tarapaca (Pica) in northern Chile, the oasis of Nazca in Peru and the valley of Tehuacan in Mexico. From Pica they were mentioned by K. Kaerger, 1901 (*Landwirtschaft und Kolonisation im Spanischen Amerika*, vol. 2, p. 251) and again described by I. Bowman. The *qanats* of Nazca are mentioned by H. Kinzl (*Zeitsch. f. Erdkunde*, 12, 1944, p. 108). The *qanats* of Mexico which I found in 1954 west of Tehuacan have never been described according to my correspondence with archaeologists. The question is: Had this system already been developed by the Indians in the pre-hispanic past, or was it imported by the Spaniards? In Mexico, the fact that the terms used to describe the features of this water-supply system (*galerías filtrantes*, *flor de tierra*) are purely Spanish, seems to me to indicate introduction from the Old World by the Spanish colonists. In South America the high development of irrigation systems in the pre-Incaic period (e.g., the *canchon* system) permits the suggestion that the *qanat* system there was invented by the Indians independently of the Old World.

I. DAN. I wanted to mention that in Rafiah, on the Sinai coast, near the coast itself, the farmers are accustomed to level and dig the dunes down to about 0.5-1 metre above the water table and grow there various crops which are usually restricted to irrigated areas, e.g., citrus, guava, etc. It seems that the winter rainfall leaches the salt which accumulates on the surface during the summer because of the low water-holding capacity of the dunes.

P. MONBEIG. On peut sérieusement douter de l'origine espagnole des systèmes d'irrigation du type « foggara » au Pérou. Tout d'abord il ne faut pas perdre de vue que les plus anciennes

civilisations préincaïques ont été des civilisations du désert littoral, ce qui suppose une agriculture active (et les fouilles archéologiques l'ont prouvé avec le maïs) qui se basait sur l'irrigation. En second lieu, l'emploi de termes espagnols n'est pas entièrement probant, car il est le fait des créoles et il faudrait savoir si le vocabulaire indien n'est pas plus riche, plus avancé. Enfin je ne crois pas me souvenir que le système des foggaras ait été utilisé en Espagne — et surtout dans les régions d'où venaient les colonisateurs.

Je désirerais savoir quelle est l'importance des surfaces actuellement irriguées par le système des foggaras. L'intérêt rétrospectif et purement scientifique de leur régime est indiscutable. Mais le problème péruvien actuel est celui du surpeuplement de la sierra et de savoir s'il est préférable de développer l'utilisation du sol dans la région côtière ou, au contraire, de faire progresser la colonisation de la montaña.

D. H. K. AMIRAN. (1) The *qanats* of Pica are known as *galerías soterraneas* and called *socavones*, a Spanish designation; so are the manholes (*lumbreras*). The Chileans have a tradition that they were introduced by the Spaniards, which looks reasonable from field evidence.

To expose a shallow ground-water horizon by bulldozing for cultivation would, at the evaporation rates of the Peruvian Desert, lead only to increased salinization of the soil. Witness the saline concentrations in shallow cultivation holes at Canchones not far from Pica in Chile.

Does moisture provided by *garúa* and *camanchaca* clouds or mist contribute to the alimentation of the vegetation?

Has Professor Kobori any information on water use by phreatophytes in the *quebradas* he showed in his slides?

(2) I am in complete agreement with Professor Monbeig that archaeological evidence has to be obtained to decide whether the *qanats* of Pica and Nazca are of Spanish, Inca or pre-Inca origin. But *prima facie* there are two reasons making a Spanish origin probable: (a) We have evidence from three localities only in Andean Latin America of *qanats*—Pica in Chile, Nazca in Peru, and the site reported on by Professor Troll from Mexico. (b) In view of all that is known of Inca agriculture, which worked by canal irrigation of terraces, it appears odd that *qanats* should have been used by pre-Spanish populations with only three remnants preserved or known to us.

THE LAND USE SURVEY OF SUDAN: SOME PROBLEMS OF CLASSIFICATION AND MAPPING

by

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The mapping of land use types for the Republic of Sudan, according to the scheme recommended by the World Land Use Inventory Commission of the International Geographical Union, was begun in 1956. The inception and early stages of this task were described in an article published in *Economic Geography* (Lebon, 1959).

Initially, the 1:250,000 topographic series (Sudan Survey Department, 1905-) was the basis for compilation, in conjunction with other maps (of Sudan or parts thereof), on smaller scales, depicting vegetation, soils, pastoral nomadism, extension of tsetse fly, etc. For some areas in the south-west and north, this method has been retained to the end; but generally for the centre, land use types have been mapped from the set of trimetrogon air photographs taken in 1943-44 by the United States Army Air Force, now kept in the Survey Department, Khartoum. More recent vertical photographs were available for some areas and were used when problems of classification could not be resolved from the trimetrogon photographs (Barbour, 1961). A set of maps on the scale of 1:1,000,000 (recommended by the WLUI Commission as the standard scale), and reduction to a single-sheet map of Sudan at 1:4,000,000, has now (January 1963) been completed. It is hoped to publish these maps. The latter is the basis of the generalized map accompanying this article (see Fig. 1). Areas of each land use type on the 1:1,000,000 sheets have been measured by planimeter, and are summarized in the table at the end of this article. A memoir, analysing and interpreting the results, has been written and will be published shortly (L. D. Stamp, editor).

For the geographical basis of land use, the earlier article may be consulted (Lebon, 1959), and Professor Barbour's recent book (Barbour, 1961, I-VII).

THE ADAPTATION OF THE WORLD LAND USE INVENTORY COMMISSION'S CLASSIFICATION TO SUDAN

Those formulating the Inventory of World Land Use scheme conceived that their nine principal types, and derived subtypes, were simply main categories of land use within which many local variants might exist (Valkenburg, 1950). It is thus desirable to state and justify the principles upon which the expanded and modified classification applied to Sudan is based. These are three in number.

First, this modified classification recognizes that the chief modes of land use are primitive, diverse and extensive. It will be shown later that the two most important subtypes are 4b (Land Rotation) and 6a (Used Unimproved Grazing). These accompany the work of simple societies and sparse population. Neither mode of land use metamorphoses or obliterates the original natural vegetation. Each mode simply modifies it, more or less. Pastoral people may alter the plant cover by burning or by over-grazing. Cultivators may thin and stunt savanna; but on their fallow, the natural vegetation is apparent in secondary stages of regeneration. Hence, the symbols for forest subtypes (7b and 7c), and for seasonal swamp (8') have been appended, in brackets, after most of the subtypes for Sudan. Thereby, important characteristics of land use subtypes are registered symbolically.

Secondly, the adapted classification conforms to actual disparities between economies. This principle is best exemplified by the contrasts between the Central Sand Zone (often called the *Qoz*) and the southern Clay Plain. The former, in open Woodland Savanna or Low Savanna is characterized by compact villages of beehive huts standing within thorn enclosures (*zaribas*), and widespread cultivation of rectangular plots. The latter reveals a much more variable arrangement of huts, cattle-shelters and much smaller cultivation plots

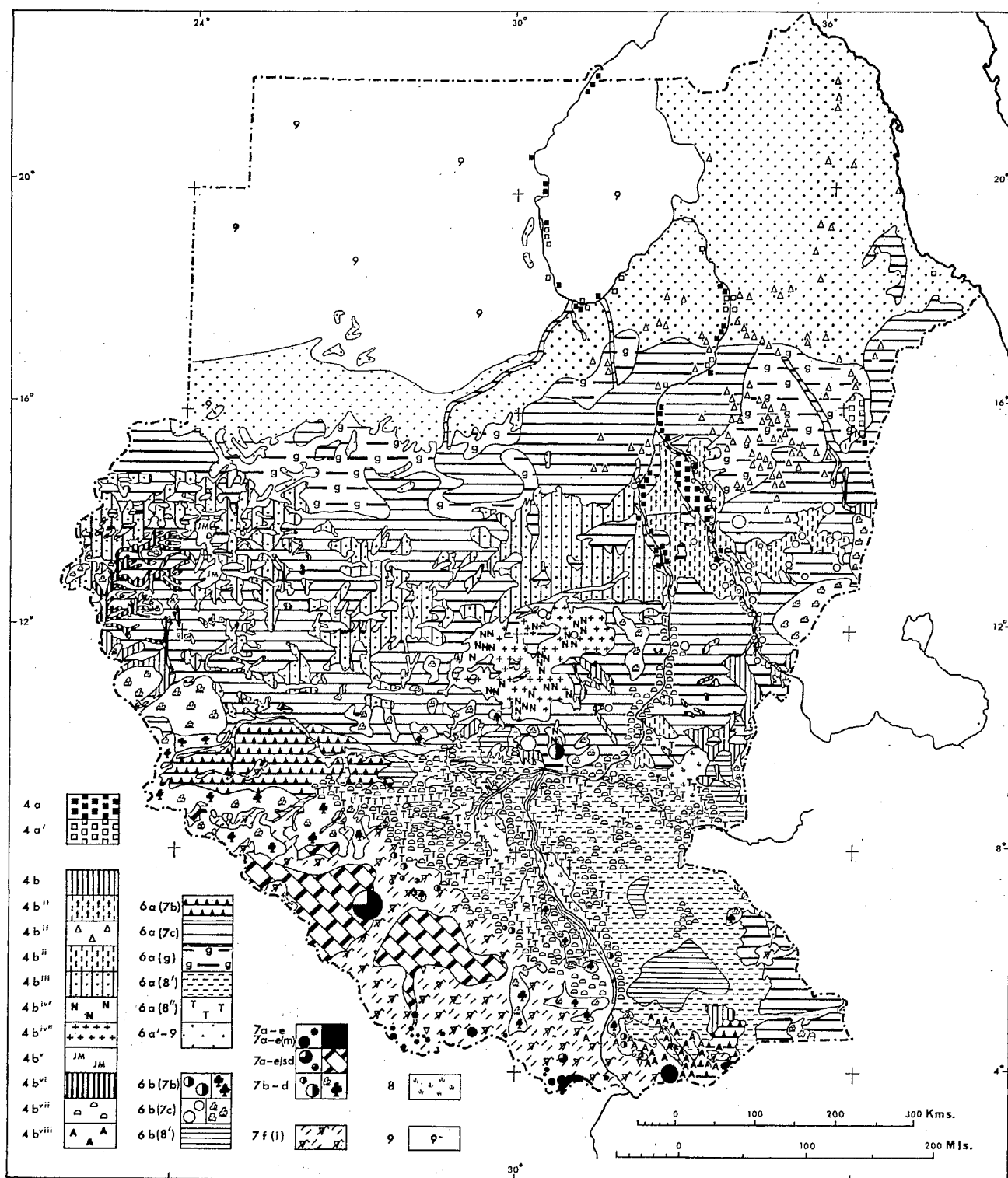


FIG. 1. The land use types of Sudan. The alternative circular symbols for 6b and 7a subtypes denote forest reserves, and are approximately proportional to the areas of the several reserves. For descriptions of the indices, refer to Table 1.

Continual and Rotation Cropping

Cropping on Flush-Irrigated Land, with
Used Unimproved Grazing in Scrub

Terraced Cultivation in Mountains,
with Used Unimproved Grazing in
Semi-Deciduous Forest (with Grass),
or Scrub (with Short Grass)

Continual Cropping, with some
Unimproved Grazing, in Semi-
Deciduous Forest with Tall Grass

Land Rotation with Used Unimproved
Grazing, in Semi-Deciduous Forest
with Grass, or Scrub with Short Grass

Used Unimproved Grazing, in Semi-
Deciduous Forest with Grass, or
Scrub with Short Grass

Used Unimproved Grazing in Seasonal
Swamp (mainly Tall Grass, but with
Scattered Trees)
(Late dry season grazing land shown
in pecked lines)

Dense (closed) Evergreen Forest

Open Semi-Deciduous Forest (with
Tall Grass)

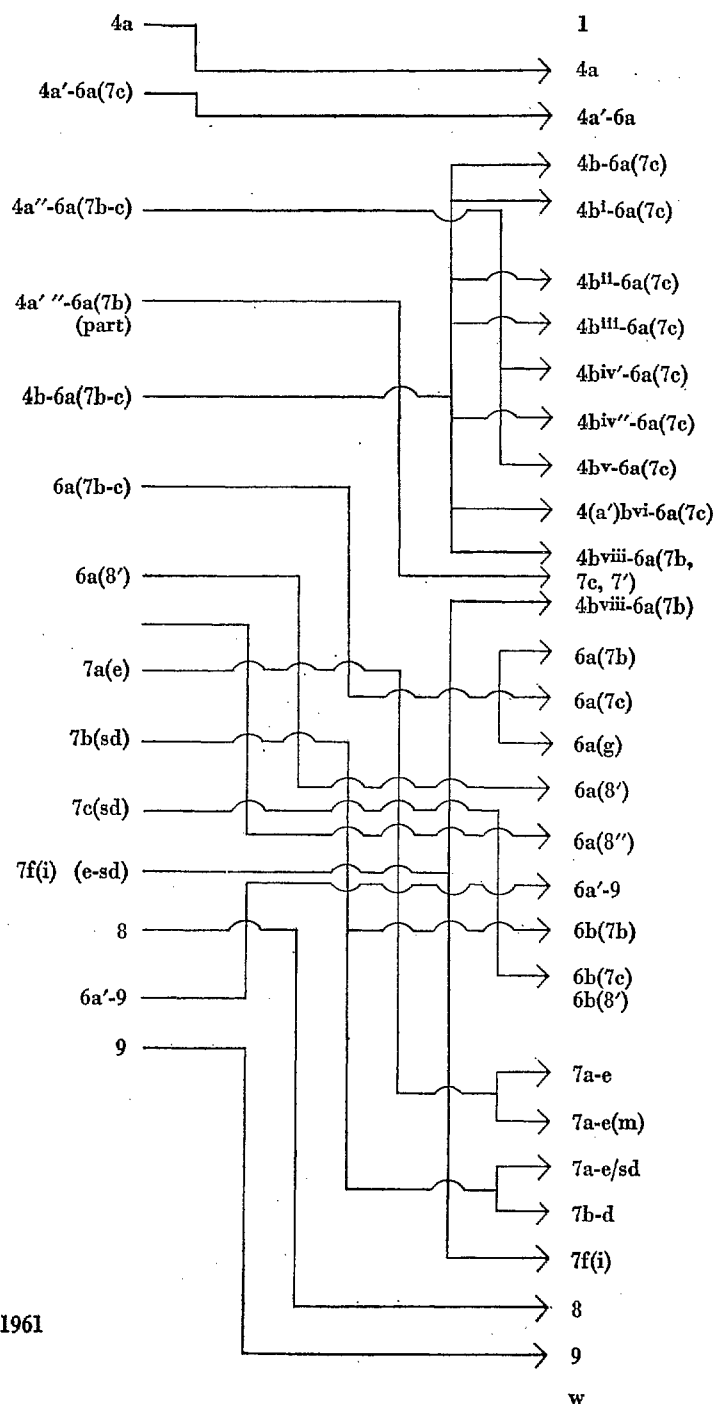
Semi-Deciduous Scrub (with Short Grass)

Evergreen and Semi-Deciduous Forest
with Shifting Cultivation

Swamp

Mainly Desert, with some Used
Unimproved Grazing

Unproductive Land (Desert)



1 Settlements (Towns)

Perennially Irrigated Cropland

Intermittently Cultivated Flush-Irrigated Cropland, with Grazing.

Land Rotation (Undifferentiated Local Types), with Grazing,
in Low Savannah or Woodland Savannah.

Land Rotation (*Terus* (4b^{lt}) and Small Areas of Flush
Irrigation (4b^{lf}), with Grazing, in Semi-Desert or
Low Savannah.

Land Rotation (Northern Clay Plain, including *Hariq*)
with Grazing, in Low Savannah.

Land Rotation (*Qoz* Types), with Grazing, in Low Savannah.

Land Rotation (Nuba Mountains Terraced Type), with Grazing,
in Woodland Savannah.

Land Rotation (Nuba *Qardud* and Clay Piedmont Plains),
with Grazing, in Woodland Savannah.

Land Rotation (Jebel Marra Terraced Type), with Grazing,
in Montane Woodland Savannah.

Land Rotation (Wadi Azum Type), with Grazing, in
Woodland Savannah.

Land Rotation (Nilotic Type), with Grazing, in Woodland
Savannah or "High" land of Southern Clay Plain.

Land Rotation (Terraced Upland and Piedmont Types
of Equatoria), with Grazing, in Woodland Savannah.

Used Unimproved Grazing in Woodland Savannah.

Used Unimproved Grazing in Low Savannah.

Used Unimproved Grazing in Semi-Desert Grassland.

Used Unimproved Grazing of Seasonally Wet Grassland
of Southern Clay Plain.

Used Unimproved Grazing of Perennially Moist Riverain
Grassland of Southern Clay Plain.

Used Sparse Semi-Desert Grazing, alternating with Desert.

Unused Unimproved Grazing, in Woodland Savannah.

Unused Unimproved Grazing, in Low Savannah.

Unused Unimproved Grazing, in Seasonally Wet Grassland
of Southern Clay Plain.

Evergreen Tropical Rain Forest.

Montane Evergreen Tropical Rain Forest.

Semi-Deciduous High Woodland Savannah, with some
Closed Forest.
Deciduous High Woodland Savannah.

Tropical Rain Forest or High Woodland Savannah with
Shifting Cultivation.
Permanent Swamp.

Unproductive (Desert).

Water Area of Principal Perennial Rivers.

141 TABLE 1. Harmonization of the 1957 and 1961
classifications

on "high" land, use of "intermediate" land for grazing, and often rather intensive use of swamp (*toich*) pasture, on which cattle-shelters and sometimes huts may be observed. On the Provisional (1956) and Revised Provisional (1957) maps, the "high" land of the Nilotic tribes was represented by the symbol for type 4b-6, which at that stage served for all forms of land rotation combined with grazing. All the literature, however, emphasized the disparities between the societies of the two regions, in economic activities as in institutions. As air photograph interpretation proceeded, it became quite clear that these two types of settlements and land use were quite distinct.

Thirdly, all types included in the classification must be readily identifiable on trimetrogon air photographs. This does not mean that every significant feature of land use and associated settlement must be thus visible. But it does mean that sufficient characteristics of land use must be apparent on air photographs to admit of identification and delineation in plotting. This principle has resulted in the exclusion, from the classification, of a type of land use which is given some prominence in the literature on Sudan agriculture, namely, the *hariq* system of cultivation after burning dead grasses, practised widely on the northern Clay Plain and on the plains intervening between the separate Nuba uplands. This mode of using land cannot be identified on oblique air photographs within a few miles of the track of the aircraft.

The application of these principles has, however, required more than subdivision of some WLUI types. It has demanded two combined categories: 4b-6a (Land Rotation with Grazing) and 6a'-9 (Sparse Semi-Desert Grazing, alternating with Desert). 4b (Land Rotation) is the commonest mode of land use among sedentary and semi-sedentary tribes, whilst 6a (Used Unimproved Grazing) is the land use type corresponding to nomadic herding, so widely prevalent in Sudan. Now in Blue Nile province, midway between the White Nile and the Ethiopian border, at about latitude $10\frac{1}{2}^{\circ}$ N., lives the Mabaan tribe (Davies, 1962), cultivating rather widely dispersed patches. During the dry season, however, their tribal lands lie athwart the migrations of the pastoral Rufa'a al-Hoi, who, in search of water and fresh grazing, move southwards as far as the Machar marshes ($9-10^{\circ}$ N.) or, occasionally, as far as the River Sobat. Thus, the Mabaan tribal lands are used for land rotation from May or June (when rainfall begins and the Rufa'a al-Hoi are returning northwards), until January (when the harvest is finally gathered). In the remaining months of the year, their lands are Used Unimproved Grazing. To prevent conflict between cultivators and pastoralists, administrative measures are taken to ensure that Rufa'a al-Hoi do not reach Mabaan lands until the end of January. Similarly, the Hawazma and Messiriya pastoralists of Kordofan cross lands cultivated by the Nuba (Harrison, 1955).¹ Moreover, all cultivating tribes practising land rotation own

domestic stock, of which cattle, sheep and goats are most numerous. These animals graze for most of the year around the villages, on fallow, and on untilled land interspersed between patches or tracts which periodically are cultivated, yet too small to be separately identified and plotted on the 1:1,000,000 scale. Since any one parcel may be cultivated for perhaps two to four years, and then fallowed for from ten to fifteen, and even during the period of cultivation is bearing a crop for, at most, six months of the year, it is evident that the grazing use of land being used for cultivation is dominant in time. In a ten-year cycle, there is a crop growing or standing for perhaps 24 months, and there is grazing use for 120. To allocate such land either to type 4b or to 6a exclusively would be arbitrary. The only course that corresponds to reality is to combine the two.

It is rather unfortunate that this expedient should be necessary. Clearly, it obscures comparisons between one country and another. Cartographically, it must hamper the preparation of maps of the whole continent or the world. Statistically, it results in lack of homogeneity. Is the area classified as 4b-6a, 4b or 6a? In part, the problem has been created by the choice of the 1:1,000,000 scale as the standard base. On larger scales, e.g., 1:250,000 or 1:100,000, the need for a combined index could be avoided by plotting on the basis of dominant use. Land near villages and in more densely populated areas, where fallowing is minimal, could be classified as 4b. More remote land, cultivated only occasionally, could be assigned to 6a, and perhaps distinguished as "Used Unimproved Grazing, with occasional limited cultivation" from "Used Unimproved Grazing, never cultivated".

Likewise, the combined type 6a'-9 (Used Sparse Semi-Desert Grazing alternating with Desert) could be avoided on a larger scale, on which areas more favourable for plant growth on the fringe of the desert (mainly watercourses and basins containing permeable deposits) could be outlined and separated from barren rock or mobile dunes, void of plants.

1. See Appendix No. 6, p. 39. This passage is worthy of quotation: "The passage through the Nuba Mountains of the Hawazma is regulated to prevent damage to the Nuba *hariq* cultivations. The Hawazma may use only certain routes and certain watering points, though the number of routes is fairly large. They must keep to these routes and they must travel through the area and not hang about. The aim of the cultivator is to keep the Hawazma north of the Nuba mountains as late as possible; then hurry them quickly through, to get them south of the Nuba mountains as early as possible. The aim of the Hawazma is to move on only when falling water supplies compel them to move on. In fact, some of the Hawazma stay in parts of the Nuba mountains throughout the dry season, though the majority are south of them for all the end part of the dry season. The Nuba themselves, who now have about the same number of animals as the Hawazma, keep nearly all of their cattle in the Nuba mountains area and few go south. The conflict between cultivator and cattle-keeper increases as cultivation expands and cotton prices go up. Not only is there a greater area cultivated, and therefore a smaller area for the cattle, but also both Baqqara, as well as Nuba, buy extra cattle with the money from the cotton. The answer would seem to be to reserve for cattle the parts of the *hariq* grassland that are better grazing, put fire-lines around them, and keep cattle completely out of the rest."

THE FINAL (1961) CLASSIFICATION FOR SUDAN

Five main types or categories of the WLUI classification have been included. These are: 4 (Cropland), 6 (Grazing Land), 7 (Forest), 8 (Marsh) and 9 (Unproductive). Two subdivisions of 4 (a and b) have been recognized; two of 6 (a and b) and four of 7 (a, b, c, and f). Types 2 (horticulture) and 3 (tree and other perennial crops) are also present, but only in very small areas and mainly in combination with 4a. Mapping these separately or in combination with 4a could not be undertaken on the 1:1,000,000 scale. But if and when mapping is undertaken on larger scales, these two types will be represented. The areas occupied by larger towns (type 1) have not been plotted on the 1:1,000,000 sheets; but have been measured on the relevant 1:250,000 sheets, and included in the statistical tables. The full classification is tabulated below, and its evolution since 1957 (when *Land Use Mapping in Sudan* was written) is shown diagrammatically (see Tables 1 and 2).

THE LAND USE TYPES AND SUBTYPES OF SUDAN

Both the 1957 and the 1961 maps disclose that there are four broad zones between the desert and the southern frontier: first, the northern grazing zone occupied by camel- and sheep-rearing tribes; secondly, the "Central Rainlands", predominantly devoted to land rotation, but including the country's most important tracts of continual cropping; thirdly, the south-central grazing zone, in the west composed of unimproved grazing in savannah and, in the east, similar grazing in seasonally-flooded grassland, and, fourthly, the southern zone of forest or high savannah and shifting cultivation (Lebon, 1959). The work since 1957 has imparted greater accuracy to all boundaries, and has also confirmed the essential correctness of the Provisional maps. The greatest modifications have been needed in southern and western Darfur, where field work and air photograph interpretation have revealed that cultivated areas are smaller than was thought in 1955-57.

Type 4a (Perennially Irrigated Cropland) is found along both Blue and White Niles, as well as the main Nile, between latitude 12° N. and the Egyptian frontier. Irrigation water is supplied by traditional methods, such as the Persian water wheel (*sacia*) and the *shaduf*, by diesel-engined pumps, and by gravity (in the Gezira and Manaqil schemes, commanded by the Sennar barrage). Small areas of type 2 (Horticulture) and type 3 (Tree and other Perennial Crops) occur within the areas mapped as 4a; but are individually too small to be shown at 1:1,000,000. At Kassala, on the Gash river, are market gardens and fruit orchards, watered from wells sunk into the silts of the Gash river alluvia. This area is just large enough to be shown at the 1:1,000,000

scale, but has been shown as 4a, to avoid employing type 2 for one instance only in the entire country¹ (Barbour, 1961; Tothill, 1948).

Type 4a'-6a (Intermittently Cultivated Flush-Irrigated Cropland) includes the Gash and Tokar inland delta of eastern Sudan, where the summer floods descending from the Ethiopian mountains are diverted by weirs and canals onto silt plains, and cotton is grown. There is variation from year to year in the extent of land cultivated; but relative constancy in the whole area devoted to this mode of exploitation, determined by the plan of the water control works. Hence, these deltas have been regarded as a subtype of 4a. The basins situated close to the main Nile below Khartoum, which are inundated by "high" floods, and afterwards tilled, have also been assigned to this subtype.

Type 4b-6a(7c) has been retained from the 1957 classification, under the title of Land Rotation (Undifferentiated Local Types), with Grazing. Its use is evident from the title: Cultivated areas about which little is known, or which are rather small in extent, have been included within this comprehensive subtype, to avoid suggesting precision, where such is not possible in the existing state of knowledge, and to avoid multiplying the number of 4b subtypes.

Type 4bⁱ-6a(7c) is Land Rotation (*Terus* (4bⁱ) and Small Areas of Flush Irrigation (4b^{if})), with Grazing in Semi-Desert or Low Rainfall Savannah. It is found mainly on the arid margin of the central rainlands and in the Red Sea hills. *Turus*, pl. *terus*, are earthen banks thrown up to check run-off on gently-sloping land within the northern Clay Plain, and thus to increase the amount of soil water available to quick-maturing *dhura* (*Sorghum vulgare*), which is almost the sole crop (Davies, 1962, ch. 4; Randell, 1963). 4b^{if} occurs in many watercourses within the northern grazing zone, where, after floods have passed, nomads sow millet on suitable patches. Basins or relatively lower land with silty or clayey soil, receiving run-off from adjacent slopes, may be used in a similar way. Maps and air photographs reveal that these local cultivated areas are far more common and numerous than the accounts of pastoral nomadism suggest. As a whole, therefore, type 4bⁱ includes land which is cultivated in virtue of water conservation, artificially-induced or natural.

Type 4bⁱⁱ-6a(7c) is entitled Land Rotation (Northern Clay plain, including *Hariq*), with Grazing, in Low Savannah. This subtype prevails to the south and south-east of the last, and where rainfall is higher. Cultivation may follow clearance of trees and bushes; and is also undertaken in unwooded grassy expanses, or *sageas*, which appear in the course of a grassland-acacia cycle. Here the land is prepared at the beginning of the rainy season by burning the close mat of dead grass accumulated after several years of growth. *Dhura* is then

1. These brief accounts of land use may be supplemented from K. M. Barbour, op. cit., chapters X-XVI, and from J. D. Tothill, op. cit., chapters X, XV, XVI, XXI, XXII, XXV-XXXI.

sown. By the aid of reservoirs (*hafirs*) filled from surface run-off, the cultivated area has been notably increased since 1945 (Lebon, 1956).

The Central Sand Zone (*Qoz*) is remarkably monotonous and is without surface drainage. Much of it, especially in the east, has been occupied by sedentary and semi-sedentary tribes depending upon water supplies from wells or *tebeli* (*Adansonia digitata*) trees. They build villages of grass-thatched beehive-shaped huts, set within thorn or millet-stalk fences, and cultivate rectangular patches almost wholly for bulrush millet (*Pennisetum typhoideum*). The gum-producing *hashab* tree (*Acacia senegal*) is naturally dominant, and regenerates when land is being fallowed. Where possible the cycle of rotation is from ten to fifteen years, during which gum may be tapped from the eighth year onwards (Jackson and Shawki, 1950). But there are over-cultivated areas, especially in the east near the railway line to El Obeid, where such lengthy fallowing cannot be practised. This subtype has been classified and plotted as 4bⁱⁱⁱ-6a(7c), or Land Rotation (*Qoz* types), with Grazing, in Low Savannah.

In southern Kordofan is a distinctive region of detached rocky uplands, surrounded by pediments merging into clay plains, and inhabited by Nuba peoples, who build their homesteads within the uplands, for greater health during the rainy season, and grow a variety of crops upon terraced fields. During the Condominium, they were encouraged to move their settlements to more accessible outer spurs and valleys, and to cultivate upon the pediments, upon what are called *qardud* (gravelly or silty) soils, also, on the silts and clays of the adjoining plains. Since about 1925, they have been growing American upland cotton for sale, helped since 1948 by many government reservoirs (Lebon, 1956). The subtype of land use corresponding with the Nuba mode of farming is 4b^{iv}-6a(7c), called Land Rotation (Nuba Mountains type), with Grazing, in Savannah. It has been possible to distinguish the terraced upland subtype (as 4b^{iv'}) from the areas cultivated upon the pediments or clay plains (4b^{iv''}).

The Jebel Marra range, in the heart of Darfur, is composed of late Tertiary lavas, and rises to more than 3,000 metres (10,000 feet). On the windward slope, the annual rainfall amounts to at least 1,000 mm. (40 in.). The basalt is an excellent underground reservoir, from which arise many perennial springs and small rivers. Fur farmers, scattered in villages, hamlets and isolated homesteads terrace the steep slopes. They also irrigate small gardens with great skill, and grow a variety of crops, of which bulrush millet is the staple cereal. (When the Jebel Marra is mapped on a larger scale, these irrigated gardens will need to be distinguished as a subtype of 4a, from the terraced lands which receive only rainfall and are fallowed for long periods). The relevant subtype of land use is 4b^v-6a(7c), defined as Land Rotation (Jebel Marra Terraced Type), with Grazing, in Montane Woodland Savannah.

Flowing westwards across the Darfur plateau are the large Wadi Azum and Wadi Kaja, flanked by silt terraces which are flooded every summer and are shaded by groves of *haraz* trees (*Acacia albida*). Villages of the Fur tribe are built on the slopes above these terraces, to avoid the cold nights of the valley bottoms (due to air drainage and temperature inversions during January and February). During the rainy season (when the *haraz* obligingly sheds its foliage), *dhura* and other crops are planted. After the harvest, the *haraz* produces a crop of pods edible by man and beast. From these, and the stubble, there is more than enough fodder to suffice for villagers' cattle, which have been grazed during the crop season on the savannah of the plateau beyond the villages. Nomadic tribes also converge from north, west and south, attracted by the easily obtained water to be found throughout the dry season a few feet below the surface of the alluvium (Lebon and Robertson, 1961). It will be noticed that the symbol for this subtype is 4(a')b^{vi}-6a(7c). (It is defined as Land Rotation (Wadi Azum Type), with Grazing, in Woodland Savannah.) Actually, it is not easy to determine whether this mode of land use is continual cropping or land rotation. The silt terraces are relatively restricted in area, and can be mapped accurately from air photographs. There is certainly an analogy with the Intermittently Cultivated Flush-Irrigated Croplands (4a'-6a) of north-eastern Sudan. But the crops and methods of cultivation broadly resemble those of other subtypes of land rotation. The rainfall is adequate for cropping. The flooding adds to the effective amount of water available and renews fertility. The limited, unchanging area in which cultivation is concentrated is but incidental.

With the next subtype we enter southern Sudan and the lands of the Nilotes, among whom the chief tribal groups are the Shilluk, the Dinka and the Nuer. On "high" land, within or along the margins of the southern Clay Plain, above the reach of annual inundation, villages are sited, crops are grown and cattle are kept when rainfall and river flood submerge the Plain generally. This subtype of land use is classified as 4b^{vii}-6a(7b, 7c, 7') and defined as Land Rotation (Nilotic Type), with Grazing, in Woodland Savannah or on "High" Land of the Southern Clay Plain. The latter is situated along the northern edge of the Ironstone plateau, where crystalline rocks of the Basement Complex replace the alluvium of the Plain, or, within the Plain, takes the form of small areas rising a few metres above the general level, perhaps stretches of old natural levees bordering abandoned river channels, or features of less certain origin such as the sandy "Bor ridge", extending northwards from the river port of Bor on the east bank of the Bahr el-Jebel. This subtype is associated within a larger pattern of subtypes or kind of catena with two subtypes of Used Unimproved Grazing (*vide infra*) (Jonglei Investigation Team, 1955).

The last of the land rotation subtypes is confined to the far south of Sudan, and almost entirely to the east

of the Bahr el-Jebel in eastern Equatoria. Here the rainfall is low for the latitude. Relief soils and hydrology resemble the Nuba uplands. The inhabitants settle at the foot of steep slopes and cultivate the nearly-level piedmont detrital "aprons", which receive additional water by seepage during dry periods. These elongated but generally fairly small cultivated areas (managed by a kind of land rotation) have been mapped as 4b^{viii}-6a(7b), and termed Land Rotation (Apron Type, Eastern Equatoria), with Grazing, in Woodland Savannah. With it is associated terraced cultivation of the Didinga and Boya hills.

Unimproved Grazing (Type 6) is the most extensive of all land use types in Sudan, because savannah and semi-desert are so widespread. Only the true desert of the north-west, the tsetse infested forest and high savannah of the south-west, and certain smaller areas of the southern Clay Plain are inaccessible to the pastoralist, and, consequently, Used Unimproved Grazing (6a) greatly predominates over Unused (6b).

In all six subtypes of Used Unimproved Grazing have been distinguished and mapped. More subtypes could be discerned on the ground, but not on air photographs; and the classification accordingly follows that of J. K. Jackson and M. N. Harrison, the latter an expert on grazing problems (Harrison, 1955).¹

Pastoral tribes utilize grazing and water sources by means of seasonal migrations. Three main groups of such tribes are generally recognized: first, the camel-owning (*jumiya*), occupying the most arid northern zone; secondly, the cattle-owning (*baqqara*), occupying the central zone, and, thirdly, the Nilotes, also cattle-owning, and living within the southern Clay Plain. Among the first two groups, it is usual to move northwards during the rainy season and southwards during the dry season. The Nilotes move towards "high" land during the rains, and towards riverain pastures during the months of drought. Actual movements of tribes and sections of tribes are much more complex, and vary from year to year according to the incidence of rainfall and new growth. The longest regular migrations, of the Rufa'a al-Hoi and the Kababish (the latter when seeking winter *gizu* grazing near the Wadi Howar in northern Darfur), are of the order of 1,000 kilometres (700 miles). But some Nilotic tribes remain in their villages throughout the year, and utilize two or three subtypes of grazing, according to season, which co-exist within a few miles. The Toposa of south-eastern Equatoria stand apart from the main groups; and have affinities with the pastoral tribes of East Africa (whence they came about 1870), rather than the rest of Sudan.

Used Unimproved Grazing in Woodland Savannah (6a(7b)) is characterized by broad-leaved deciduous trees and moderate to tall, mainly perennial, grasses. It is grazed during the dry season and at the beginning of the rainy season by some *baqqara* tribes.

Used Unimproved Grazing in Low Savannah (6a(7c)) is the most extensive subtype of 6a, in which scattered

thorny bushes, chiefly *Acacia* spp. grow with short grasses, generally annuals, and some herbs. It is used during the rains by *baqqara* tribes, and in the dry season (farther north) by camel-owning tribes.

Used Unimproved Grazing in Semi-Desert Grassland (6a(g)) is found in the extreme north of the Clay Plain, most typically in the Butana (between the Blue Nile and Atbara river), where trees are absent and naturally there are almost pure stands of the herb *Blepharis*, much liked by sheep and camels; but overstocking has caused grasses to appear in many places. Similar types of treeless grasslands, bearing mainly short annual grasses, extend west of the main Nile in northern Kordofan.

Used Unimproved Grazing of Seasonally Wet Grassland of the Southern Clay Plain (6a(8')) comprises level clay expanses upon which, during the rainy season, water usually stands to a depth of one or two metres, as a result of rainfall and overflow from rivers. Few trees grow, but tall perennial grasses flourish, which can be grazed in the earliest stages of growth, after the first rains, and also (after waters have disappeared) in December, if dead stems and leaves are burned to stimulate regrowth from residual moisture. This is the "intermediate" land in the nomenclature of the Jonglei Investigation Team (1955).

Late in the dry season, after grazing has been exhausted on "intermediate" land, Nilotic tribes drive their cattle to moist pastures near permanent rivers, characterized by *Echinochloa* spp. These are classified as Used Unimproved Grazing of Perennially Moist Riverain Grasslands in the southern Clay Plain (6a(8'')). This is the third land use subtype utilized in an integrated manner by the Nilotic tribes: the other two being 6a(8') and 4b^{vii}-6a(7b, 7c, 7').

The last subtype of Used Unimproved Grazing forms the transition from low savannah to desert, and is termed Used Sparse Semi-Desert Grazing alternating with Desert (6a'-9). It consists of patches of annual grasses, stunted *Acacia* and other xerophilous species (mostly browsed by camels), which grow more thickly in the beds of watercourses. The *gizu* grazing, already mentioned, includes herbs and low woody plants, growing mainly on sandy land in northern Darfur both north and south of the Wadi Howar, flourishes after years of good rains at the beginning of the cool season (from October onwards) and then provides excellent grazing for camels.

Unused Unimproved Grazing (6b) is not very extensive, because pastoral migrations are so far-ranging. 6b(7b) (Unused Unimproved Grazing in Woodland Savannah) is found locally near the southern limits of the *baqqara* tribes, usually where water supplies are poor in the dry season, or where tree growth is close. 6b(7c) (Unused Unimproved Grazing in Low Savannah) occurs only in some hilly parts of Darfur,

1. op. cit., Part One.

and near the Ethiopian frontier, mainly in the Dinder Game Reserve. Somewhat more extensive are areas of Unused Unimproved Grazing in Seasonally Wet Grasslands of the Southern Clay Plain (6b(8')) remote from "high" land and perennial streams, and therefore inaccessible to both Nilotic tribes and the Toposa.

Of type 7 (Forests) in the WLUI classification, five subtypes have been distinguished and mapped in Sudan. Evergreen Tropical Rain Forest (7a-e) is to be observed locally near the frontiers with the Congo Republic and Uganda, mainly in forest reserves. A montane variant (7a-e(m)) covers the Imatong mountains, east of the Bahr el-Jebel, and on the smaller uplands of Dongotona and Lotuke. Immediately to the north, on the Ironstone plateau, is a zone distinguished by Vidal-Hall (1952) on the ground of its greater wealth of trees and the frequency of gallery forests and thickets, under the name of Closed Savannah; although J. K. Jackson includes this zone within his larger High Rainfall Deciduous Woodland (Harrison, 1955).¹ In the quest of making the classification as comprehensive and detailed as present means allow, Vidal-Hall's Closed Savannah has been recognized as a subtype of forest: Semi-Deciduous High Woodland Savannah, with some Closed Forest (7a-e/sd). The remainder of Jackson's High Rainfall Deciduous Woodland has been mapped as 7b-d (Deciduous High Woodland Savannah). Apart from the presence of the tsetse fly, this form of high savannah could be grazed, and accordingly mapped as 6a(7b) or 6b(7b). In Sudan, 7b-d is a type of unimproved grazing, unused because of the tsetse fly. 6b(7b) is similar vegetation unused for other reasons.

Shifting cultivation is practised within and on the fringes of tropical rain forest, on the Ironstone plateau in western Equatoria and south-western Bahr el-Ghazal. (Tropical Forest of High Woodland Savannah with Shifting Cultivation: 7f(i).) There are a number of tribal variants, and one, the livelihood of the Azande, besides being the best-studied (De Schlippe, 1956), has also been modified by the introduction of cash crops and relocating homesteads close to a grid of tracks (Barbour, 1961, p. 254-256). Eastwards, towards Yei, the traditional method of using land has persisted, and led to much degradation of natural woodland and

to soil erosion. Yet a third variant is to be seen near Maridi, where the Moru practise the *katiri* system of land use by clans (Barbour, 1961, p. 258-359); Catford, 1951).

Type 8 (Permanent Swamp) is found in Sudan mainly along the Bahr el-Jebel in the reach between Bor and Malakal. This is the notorious *sudd*, where, in the past, floating vegetation choked the navigable channels, and the river steamers still make their way for days between unbroken walls of papyrus. But the permanent swamp does not extend far from the main channels and some backwaters. After a few miles, it is generally replaced by 6a(8').

Unproductive Land (type 9) stretches away to the north-western frontiers from the limits of 6a'-9. It has been defined as coincident with true or absolute desert, i.e., absence of plant life. Average rainfall is 25 mm. (1 in.) or less. On the 1 : 1,000,000 sheets, the continuity of desert is broken by a few patches of stunted plant growth, chiefly near wells: and here 6a'-9 is shown. But these patches are mere dots in the immensity of sand, rock and gravel. Because of the lack of plants and water, the desert is beyond the migrations of the camel-owning tribes; but occasional caravans still follow routes from well to well.

There is no provision in the WLUI scheme for the mapping and measurement of water areas. Presumably it is intended that rivers and lakes shall be excluded from the mapping of land use. For much of Sudan, on the 1 : 1,000,000 scale, the inclusion of water areas with riverain areas of different land use types does not lead to serious error; but in northern Sudan, where the main Nile is bordered by very narrow strips of 4a or 4a'-6a, inclusion of the river leads to serious exaggeration. Therefore the water area of the main Nile has been measured on the 1 : 250,000 sheets, and the results have been used to adjust the areas of riverain land use types to their true values. There is the added advantage that the total measured area of all land use types plus the water area equals the area of the country as ordinarily defined.

1. *op. cit.*, Appendix no. 2, p. 22-24.

TABLE 2. Areas of land use types in Sudan¹

Type		Area (km. ²)	Percentage
1	Settlements (Towns)	145	0.0006
4a	Perennially Irrigated Cropland	6 017	0.24
4a'	Intermittently Cultivated Flush-Irrigated Cropland, with Grazing	3 587	0.14
4b-6a(7c)	Land Rotation (Undifferentiated Local Types), with Grazing, in Low Savannah or Woodland Savannah.	32 021	1.27
4bif-6a(7c)	Land Rotation (Small Areas of Flush Irrigation), with Grazing, in Semi-Desert or Low Woodland Savannah.	3 348	0.13
4bit-6a(7c)	Land Rotation (<i>Terus</i> of Northern Clay Plain), with Grazing, in Semi-Desert or Low Woodland Savannah.	14 859	0.59
4bii-6a(7c)	Land Rotation (Northern Clay Plain, including <i>Hariq</i>), with Grazing, in Low Savannah.	37 368	1.48
4biii-6a(7c)	Land Rotation (<i>Qoz</i> types), with Grazing, in Low Savannah.	149 863	5.95
4biv'-6a(7c)	Land Rotation (Nuba Mountains Terraced Type), with Grazing, in Woodland Savannah.	3 407	0.14
4biv''-6a(7c)	Land Rotation (Nuba <i>Qardud</i> and Piedmont Clay Plains), with Grazing, in Woodland Savannah.	36 308	1.44
4bv-6a(7c)	Land Rotation (Jebel Marra Terraced Type), with Grazing, in Montane Woodland Savannah.	3 327	0.13
4bvi-6a(7c)	Land Rotation (Wadi Azum Type), with Grazing, in Woodland Savannah.	7 976	0.32
4bvii-6a(7b)	Land Rotation (Nilotic Type), with Grazing, in Woodland Savannah.	29 860	1.19
4bvii-6a(7c)	Land Rotation (Nilotic Type), with Grazing, in Low Woodland Savannah.	2 901	0.12
4bvii-6a(7')	Land Rotation (Nilotic Type), with Grazing, on "High" land of Southern Clay Plain.	35 046	1.39
4bviii-6a(7b)	Land Rotation (Terraced Upland and Piedmont Types of Eastern Equatoria), with Grazing, in Woodland Savannah.	2 474	0.10
6a(7b)	Used Unimproved Grazing in Woodland Savannah.	49 021	1.95
6a(7c)	Used Unimproved Grazing in Low Savannah.	561 994	22.32
6a(g)	Used Unimproved Grazing in Semi-Desert Grassland.	123 787	4.92
6a(8')	Used Unimproved Grazing of Seasonally Wet Grassland of Southern Clay Plain.	151 509	6.02
6a(8'')	Used Unimproved Grazing of Perennially Moist Riverain Grassland of Southern Clay Plain.	28 516	1.13
6a'-9	Used Sparse Semi-Desert Grazing, alternating with Desert.	383 985	15.25
6b(7b)	Unused Unimproved Grazing, in Woodland Savannah.	5 096	0.20
6b(7c)	Unused Unimproved Grazing, in Low Savannah.	58 052	2.31
6b(8')	Unused Unimproved Grazing, in Seasonally Wet Grassland of Southern Clay Plain.	35 607	1.41
7a-e	Evergreen Tropical Rain Forest.	3 859	0.15
7a-e(m)	Montane Evergreen Tropical Rain Forest.	1 150	0.05
7a-c/sd	Semi-Deciduous High Woodland Savannah, with some Closed Forest.	59 989	2.38
7b-d	Deciduous High Woodland Savannah.	48 062	1.91
7f(i)	Tropical Rain Forest or High Woodland Savannah with Shifting Cultivation.	130 897	5.12
8	Permanent Swamp.	26 663	1.06
9	Unproductive (Desert).	478 560	19.01
w	Water Area of Principal Perennial Rivers.	2 585	0.10
		2 517 839	99.92
			99.92

1. From measurements by bar planimeter on 1:1,000,000 sheets, adjusted to computed areas of sheets.

DISCUSSION

Y. KARMON. The land use survey of the Sudan is a pioneer work in an area where land use mapping cannot be based on the description of crops on fixed fields, but has to cope with shifting cultivation and grazing. Therefore the survey had to develop completely new categories, which were well presented in the written paper.

However, this survey touches an elementary question, namely, whether land use mapping should represent the actual occupation of the land or describe types of agriculture and land utilization.

J. H. G. LEBON. Dr. Karmon has raised an interesting and important question, which would require a good deal of time to answer fully. In principle, I think it is possible to map types of land use and agricultural systems separately. The former is more objective, because (given a suitable classification) it can be achieved simply by field work, whereas the latter demands inquiry into farmers' systems of husbandry and considerable judgement both in formulating a classification and in applying it.

The World Land Use Inventory Classification is a scheme neither of land use types nor of agricultural types. It incorporates something of each, together with some vegetation types. In it, types 1, 2, 3 and 5 are categories of land use *in sensu strictu*; types 4a, 4b, 6a and 7f(i) are types of agriculture and grazing; whilst types 7a-d and 8 are vegetation types. I should add that I regard it as a very well-conceived scheme for the purpose it is intended to serve; and this conviction has been strengthened by my experience in mapping the Sudan. The scheme is not, however, precisely described by its title. But this is common enough: how many books have correct titles, corresponding exactly to the contents? If Dr. Karmon can provide a more accurate title for the WLUI scheme, I am sure Professor Stamp will be grateful.

D. H. K. AMIRAN. In view of the many storage reservoirs (*hafirs*) used in the Sudan, could Professor Lebon give an indication of the percentage of the water impounded in them available for actual use, and the percentage lost by evaporation?

J. H. G. LEBON. Evaporation is, of course, notoriously

difficult to measure. In Sudan, Piche evaporimeters are installed at fully equipped climatological stations, and in the areas containing most reservoirs (*hafirs*) they record average daily values of 13-19 mm. during the months (October to May) of the dry season when the stored water is being consumed. Some measurements of evaporation from large pans and reservoirs were made by A. Aziz S. Saeed at Khartoum in 1956-57, and reported in Technical Note No. 1 of the Sudan Meteorological Service (Khartoum, mimeographed, 1957), which reveal values of 6 to 8 mm. per day for the cooler months (December to February) and 8 to 11 mm. per day for the hotter months (March to June) of the dry season. If we accept the latter values, and reject the Piche (as being in excess of the actual loss from water surfaces), it seems apparent that reservoirs (*hafirs*) must lose about 0.25 metre of water a month by evaporation during the cooler months of the dry season, and 0.3-0.35 metre per month during the hotter months. The total loss between 1 October and 30 June is likely to be about 2.5 or possibly 3 metres. These reservoirs are excavated to an average depth of 8 metres. Therefore, from a third to two-fifths of impounded water is lost during the season of need to the persistent dry northerly wind of these latitudes. It is the practice to equate the size of the *hafir* with the anticipated or desirable demand for stored water and to add 50 per cent to allow for silting and storage.

H. NIEDERBÖSTER. In what manner is this magnificent material used in agricultural planning or in other development projects?

J. H. G. LEBON. Both the memoir and maps are at present in manuscript, but are being prepared for publication, which it is hoped will not be long delayed. The project has been encouraged and supported by the Department of Land Use and Rural Water Development in Khartoum. It is my belief and hope that the results of the work will contribute towards the understanding and solution of the increasingly serious land use problems of the country, and be an example of the help university geographers can give to the new countries of Africa.

I appreciate the complimentary manner in which this question has been put.

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LAND USE MAPPING IN CYPRUS

by

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INTRODUCTORY

Mapping of land use of a country in a regional or wider context has to fulfil two requirements which are not always easy to reconcile: it has to depict faithfully the land use of the country—not excluding its distinct peculiarities—on the one hand, and to preserve comparability with the rest of the continent or some such larger unit on the other.

GENERAL BACKGROUND

It might be thought that Cyprus, because of its size, presents fewer problems of mapping than other countries. That is far from being the case. In fact Cyprus land use recording is a study of the elaborate rather than of the grandiose, its pattern being as detailed as that of the country's famous lacework.

There are many reasons for this: (a) Its physical features are varied to an extraordinary degree: rock types, structure and relief (and consequently soils) present unusually rapid changes from place to place; climatic conditions are also equally varied. (b) What makes for an even more elaborate pattern is the punctuation at irregular intervals of the landscape with islets of irrigation, that is of intensive land use and multiple cropping.

It should be further stressed that extreme fragmentation of holdings makes for minute fields (average 0.5 hectare, but in intensively used areas much smaller) and vestiges of subsistence mentality as well as possibilities of irrigation lead to putting such small fields to two, three or even more crops side by side. For mapping purposes such crops may belong to different categories or groupings.

Mapping of land use was carried out in Cyprus in various ways and on different scales. It should be stated at the outset that limitations are imposed by the existing base maps. Cyprus possesses maps on scales which for

land use mapping constitute the two poles, but nothing intermediate. Thus on the one hand there are topographic maps on scale 1:63,360, 1:50,000 and 1:31,680. Of those mentioned the first one is old (late nineteenth century) and out of print; the second is a wartime effort and not of a very high quality; and of the third (unfortunately never printed and without contours) copies can be obtained only as poor sunprints.

There are also cadastral plans on the scales of 1:5,000 or 1:2,500 covering practically the whole island but they are of varying accuracy and usually considerably out of date. Furthermore, being cadastral, they do not necessarily correspond to the fields as found on the ground, but units of registered land rights. That makes identification on the ground difficult and at times hazardous.

LAND USE MAPPING ON CADASTRAL PLANS

Experience of this kind of mapping covers a very small number of villages only. Mapping in the field was done by entry on the plan of the name of the actual crop or tree and other information necessary for later classification. There was a good deal of experimentation as to what broad groups should be set up. The best example to illustrate the final product is that of Anayia which the writer and a collaborator mapped in February 1951. The land use results were presented on two maps, one showing the trees and vines (perennial crops) identified by name and the other showing the annual crops as follows: Cereals, Legumes, Potatoes, Fallow (some of which was in preparation for vegetables as a summer [irrigated] crop), Uncultivated. This village presented most of the problems of mapping likely to be met in Cyprus: the perennially irrigated and the unirrigated

1. The author attended the meeting and submitted this paper with the approval of the Director-General, FAO, in his personal capacity.

parts; the small fields and multiple cultivation of the former; the intermingling of trees themselves as well as the trees, vines and annual crops. It also brought home the need to subdivide fallow itself.

LAND USE MAPPING ON SKETCH MAPS

For this purpose blown-up sketch maps from the 1:50,000 map were prepared and were used for rapid mapping of dominant land use within a village area (say 3 to 20 square miles) by college students under the writer's guidance. This was done in various parts of Cyprus and at the time no attempt was made to force each map into a pre-arranged classification. There are a number of such sketch maps in existence but the work of a broad land use classification on the basis of those records has not yet been done. An example of such work is Akanthou.

LAND USE MAPPING BY A COMBINATION OF THESE METHODS

A large continuous area of some seventy square miles in the west of the Central Lowlands of Cyprus was mapped in 1952-53 by a combination of methods. Some important parts, especially where field workers were available, were mapped on cadastral plans, while the rest of the area was mapped on the rapid mapping principle on sketch maps of 1:50,000 scale.

The whole was then transferred on a 1:50,000 base map and checked on the ground. The classification used was as follows, and it indicates an attempt to adopt the World Land Use Survey Classification of the International Geographical Union:

Dry Farming	(Cereals with fallow or in rotation) (Cereals intercultivated with trees (symbols for important trees))
Perennially Irrigated	(Vegetables or green fodder) (Industrial Crops)
Tree and Bush Culture	(with symbols for important trees)
Forest	(State) (Private)
Uncultivated Grazing Land	
Land Agriculturally Unproductive	(Built-up, mining, etc.)

Where more than one category was involved it was indicated by hatching in the relevant colour.

This combination was interesting in that for selected areas one had a detailed land use map while its place in the general pattern could be viewed from the smaller-scale map.

LAND USE MAPPING FROM AERIAL PHOTOGRAPHS

Only three of the attempts made at land use mapping from aerial photographs need be mentioned here.

1. The most complete work which covers the whole of the island is the one leading to the published *Land Utilization Map of Cyprus* prepared at the London School of Economics under the direction of Mr. R. R. Rawson and Dr. K. R. Sealy on the scale of 1:250,000. This is now a well-known map and its preparation has been described on the map itself and in various articles and papers.
2. The Pasture Survey of Cyprus was carried out for the Government of Cyprus by Huntings Technical Services and the maps, which are printed on the scale of 1:50,000, cover the whole island in sixteen sheets. The maps contain information not only concerning pasture but also on other land use aspects such as irrigated area.
3. The work was based on up-to-date aerial photographs and it combined field and office activities.
3. Topographic Map of Cyprus on the scale of 1:20,000, with some sheets on 1:10,000. This map was based on photographs obtained for the purpose in 1958. On the suggestion of the writer, some land use information including field boundaries will be included. The work is still in its initial stages.

DISCUSSION

The efforts recounted above can be discussed under two headings: (a) the success of mapping as such, and (b) its utility.

(a) There can be no doubt that the efforts made were either amateur activities born out of the enthusiasm of the workers and based on makeshifts and with a good deal of experimentation or were *ad hoc* projects with emphasis on rapid results. Land use mapping needs careful preparation, considerable resources and systematic handling. The results obtained so far can be used only to provide experience for adequate mapping.

The lessons to be drawn from mapping conditions like those found in Cyprus can be summed up as follows: the pattern is intricate and extremely detailed and generalizations mask much information of key importance. That difficulty arises mainly in areas of perennial irrigation where up to three crops in a year are possible and intercultivation with a variety of trees and other perennial crops is prevalent. An ingenious use of symbols, colours and shades is called for. The classification of trees needs to be much more detailed: there is, for instance, a world of difference between citrus groves and olive groves or between those and, say, almonds. Sound knowledge of the ground and thorough familiarity with institutional as well as physical conditions are

absolutely essential especially in mapping from aerial photographs.

(b) The utility of land use maps is well known and need not be argued here. We in Cyprus were always hampered by the lack of basic knowledge even of the areas involved in the various land use classes as well as their precise distribution. We simply did not know what we had. There has always been a substantial portion of agricultural land unaccounted for in our statistics, which are based on returns. We did not know the location of our unutilized but utilizable land—if it existed at all! Our guesses were as wild as our imagination or optimism would urge.

Apart from not knowing the precise distribution of the general pattern we were even more ignorant of the details of the pattern. Between the knowledge of the experimental agronomist and the general notions of the casual traveller there has been no bridge. Correlations with other known relevant factors beyond the field level with any semblance of validity were (and still are) impossible.

For a country pressing hard on its resources, competent land use mapping is absolutely essential—especially since it is now embarking on some form of planning.

The value of land use maps will be enhanced if other relevant facts are mapped on identical scales. But land use mapping should start the ball rolling by (as it usually does) providing some answers but asking even more questions.

THE USE MADE OF LAND USE MAPS TO DATE

Elsewhere, namely in *The Evolution of the Rural Land Use Pattern in Cyprus* (see bibliography), I have

described the history of land use mapping in Cyprus; in the same text are given also, *inter alia*, two maps dated 1853 and 1882 respectively, containing land use information referring to those two periods. As mentioned in the publication referred to, that information is today largely of historical significance, but it points out the intrinsic interest that land use in Cyprus had held for students or observers even in less scientific ages. Modern efforts concentrate largely within the 1950s when economic development was becoming uppermost in the minds of both officials and students.

Besides mapping of rural land use to which this paper refers, there have also been attempts at urban land use mapping by the Department of Housing and Planning of the Government of Cyprus.

Thus slowly but steadily a record was being built up to furnish basic information and fashion tools to aid economic development. The political events that intervened, culminating in the declaration of independence of the island in 1960, put an end to that phase of land use mapping. The current readjustment and re-appraisal of the whole policy and economy of the island have not yet included problems of land use mapping.

However there can be no doubt that, with the now enhanced emphasis on economic development and the need for the Cyprus economy to adjust itself rapidly to its main markets, namely the European Economic Community and Britain, a far greater impetus will be provided for the building up of basic information on a systematic basis. Towards that end such basic records and important tools as comprehensive and adequate land use maps are well-nigh indispensable.

With regard to rural land use mapping, the projected Agricultural Research Institute, which is being set up under the United Nations Special Fund with the active participation of FAO, will undoubtedly promote and systematize the whole work.

DISCUSSION

X. DE PLANHOL. Je désirerais savoir s'il existe dans la Mesorée un arrangement du terroir villageois en grandes soles, alternativement cultivées et laissées en jachère, et occupant respectivement deux parties distinctes du terroir, ou si les parcelles de culture sont réparties au hasard.

D. CHRISTODOULOU. There can be no clear-cut answer to this. Certainly the two-field system wherever it held sway has in recent decades been breaking down as a result of subdivision and fragmentation of holdings and because of the transformation of the land use pattern on account of such developments as irrigation, tree-planting and the introduction of new crops. One of the powerful factors maintaining the alternate use of large blocks of the village lands

is the grazing system based on roaming flocks. Graziers have interest in the alternate use of blocks because they ensure free use of large contiguous areas of fallow on other people's lands.

Casting a look at the prevalence of the two-field system in earlier days, one discovers that the system was quite widespread—prevailing not only in the lowlands, but also in hilly areas. Expressions like "upper yoke" and "lower yoke" are still heard in the hilly and plateau areas of Paphos. As a matter of fact there is today a direct relation between the prevalence of the two-field system and the degree of vestigial subsistence economy. Thus the two-field system is more likely to be found in poorer or remote districts than in prosperous, especially irrigated, lowlands.

Y. KARMON. The map of Rawson and Sealy shows the Mesaoria as an irrigated area, and this raises the question of the correct definition of irrigated lands.

D. CHRISTODOULOU. In this particular case the classification system adopted is the outcome of the method used in the preparation of the map. The map was based on the interpretation of aerial photographs. All areas served by irrigation channels were indicated as "irrigated". In all fairness it must be said that, given the method used in the preparation of the map, the distribution shown on this map is remarkably accurate. It shows, of course, the areas likely to be irrigated one way or another, *some time*.

It is well known that there is a world of difference between

the seasonal (i.e., winter and early spring) and the perennial (i.e., in effect summer) irrigation. Cyprus may irrigate barely up to 5 per cent of its agricultural land in years of good supplies of irrigation water in the summer season. The actual areas irrigated fluctuate widely from year to year under both heads. Even field-to-field mapping will be faced with difficult problems when it comes to the sorting out of the plots to be classified as "perennially" or "only seasonally" irrigated, because many plots are usually only seasonally irrigated and in years of plentiful supplies they may receive perennial irrigation. There is, of course, also the problem of "fallowing" of even perennially *irrigable* land and the use of such land for a winter, not a summer crop.

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SECTION III

LAND USE MAPPING AND URBANIZATION

CARTOGRAPHIE DE L'UTILISATION DES TERRES ET URBANISATION

LAND USE MAPPING IN THE ARID ZONE¹

by

L. DUDLEY STAMP

*Chairman of the Commission of World Land Use Survey,
International Geographical Union*

The nine major types of land use defined by the World Land Use Survey of the International Geographical Union were designed to be applicable to every country in the world and to all types of conditions. It was laid down as a first principle that these world categories should be adhered to and in no case combined, but that any country should be free to make as many *subdivisions* as local circumstances might require. Although the term "land use" is used, it is understood that all parts of the land surface are included, whether used directly by man or not. In arid lands it is clear that large areas are in fact, unproductive.

It is instructive to look at the world system and to note modifications normally required in arid lands.

1. Settlements and related non-agricultural land uses.
In arid lands mining enterprises may be important and occupy considerable areas (red).
2. Horticulture and intensive farming. Cultivation in many cases and where irrigation water is available, as along rivers, is often of an intensive character and is best included in this category (deep purple).
3. Tree and other perennial crops. In arid lands there are certain types of cultivation which can almost be described as standard and merit special subdivisions, such as the date palm groves of Iraq (light purple).
4. Cropland (brown). In arid lands an immediate separation into irrigated land is needed as well as a distinction between lands permanently cultivated and those intermittently used.
5. Meadows and improved pasture (light green). It is possible that some irrigated meadows may be found which should be included here.
6. Unimproved rough grazing (yellow and orange).
7. Forest and woodland of different types including scrub (uneconomic) (olive green). These will obviously be important categories in semi-arid lands.

It is not always possible to distinguish between "used" and "unused" rough grazing though this should be done where possible. It is suggested that each country should develop its own subdivisions based on the vegetation, natural or semi-natural, linked wherever possible with the use made of the vegetation, e.g., grazing for goats, camels, sheep, etc., with some indication of the intensity of stocking. Where land ceases to carry enough vegetation to be of use in grazing, it should be classed as category 9.

8. Swamp and marsh. In arid lands *playas* and similar areas periodically covered with water may form an important feature of the landscape and, properly described, should be included here (blue).
9. Unproductive (grey). Clearly a large proportion of the truly arid lands must be included here and it should be possible to distinguish various types of desert—rocky desert, gravel desert, sandy desert, dune areas, loess and clay deserts. The subdivision becomes a physical one and in many areas the geology and geomorphology are of the greatest importance in suggesting potential use and may be used as the basis of subdivision. Although vegetation has been suggested as the normal index for different types of unimproved grazing, geology, geomorphology, hydrogeology and soils (such as indications of saline incrustations) are often equally important in distinguishing local categories.

In the arid lands, the broad principle in mapping remains, as in all parts of the world, to record what is actually present at the time of the survey and to include careful and accurate descriptions which will permit world-wide correlation. Wherever possible categories of land should relate to dominant physical features and causative factors.

1. For discussion of this paper see p. 162.

LAND USE SURVEY IN MEDITERRANEAN COUNTRIES: CARTOGRAPHICAL SUGGESTIONS

by

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I

The need for a comprehensive survey of land use in different countries and for a world map of land utilization has been stressed many times, especially by the Food and Agricultural Organization of the United Nations (FAO) and by the International Geographical Union. The latter, at the International Geographical Congress in Lisbon (1949), set up a Special Commission on World Land Use Survey—referred to in this paper as the Commission. Starting under the chairmanship of S. van Valkenburg, and now headed by L. Dudley Stamp, the Commission has encouraged many countries to undertake partial or national surveys and has also published a master key for land use, categories and their cartographical representation.¹ Since then, a number of land use maps have been published,² but not all of them have adopted the key proposed by the Commission. This may be due mainly to the fact that because of the generalized character of the proposed key, which makes it useful for a world map, its particulars do not fit into every regional type of agriculture and land use. The different agencies and governments sponsoring a land use survey naturally lay stress on those facts and crops whose mapping will enable them to plan agricultural or general development of the region concerned. The key proposed by the Commission in 1949 was apparently too much bound to the experience of the land use survey of Britain, which in its time too served a specific purpose—i.e., to plan the food supply of Britain during the Second World War.

With the publication of a number of land use maps of different regions of the world, the variety of differentiations and cartographic representation is so great that there exists the danger of lack of a common denominator, and it is necessary to try to find a new common base for land use mapping. It seems that a common key for categories of land use under all climatic and socio-economic conditions of the globe is possible only for a very much generalized world map on a scale of

1 : 1,000,000 or smaller, but that a more detailed survey needs its specific means of mapping. A common key should therefore be sought for on a regional basis, according to climatic or topographic similarities, e.g. tropical lands, monsoon areas, highlands, etc., which of course should adopt the general principles of the world land use maps, but develop its own key for particulars. Countries of continental extent would use the regional key for detailed land use mapping, and the world key for national maps, which anyhow would be published in a very small scale.

It is the purpose of this paper to suggest a common key for regions of semi-arid climate (Mediterranean type) which could be adopted by all countries of similar conditions. By stressing the types of crops and farming—and other ways of land use—that characterize this region, the proposed scheme tries to remain as near as possible to the key suggested by the Commission.

II

Agriculture in semi-arid regions, and especially in the Mediterranean realm, shows some very distinct features, which are the main concern of any planning or agricultural authority, and which should stand out very clearly on any land use map:

1. The amount of irrigated or partly irrigated land is one of the most important denominators for the intensity and development of agricultural land use.
2. The importance of fruit orchards—as one of the main cash and export crops—demands a distinct marking of the various species.
3. The intercropping of trees and arable land is a very common feature in most Mediterranean countries.

1. *Report of the Commission on World Land Use Survey for the period 1949-1952*. IGU, published with the co-operation of Unesco (Worcester, 1952).

2. For list of land use maps see *IGU Newsletter*, Vol. XI, 1960, No. 1/2.

4. Grazing in semi-arid regions is very different from grazing under Atlantic conditions: instead of cattle grazing on meadows there are sheep and goats on mountain slopes or stubble.
5. Utilization of slopes by terracing is a common feature in parts of the region.
6. Subsistence economy is still the rule in large parts of the region and expresses itself in scattered holdings or even patch-cultivation.
7. Forests are completely different from those in humid regions, and occur mainly in degenerate forms of maquis or garrigue, except where modern afforestation has taken place. Their main use is not forestry but grazing.
8. Soil erosion has destroyed large tracts, leaving barren soils or badlands, and a differentiation in types of unused lands seems necessary.
9. A comprehensive land use survey should not confine itself to the mapping of agricultural lands; although in urban land use there is a greater similarity to other regions, special attention should be given to recreational or touristic land use, whose importance is very great in the Mediterranean region, and which provides a much larger income from land than agriculture.

III

In accordance with the above-mentioned characteristics of agriculture in the Mediterranean region, the following types of land use should find expression in mapping:¹

1. Settlements and associated non-agricultural lands.
 - a. Dense housing (urban centres, compact villages, camps).
 - b. Dispersed housing (suburbs; dispersed villages, isolated farms).
 - c. Industry and transport (factories, railways and yards, roads, ports, airports, mines, quarries).
 - d. Gardens and recreation (large domestic gardens, parks, sports grounds, beaches, public gardens).
2. Horticulture. In semi-arid countries this category should include only irrigated intensive vegetable farming or flower gardening in plots no smaller than 0.4 hectares (1 acre) and no larger than 1 hectare (2.5 acres).
3. Tree and other perennial crops. This category is of utmost importance in Mediterranean regions and should be as detailed as possible. The main distinction should be made between irrigated and non-irrigated plantations, using a special symbol for intercropping. The different types of trees could be marked by symbols, mixed plantings being indicated too. Thus there should be three main categories:
 - a. Non-irrigated fruit trees, such as olives, figs, carobs, vines, deciduous fruit trees.
 - b. Irrigated fruits, such as citrus, bananas, subtropical fruit, deciduous fruit trees, irrigated grapes.
 - c. Intercropping of fruit trees and arable land.
4. Cropland. Here too the main distinction should be made between irrigated and non-irrigated crops (with a special sign for partly irrigated crops). In addition, it seems necessary to introduce another distinction: the purpose of the crop, i.e., for food, fodder, or industrial purposes. A

division on these lines would provide clues to the type of farming: e.g., dairy farming with stress on fodder-crops; industrial crops would indicate mainly large farms; a special symbol for patch-cultivation and scattered fields—usually of small extent—would indicate a prevailing type of subsistence agriculture.

In hilly regions a distinction between terraced and non-terraced lands seems necessary.

Examples for representation of various crops are given in the following list:

Purpose	Irrigated	Non-irrigated
a. Food crops	Vegetables (large scale), potatoes, rice.	Cereals (including maize, if used for food consumption).
b. Fodder crops	Alfalfa, fodder-grass, clover, maize.	Barley, oats, sorghum, fodder, grass.
c. Industrial crops	Cotton, peanuts, sugar beet.	Oil-plants, flax, sisal, hemp, tobacco.
d. Patch-cultivation	Without differentiation.	
e. Fallow	Would be indicated only on large-scale maps.	

5. Improved permanent pasture. As this type of pasture plays a small part in semi-arid countries, it should not appear as a separate category, but as a sub-category of rough grazing. Irrigated permanent pasture would appear under category 4b.
6. Unimproved grazing land. Actually every area, except plantations and other perennial crops, is used for grazing in the rainy season or after harvest. It would be unnecessary to mark this type of additional land use. The category should include only these areas, where no other land use exists, and where grazing is not confined to the rainy season. Where transhumance is the prevailing type of economy, a special sub-category—seasonal grazing—could be used.
7. Woodlands. Here a distinction seems necessary between newly afforested land (i.e., since the beginning of the twentieth century) and natural forest, marking the prevailing kinds of trees. The suggested division is:
 - a. Afforested land.
 - b. Natural forest.
 - c. Maquis and other types of degenerate forest. This type will mostly be identical with unimproved grazing.
8. Water bodies.
 - a. Lakes or water-reservoirs.
 - b. Fish-ponds.
 - c. Swamps.
 - d. Salt pans and *playas* (if utilized for production of salt, with special indication of industrial activity).
9. Unproductive land. The main reason for non-productivity should be indicated, e.g.:
 - a. Sand dunes.
 - b. Badlands.
 - c. Barren rocks.
 - d. Ruins (with indication of touristic value).

1. The partition into sub-types 1-9 is according to the World Land Use Survey.

IV

The cartographic representation of the many varieties of land use can easily lead to a maze of details which may obliterate the actual purpose of land-use mapping, namely to point out a special relationship between types of land use and regions by easily recognizable colours and symbols.

In order to facilitate easy distinction, the Commission has laid down the rules: to mark the main land use categories by a certain combination of colours, and sub-categories by the use of symbols. This rule has been accepted to a certain degree by most of the published land use maps, but there exists a wide variation in the use of colours.¹

The problem of colours in geographical maps—other than topographical ones—has not yet found a solution that would be generally accepted by all map producers. A glance at vegetation maps or soil maps, for instance, in different atlases shows that almost every one uses a different colour scheme, which necessitates constant reference to the legend in order to understand the map. In some types of maps a kind of understanding has been reached, e.g.: a scale from yellow to blue in rainfall maps; the representation of low temperatures by shades of blue and of high temperatures by shades of red; a scale from yellow to red in population-density maps.

A general colour scheme for land use maps has been laid down by the Commission, but it seems necessary that for specific purposes certain changes should be introduced into it.

The colours and symbols in any geographical map should be as near as possible to established conventional signs, and where these are lacking, should seek guidance in natural colours connected with the object of cartographic representation. In the case of land use maps, colours should resemble natural colours, thus suggesting the type of land use. But as most vegetational cover is green, a too extensive use of green tints would interfere with a clearly visible differentiation of main land use types. Therefore the green colour should be reserved for representation of perennial tree cover, in forests as well as in fruit plantations. For field crops, the natural colour of the ripe grain could be used, represented by yellow. For any occurrence of water—in form of water bodies, or to indicate irrigation—blue has been adopted generally and should be retained in land use maps too. Red colours are usually reserved for representation of settlements, and there is no reason why land use maps should not use them in the same capacity.

A reappraisal of the colours as suggested by the Commission in the light of the above would lead to the following purposed changes:

1. Purple, as laid down for horticulture and tree crops, has no connexion with any natural colour, and should not be used to indicate vegetation. It is suggested that this colour be reserved for industrial land use and communications.

2. For cropland the Commission advocates the use of brown colours, which could be interpreted as being the colour of the ploughed fields. For cartographic reasons yellow is suggested instead, for cropland is the category having the largest number of sub-categories indicated by the use of symbols. These stand out much more clearly on a yellow background than on a brown one.
3. Yellow has been chosen by the Commission for unimproved grazing land; as this colour is suggested for field crops, grazing land could be indicated by brown colours, representing the general aspect of semi-arid landscape in the dry season.
4. The Commission uses light green for improved permanent pasture—a type of land use specific for Atlantic climates; as this type of land use is almost non-existent in semi-arid countries, except under irrigation, it does not appear in the list. Nevertheless the colour light green is not proposed for any other category.

In order to increase the indicative value of colours, a colour accepted to indicate one of the major land use categories should be used also for symbols in secondary categories; thus brown would indicate all activities connected with grazing and animal husbandry—e.g., to indicate fodder crops, while purple would indicate all industrial activity—e.g., industrial crops or extraction of salts from salt pans.

An indefinite variety of symbols, indicating secondary categories, is available, but here too some general rules should be accepted: (a) No letters should be used as symbols, as this would create difficulties of language. (b) Permanent land use and rotation should be represented by different types of symbols: upright signs for permanent use, horizontal ones or dots for rotation. (c) As it will be necessary in some areas to indicate land use by multiple symbols, the different colours and signs should be chosen in such a way as not to interfere with legibility of the map.

V

In accordance with these assumptions the following scheme of colours and signs is suggested for land use maps in Mediterranean regions.²

1. Some examples of land use maps:
Japan: green, paddy; orange, dry fields; purple, mulberry; red, orchards; yellow, forests.
Ceylon: green, paddy; yellow, coconut; brown, tea; purple, rubber; red, field crops; pink, forest reserve.
Congo: green, palms; yellow, cotton; pink, rice; different colours for different types of plantation (coffee, cocoa, rubber).
Malaya: green, rubber; yellow, paddy; light green, field crops.
Gambia: green, fallow bush; light green, grass; red, groundnuts; purple, mangrove; blue, rice.
Most of these examples are taken from tropical countries. The diversity of symbols appears also in other regions, but the tropical examples show clearly that these countries were unable to adopt the key proposed by the Commission.
2. The colours and symbols are intended for large-scale maps, larger than 1:100,000. Smaller scales would necessitate generalizations. First the different symbols will be omitted; the main colours would be preserved in the small scales too.

1. Urban Land use and housing (red components).
 - a. Dense housing (dark red).
 - b. Dispersed housing (light red).
 - c. Industry and transport (purple).
 - d. Recreational and touristic value (red triangles).
 - e. Gardens (orange with red triangles).
 - f. Parks (green tree symbols on orange).
2. Horticulture (orange).¹
3. Cropland (yellow colour).
 - a. Food crops (yellow, without addition).
 - b. Fodder crops (brown dots on yellow).
 - c. Industrial crops (purple dots on yellow).
 - d. Irrigated land (blue vertical lines on yellow).
Partly irrigated (blue vertical dash-lines).
Purpose of crop (indicated as above).
 - e. Fallow (alternating yellow and white diagonal stripes).
 - f. Patch cultivation (grey diagonal lines on yellow).
 - g. Rice-fields (blue dots on yellow, without symbols for irrigation).
 - h. Terraces for all categories (black vertical lines).
4. Tree crops (green symbols).
Plantations are indicated by green upright signs on:
 - a. Yellow background (for unirrigated land).
 - b. Turquoise background (irrigated land).
 - c. Double cropping (indicated by black horizontal lines on background showing type of field crops with signs indicating type of trees—only on large scale maps).
5. Woodlands and grazing land (green colours).
 - a. Afforestation (dark green with black upright signs indicating prevailing type of trees).
 - b. Natural forest (dense dark green stripes with signs as above).
 - c. Maquis, and other types of degenerate forest (olive green).
 - d. The same, used perennially for grazing (olive green with brown diagonal stripes).
 - e. In case of seasonal grazing (transhumance) the stripes will be interrupted (dash lines).
 - f. Improved pasture—not irrigated (brown).
 - g. Marshy pasture (brown diagonal stripes on symbols indicating swamps).
6. Water-bodies.
 - a. Swamp (conventional sign in blue).
 - b. Salt marshes (blue dash lines on white background).
 - b₂ Salt extraction (with purple triangles).
 - c. Lakes and reservoirs (blue).
 - d. Fish ponds (blue, with black signs).
7. Unproductive land.
 - a. Sand dunes (grey dots on white background).
 - b. Barren rocks (grey colour).
 - c. Badlands (grey diagonal stripes).
 - d. Abandoned agricultural land (grey horizontal stripes).
 - e. Ruins (red diagonal lines on grey).
 - f. Touristic use of sand dunes (beaches) or ruins (red triangles on above signs).
 - g. Spoil heaps of mining or industrial activity (purple triangles on grey).

VI

Only a few countries in Mediterranean regions have so far conducted land use mapping, and only two countries have printed land use maps, which can be compared with the suggestions made in this paper. The Land Utilization Map of Cyprus² uses a system of only two colours—brown for cropland and black for trees, and is therefore restricted in its possibilities for representing more detailed divisions of land use. Italy has prepared a land use map on the scale of 1 : 200,000 in 26 sheets.³ This map comes nearest to our suggestions except for its colours, which are chosen in a different way—red for tree crops and blue for grazing land.

In the Atlas of Israel⁴, sheet VIII.3, some maps have been reproduced to compare land uses of 1910 with those of 1960. Their colour schemes and symbols have been chosen in accordance with the suggestions made in this paper, and they can serve as an illustration of the final look of a map of this type. Their original scale of 1 : 100,000 has been reduced to fit the format of the atlas.

1. A combination of yellow for field-crops with red for urban activity.
2. *Land Utilization Map of Cyprus*; published for the World Land Use Survey by Geographical Publications Ltd., Bude and London, 1956.
3. *Carta della Utilizzazione del Suolo d'Italia*; Consiglio Nazionale delle Ricerche, Centro Studi di Geografia Economica, 1954.
4. *Atlas of Israel*, published by the Department of Surveys, Ministry of Labour, and the Bialik Institute, the Jewish Agency, Jerusalem, 1956 (Hebrew).

DISCUSSION

D. CHRISTODOULOU. To paraphrase a well-known expression, land use mapping should be thought of as the art of the possible. But we must bear in mind that the degree of detail we put on the map may reach the point where the picture portrayed becomes qualitatively different, in other words we come to map entirely different things. For instance, a field-to-field map of land use covering a Mediterranean village gives a picture entirely different from that of a small-scale map of the area. In the second instance the map is in effect a generalized picture which bears little resemblance to the detailed one. A detailed map may even vary from season to

season in the Mediterranean. Even fallow should be subdivided into classes in that case.

In this sense we must be clear as to whether by mapping what we call existing land use we do not in fact map dominant land use which in the end obscures very important uses. Some land use maps are often in effect no more than farming systems or types.

Land use is a complex, and mapping of existing land use as observed on the ground should be the beginning of mapping of land use in its broader sense. I should like to see other aspects of land use, such as land tenure, density of population,

etc., mapped also, so that a more complete picture of land use can be built up. I should like to see as many as possible of the suggestions put forward by Dr. Karmon taken up. The suggestion was made that industry should be mapped in order to throw light on agriculture. That will depend on the kind of industry in question—some are directly linked with agriculture, e.g. sugar-beet factories, but other industries may be entirely adventitious with no relation to agriculture at all.

It has been suggested by Dr. Karmon that places of touristic interest should be indicated on the map. That will be admirable if it can be done adequately. But where does one draw the line? Who is to know what interests the modern tourists? Even antiquities do not interest all tourists, while scenic beauty is certainly an attraction to many.

The problem of mapping of intensity of cropping still awaits solution. There are different intensities of cropping, (a) within one crop, and (b) between crops. That applies to intercropping also. There are areas in the Mediterranean lands where one field contains up to eight or ten different crops and trees or vines. They present a baffling problem of mapping.

L. D. STAMP. I agree with Dr. Christodoulou that a land use map was only one of a series of maps needed for the understanding of the rural economy of a region but it was a map which was fundamental because it was factual and any planning for the future must start from the present position.

X. DE PLANHOL. Je constate que la légende des cartes de M. Karmon, qui semble bien adaptée à un pays neuf comme Israël, à cultures généralement bien délimitées et intentionnellement choisies, l'est beaucoup moins aux vieux pays méditerranéens où les paysages sont beaucoup plus complexes (forêts d'usages divers comme la forêt de chênes-lièges kabyle ou les semi-forêts de *Quercus aegyleps* en Turquie ou *Quercus ilex* en Espagne; régions de « cultura promiscua »; technique « sahélienne » de l'olivier, semi-irrigué, etc.). Même en admettant qu'une gamme de signes suffisamment détaillée puisse être établie, j'ai peur que le résultat ne soit trop compliqué, et je préférerais qu'on s'attache à des cartes plus synthétiques, exprimant des combinaisons, des associations de types élémentaires d'utilisation du sol.

L. D. STAMP. Mr. de Planhol had touched on a very important matter when he asked that maps should not be made too complicated. It would be easy to cite land use maps which had indeed been made so complicated that only their authors could interpret them.

H. M. GAUSSEN. Sur une même carte on peut placer l'utilisation actuelle du sol et son utilisation possible par l'indication des conditions du milieu. La Carte internationale du tapis végétal qui comprend ces deux questions montre donc tout ce qui est dans la carte du Land Use Survey et beaucoup d'autres choses.

Pour l'emploi des couleurs je rappelle qu'un colloque international du Centre mondial de la recherche scientifique a eu lieu à Toulouse en 1959. Un volume a été publié sur cette question.

Les possibilités de transformation de l'utilisation du sol sont évidemment largement soumises à l'action de l'homme, mais le milieu est une base fondamentale. Une prairie à 1 800 mètres d'altitude n'est pas la même chose que la prairie au bord de la mer. Une forêt de chênes-lièges n'est pas la

même chose qu'une forêt de sequoias et l'action de l'homme n'y peut pas grand-chose.

Représenter le milieu est donc fondamental et plus important que représenter l'état actuel qu'on trouve sur les photographies aériennes. Il est insuffisant, dans les cartes de *land use*, de représenter de la même façon une forêt de sequoias et une forêt d'eucalyptus.

Dans les cartes de tapis végétal, l'emploi des couleurs permet d'indiquer les conditions du milieu mais le carton botanique annexé représente le dynamisme de la végétation en indiquant ce qu'elle deviendrait si l'homme disparaissait durant une centaine d'années.

L. D. STAMP. The difference in point of view with Professor Gausson had been argued on many occasions, at many conferences in many parts of the world. Mr. Gausson believed it was possible to select the colours for his maps so that they would show not only the existing vegetation but also the environmental factors which were responsible. The World Land Use Survey considered that the two stages in study should be kept separate. Existing land use and vegetation were facts which could be exactly observed and mapped whereas the factors involved might be different from those which with the present state of knowledge appeared to be responsible. The resulting maps were therefore subjective—they relied on the judgement of the investigator.

I. DAN. I want to emphasize the differences and relations between four maps, i.e., a topographical map, a land resource map which should include a combined soil-vegetation map (which reflects also the morphology of the area), a land use map, and a land use capability map. All these maps are different and should be published in different forms but I suppose that it would be advisable to use a topographic and a soil-vegetation map as a background for the other two maps, so that they might be more practical for use in planning, etc.

I want to emphasize that the land use capability map is only an interpretive map compiled according to the data assembled in the three other maps and it might change according to economic requirements.

L. D. STAMP. Mr. Dan has named four maps which were definitely needed—in many cases others could be named.

D. H. K. AMIRAN. (1) Concerning the remarks of Messrs. Gausson and Dan on land use capability maps it should be absolutely clear that for our purposes we are not concerned with those but with actual land use maps only. There is no such thing as a definite land use capability map, as land use capability depends on three factors: physical, agrotechnical and economic.

(2) I am in complete agreement with Professor Stamp who stressed the importance of large scale in land use maps. The purpose of the World Land Use Survey to my mind is equal standards, but not necessarily identical scales, or small scales.

(3) Consequently I do not share Dr. Christodoulou's apprehension about overloading land use maps. This will not affect large-scale maps, and will automatically be avoided in small-scale maps by generalization.

(4) It will be important to map the dominant land use, possibly by methods like the crop combination systems devised by Weaver.

(5) A land use map—like a geological map—needs inset maps to complement the information given on it. Dr. Christodoulou has shown this in his maps of Cyprus.

(6) Land use maps should show *all* land uses, not only agricultural ones.

(7) As for land use in arid regions, industrial installations requiring large areas of land become increasingly typical here.

(8) Concerning Dr. Karmon's proposal, a specific symbol for terraces in Mediterranean countries is definitely necessary. I would agree to the application of colours for areas of industrial and touristic land use, but I am apprehensive of showing the *purpose* for which crops are grown; to elicit this is often so difficult that it would be impractical for economic reasons.

(9) The yellow colours proposed appear to me too similar. Colours must be selected so that they are clearly distinguishable by artificial light.

L. D. STAMP. I am in full agreement with Professor Amiran—especially his first seven points.

J. H. G. LEBON. (1) I have two combined categories of land use—an expedient which Professor Stamp expressly forbids. 6a'-9 is justified mainly by the scale of the mapping. On scales larger than 1:1,000,000, unproductive land on the margin of the desert could be shown separately from sparse unimproved grazing. 4b-6a is a bigger problem; in addition to the Mabaan and Nuba tribal areas, described in my paper, I should draw attention to a large area in the south-east of the El Fasher 1:1,000,000 sheet, which is used not only by sedentary tribes for land rotation and grazing their stock, but also by cattle-drovers proceeding from southern Darfur to markets further east and northern camel-owning tribes such as the Kabbabish when in dire need, after drought in their tribal area proper.

(2) I understood when I started the Sudan survey that the World Land Use Survey was in the pilot and experimental stage. As I have shown, I proceeded by an insensible transition to the definitive stages of the work, but may I ask whether the Commission has ever reconsidered the classification on the basis of the experience gained in the first ten years?

Y. KARMON. Colour printing is much more refined today than it was thirty years ago and some maps have a multiplicity of hues, some of which are not easy to distinguish by that 10-15 per cent of the population suffering from the milder form of colour blindness. Therefore, *slight* colour differences should be reinforced by ruling, stippling or symbols.

L. D. STAMP. There were of course cases where an intimate mixture of two major categories could only be expressed by using a system of stripes. The important thing was to avoid setting up a new major world category which others would not be using. Two significant modifications had been introduced into the original classification proposed by the World Land Use Survey. For Category 6 (Unimproved Grazing) it had been intended to separate "used" from "unused" and the two colours yellow and orange had been allotted. The separation at least in most cases had proved impracticable. On the other hand it had been found important to show irrigated land distinctly, noting the type of irrigation.

J. DESPOIS. Puisqu'on me demande mon avis, je dirai que le reproche que l'on pourrait faire à ces cartes, souvent remarquables, comme celles que l'on vient de nous soumettre sur Israël, c'est qu'elles sont plus économiques (agriculture, élevage, etc.) que véritablement géographiques. Ce sont des

cartes « inhumaines », plus exactement peu humaines. Elles ne tiennent pas assez compte, du moins pour les pays méditerranéens, semi-arides et arides, des genres de vie, des systèmes de culture et d'élevage, faits synthétiques qui introduisent l'homme dans le paysage. Je suis d'accord avec ce qu'a dit sur ce sujet M. de Planhol. Je fais exception pour la carte de M. Lebon sur le Soudan, qui, en fait, traduit à la fois l'utilisation du sol et les genres de vie. Je m'excuse de ces remarques purement critiques qui ne m'empêchent pas d'apprécier la qualité et l'utilité des « cartes de l'utilisation du sol ».

L. D. STAMP. Professor Despois was certainly right in calling attention to the importance of cultural systems: it was sometimes possible to give the necessary indications on the land use maps, in other cases separate maps were needed.

A. W. WILSON. Urban mapping uses a colour scheme overlapping the colours of the rural scheme; it shows rural land uses in green, usually, while rural mapping shows all urban uses in red, a colour used on urban maps only for business. Only for industry does the same colour appear for both the urban and rural schemes. I urge inclusion of as much detail as possible on industrial uses.

The type of mapping discussed here is rural land use mapping, and not complete mapping of *all* land uses, because it does not show the details of urban use needed for a complete understanding of land use.

L. D. STAMP. It was certainly necessary to break down the red used for urban land where a study of towns was involved. The town planners had worked out an international scheme with agreed colours: it might be noted that the Japanese, however, in their very beautiful detailed maps had combined urban and rural features. It was possible to add in some areas, as Mr. Kolodny has proposed, details of type of settlement, population, etc., so long as the basic land use was not obscured and the map not made too complicated.

Y. KOLODNY. En vue de mieux mettre en valeur l'aspect du peuplement humain dans les cartes sur l'utilisation du sol, ne serait-il pas intéressant d'introduire des notions supplémentaires sur le genre et la distribution de la population? Les cartes sur le *land use* ne montrent en général que l'emplacement de l'établissement humain (terrain bâti, industries, etc.) sans en souligner toujours le type (ville, village, campement) ou l'importance numérique (effectif et densité) ou le genre de peuplement (sédentaires et nomades, peuplement autochtone ou récent, minorités ethniques ou linguistiques, etc.). L'introduction de telles données pourrait certainement aider à la compréhension de la carte; dans certains cas on ajouterait une carte à petite échelle en marge de la carte principale, ce qui aurait l'avantage de mettre en relief les genres de vie tels que les cartes de l'utilisation du sol sont censées les reproduire.

C. TROLL. I can underline what Professor Despois said about the human (or sociological) side and what Dr. Karmon explained about the question of scale and generalization. German geographical schools have had very wide experience of land use survey for about thirty years, experience which has never come up in international discussion (Atlas of Land Use of Western Germany, in preparation for many years; about thirty-five theses from the Institute of Bonn alone,

giving all types of land use in the Rhineland on a 1:25,000 scale mostly).

Regarding generalization it is clear that, for example, the Italian land use map of Southern Italy at 1:200,000 can only be very generalized. P. Schmidt in his thesis on Calabria, giving maps on the scale of 1:50,000, showed the full complexity of property and land use (*mezzadria, coltura mista*, etc.). Mediterranean land use can hardly be understood without the very complicated sociological basis.

Some it is even difficult to separate primary production from the manufacture of agricultural products. For instance, the hemp industry in the *vegas* of eastern Spain (Elche-Murcia area) shows a complete intermingling of agricultural and manufacturing processes: hemp cultivation (partly in the shade of date palms), hemp steeping in the irrigation basins, hemp beating and breaking done in the fields, spinning, weaving and hemp shoe manufacturing done in the villages.

The only way to combine the general picture of land use and the complex structure in details seems to me the combination of a medium-scale map (e.g. 1:200,000) with an insert map on a very large scale showing the most important examples occurring within the sheet.

L. D. STAMP. Experience in Britain confirms Professor Troll's in Germany that large scales and detailed work are needed if the land use maps are to serve practical purposes in planning. Small scale maps can only give a first, generalized picture.

There is growing international co-ordination on land use, especially the acceptance by FAO of the definitions of land use laid down by the World Land Use Survey; the countries of Europe are now supplying statistics on this basis.

The actual printing inks used on coloured maps are important: some inks may be very heavy and obscure detail; a fine example of clear colouring is to be found on the beautiful and detailed maps of Japan. It is agreed that terracing and, in certain cases, comparative yields may be added to land use maps but that usually systems of cultivation or types of farming need separate map or treatment in the memoir. The Land Classification map of Britain is exhibited to show how utterly different are aspects of capability from actual use.

Hong Kong, with 3 million people on a tiny area, and Israel with 2 million—mainly highly trained enthusiasts—are cases where the conditions are very different from those in surrounding areas and where therefore land use and the reasons for it are highly specialized. In the original recommendations of the World Land Use Survey Commission too much emphasis was placed on the publication of 1:1,000,000 maps which could only be very generalized. Large scales are essential for planning. Other changes are the increased recognition of different types of irrigation and the need to separate types of rough grazing by vegetation rather than by use or non-use.

Attention is again called to the publications of the World Land Use Survey, obtainable from Bude, England, and those of the Unesco Arid Zone Unit.

URBANIZATION IN ARID LANDS¹

by

L. DUDLEY STAMP

According to the calculations of Unesco and FAO, 23 per cent of the earth's surface may be classed as falling within the arid zone. Or this, 3 per cent may be rendered fertile by the application of known sources of water, but there remains 20 per cent, a vast area of some 11,502,000 square miles where little or no additional water is known to be available.

At present the whole concept of development in arid lands is almost synonymous with irrigation, the extension of cultivated land and the establishment of permanent settlements. But this concept overlooks several facts of fundamental importance.

First, the traditional mode of life of the scattered people of the arid lands and their fringes is nomadism or semi-nomadism. The sheep and goat herdsman, the cattle raisers, move their tent-homes with the seasons and the availability of pasture. Even in relatively well-watered tracts there is a move from semi-permanent winter quarters to temporary summer quarters, or vice versa. Transport, communications and trade have long been maintained by the still more mobile camelmen who may have no permanent base. In some modern developments it has been recognized that the love of these "traditional" modes of life is very deep-seated and is at least as old as the separation of Cain and Abel in their choice of mode of life. In southern Israel the "Cain and Abel experiment" combines the attempt to improve grazing for cattle by actually planting drought-resisting fodder plants over the open hill sides for the benefit of the Bedouin, with enclosed irrigated plots for the new settlements.

Elsewhere it seems far too often to be assumed that the nomad, because his material comforts and possessions are few, and his food supply precarious, will automatically appreciate the greater material comfort of a fixed abode and a food supply rendered relatively certain if he devotes himself assiduously to the tasks of cultivation, assisted by irrigation. He is expected to exchange a free, if not carefree, roaming life for the day in, day out, year in, year out servitude to a

plot of land—and to appreciate this exchange. This he is expected to do when the highest civilizations in the world are reverting to varied forms of semi-nomadism. All Swedes who can afford it move from their centrally heated Stockholm flat or apartment to their waterside cottage for three months of glorious summer freedom. There are 15-16 million permanent homes in Britain; the three-quarters of the population who go away for a summer holiday are ever going farther afield, and it is probably true to say that not less than half-a-million caravans and tents are used to satisfy partly the summer wanderlust and search for freedom. In the United States of America the reversion to nomadism resulted from the great depression of the early 'thirties. Innumerable families gave up their homes, piled their most important moveable possessions into the back of the car and drove off to seek work elsewhere, many never to return. But the new movement is by choice, not by necessity, when the family sets off, again by automobile, destination unknown, for a month's freedom, stopping at motels or camping by the wayside. Others will be making for the modern equivalent of the Norwegian *seter* or the Welsh *hafod* and Scottish *shieling*—a mountain or lakeside hut in the wilds. When this nomadic instinct is so deeply ingrained in human nature, is it reasonable or right to expect the nomad, born free, to take happily to the humdrum life of the peasant farmer?

Further, is it right to be creating more peasant farmers? It is the unvarying accompaniment of an increased standard of living that subsistence farming gives place to commercial farming and a steadily smaller proportion of the total population finds employment in agriculture. Farming in all developed countries has become a highly skilled profession wherein experts undertake the task of producing the food and agricultural raw materials for the community. Whereas in

1. The discussion on this paper, which touched upon many subjects not immediately related to the topic of the symposium, has not been reproduced here, by agreement with Professor Stamp.

the so-called undeveloped lands 80 per cent of the population may be working on the land, the proportion drops to 30, 20 and even lower as development takes place and the standard of living rises. It is roughly true to say that 10 per cent of the world's people could most efficiently produce the food for the remainder. Admittedly one of the great world problems then becomes the employment of the displaced.

The two simple conclusions which one may draw are that irrigation in the arid lands should be primarily for large-scale commercial farming and that far more attention should be given to the improvement of natural rough grazing where "range farming" or "ranching" will continue to have a place.

There is another neglected aspect of the development of arid lands, and that is the most efficient use of scanty water supplies. In what may now be regarded as primitive or at least archaic forms of irrigation—the large storage reservoir and open canals exposed to full evaporation, the water supply to fields empirically determined—the loss of water before it serves a useful function in promoting plant growth may be appallingly high. In the new Aswan high level dam it is anticipated that 40 per cent of available water may be lost by evaporation from the surface of the lake itself. The most efficient use of irrigation water achieved to date is almost certainly that piped from the streams of humid northern Israel to the arid Negev of the south, there to be distributed in quantities exactly determined by plant needs through pipes to the fields. The prime need of Israel is extension of cultivable land, but in other circumstances it may be that a still more efficient use of small supplies of water would not be irrigation at all, but the supply of domestic water to an urban community. It is well known that where water has to be hand pumped or carried for considerable distances, 2 or 3 gallons a day per head of population easily suffice. Instal a piped system with bathrooms and water-flushed lavatories and it jumps to 10 gallons. In a modern town 30 gallons a head is not excessive; with unlimited supplies for watering gardens in a dry area,

the demand may reach 100 gallons a day. But even at these higher figures, the requirements per head of population are small when compared with irrigation farming.

Instead therefore of using a scanty water supply to extend irrigation in an arid region, might it not be better to establish an industrial township and to bring in food supplies from elsewhere? The rapid growth of industrial towns in Arizona and other parts of the arid south-western United States affords valuable information on the problem and points the way to developments elsewhere. The occurrence of minerals is not related in general to climatic conditions, so that oil or coal for cheap power may be available locally and so, in certain circumstances, may hydro-electricity. There may be local mineral resources, but even when raw materials—and food—have to be brought in from outside there is much to be said for the dry regions. Living conditions, especially for the family man, may approach the ideal, with sunshine, invigorating air, abundance of space and, with relatively little water, the desert garden can blossom as the rose. The need for expensive winter heating is replaced by air conditioning, now rendered simple, efficient and cheap for factory, shop and home. Not enough attention has yet been given to the best artificial climate to be produced: where there is frequent movement from air conditioned rooms to the outdoors, contrasts must not be too great either in temperature or humidity, and the tendency has been to overdo the air conditioning. A good working standard of 75° F. and relative humidity of 60-65 may be varied so as not to give more than 15-20° difference with outside temperatures, and not more than 20 per cent in relative humidity. When to provide movement of air is another important consideration, but in thinking of a modern city in the desert gone (or should be) are the days of expensive thick walls, wide, wasted verandas and other traditional forms of construction against the climate. There must be new architecture in new towns for the new industries of the old deserts.

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