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Part I. Introduction

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1. Background

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The objective of research in the grassland habitat theme of IBP was to learn more about the organic production and overall energy flow and nutrient circulation through this important type of ecosystem. While emphasis was to be given to natural grasslands, wherever resources permitted concurrent studies were made in managed areas (pastures and cropland) under comparable conditions of soil and climate. Early in the development of IBP 30 nations started grassland studies (SCIBP, 1969).

This is one of two volumes in which the results of these studies are discussed. Here we will consider trophic structure and function in each of several kinds of grassland (and some related herbaceous ecosystems). In the companion volume, *Grasslands, systems analysis and man* (Breymeyer & Van Dyne, 1979), the processes of production and flow of energy and matter are emphasised by bringing together for each of them information from all studies. The processes are then combined into subsystem and system models in both diagrammatic and analytic presentations. Thus, one wishing to know about annual production of herbage in tropical grasslands, for example, will find a detailed treatment in Part IV of this volume based principally on interpretations by the biomass (harvest) method. However, for a consideration of the dynamics of the photosynthetic process in grasslands as a whole, the reader is referred to the companion volume.

Because of the increasing degree of intensity of management for crop and meat production, natural grasslands are being changed at an accelerating rate. It is urgent to obtain more information about grasslands in their present condition before they are further modified. This is essential to an understanding of mechanisms and processes that control various components of grassland ecosystems. This basic information is required to manage these resources effectively and efficiently. One of the major goals of IBP was to further an understanding of how ecosystems work and the extent to which they can be manipulated by man (SCIBP, 1969). This problem also involves the relationship between the structure and function of communities of organisms within ecosystems. Multidisciplinary studies were established in several countries to provide the necessary information. Each of these intensive studies provides data within one grassland ecosystem, for an analysis of trophic structure, interspecies relationships, primary and secondary production, decomposition, energy flow, nutrient cycling, and the mechanisms by which these observed characteristics are achieved and maintained. Resources were available in only a few study sites for all these undertakings. Many of the studies are concerned solely with an evaluation of organic production or

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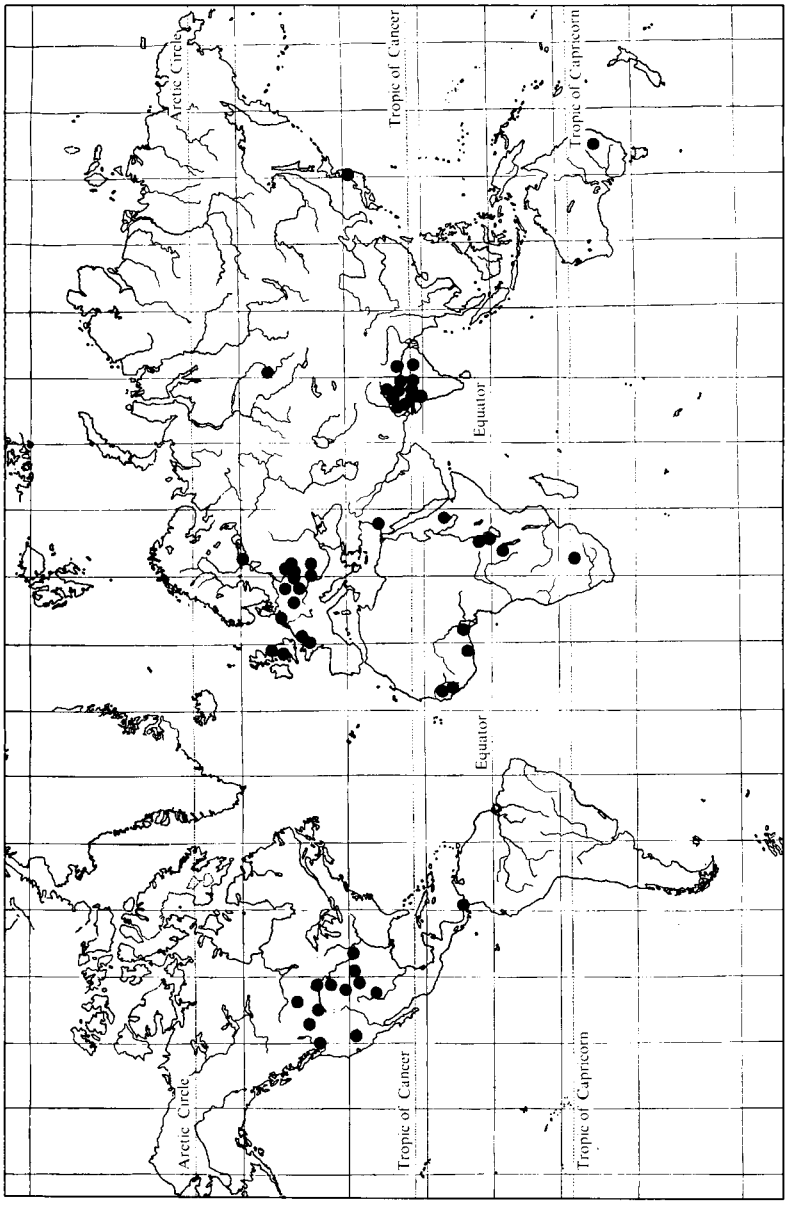

Fig. 1.1. Location of the study sites from which the data discussed in this volume were collected.

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energy flow of a plant community of a given level of consumers. Nevertheless, they constitute supporting studies which permit the application of knowledge gained from the intensively studied sites to these less intensive ones. The distribution of study sites that are discussed in this volume is indicated in Fig. 1.1.

Activities of the IBP Grassland Working Group

Because of the vast combined undertaking that was implied by the large number of grassland studies that were undertaken in IBP, it was necessary to develop various means of coordination. The first step in this direction was the development of a manual of methods. A draft was discussed at an international meeting held in Saskatoon, Canada, in 1967 in which 27 participants from five countries took part. The resulting manual (Milner & Hughes, 1968) was publicized among all projects. As studies proceeded many advances were made in methodology, and the original IBP guide on methods rapidly became outdated. The need for continued exchanges among the participants became evident as more sophisticated methods were developed.

The format for five meetings to review progress of IBP grassland studies was set by a meeting in Canada in 1969 (Coupland & Van Dyne, 1970). Subsequent meetings were held in 1971–2 in the Ivory Coast (IBP/PT Grassland Working Group, 1973), in 1972 in the USA (IBP/PT Grassland and Tundra Working Groups, 1972), in 1973 in Poland, and in 1974 in India (IBP/PT Grassland Working Group, 1974) (Appendix 1*a*, *b*). In each instance papers were presented from each study site and the local study areas were visited. Two meetings were held on study sites, at Matador in Canada and at Lamto in the Ivory Coast. The duration of each meeting was from 5 to 12 days and the participants numbered from 31 to 86, representing 8 to 19 countries.

At the first of these meetings a Coordinating Committee (Appendix 1*c*) was set up to act as an executive to the group. Continued contact between meetings was arranged through a Grasslands Newsletter which was edited and distributed from the Canadian study site, designated at that time by SCIBP as the 'International Centre for IBP Grasslands Studies'. This newsletter appeared in a series of eight numbers from May, 1969 to April, 1973. The Coordinating Committee arranged for the review meetings and studied the problem of achieving worthwhile synthesis of the data. It was soon realised that traditional means of data analysis, based on summaries of averages, were not sufficient to cope with the necessity of developing dynamic models of ecosystem function.

Data synthesis was developed by means of 'workshops'. The first such meeting was arranged to be held in 1970 at the time of the XI International Grassland Congress in Australia. Researchers were encouraged to submit

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data summaries well in advance of the meeting, but too few were received to provide an adequate basis for workshop sessions, and the meeting, therefore, concentrated on discussing problems associated with international synthesis. The outcome was a proposal to set up an international centre for synthesis of grassland data. This plan was discussed at the Australian Arid Zone Conference in 1970 and was presented to FAO at the time of the IBP General Assembly in Rome later that year. The plan was then modified into the 'International Grazing Lands Project', to include tundra, and was presented again to FAO and UNESCO officials in 1971. It was received sympathetically, but the magnitude of the funding required was such that it could not be developed in time to satisfy IBP data-synthesis needs. Accordingly, the Coordinating Committee turned its attention to arranging further workshops.

The second workshop was held in conjunction with the Tundra Working Group in 1972 in the headquarters of the USA Grassland Biome Study (IBP Grassland and Tundra Working Groups, 1972). Much effort was expended on data in advance and they were processed into computer memory for use during the workshop. Data sets were supplied from 51 grassland study sites in 20 countries. This meeting was very successful as an educational exercise, in developing some preliminary submodels, and in acquiring a data base. Preliminary plans were made for a two- to three-month workshop in 1974 which would permit combined data-synthesis activity by authors of the planned volumes, but this workshop never reached fruition.

Concurrently with these data-synthesis activities considerable effort was given by the Coordinating Committee to the development of a data bank. This was first discussed at the 1969 general meeting, and a decision was reached to make a modest beginning by filing data sets in the International Centre. The first real progress in acquiring such data sets was achieved at the 1972 workshop. As a result, it was decided to concentrate data-bank activities at the headquarters (in Fort Collins) of the USA/IBP Grassland Biome Study. This decision was subsequently given general support at a general meeting in Warsaw in 1973 as the method to be followed for acquiring data sets for the preparation of this and the companion grassland volume. Arrangements were made for transmission of data sets to authors. Thus, the plans for joint data-synthesis activities at one data centre never materialized. Instead, data analysis was mostly done at project level and the authors used, for the most part, data summaries supplied to them. Researchers were not equally effective in transmitting data sets to the data bank. Some failed to comply with the Coordinating Committee's requests, even though they were advised that failure to do so could result in lack of full recognition of their contribution to IBP. Nevertheless, authors were asked to solicit data directly from project participants, to supplement data from the data bank, and to review published records of IBP and IBP-related studies. Consequently, the intention here is to report on the state of knowledge available in the mid

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1970s concerning structure and function in grassland ecosystems. Failure to recognise IBP research in some sites results from failure of workers to make their data available to the data bank, in some cases no doubt because progress in data collection and analysis was not sufficiently advanced.

An Editorial Committee (Appendix 1*c*) took over the coordinating role from the Coordinating Committee late in 1972. This change was associated with the official conclusion of the data-gathering phase of IBP and the emphasis on publication. This group met on three occasions and is responsible for the general structure of this and the companion volume. It also continued the coordinating role in connection with the 1973 and 1974 general meetings, which became a basis for acquiring data and information for the synthesis volumes. From 1974 onwards coordination between the volumes was by exchanges between editors under the supervision of the PT representative on the IBP Publications Committee and through the Executive Secretary of that Committee.

The activities of the Grassland Working Group were synchronised to some extent with those of the Tundra and Aridlands groups. This was possible through the keen interest of the PT Convenor in the activities of all groups, by the attendance of members of one group at the meetings of others and by exchanges of newsletters. As has been mentioned already, the three groups cooperated in the presentation of the International Grazing Lands Project to United Nations agencies. As well, the Grassland and Tundra groups worked together in the major data-synthesis workshop (1972) at Fort Collins. An 'input workbook' was prepared in advance of this meeting to provide each of the 62 participants with access to available data. The 'output workbook' (IBP/PT Grassland and Tundra Working Groups, 1972) was distributed more widely.

The Grassland Editorial Committee was conscious not only of the large amount of information which had been collected on grassland ecosystems but of the differences in approach which had been followed at different centres. Considerable thought was given to the problem of how best to weld these differences into a worthwhile synthesis. It was finally agreed that the work should be presented in two complementary parts, each part requiring a volume to itself. This has allowed the editors to make use of a large number of contributors familiar with particular kinds of grassland (this volume) and to allow others to make an assessment of processes applicable to grasslands in general.

Thirty-five authors from 10 countries spread over four continents have collaborated in the production of the present volume. Each author has been associated wih an IBP grassland study in his own country and has compared, as far as possible, the results of one major component of the ecosystem with studies elsewhere in the kind of grassland with which he is familiar. These contributions from each kind of grassland have been assembled by subeditors

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who, for the most part, have been leaders in IBP grassland studies within their own countries. The numbers of scientists involved in these studies were too large for all to be authors. To those who contributed information and data to this synthesis we are thankful. An attempt has been made in Appendix 2 to acknowledge the cooperation of some of these participants by indicating the names of those who should be contacted for information about a particular ecosystem component in a particular site.

A great variety of both published and unpublished information resulted from IBP grassland studies. At the time the contributions to this volume were being prepared, most of this information had not yet appeared in the 'open' literature. Much of it was in the form of technical reports, the theses of post-graduate students, local publications, and in manuscripts of scientific papers and other synthesis volumes. Authors did not always have access to this information.

Types of grasslands

For the purpose of interpreting the results of IBP research in a large number of sites of varying nature, it was considered desirable to distinguish groups of sites, within each of which similarities are greater than between groups. The similarities of importance here are in respect of attributes that might be expected to account for differences in trophic structure and ecosystem function.

Various approaches have been used to classify the grasslands of the world (Shantz & Marbut, 1923; Bews, 1929; Clements & Shelford, 1939; Roseveare, 1948; Moore, 1970). While local and regional classifications are typically and justifiably based on botanical composition, this is an inadequate basis for an inter-continental classification, because of discontinuities in the distribution of plant species. Instead it is necessary to consider similarities in conditions of climate and soil in grouping of sites.

The classification of grasslands followed in this volume was developed to facilitate the presentation of IBP results. Although arbitrary, it permitted the regional grouping of study sites and so, to a large extent, it simplified problems of communication. Six kinds of grassland are recognised on the basis of climate, successional status and land use. These are discussed in five parts of this volume, as indicated by Fig. 1.2. Tropical grasslands are separated from temperate grasslands. Within the temperate zone the natural grasslands are distinguished from semi-natural types. The semi-natural types have been divided further into those used primarily for hay and those that are grazed by domesticated livestock. Finally, two types of arable grasslands are recognised that may be present in any of the other grassland regions, but were primarily studied in the temperate zone, namely, those seeded to perennial forages and those planted to annual crops.

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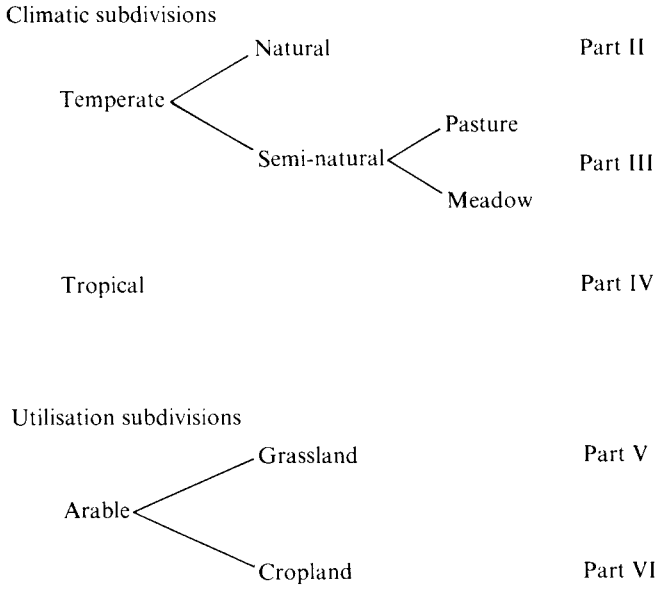

Fig. 1.2. Arrangement of sections in this volume.

The degree of human interference is reflected in this classification. Natural grasslands are those in which climate is the prime controlling factor under light to moderate grazing pressure by ungulates. However, even in this group, some sites have undergone considerable modification because of grazing by domesticated herbivores. Semi-natural grasslands are deforested areas, in regions of forest climate, that are held in a relatively stable condition by various natural and man-induced means, such as flooding, mowing, grazing and other treatments that prevent reinvasion of natural forest. They are dominated by perennial graminoids (grasses and grass-like plants) mostly native to the region. Arable grasslands are generally maintained with a cover of perennial exotic species (usually dominated by grasses, but sometimes with associated legumes) usually by periodic tillage and reseeding. Cropland implies annual tillage and seeding of annual herbaceous species. Both croplands and arable grasslands occur in all zones. Grasslands of the tropics are considered as one group because of the difficulty of interpreting their successional status in many instances and because their nature is often quite different and less understood from those of the temperate zone.

Some laxity has been tolerated in application of these groupings to allow freedom of action to authors who have greater familiarity with particular sites. For example, the semiarid grasslands of India and Africa are treated as tropical grasslands, while a site in desert grassland at a similar latitude in the southern USA is grouped with other North American sites.

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Part II deals with the natural temperate grasslands. The largest expanses of these occur in central North America, in eastern Europe and the middle latitudes of Asia, and in northern Argentina and adjacent areas, while smaller areas occur in South Africa and Australia. The contributions to Part II in this volume are principally from North America. Important IBP studies were made in natural temperate grasslands in the USSR, but language and communication difficulties have interfered with adequate incorporation of their results. Some contributions from the USSR are included in Part III, including results in natural temperate grassland. Also, a summary of grassland studies in the USSR is included in the companion volume. The major IBP study in natural temperate grasslands in the southern hemisphere apparently took place in Argentina, but had not progressed to the data analysis stage at a date early enough to be included here.

Part III is concerned with semi-natural meadows and pastures in the temperate zone. All IBP research in semi-natural temperate grasslands, of which we are aware, took place in the northern hemisphere in Europe and Asia. It was planned to present IBP results on semi-natural meadows and pastures in two separate parts. However, deficiencies of contributions to the part on pastures necessitated last-minute adjustments to combine the available material on pastures with the section on meadows. This has resulted in an inadequate treatment of semi-natural pastures in this volume and failure to recognise some substantial IBP research.

IBP activities in tropical grasslands (Part IV) were concentrated in India, but the discussion also incorporates results from sites in Africa and from one in the western hemisphere. No contribution appears from South America. Unfortunately, this synthesis does not include some important studies that were carried out independently of IBP, in particular the very important one in Serengeti National Park in Tanzania. Communication difficulties are cited as the major reason for these gaps.

In Part V a group of workers in Australia give a detailed account of a seeded grassland ecosystem in east-central Australia and make reference to only one other study (in Israel) that has produced comparable data.

In Part VI an ecosystem analysis in croplands in Poland is reported without comparison with studies elsewhere.

Use and management of grasslands

The natural grassland areas of the world have been used primarily either as cropland or as rangeland. Tillage is most intensive, and began in earlier times, near the forest margin; an increasingly larger proportion of the land is devoted to grazing along the climatic gradient from forest to desert. In some regions tilled agriculture has invaded too far into the semiarid zone, with resulting crop failures and severe erosion of soil by wind during dry phases

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of the weather cycle. These lands have often been returned to perennial grass, either by seeding or by natural succession. Overgrazing has caused depletion of the grass cover in many areas and is a hazard to the continued productivity of rangeland, particularly in semiarid areas. Overgrazing has caused some grassland landscapes to become desertic in character. The major management practice used in rangeland is control over the numbers of livestock and their distribution on range. In some areas control of invasion of woody plants is necessitated by the use of fire and herbicides. Grazing capacities in natural grassland vary from as high as 2 hectares/animal unit (450 kg bovine animal or 5 ewes) to 20 hectares or more/animal unit in some unproductive semiarid areas.

Semi-natural grasslands are used for hay or pasture. The management regimes applied determine the character of the plant cover. While grazing and mowing restrict reinvasion by trees and shrubs, additional practices that are frequently used include fire and fertilisers and control of flood water. Because the climate within which semi-natural grasslands occur is more favourable to plant growth, they are more productive of forage than are natural grasslands.

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