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ABSTRACT

This handbook, developed for training Peace Corps volunteers, reviews the basic principles that underlie sound grazing land management and indicates the application of these principles for livestock production in the tropics and subtropics. The handbook is made up of three technical series bulletins. The first bulletin covers management of rangelands and other grazing lands of the tropics and subtropics for support of livestock production. Topics included in this section are land use and livestock, the natural resources base of permanent grasslands, coping with restraints affecting forage production, the elements of productive grassland management, measuring productivity of rangelands and other permanent grasslands, and estimating feed requirements of ruminant livestock in tropical and subtropical regions. The second bulletin explains how to grow "Leucaena leucocephala," a plant that can be used for livestock feed, among a multitude of other uses. The final bulletin discusses combined crop/livestock farming systems for developing countries of the tropics and subtropics and offers suggestions for improving the profitability of such systems. Materials in the handbook are illustrated with line drawings and photographs. (KC)

APPROPRIATE TECHNOLOGIES FOR DEVELOPMENT

Grazing and Rangeland Development for Livestock Production

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GRAZING AND RANGELAND
DEVELOPMENT FOR LIVESTOCK
PRODUCTION

AGRICULTURE TECHNOLOGY
FOR
DEVELOPING COUNTRIES

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Agriculture Technology for Developing Countries

Technical Series Bulletin No. 23

Management of Rangelands and Other Grazing Lands of the Tropics and Subtropics for Support of Livestock Production

May 1979

Office of Agriculture
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MANAGEMENT OF RANGELANDS AND OTHER GRAZING LANDS OF THE TROPICS AND SUBTROPICS FOR SUPPORT OF LIVESTOCK PRODUCTION

Prepared by: Howard B. Sprague

DIVISION OF LIVESTOCK PRODUCTION

Office of Agriculture
Development Support Bureau
Agency for International Development
Washington, D.C. 20523

PREFACE

The rangelands and other grazing lands of the tropics and subtropics constitute enormous natural resources that have received scant attention of science and technology. They provide nearly all of the feed for ruminant livestock (cattle, sheep, goats and buffalo); and deficiencies in feed resources profoundly affect the domestic supplies of milk and meat for herders and farmers, as well as the quantity of live animals for market. There appear to be substantial opportunities for improving the feed producing capacities of all grasslands, by the application of management practices found effective in developed countries. These practices should substantially increase the incomes of livestock producers.

This bulletin undertakes to review the basic principles that underlie sound grazing land management; and to indicate the application of these principles for practical support of economic livestock production in the tropics and subtropics.

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Director
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Agency for International Development
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MANAGEMENT OF RANGELANDS AND OTHER GRAZING LANDS
OF THE TROPICS AND SUBTROPICS
FOR SUPPORT OF LIVESTOCK PRODUCTION

Howard B. Sprague
Agricultural Consultant

I. Introduction

To achieve effective development of many tropical countries, livestock production must have a high priority. The recurring widespread droughts in many regions have clearly indicated that the production of forages for support of livestock often dominates the situation. Even in humid regions, forage production is generally deficient. Without adequate supplies of feedstuffs, the other management measures for efficient production, as well as for protecting animal health, improved animal husbandry, animal improvement, and marketing, are made ineffective.

The necessity of having adequate feeds to meet nutritional requirements of livestock must be recognized, not only for the seasons when rainfall fosters growth of herbage on grazing lands, but also for the dry periods when forage growth ceases. Ensuring adequate reserve supplies of feed in seasons when little or no plant growth is possible has long been recognized as a prime requisite for productive animal enterprises in the temperate zones of the world. There, the feed reserves include hay, silage and dry fodder for feeding during the winter period.

The comparable principle for the tropics and subtropics should recognize that livestock feeds must be provided for dry seasons when plant growth ceases. These dry season feeds may include protected grazing reserves, or feeds that have been harvested and stored for support of stock in these seasons. Unfortunately, violation of this principle is widespread in the tropics and subtropics to the great detriment of agricultural development.

1. <u>Land Use and Livestock Populations</u>

There are enormous potentials for improvement in feed production to support ruminant livestock enterprises in the tropics and subtropics. The permanent grasslands of the tropics and subtropics occupy about 2½ times as much land area as all arable lands plus land in permanent crops (Table 1). These vast grassland areas are useful to man primarily through the support they give to livestock. Every country with extensive grasslands should be concerned with the most effective utilization of these lands and the means by which these forages may be produced and conserved. In addition, however, each country has need for the products of these lands as live animals, meats, milk, and hides and skins. The edible animal products are valuable for export; and the meats and milk products are indispensible for domestic human diets since they supply animal proteins which are deficient in the food supplies of virtually all tropical and subtropical peoples. These two needs are ample justification for intensified programs to effectively utilize these vast land areas and to greatly increase production of animal protein foods.

The difficulties that less developed countries have in producing enough staple foods to keep pace with growing populations are compounded by the low nutritive quality of the food supply, when insufficient quantities of animal proteins are produced. Substantial advances may be made by making more effective use of permanent grasslands, both to enhance economic status of individual producers and of whole nations, at the same time that the highly nutritious animal proteins are made more abundant.

Table 1. Land Use and Livestock in the Tropics and Subtropics

Continent	Number of Countries Included	(1) Total Arable Lands (Millions Hectares)	Permanent Grasslands (Millions Hectares)	Numbers of Ruminant Livestock (Millions of Animal Units) (2)
Africa	46	193	757	203
Asia	26	340	312	451
Central America and Caribbean	13	35	100	49
South America	10	58	413	174
TOTALS	95	626 (mil. Ha.)	1,582 (mil. Ha.)	877 (mil. A.U.) (2)

(1) Arable land includes those occupied by permanent crops (fruits, nuts, etc.).

(2) One Animal Unit (A.U.) = 1 bovine, buffalo, or camel; or 5 goats; or 5 sheep.

This technical paper undertakes to assemble and summarize available information on tropical and subtropical grasslands, with particular reference to their potential development and utilization. In a few regions there are notable examples of outstanding success in increasing the total forage production and nutritive values of permanent grasslands, with the result that animal production has been made more profitable. These isolated successes may be enlarged to encompass nearly all ranges and permanent grasslands.

In subhumid (savannas) and semi-arid (semi-desert) regions, the cushioning effect of prudent management against the impacts of the inevitable recurring droughts, has been demonstrated in terms of protecting livestock herds and fostering production of the forage plants that are adapted to the region.

Certain basic principles are illustrated in those isolated successes that are available for observation, and adapted to the varying conditions in specific regions. One basic premise underlies the following presentations namely, that the application of a complete package of superior practices will invariably be more rewarding than the application of individual practices. Wherever a complete package is not feasible, it is essential to undertake those treatments that are most essential to development of a situation on which future improvements may be added.

II. Inventory of the Natural Resources Base of Permanent Grasslands.

Grasslands vary tremendously from region to region as a result of the natural resources present, as well as the cumulative effect of man's management practices. The basic natural conditions of climate, land forms and soil types, usually have been greatly modified by grazing practices that often have depleted potential vegetative cover, and dissipated rainfall in harmful ways. The low regard for grassland productivity that is widely prevalent has resulted in declining plant growth and lack of dependability in forage production under unwise management.

1. Climate.

Effective utilization of every kind of grassland must recognize and adjust to the conditions at hand. There is little that can be done to change climate; but man should be aware of the typical variability in each region in the amount of rainfall, its seasonal distribution, and the kind of rainstorms that occur. Another important climatic factor is the typical air temperature, particularly in the seasons of significant rains. In the tropics and subtropics, some regions are characterized by rains in cooler seasons, and in other regions by summer rainfall. Rainfall that comes in heavy showers normally tends to have high runoff losses, particularly on sloping lands on which soils with low permeability occur. Table 2 summarizes types of regions, in terms of average rainfall.

Climate controls the production of feedstuffs in the following ways:

a. Rainfall. The rainfall that occurs, as to the total amount, its distribution through the seasons, and the character of rainstorms (gentle or sporadic downpours, and amount per storm), constitute a

Table 2. Average Annual Precipitation

Total Yearly Rainfall		Descriptive Terms	
Inches	MM.	Tropics & Subtr. cs	Vegetation
over 80	over 2000	Continuously humid -	Tropical rain forest
60 - 80	1500-2000	Humid -	Wet-dry tropics
40 - 60	1000-1500	Moderately humid -	Mixed vegetation
20 - 60	500-1000	Subhumid -	Savanna, Steppe
10 - 20	250-500	Semi-arid -	Semi-desert
0 - 10	0-250	Arid -	Desert

(See Figure 1, for world distribution of rainfall zones.)

major climatic factor. The duration of the seasons without significant rain is highly important. The effects of rainfall are moderated by soil conditions and the nature of the vegetative cover. A cover of forage grasses and legumes provides a most effective means of retaining rainfall on the land where it falls, to infiltrate into the soil where it may be used by plants growing in the soil.

b. Sunlight. Sunlight in the tropics and subtropics, influences plant growth through the intensity of solar energy, the light quality (higher in ultraviolet rays than in temperate zones), and the length of daylight periods. Many tropical plant species are poorly adapted to the temperate zones which have longer days in summer and shorter days in winter. Thus, some entire plant species, and some varieties within widely distributed species are either adapted to temperate zone lengths-of-day, or to tropical zone lengths-of day (11 to 13 hours day length).

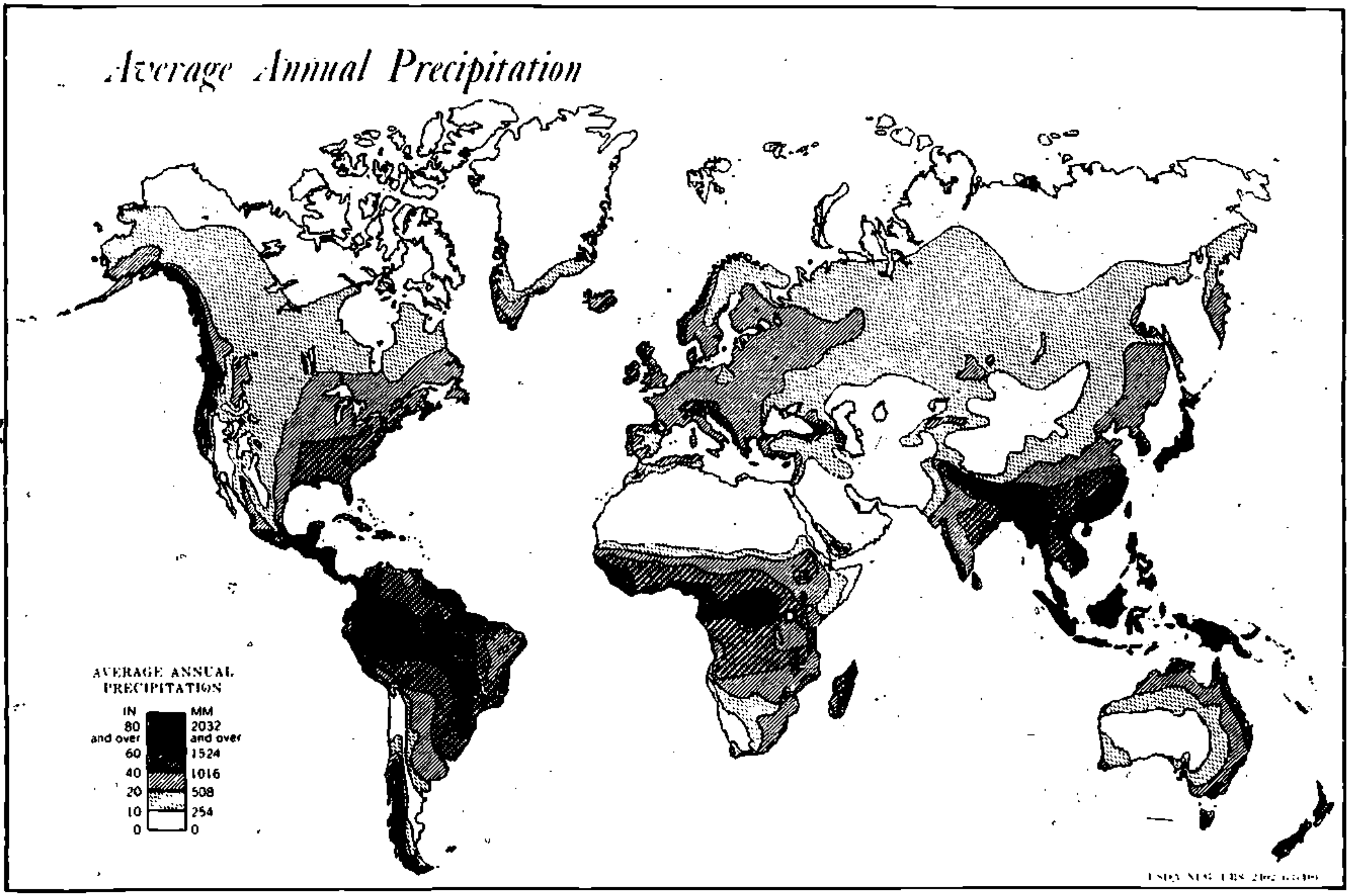


FIGURE 1. World Distribution of Rainfall Zones

c. Temperatures. Temperatures in the tropics and subtropics are not only generally higher than in the temperate zones, but the cooler season is usually warm enough to sustain plant growth throughout the year whenever rainfall is adequate. Night temperatures are relatively warm, except at higher altitudes where dissipation of daytime heat is quite rapid, particularly at elevations above 3000 ft. (= 1,000 meters).

d. Evaporation and humidity. The rates of evaporation rise rapidly with higher temperatures so that considerably more rainfall is needed to maintain equivalent air humidity, than is needed in the temperate zones. The greater evaporation losses are accompanied by higher transpiration losses of water from plant leaves and stems. Even the humid wet-dry tropics, because of the extended dry season, produce substantial moisture stresses in plants.

Evaporation from free-water surfaces (lakes, ponds, streams), and from soils and the water losses directly from plants, are very high in warm dry situations. Growing plants must maintain a minimum water balance between uptake by roots and losses from leaves and stems, to remain active in growth and in storage of plant food reserves. Unless a positive balance is achieved, the plant ceases to function and either becomes dormant or dies. The length of the periods during which plants can function, is a fair measure of how much growth can be made in the course of a year, whether the growth be in foods and fiber used directly by man, or as forage for consumption by livestock. As the climate becomes more severe in terms of water balance for plants, the growing of crops tends to dwindle, and prime reliance is placed on forages (grasses, legumes and browse plants) that must support grazing livestock enterprises to yield products that man can use to meet his needs.

e. Length of the dry season. A significant measure of the suitability of climates to support plant growth, is the average length of the dry season each year. For convenience in determining the regions where different species of plants are capable of surviving and making substantial growth, the following conditions are recognized:

1. Humid - having less than 2½ months with little or no rainfall;
2. Intermediate-humid - having 2½ to 5 months with little or no rainfall;
3. Intermediate-dry - having 5 to 7½ months with little or no rainfall;
4. Semi-arid - having 7½ to 10 months with little or no rainfall;
5. Arid - 10 to 12 months with little or highly variable rainfall.

The general geographic distribution of the dry seasons according to their average yearly duration is shown in Figure 2.

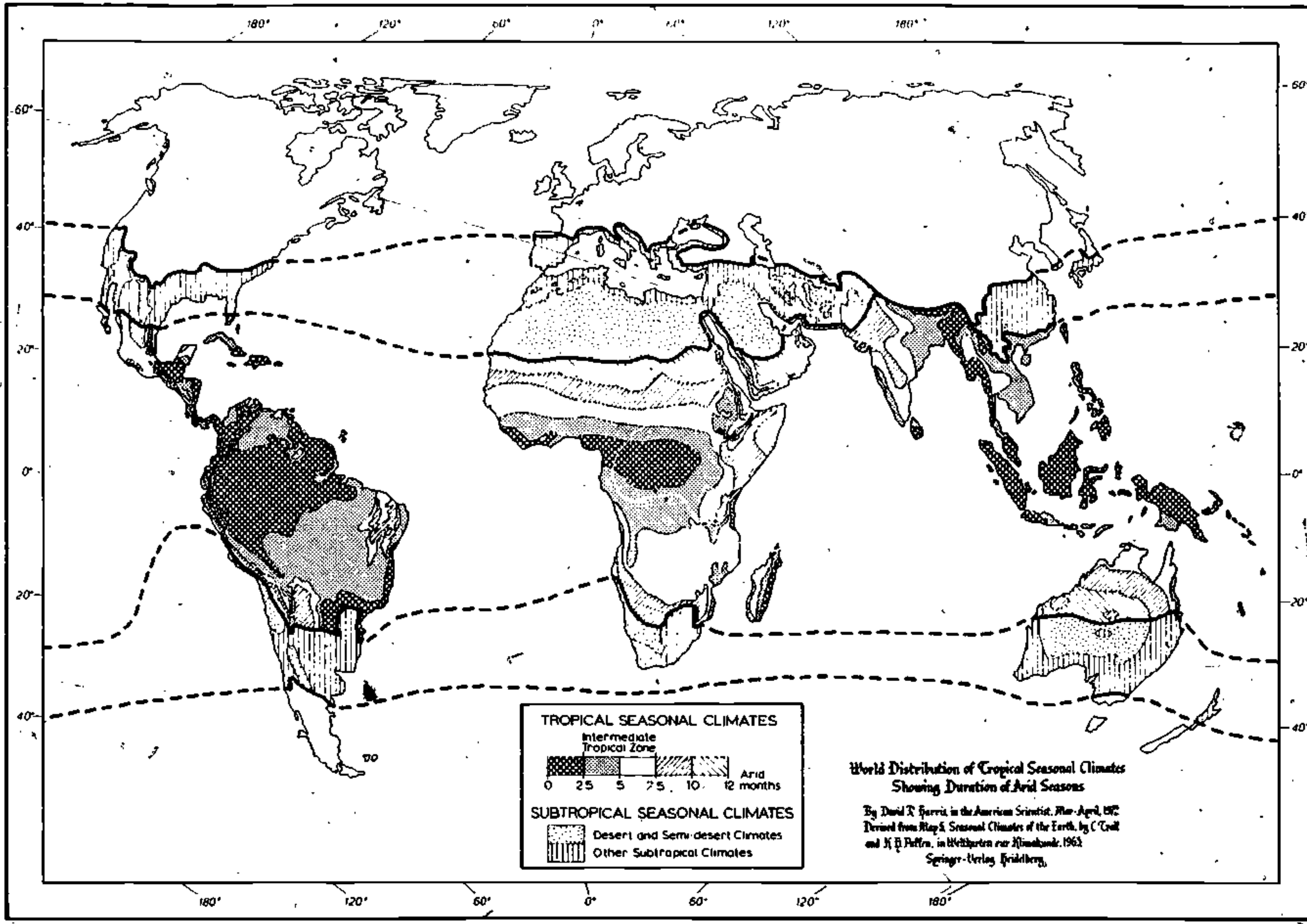


FIGURE 2. Length of the Dry Season

f. Monsoon climates. The monsoons have a strong influence on plant growth of all types because of the effect they have on the seasonal occurrence of the rainy season. The basic causes of monsoons are poorly understood, but they can be predicted to some extent. They have considerable variability in the dates of beginning and their duration. The name "Monsoon" is Arabic, and was originally applied to the seasonal winds of the Arabian (Persian) Sea, that blow about six months from the southwest. The winds are caused by differences of annual temperature trends over land. Temperature changes are large over land, but small over oceans. The monsoon blows from cooler to warmer regions; from sea toward land in summer (bringing rains), and from land toward the sea in winter (without rains). Atmospheric pressure is relatively high in cooler regions and lower in warm regions, permitting air-mass movement to take place.

The monsoon type of air movement by seasons occurs throughout the tropics, and is perhaps better known in the Indian subcontinent than elsewhere. However, monsoon type climates are widespread in the tropics and subtropics. Monsoon winds blowing from oceans toward and across land masses of Africa and South America are important factors in producing the rainy season of those tropical climates; and the reverse flow of air masses from land toward the ocean causes the dry seasons. The periodicity of rainfall in the tropics is well established by rainfall records that are now available in virtually all developing countries.

g. Mediterranean climates. These are produced by a unique combination of land forms, latitude, and monsoonal winds. Rainfall characteristically occurs in the cool months, and the summers are relatively dry. In the Mediterranean basin, and extending eastward to Iran, air masses flowing from the Atlantic bring rains in the winter period, thus producing a type of agriculture based on plant growth suited to the cooler moist winter season.

h. Categories of climates (Figure 3). The categories of climate that recognize dominant characteristics may be identified as follows:

(1) Warm temperature and subtropical zones:

(a) Dry summer, Mediterranean climates with humid winters.

(b) Dry summer, steppe (subhumid) climates with humid winters.

(c) Steppe (subhumid) climate with short summer humidity.

(d) Dry winter climate with long summer humidity.

(e) Semi-desert climate with short seasons when rains occur.

(f) Permanently humid grassland climates.

(g) Permanently humid climates with hot summers.

(2) Tropical zones:

(a) Tropical yearlong rainy climates.

(b) Tropical humid summer climates

1) with humid winters

2) with comparatively dry winters.

*For representative data, see "Climates of the World," published by the U.S. Department of Commerce, and available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. (35¢).

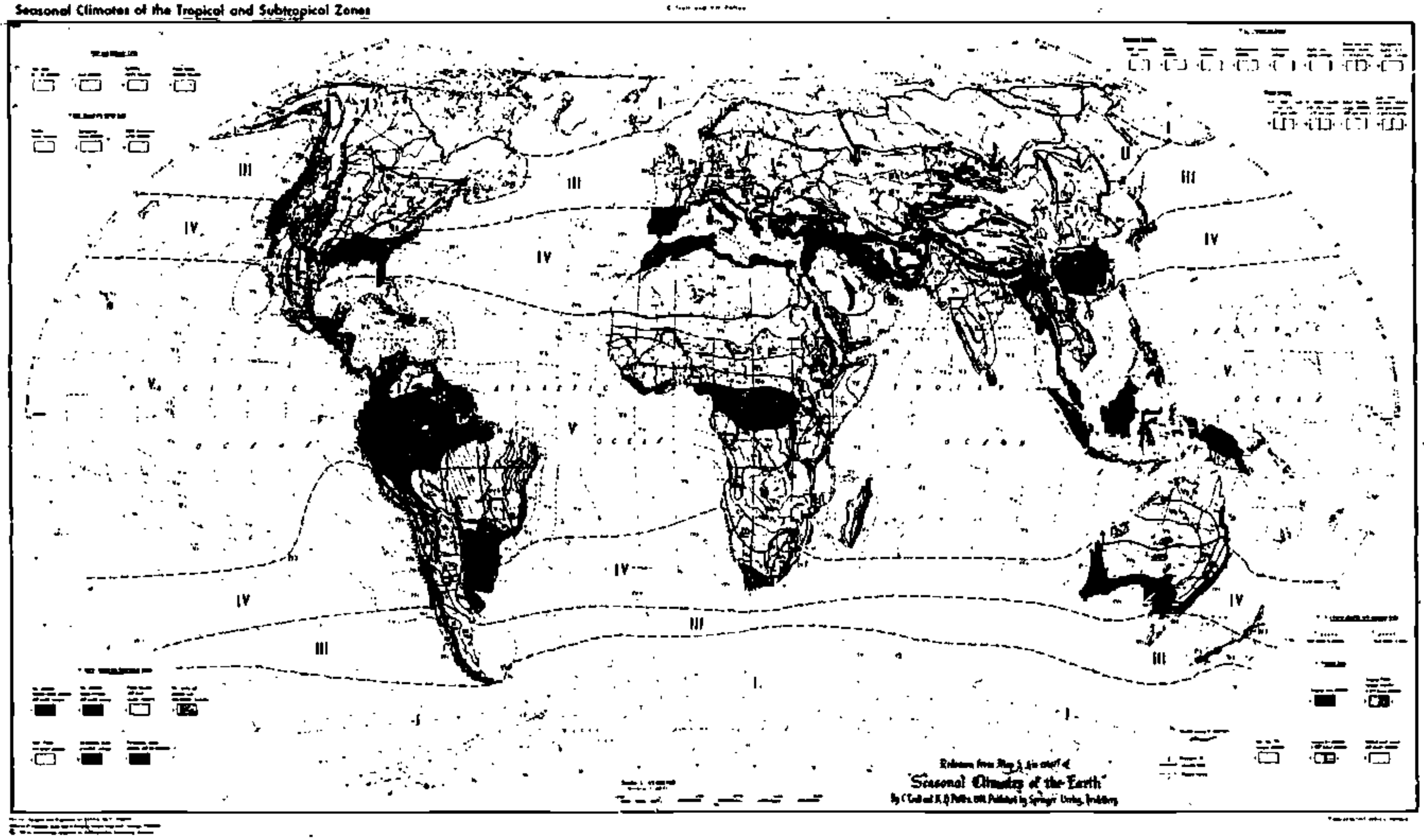


FIGURE 3. Seasonal Climates of the Tropics and Subtropics

(c) Wet and dry tropical climates.

(d) Tropical dry climates

1) with humid winters

2) with dry winters.

(e) Tropical semi-desert climates.

(f) Tropical desert climates.

The significance of these zones is that for forage production of the plant species adapted to a particular climatic zone will probably be useful in any other part of the world where there is similar climate.

2. Land forms and elevation.

The surface topography of lands, and their altitude above sea level, have pronounced effects on climates, and thus on plant growth. The principal classes of land forms are shown in Figure 4. However, within each of the land forms shown there are local variations in surface topography that have major significance in their suitability for growing crops, for production of forages on pastures and rangelands, and other uses. As the elevation of land increases the temperatures are lower, since the daytime heat is dissipated more rapidly after sundown at higher elevations.

Land elevation also modifies the rainfall substantially. Moisture laden air masses moving toward ranges of hills or mountains deposit rain as the air moves upward. However, on the leeward side of these uplifted land forms, the same air masses having lost much or most of their moisture vapor, do not contribute substantial precipation. Thus, the eastern slopes of the Andes mountain of South America have abundant rains, and the western

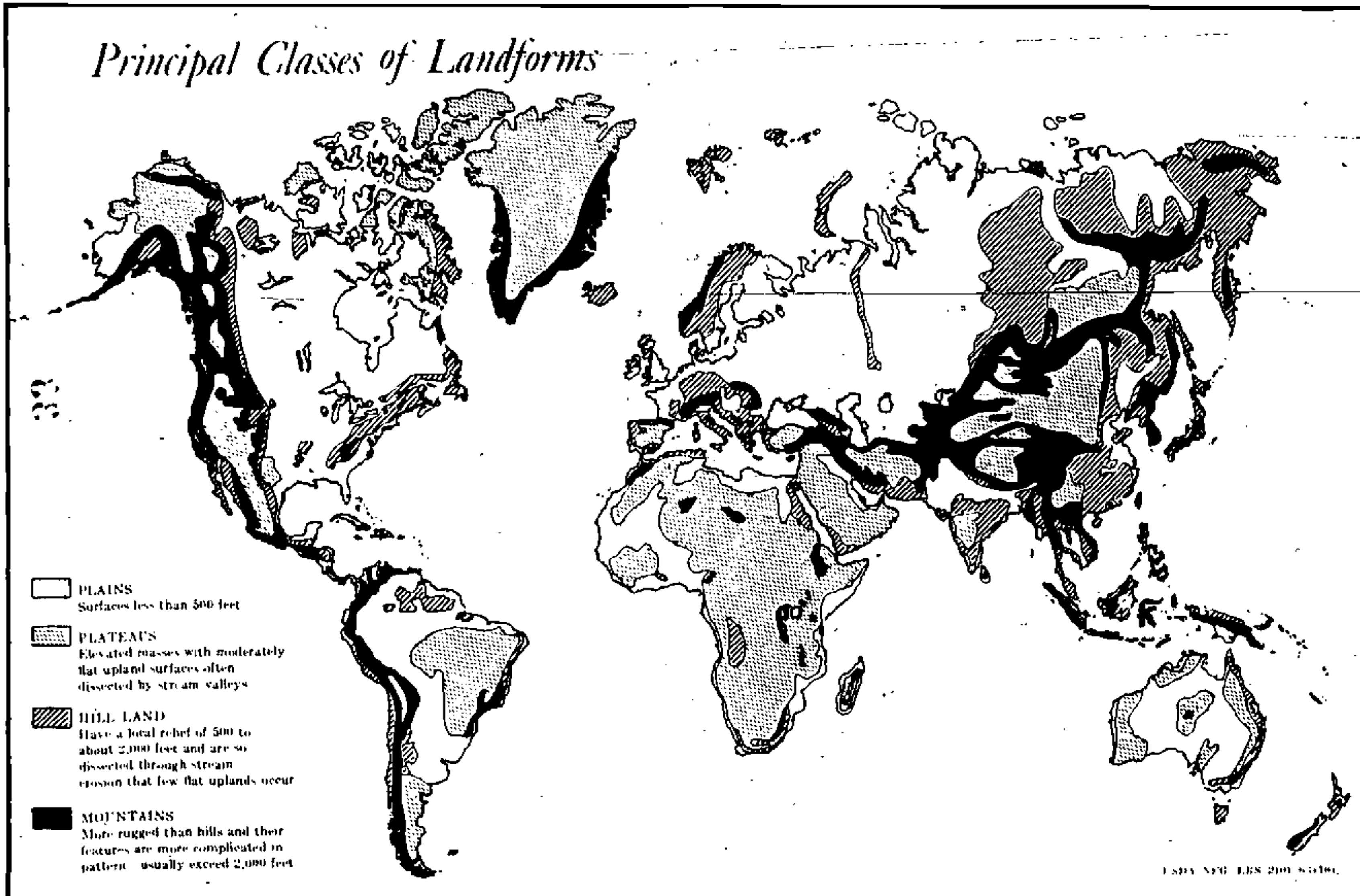


FIGURE 4. Principal Classes of Land Forms

sides are quite arid. Similarly, the northern slopes of the Atlas mountains in North Africa have much more abundant rains than the southern slopes. The native vegetation as well as the crops, and the range and pasture lands, are profoundly affected by such changes in rainfall, generally becoming more abundant as rainfall increases.

Within each of the principle classes of land forms there are important local variations in topography and in present agricultural use. In general, cropping tends to be concentrated on smoother land areas, less subject to erosion and rapid rainfall runoff, and with a deeper soil profile that favors root occupation. On other soil areas that are poorly suited to cropping, the lands are generally occupied by rangelands or pastures, except in humid regions where the vegetation is usually trees and forest. Thus, in a single locality with humid wet-dry climate, or in a subhumid climate, the crop lands may be intermingled with less favorable lands that are grazed. In drier regions not favorable for cropping, all land classes may be used solely for grazing.

3. Natural vegetation as an index of agricultural potential.

The native vegetation of a region is determined very largely by the climate. The yearly impact of rainfall, temperatures, evaporation and humidity, and winds determine the types of vegetation that can survive and propagate. The nature of local soils modifies the climatic environment to some extent. Insofar as the native vegetation of an area may be discerned despite man's occupation and use of it, such vegetation may serve as an index of the combined effect of climate, land forms, and soil conditions to support plant growth. Native vegetation does not reveal what may be the conditions that limit plant growth, nor the extent that these limitations may be corrected by suitable treatments. Where these plant resources have been depleted by severe over-grazing, or by uncontrolled burning, by uncorrected soil erosion by wind or water, it may be difficult to identify the natural vegetation.

Figure 5 shows generalized native vegetation zones on a global scale. Compare this map with the rainfall shown in Figure 1. As noted above, such vegetation may persist only in protected or isolated areas where cropping is nearly universal, or where severe overgrazing by livestock has largely destroyed the native vegetation. The natural vegetation zones are as follows:

Low latitude (tropical) forests

Tropical rain forest

Lighter tropical forest

Scrub and thorn forest

Middle latitude forest

Mediterranean scrub forest (subtropical)

Coniferous forest (north temperate zone)

Broadleaf and mixed forest (temperate zones)

Grasslands

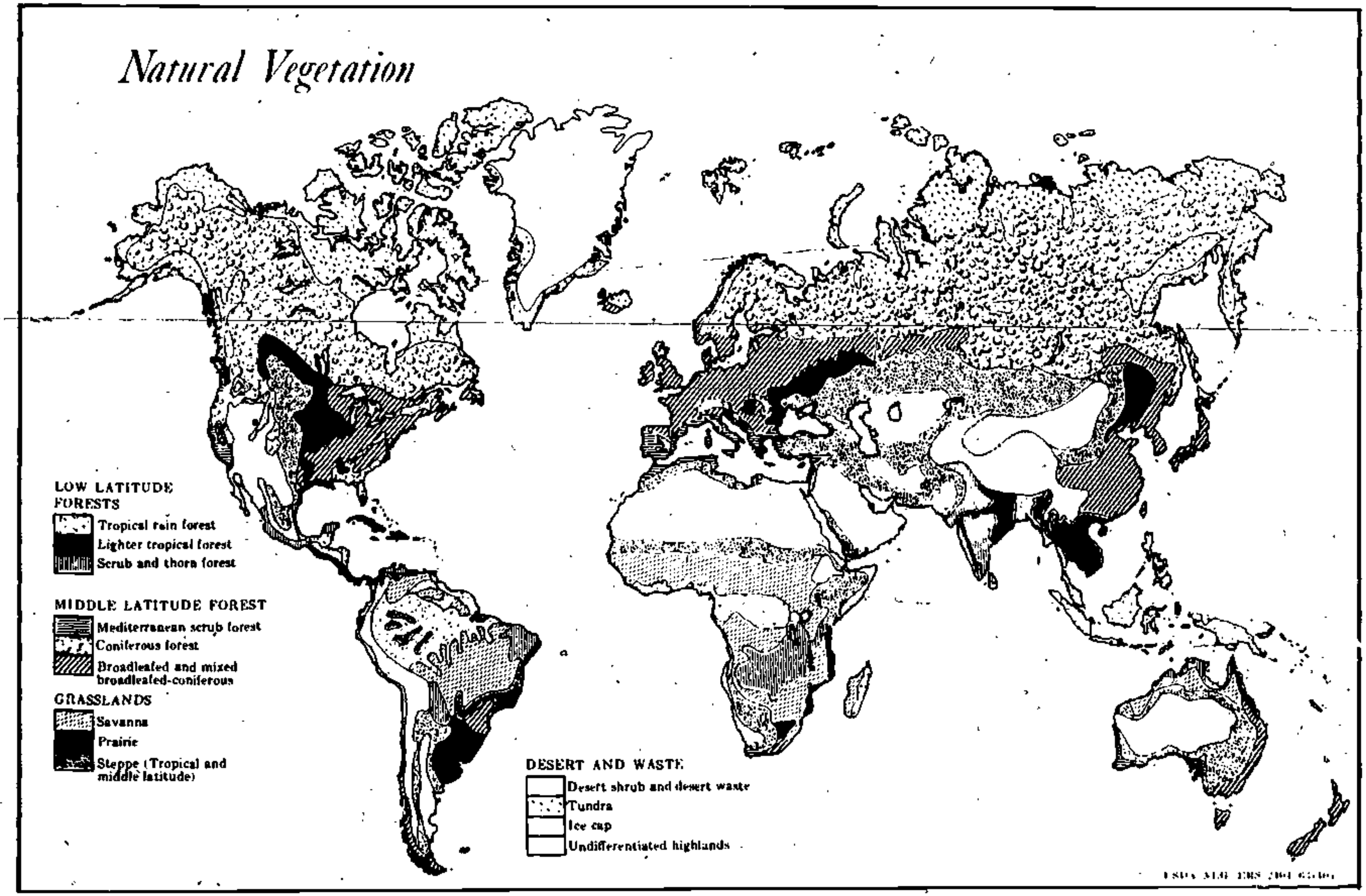
Savanna (tropical)

Prairie (temperate zones)

Steppe (tropical and temperate zones)

Desert

Desert shrub and desert waste (tropical and temperate zones)



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35 FIGURE 5. Natural Vegetation Zones of the World 36

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The steppe is predominately occupied by bunch grass and scattered shrubs. Following the occurrence of rains, any open ground surface is occupied by short season annual grasses and herbaceous plants.

It may be noted that the only vegetation zones that occur in both tropical and temperature zones are the steppe and desert shrub. Even in these zones, the tropical plant species are quite different from those of the temperate zones. The vegetation zones of the tropics are unique, which means that the research and technology needed to utilize them to support man cannot be transferred from one zone to another without considerable modification. Much adaptive research will be needed, as well as original research on specific problems, to fully exploit the potentials of the tropics. Subsequent sections of this report summarize present knowledge on the adaptation of superior forage grasses and legumes to different environments, and their management and utilization by livestock to produce economically attractive returns.

4. World soil grouping for forage production.

The characteristics of the major soil groups of the world are determined partly by the climates in which they occur, partly by the geologic material (rocks, sediments, etc.) from which they have evolved, partly by their geologic age (very old weathered soils are quite different from recently deposited alluvial or volcanic soils), and partly by the vegetative cover under which the soils have developed in recent centuries. Soils may be classified by their own characteristics (color, texture, depth, composition, etc.), but their economic value depends on their suitability for growing plants.

a. Tropical soils. Tropical soils are unique in many respects because of the climatic conditions under which they have developed. The effective management of tropical soils must recognize the properties of each distinctive soil group, and adjust the land utilization practices to protect the type of plant growth that they will support on a continuing basis. The following major soil groups are recognized by soil scientists.

b. Major soil groups. The seeming endless diversity of tropical soils can be resolved into major groupings on the basis of their predominant characteristics. The following classification is useful, which also are shown in Figure 6.

Great Soil Groups of the Tropics and Subtropics*

		Total land area in millions of hectares
1.	Dark Grey and Black Clay Soils (inclusions of chernozems, reddish chestnut soils, and hydromorphic soils)	500
2.	Sierozems, Desert and Red Desert Soils (inclusions of lithosols, regosols, and saline soils)	2,798
3.	Latosols, Red-Yellow Podzolic Soils (inclusions of hydromorphic soils, lithosols, and regosols)	3,214
4.	Red-Yellow Mediterranean Soils (inclusions of terra rosa soils, some mountainous areas, and many areas of rendzina soils)	112

*Derived from article by C. E. Kellogg and A. C. Orvedal, published in "Advances in Agronomy" Vol. 21, 1969, by Academic Press, New York.

5. Soils of Mountains and Mountain Valleys (Inclusion of many lithosols) 2,165

6. Alluvial Soils (Includes innumerable areas in all regions, that are included in other soil groups. These soils have been estimated to support 25% of the world population. Alluvial soils are formed by sediments from flowing waters in river and stream valleys and deltas, and in intermittent channels of rainfall runoff in watershed basins. These soils lie in the present day flood plains of these waters, or as terraces and benches of earlier geologic periods.) 590

The major soil groups are shown in Figure 6. This map may be useful in connection with the data given in Table 1, which reports a total of 1,582 million hectares of "permanent grasslands" in the tropics and subtropics, in contrast to 626 million hectares of arable lands used for tilled crops and tree crops of various kinds. Comparatively little research has been done on soil management of grazing lands that support livestock, in contrast to the studies on soils for crops. Enough information has been collected, however, on rangelands and other grazing lands to indicate that the potentials for improvement are often very substantial.

Most upland tropical soils that are cropped are low in organic matter, since the high temperatures foster rapid decomposition of roots and other plant parts that account for production of soil humus in temperate zones. Perennial grasses and legumes on tropical and subtropical grasslands make yearly contributions of fresh organic

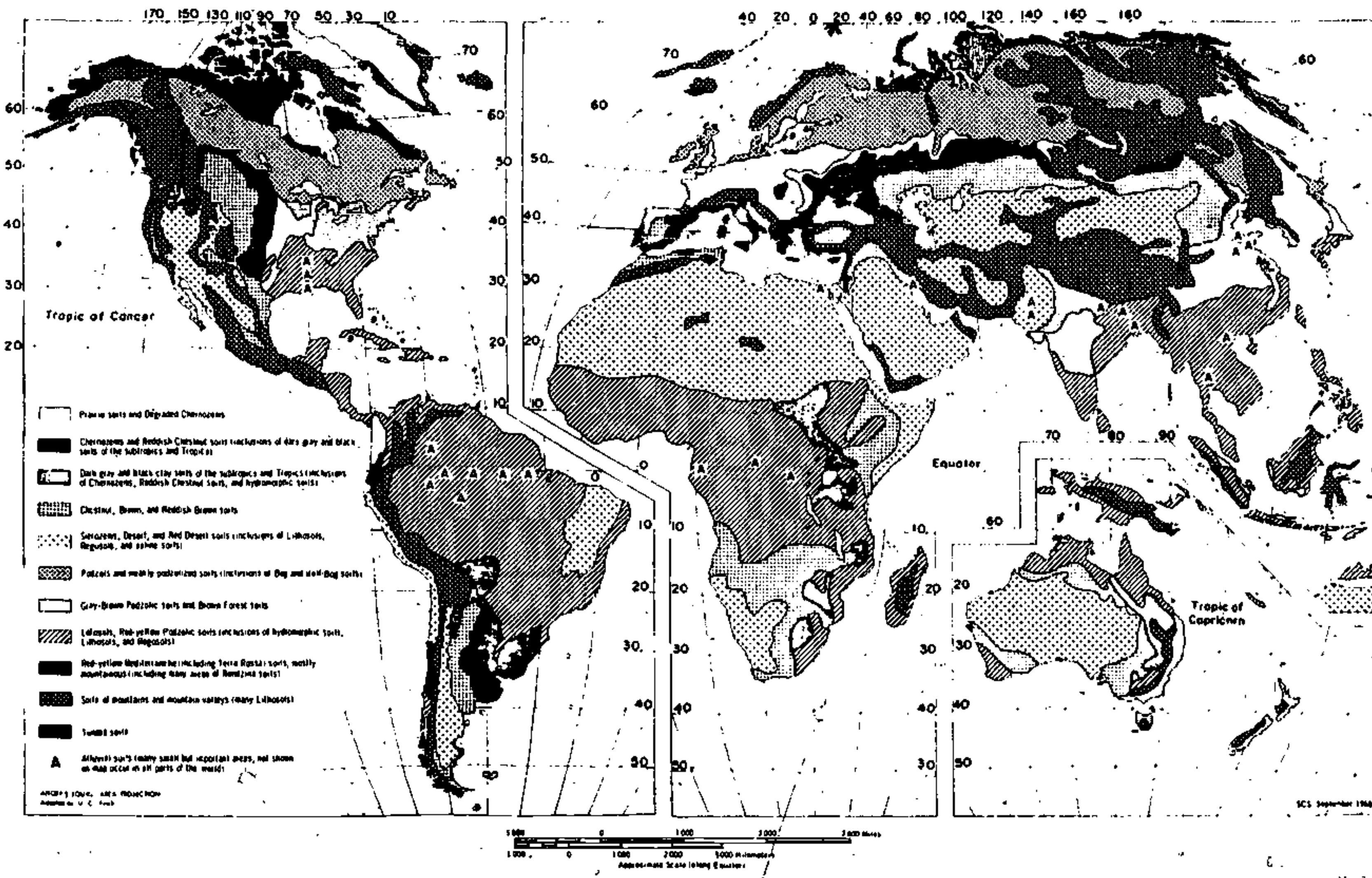


FIGURE 6. Generalized Soils Map of the World

matter within the soil profile and at the soil surface, thus improving soil permeability to rainfall and recycling minerals from plant tops back into the soil profile. However, any characteristic mineral deficiencies of a soil type must be recognized and corrected by suitable treatments to more fully exploit the forage producing potentials of rangelands and other perennial grasslands.

The basic philosophy is that man either adjusts land management practices to the inherent capabilities of soils as they occur, or he identifies those limiting factors that can be altered by application of modern technology, and exploits those opportunities that are economically feasible. Man cannot change the climate, but he can make the most effective use of rainfall, temperatures, and humidity that may be expected to occur. Protection of native forage plants is a first requirement, but introduction of superior adapted forage plant species may also be rewarding.

c. Soil deficiencies and plant growth. Plants grown on different soils in the same climatic zone may make quite different amounts of growth as a result of some important soil factor or factors. Moreover, the nutritive values of forages grown on deficient soils are often much reduced from the status when grown on more fertile soils. The most encouraging aspects of soil deficiencies are (1) that there are practical methods for determining the presence of such limiting factors, and (2) many of these limiting factors can be altered by man to produce benefits in terms of increased forages for livestock that are much greater than the costs of the practices or treatments. These will be discussed in more detail in a later section of this report.

d. Dependence of plants on soils. Favorable soils must be suitable for root occupation as to soil permeability and aeration and have good soil moisture relations (permeable to rainfall) with favorable texture and structure to store rains in the soil profile for subsequent uptake by plant roots. Also, soils must supply all of the mineral nutrients required for plant growth. These include the major elements: nitrogen, phosphate and potash; and the secondary elements: calcium, magnesium, and sulfur. In addition, there should be a modest supply of the minor elements required in "trace" amounts for normal growth: zinc, boron, molybdenum, copper, iron, and maganese. Further, the suitability of soils may be altered by excessive alkalinity in dry regions, or acidity in humid regions.

e. Laterites and laterite soils. In the tropics, a unique soil formation often occurs, known as laterite. Laterites are characterized by very high contents of iron and aluminum oxides. There are several forms of these reddish soils, which differ markedly in their characteristics and agricultural usefulness: (1) There is the ground-water laterite which has a layer (horizon) indurated with iron compounds, and thus with low permeability to rainfall. It may be very thick and can be formed on any parent rock material and drainage conditions under the typically high temperature of the tropics. (2) A second type is a deep red soil rich in iron and aluminum, which is only formed by weathering of basic igneous rocks under conditions of good to moderately good drainage, in regions of seasonally high rainfall. They nearly always show signs of impeded drainage in the subsoil. There is a soil horizon containing small pea-sized laterite gravel concretions, whose concentration increases with increasing amount of impedance in the internal drainage. Below that layer is a deep reticulated mottled red layer, which may be soft in continuously humid regions, but dries out to hard lumps when exposed to drying weather.

The hardened types of laterite near the ground surface are often quarried for use as road building material. The indurated laterite soils are generally considered non-arable, and are occupied by brush and scrubby tree growth, interspersed with some grasses and legumes that may be grazed. Research on how to improve laterite soils for forage production has yet to be done.

5. Characteristics of permanent grasslands.

There are a variety of reasons why the "permanent grasslands" are not now cropped (See Table 1). In the semi-arid and subhumid regions, the rainfall is too uncertain to make cropping successful under natural rainfall. Only the deeper soils with good rainfall storage capacity, that are inherently fertile are cropped in regions of limited rainfall. Other soil types that are too shallow, or are highly erosive and badly gullied, or are stony, or poorly drained, or infertile for any other reason (such as laterite soil areas that are relatively impermeable to rainfall), are relegated to native vegetation. To the extent that the plant growth on such soils is feasible, these areas are used as grazing lands.

A notable exception to the above types of "permanent grasslands" are the tsetse-fly infested areas across Central Africa, that are estimated at some 10 million hectares. These lands now are largely unoccupied by man because of the trypanosomiasis (sleeping sickness in man, N'gana in livestock) carried by tsetse-fly as it feeds on man and animals. As the tsetse-fly is controlled on these lands, they will become available for cropping where soil conditions are favorable, and for grazing on nearly all soils.

It should not be assumed that perennial forage grasses and legumes have no role on cultivated lands. Rather, they are most productive on lands and soils commonly used for crop production. The use of planted forages is crop rotations, or as longer term occupation of arable soils, as a type of profitable enterprise in farming systems is discussed in some detail in Technical Series Bulletins No. 13, 19 and 20 (see Appendix). Such planted pastures provide essential year-round livestock feed for animal enterprises in integrated crop/livestock farming systems. They contribute strongly to maintaining soil fertility under continuous cropping. Where such improved grazing lands are available they should be managed in conjunction with the associated grazing lands that are not used for crop production.

6. Soil surveys and land capability classes.

Some progress has been made in various regions in making soil surveys to determine the location of specific soil types, and in preparing soil maps of these, area by area. Some soil survey maps are quite detailed, but most of these in the tropics are of the reconnaissance type showing general soil conditions. Such maps are immensely useful in determining the characteristics of soils for crop production, as well as for producing grazing and harvested forage for livestock. The identity of soil types and grouping of these provides a means of exchanging information on soil improvement and management between countries and regions, thus facilitating the accretion of knowledge for the benefit of agricultural development whenever similar soils occur.

Another exceedingly useful classification of soils, that may be usefully applied where detailed surveys have not been made, is the land capability classification. These classes are based on land slope; soil depth and drainage; susceptibility to erosion; water and nutrient supplying power of the soil for plants; and the presence or absence of stone, hardpan or other impervious layers; any excessive salinity, acidity or alkali; and similar characteristics. These classes embrace all soil types and conditions, and therefore are applicable worldwide.

Land capability classification (indicating suitability for specific agricultural uses).(1)

a. Lands suited for cultivation, and for forage production.

Class I. Very good land, with wide usefulness. Excellent for cropping, and also for grazing and forage production. Land is level to moderately sloping. Low susceptibility to erosion. Soil deep, well drained, fertile and productive.

(1) For detailed criteria, see "A Manual on Conservation of Soil and Water," U.S. Department of Agriculture Handbook No. 61.

Class II. Good land. Useful for cropping, but should have soil conservation management to protect against degradation. Land has gentle slopes, only moderately susceptible to erosion hazard. Soils moderate in depth, good water relations, and fairly productive; supports strong growth of forage grasses and legumes for grazing and for harvest.

Class III. Moderately good land. Requires more intensive soil and water conservation practices to support sustained crop production. Inclusion of perennial grasses and forages in the farming rotation usually needed to protect against land degradation. Well suited for permanent grasslands to support livestock enterprises.

Class IV. Fairly good land, but not suited for tilled crops because of steeper slopes and other soil conditions, such as erosion and excessive runoff of rainfall, shallow soils, etc. Best use is for tree crops and for permanent grasslands. Productivity of land may be sustained by suitable management practices, under such useage.

b. Land capability classes not suited for tilled crops.

Class V. This class includes land not suited for cultivation but capable of supporting perennial vegetation (grazing or forestry) with few limitations from a soil conservation standpoint. The land may be nearly level. It includes lands on which vegetation has been depleted by misuse; and restrictions on use are needed to improve the vigor of the vegetation. Class V also includes many of the swampy areas that cannot be drained easily, as well as relatively level lands that are too shallow or stony to be used for crops.

Class VI. These lands are subject to moderate limitations under grazing or forestry use. It is too steep, subject to erosion, or too shallow, wet, or dry for cropping, but with careful management is suited to either grazing or forestry. It may be tilled just enough to establish pastures. When used for grazing, there should be adjustment of animal stocking rates, so as not to exceed the forage producing capacity. Other necessary range management practices include deferred or rotational grazing in the season of rains to permit periodic recovery and natural reseeding of forage plants, and to protect against excessive depletion of plant vigor. Special measures usually are needed to control gullying; and water spreading by contour furrowing or other soil structures may be used to carry runoff water to less sloping land where infiltration and water storage in soil profile is feasible.

Class VII. These lands are subject to severe limitations or hazards under either grazing or forestry use. It includes lands with severe moisture deficiencies (semi-desert to desert); and lands that are very steep, eroded, stony, rough, shallow or otherwise unfavorable, that can be used successfully without degradation only if carefully handled. Because of these limitations, the productive capacity is only fair to poor for grazing (requiring carefully controlled stocking rates); and areas allocated for forestry must be protected from virtually all grazing.

Class VIII. These lands have such unfavorable characteristics as to be unsuited for cultivation, grazing, or forestry. Their principal values are for wildlife or for watershed protection uses. Class VIII lands include deserts, marshes, badlands, deep gullied areas, high mountain land, and very steep, rough, stony or barren land. They often occur in small areas, but elsewhere may be quite extensive, as dry hilly areas, or moving sand dunes. Any management practices are usually limited to those necessary to protect adjoining lands that have greater economic values.

a. Lands suited for grasslands. It should be noted that permanent grasslands may constitute a productive use of all land capability classes except Class VIII. Perennial grasslands for support of livestock are an optional use of land in Classes I-III. Classes IV-VII have potential as managed permanent grasslands. The full use of all land resources of a country or a region will certainly involve substantial land areas that are unsuited for tilled crops. The important consideration is to devise management systems that will make the most profitable use of each type of grasslands, for grazing and for production of harvested forage (as hay or silage).

7. Present land use patterns, by ecological zones.

a. Dry rangelands in semi-desert zones.

The predominant controlling factor for such lands, is the limited amount of annual rainfall and the uncertainty as to when it will occur. There is little or no crop production in this zone, except where localized irrigation from shallow wells is feasible. Much of the land fed by natural rainfall is partially occupied by forage and browse plants, with open ground between plant clumps. After a period of showers, this open ground may be occupied briefly by short-season annuals, that quickly produce seed and die. The total amount of palatable forage for livestock is usually quite limited, but is greatest on areas of permeable soils on which runoff of rainfall is not rapid, and there is opportunity for rains to infiltrate into the soil profile where much of it is stored for subsequent uptake by plant roots.

Most of the rangelands in regions of limited and uncertain rainfall are not now being managed to fully develop their potential for producing forage and supporting livestock enterprises. Too often there is severe and ruinous competition between herdsmen for limited supplies of forage and water, during relatively short grazing seasons. Such a situation is not conducive to learning the principles of rangeland and livestock management by trial and error. This may explain the almost universal overgrazing, caused by overstocking the rangelands, which severely damages the vegetation and the soils, particularly in semi-desert regions in periods of protracted drought.

The pity of such damaged rangeland is that recovery is very slow even when grazing pressure is reduced, and the real potential for support of livestock is never allowed to develop.

It is probable that the vast areas of drought plagued lands of Africa, the Near and Middle East and elsewhere could be made continuously far more productive than it has been in recent decades; and that methods of cushioning against recurring droughts can be made effective. These management principles will be detailed in a later section of this report. The implementation of basic principles must be compatible with the social, economic and political situation in each country, with such adjustments as will permit full exploitation of climatic conditions, land and soil capabilities, the strenghthening of plant growth, and the reduction of unnecessary runoff of precious rainfall. However, a first step would be recognition of the basic principles of managing the natural resources, and the rewards that will follow prudent management. Changes in social, economic, and political policies may be feasible once the economic benefits of improved management become visible.

b. <u>Savanna lands</u>. These occur in subhumid regions, where the natural vegetation consists of forage grasses and legumes, interspersed with variable amounts of bush and scrubby trees. Overgrazing and uncontrolled burning have usually damaged the palatable vegetation and permitted the bush and scrubby tree growth to dominate. Throughout the savanna regions, crop production occupies the localized soil areas that are fairly deep and capable of storing rainfall to support crop growth. Millet and other short-season crops predominate in drier regions; sorghum replaces millet where moisture is more adequate; and maize replaces sorghum where rainfall permits a longer growing season.

Intermingled with soils that will support cereal grain production and other food and cash crops (foodgrain legumes, oilseed crops, root crops, etc.) are lands that are better suited for permanent grasslands. Usually, attention is concentrated on the crop lands, and the grasslands receive little consideration. In general virtually nothing has been done to improve the productivity of the grasslands, but important potentials do exist. At present, village communal herds of livestock are grazed on any grasslands within reach of villages. The herds are composed of family owned animals, but there is little concern as to the effect of grazing practices on forage production, and there has been no effort to improve the vigor of forage plants and their nutritive value. Even less consideration is given to the production and preservation of forage to carry livestock through the long dry seasons when forage grasses and legumes are dormant.

The livestock enterprises in savanna lands are crucial to the supply of meat and milk required by villagers; but the goats, sheep, cattle, and camels are used largely as scavengers for any available forage, rather than as farming enterprises to more fully utilize the natural resources available. There are important unused opportunities for mixed farming systems,* in which both crop and

*See Technical Bulletins 19 and 20, listed in the appendix of this bulletin.

livestock enterprises are combined to produce balanced farming systems that are more productive than systems that depend solely on crops, or solely on herded livestock. A first stage may be the inclusion of perennial grass-legume forages for one or two years in a five-year cropping system, to maintain productivity of the land as well as to provide feed to support livestock during the dry seasons. This would permit marked improvement in livestock reproduction and growth, and in milk production.

A major factor in subhumid regions in utilizing all types of permanent grasslands most effectively is the absence of any system that would place the management of these resources firmly with the major users, so that the benefits from good management, and the penalties for poor management that result in lowered productivity, would be felt by those users. Under the current situation (with unfenced and uncontrolled grazing on lands), the permanent grasslands are largely neglected, and subject to overgrazing and other mismanagement that degrades productivity of the lands, and causes severe damage to the rangeland that could be avoided.

There are important opportunities in subhumid (savanna) regions to produce and preserve the forage needed to carry livestock through the long dry season when there is not plant growth. These include the following:

(1) Reservation of grassland areas left ungrazed in the season of rains for use during the dormant dry season. The areas thus reserved should be large enough to feed livestock

until the subsequent rainy season occurs. Such standing forage gradually declines in nutritive value during the dormant season, but will contribute significantly to a sustained feed supply.

(2) Harvesting forage that is surplus to grazing needs during the growing season, and preservation as hay. If cut before the grasses produce seed heads, the forage has good nutritive value. Such forage is quickly dried in the field, and this hay may be stored indefinitely if protected from rain and termites.

(3) Harvesting forage and preserving it as silage. There is little or no loss from shattering-off of dry parts in making silage, such as occurs in making hay; and the feed value is high if silage is properly made. The green forage is chopped in lengths of 2 to 5 cms., and packed tightly in well-drained trench silos, covered with impervious polyethylene sheeting, and allowed to ferment until cured, and remain in place until fed. Exclusion of air is essential for fermentation and preservation. When properly made, grass silage preserves as feed, the maximum percentage of the green harvested crop.

It should be noted that hay and grass silage may be produced as a crop on tilled land, or these forages may be harvested from permanent grasslands. It is feasible to produce surplus forage by these means, that can be used to feed livestock brought in from semi-desert areas in the dry season.

c. Wet-dry tropics. Lands on which tree growth has been cleared, but which are not occupied by crops because of erosion or declining fertility, are capable of producing relatively high yields of nutritious forage. Well managed grasslands should not suffer erosion. The seasons of abundant rains usually occupy six to nine months, during which adequate growth is made on grasslands for grazing. There is normally a season when forage growth exceeds grazing needs, and the surplus forage at that time should be harvested and stored as hay or silage, at the growth stage when the feed is most nutritious. Such feed should sustain the ruminant livestock during the dry season, both for reproduction and growth, and for sustained milk flow in all seasons.

The potential for forage production on all lands in the wet-dry tropics, greatly surpasses that possible in subhumid, and semi-desert areas. When soil deficiencies are corrected, and adapted forage grasses and legumes are established, livestock production may constitute a stable and profitable form of agriculture. Such lands may be effectively used to grow and finish meat animals for market, that are moved from drier regions after the grazing seasons in those areas is terminated because of lack of feed.

d. The humid tropics usually have abundant rains for nine or more months, and thus have relatively short dry periods. Perennial forage grasses and legumes adapted to such climates and capable of flourishing on soils of these regions, may provide fresh forage throughout the year. The deeper rooted forage species will continue growth in dry periods on moisture stored in the soil profile. However, any surplus forage that is present on lands at the beginning of the normal dry season may easily be made into hay or grass silage to sustain ruminant livestock during the short dry seasons.

One of the major advantages of forage grasses and legumes on cleared land in the humid tropics, is that such forage plantings made in rotation with tilled crops, will greatly assist in maintaining continuous soil productivity, without the obsolete method of resting land for several years to allow native growth of trees and vines to partially restore fertility.* Forage planting may constitute a necessity for sustained crop production; and this would greatly increase the total land areas available to feed the rapidly growing populations in developing countries.

Forage plantings also are useful means of utilizing lands that have been damaged by gullying and erosion, or have other limiting characteristics. Forages may grow well on cleared lands that are unsuited for cropping.

*See Technical Bulletins 19 and 20, listed in the appendices.

III. Coping with Constraints Affecting Forage Production and Utilization on Rangelands and Other Permanent Grasslands.

1. Climatic constraints.

The first step is to acquire information on the average status of weather conditions to be expected in a specific region, on the basis of accumulated weather records. These data will include seasonal and total rainfall, seasonal temperature means and extremes, air humidity and evaporation rates, cloud cover and important prevailing winds. These climatic conditions dominate the environmental controls of plant growth in semi-desert regions, and are of major importance in subhumid regions, but are less significant controlling factors in wet-dry humid tropics, and in the continuously humid tropics.

Attempts to control climate have not been fruitful, but much can be done to cushion against the adverse effects of those conditions that retard or inhibit growth of forage plants. Thus, conservation of limited rainfall in dry regions through management practices that improve infiltration of rainfall into the soil profile for storage and use by plants, and the husbanding of forage growth made in moist periods for consumption by stock in dry seasons, are two examples. In humid climates, the choice of palatable productive forage species that are adapted to both the higher rainfall and to the soils that occur in such regions; are important measures for adjusting to excessive rainfall and high air humidity.

Even in semi-desert regions, the choice of forage species that survive from year to year and produce substantial forage when rains occur, is an adaptive measure within the capability of man, that has only begun to be used in the tropics. Yet there is good evidence from rangelands of Australia and some other countries that introduction of drought resistant species is effective. It is clearly evident in all climatic regions (semi-desert, savanna, wet-dry tropics, and humid tropics) that the native forages may be effectively supplemented by well adapted species discovered in other parts of the world, to substantially improve the capacity of these lands to support livestock. However, more efficient management of natural forages should be considered a necessary stage to precede introduction of improved forage species from other regions.

2. Soil degradation.

In regions of limited rainfall, the depletion of the forage grass and legume cover by overgrazing results in surface soil compaction that reduces infiltration of rainfall into the soil, and increases the runoff and loss of precious water. Overgrazing also reduces forage plant vigor, and the depth of occupation of soil by plant roots. The weakened root development on enfeebled forage plants results in degraded internal soil structure and the impaired capacity of the soil profile to store rain water for subsequent use by forages.

The weakening of the vegetative cover provided by forage grasses and legumes often fosters severe gullying of land and sheet erosion of soils, particularly in semi-desert and savanna regions. Overgrazing sets in motion the process of soil degradation that often causes irreversible damage. The top soil losses from erosion, whether by water or by winds, removes the more fertile soils and exposes relatively infertile subsoils.

3. Depletion of plant cover.

a. Loss of perennial forage plants. Overgrazing by excessive numbers of livestock, reduces top growth and weakens individual plants. Perennials survive and maintain vigor only when allowed to make regrowth periodically, and to produce seed and establish new seedlings. Uncontrolled burning has much the same effect as overgrazing, and the damage to forage plants is compounded by combining burning with subsequent overgrazing that prevents plants from making necessary regrowth.

b. Invasion by bush and tree growth. Invasion of grazing lands by woody bush and scrub growth that has little forage value is serious, but is reversible. These useless invaders are native plants that propagate rapidly where forages are weakened or killed by uncontrolled grazing or burning. While it is often true that some of the invading woody types of plants are legumes--capable of meeting their own nitrogen needs by root nodules, they have serious weaknesses for the livestock man. Their feed value is limited in amount and accessibility to grazing livestock; their root systems are deep but contribute very little nitrogen to the associated grasses; they are decidedly inferior in controlling gullying and sheet erosion of land, and they compete strongly with more desirable forage plants for light. The invasion of any grazing lands by unpalatable brush and scrubby trees, whether in regions of limited rainfall or in humid regions, indicates a deterioration of the feed producing value of grazing land, that should be countered by positive management practices.

c. Loss of forage legumes. An important type of degradation that is frequently unnoticed is the loss of native leguminous forages. This is quite serious; such legumes are usually highly palatable, nutritious, and a major source of mineral nutrients that are indispensible to reproduction, growth of young animals, and milk flow. Moreover, such legumes are the prime source of nitrogen in most grasslands, which is "fixed" by root nodules by drawing on nitrogen in the soil air to produce proteins in all forage plants. Destruction of legumes by overgrazing is much more rapid than loss of grass cover, and such loss cuts off the major source of nitrogen for the rangeland or other permanent grasslands. Since it is rarely feasible to apply nitrogen fertilizers to grasslands particularly in semi-desert or savanna regions, the loss of legumes results in a sharp decline in capacity of the grasslands or rangeland to produce forage, and a similar decline in the nutritive value of the forage and in productivity of livestock herds and flocks.

For virtually all ecological conditions, there are forage legumes that are adapted to local conditions of climate and soil, and will survive and multiply under careful management. This potential is astonishingly effective where legume protection and management has been followed. It is highly unlikely to occur however, without the skillful intervention by man in managing his grazing lands.

d. Shortened grazing season. The decline in periods of active growth of desirable forage grasses and legumes (and of browse* plants in very dry regions) is a consequence of those management practices

*Browse plants are generally woody bush, brush and short trees, that provide feed as leaves or smaller branches or twigs. Browse is a major type of feed for camels, goats and sheep, but has minor value for cattle. Browse is richer in protein and minerals than mature grasses, and it supports browsing animals when grass forage is in short supply.

that reduce vigor of the important forage plants. The most rapidly invading plant species on weakened grazing lands are usually weedy annual plants that have limited forage value and short growing seasons. The total plant cover may seem adequate at certain seasons, but when the grazing lands are examined closely to observe whether or not the better forage species are declining in abundance, the true status may be diagnosed. Early action to correct harmful management practices should be taken. The greater the deterioration, the more difficult and time consuming will be the restoration and recovery process. The most difficult problems are those of semi-desert rangelands; the next most difficult are the permanent grazing lands of the savannas. The present status of grazing lands in most tropical and subtropical regions of limited rainfall is rarely a natural condition. Instead, it is a condition resulting from long sustained and severe mismanagement. Until this fact is demonstrated by practical means, there will be little enthusiasm by herders for improved management of grazing lands.

4. Unbalanced animal nutrition on depleted grazing lands.

a. Reduction in feed supply. A first consequence of mismanagement of grazing lands is reduction in total feed supply. When this reduction in forage growth is accompanied by increased numbers of grazing animals, the results may be disastrous. This is evident whenever there is the inevitable recurrence of sustained deficiency in rainfall in regions that are characterized by limited and uncertain rainfall. A drastic reduction in forage growth causes grevious losses in livestock, because no provision has been made for such an occurrence. Livestock numbers that increase in years of abnormally abundant rainfall must be rapidly and drastically reduced when feed supplies dwindle, if disaster is to be averted.

There are various means of coping with reduced forage growth: (1) reservation of grazing areas to be used only when the need is acute, to provide supplemental feed; (2) moving animals quickly to areas where preserved feeds (hay or silage) has been harvested and stored for such purposes; (3) reduction of livestock numbers by marketing all animals that cannot be supported by visible feed supplies, and completing marketing promptly before weight losses become serious. It is assumed that the active breeding herd will be protected at times when the herd size must be drastically reduced.

b. Reduced nutritive value of forages. Certain nutritional deficiencies in feeds for ruminant livestock maintained on grazing lands are the result of mineral deficiencies in soils. Phosphorus is often widely deficient in forages of semi-desert and savanna regions, because the soil content is low. This is aggravated by the predominance of forage species (mostly grasses) that have low phosphorus contents. The introduction of forage legumes that accumulate phosphorus from the soil is often useful. A more positive practice that has been proven quite effective on rangelands of several continents is to provide stock with mixed salt-mineral mixtures rich in phosphates. A more sophisticated practice is the addition of soluble phosphate compounds to drinking water. Correction of phosphate deficiency by any means results in more effective utilization of forage; it improves reproduction and growth of grazing stock.

The calcium and magnesium content of forages grown on acid soils in humid regions may be deficient from the standpoint of livestock needs, but this is less likely to occur in semi-desert or savanna grasslands. The content of certain essential "trace" elements needed in very small amounts by both plants and animals may be below acceptable levels in forages. These deficiencies result from the soil's low content of such "trace" elements as boron, zinc, copper, molybdenum, manganese, and iron. Cobalt also is highly essential for livestock, but not for plants.

As the inherent deficiences of specific soil areas for individual "trace" elements are identified, their correction may make spectacular improvements in the vigor and productivity of the grazing livestock. Some soil areas are deficient in one element; and others have different deficiencies. In some regions where "trace" element deficiencies were suspected but not individually identified, the supplying of a mixture of all essential trace elements in a general purpose mixture with salt has produced great improvement in livestock performance, and resulted in more efficient use of available forages.

In general, the leguminous forages tend to be richer in all minerals that are essential for livestock, as well as being higher in protein content, and generally are more palatable and nutritious than other types of forage. Those management practices that foster an increase in forage legumes in the available herbage generally improve the value of the feed for support of livestock. This is so important that in some regions (Australia, for example), the entire grassland improvement program is built around the forage legume component.

The most sensitive segment of livestock herds to any nutrient deficiencies (protein, phosphorous, calcium, magnesium, and the "trace" elements) are the breeding females, lactating animals, and young stock. The rates of conception and reproduction, growth of the young while nursing, and weight gains after weaning are significantly improved by access to feeds with adequate mineral content. Older animals are less affected.

5. Overstocking and overgrazing.

Overgrazing that weakens the forage producing capacity of grasslands is caused by failure to estimate the amounts of forage that will normally be produced by lands in the climatic zone where located, and insistence on carrying larger herds and flocks than may be adequately fed on a yearround basis. This practice is less ruinous in cycles of increasingly adequate yearly rainfall. The greatest penalty comes in cycles of decreasing rainfall, when feed supplies fail and stock starve and die, or succumb to diseases, or stock become emaciated and finally are sold at ruinously low prices. The breeding herd always suffers the greatest losses.

The question may well be asked: Why are livestock populations not kept in a more rational balance with forage supplies? To some extent, the answer is that the principles of sound grassland management have not been transferred to less developed countries. A more fundamental reason is that the herders have no firm attachment to specific grazing lands. These lands are open to all, and the herders vie with others to put stock on grasslands and consume it before others arrive. The competition occurs without regard to the resulting long-term damage to forage producing power of the lands.

Any undertaking to improve the productivity of rangelands and other permanent grasslands for the support of livestock enterprises must not only invoke sound technology but also provide incentives to the people directly involved. Methods must be developed for providing a continuing proprietary association of the using people with the lands needed to support their livestock. The relationship of people to land must be such that the benefits of good management and of improvements and restoration practices will be enjoyed by the people directly concerned; and the penalties for failing to conserve and husband the grassland resources will fall on these same people. This will be a far cry from the present situation where no persons or agencies carry responsibilities for rangelands and other grasslands that are grazed on a communal basis.

It should be possible under the social systems of each country to give specified groups of people (villages, ethnic groups, etc.) prior and exclusive rights to use of well defined grazing land areas, even where ultimate land ownership rests with the government. The government in such cases must accept responsibility for insisting on sound management of these grazing lands to strengthen the economy of the nation, as well as to reduce the hazards of economic disaster for the herdsmen.

6. Lack of stored feeds, and/or reserved grazing lands to support livestock in dry seasons.

Figure 2 in an earlier section, shows the duration of dry seasons, when plant growth ceases. This varies from $7\frac{1}{2}$ to 10 months in semi-desert regions, from 5 to 7½ months in savanna (subhumid regions, from 2½ to 5 months for the wet-dry tropics, and from 0 to 2½ months for the humid tropics. Forage plant growth may continue for a few weeks after rains cease, on certain deep soil types that will store considerable water in the soil profile. For the most part, however, livestock must survive on the scanty forage (usually of low quality) left standing as dried growth. Under these conditions all animals lose weight, females fail to conceive or produce young under nutritional stress, lactation ceases, and prematurely weaned sucklings are stunted.

This problem of herdsmen in tropical and subtropical regions is similar to that of farmers in temperate zones where there are long winter or cool season periods when no plant growth is made. The logical solution is the same in both environments--to harvest and store feeds produced during the growing season to sustain livestock in plant-dormant periods. For poorly understood reasons, this method of supporting livestock with stored feeds during dry seasons has not been recognized in the tropics and subtropics.

It is entirely possible to make hay and/or silage during the plant growing season to sustain animals during dry periods when no new forage is being grown. For the individual herdsmen or farmer, he may either choose to produce stored feeds, or move his stock to regions where feed is available. There is no evident need to follow the common practice of slow starvation. It is not difficult to determine feed requirements per kilo of animal weight for the average duration of the dry season (see later section). This is basic information that might well be provided by government agencies to guide livestock producers.

This does not rule out special relief measures in periods of disasters, when feeds must be moved in to protect starving herds. In such cases, government intervention (with or without external assistance) is required; and it has been found effective to supply concentrated feeds such as oilseed cake or meals, and mineral supplements containing salt, phosphate, and essential "trace" minerals. Relatively small amounts of such feedstuffs enable ruminants to utilize lowgrade roughages that have little feed value otherwise. The goal however, is to prevent disasters by anticipating probable feed needs, and by storing some reserve feed supplies for emergency use.

7. Uncontrolled burning.

Controlled burning to reduce occupation of rangelands by woody bush and scrubby trees may be useful, when it is done under conditions that minimize any damage to desirable forage plants, particularly grasses and herbaceous legumes. However, the yearly burning, that is widespread in savanna lands and occasionally in semi-desert rangelands of the tropics and subtropics, is destructive, and contributes to continuing degradation of such grazing areas. Indiscriminate burning during the dry season is practiced by herdsmen for the sake of the short-term benefits of nutritious green grass that may be grazed soon after the rains begin. When there is no control; fires are started and allowed to burn as long as dry plant material is available.

By contrast, controlled burning is allowed when the fire will destroy the maximum of useless woody growth and do the minimum amount of damage to desirable forage species. Fires should be allowed only when winds and humidity are favorahle on the selected areas, and where fire control is made feasible by firebreaks or natural barriers. Controlled burning is beneficial only when it constitutes a conservation measure, and on limited areas to minimize danger to wildlife and domestic livestock. It must be directed by specialists who are skilled in using this drastic practice. It should be prohibited at the hands of herdsmen.

IV. The Elements of Productive Grassland Management.

1. Adjusting livestock numbers to match year-round feed supplies.

a. Identifying available grazing areas. The first requirement is to designate the rangeland areas open to specific herdsmen and their stock. The common practice of allowing any herdsmen who arrive first to use the forage for his herds should give way to assignment of specific grazing lands to designated groups of herdsmen. This is doubtless a government function.

b. Probable feed supplies. The probable forage producing capacity of these specific grazing lands may then be estimated, with revisions each year to adjust to apparent forage plant vigor. The number of animal units authorized to use these grazing lands may then be determined. Some flexibility is permissible if there are supplemental feed sources that the herdsmen may use. For example, if it is determined that the feed supply on a specific rangeland area will carry 100 animal units* for 12 months (or 1,200 animal unit months per year), the herdsmen may graze more animal units for a shorter period, but the total permissible grazing pressure must not exceed 1,200 animal unit months per year. The herd size must be adjusted to stay within the allowable number, by one of several methods, such as removal of livestock to other feed sources, or sale of merchantable stock, and additional reduction if necessary, by culling the breeding herd.

*One animal unit = 1 bovine, or 5 sheep, or 5 goats.

c. Selecting grazing land units for developing a grazing system. Dividing the total grassland area into several sectors, and grazing these in rotation, is a useful method of maximizing feed production and utilization without degrading carrying capacity of the grasslands. The yearly sequence of grazing the several sectors should be rotated, so that every sector will be protected every three to five years for production of seed and seedling establishment. The feeding of salt-mineral mixtures as needed to supplement the grazed forage usually increases the feed value of native plants.

d. Balancing livestock numbers in relation to available feed supplies. The yearly balancing of the grazing animal numbers against actual feed supplies should prevent the prevalent ruinous practice of overstocking that results in degradation of the rangelands, and a decline in reproduction, in growth and in physical condition of the herd. Prevention of such deterioration is feasible; and it is sound economics to avoid the heavy expense involved in restoring grazing land productivity, and in rebuilding a decimated livestock herd after a severe drought strikes an overstocked range.

e. Providing feeds for the dry season. Supplemental feeds may be provided in several ways.

(1) Additional grazing lands are held in reserve without stocking, until such time as they are required to support the herd when normal grazing lands are not sufficient.

(2) Feeds maybe grown and stored as hay or silage, on lands not included in the grazing areas. These can be used for breeding herd and young stock in periods of feed shortage.

(3) Crop products (stalks, vines, straw, screenings) may be saved and fed.

2. Providing mineral supplements to native forage.

Native forages are very often deficient in the essential minerals required by livestock for normal reproduction and growth. The improvement in overall performance of livestock herds is frequently quite outstanding when mineral supplements are fed. Thus, on the Llanos of eastern Colombia, the following mineral mixture has been proposed:

	Compound	Percent by Weight
blended mixture	Salt	47 percent
	Dicalcium phosphate, or bone meal	47 percent
	Minor element mixture	6 percent
		100 percent

The minor element mix contained the following: copper sulfate - 1.95%, iron sulfate - 5.00%, zinc oxide - 1.24%, magnesium sulfate - 3.09%, cobalt sulfate - 0.20%, potassium iodide - 0.07%, and ground cereal grains (to provide volume) - 88.45%.

The mineral mix was offered to stock at a considerable distance from the watering point, to avoid abnormal consumption in harmful amounts.

This Colombia mixture was a general purpose mixture formulated without specific information as to which trace elements might be seriously deficient. However, it may be assumed that phosphate is widely deficient in forage on grasslands of the semi-desert and subhumid regions. Dicalcium Phosphate was used as a source of phosphate since bone meal was not available.

3. Rotation grazing to permit forage growth periods for natural restoration of vegetative cover, on a regular sequence.

When specific herdsmen are assigned well-defined grassland areas for their sole use, then it becomes feasible to establish a pattern of rotating the grazing herd over the available areas. By dividing the total areas into four or more sectors, the livestock herd maybe grazed for a few weeks on each sector in rotation. This provides every sector with a rest period for regrowth. If the season when rains occur, for example, is four months, the grazing herd should not be kept on any single sector for more than one month. The concept is to control grazing pressure so that all sectors are used about equally during the full grazing season.

It is highly desirable to select a different sector each year, for protection from grazing throughout the entire growing season so that natural seed production and seedling establishment can occur. It is desirable that each sector be protected in this manner for natural rejuvenation about once every three to five years. Experience on several continents has shown that forage production and livestock carrying capacity can be markedly increased by this practice.

4. <u>Prohibit uncontrolled burning of all grassland, and invoke other methods of controlling undesired vegetation.</u>

a. The motive for uncontrolled burning will largely be removed when management practices increase feed supply, and the stocking rate is adjusted to current feed supplies. Providing the necessary mineral supplement also is helpful.

b. Any burning to reduce invasions of the rangeland by woody shrubs and scrub trees, as well as reduction of other useless vegetation, should be done under carefully controlled conditions as noted in section III.7. Controlled burning also is a useful practice in preparation for introduction of promising new grasses and forage legumes.

c. Other methods of reducing the abundance of undesired vegetation may include tractor bulldozing or root plowing, hand grubbing of sparse stands of invading species, and the application of herbidide chemicals by ground applicators or by aerial application. Each of these methods is costly and should be undertaken only under recommendation by qualified specialists, and with close supervision by a qualified expert.

d. Before undertaking costly control methods, it would be prudent to make limited field trials of the proposed practices and materials, to determine their effectiveness as well as costs. It is clear that any costly practices should be limited to land areas having favorable soil conditions for growth of forage grasses and legumes. The benefits to be derived from controlled grazing to limit invasions of useless vegetation may be evaluated at low cost, and more expensive methods should be undertaken only as a supplement to controlled grazing.

e. Browse forage plants. It must not be assumed that palatable nutritious forage consists solely of grasses and herbaceous legumes, particularly in regions of limited rainfall. Browse plants include a wide variety of low-growing species with woody main stems, but which have palatable leaves and finer stem branches. Cattle make little use of such browse, but sheep, goats and camels may subsist quite well on palatable browse alone. There are marked differences between browse species, and the management practices should be designed to foster the better species.

Browse is important in desert ranges for feed production on land areas in runoff channels that are normally dry, but contain water-borne sediments (sand and silt). Where these alluvial sediments have appreciable depth, they act as reservoirs for runoff water, and browse plants make intermittent growth throughout the year, drawing on water stored in these sediments from occasional rains.

It is obvious that useful browse plants should not be regarded as undesirable woody vegetation in situations where grasses and forage legumes are not well adapted. Browse plants are usually native species, but there may be substantial opportunities for introducing superior species from other continents or regions, such as mesquite (Prosopis species) from North America, and reintroducing browse forage species that were once present but have been destroyed by over-grazing.

5. Adoption of management practices to protect against wind and water erosion, and to improve water conservation in regions of limited rainfall.

a. A comparatively dense cover of grasses and forage legumes on the land provides the best protection known against soil erosion from rainfall runoff, and against wind erosion. A ground cover of grasses and legumes, also is the most effective method yet found for increasing infiltration of rains into the ground surface, and of holding it in the soil profile for use by plants for as long as it lasts. Further, water losses from the soil by direct evaporation, and by transpiration from leaves of plants is reduced by a grass-legumes cover on the soil. In general, the most effective use of water stored in the soil profile for production of usable forage for livestock is that provided by a strong growth of forage grasses and legumes composed of species that are adapted to local climate and soil. Such plant cover is more efficient in use of water to grow forage than is true of brush and scrub trees. Where forage grasses and legumes are not adapted and do not survive in semi-desert regions, the browse plants may constitute the most efficient species for livestock support (See item 4.e.).

From the foregoing, it is evident that maintenance of a strong grass-legume cover will result in the most efficient use of rainfall in semi-arid and subhumid regions. Where overgrazing and other harmful management practices have denuded the land, the re-establishment of a grass-legume cover on the land should result in retention and utilization of rainfall that currently runs off and is lost, and produce the growth of forage in greater abundance than now occurs. It must become clear to the herders who use the land, that it can be made much more productive by prudent management.

When this relationship has been demonstrated by practical field trials, the users may then be persuaded to avoid over-stocking and to practice rotation grazing so that all range areas are allowed periods of "resting" and re-growth. This means that the herdsmen must focus attention on the land and forage supply and the means for protecting and nurturing it.. It should become clear that the success of livestock enterprises depends on both the protection of land and forage resources and on the welfare of his livestock. The outlook for successful livestock enterprises without stabilized supplies of feed is forbidding. For herders in semi-arid and subhumid regions, this basic dependence of livestock on feed supplies is emphasized with every recurring drought.

b. Waterspreading is often a useful practice in both subhumid and semi-arid regions, as a means of controlling rainfall runoff that would otherwise be lost. By this practice, runoff water is diverted from stream channels or drainage courses that are normally dry but have flowing water after rains occur. The water spreading may have two functions: (1) increasing forage production by spreading the water over nearby smooth sloping land so that it infiltrates and is stored in the soil profile, and (2) reducing gullying and downstream flooding. Rangeland flood waterspreading systems are constructed so that operation is automatic whenever storms result in flood flows. The gentle slopes into which directed water is led should have fairly permeable soil to depths of 30 cm. or greater. Grades of 1 to 2% are preferred, but grades of 5% may be used if the soil is highly permeable. The water spreading system must be constructed to fit the local terrain. The essential features are a diversion barrier or berm and a system of meandering channels and dikes to direct the flow gradually down slope with sufficiently slow flow to allow infiltration into the soil profile. Dikes and/or furrows are placed to facilitate spreading on the area selected. Design of the water spreading system is best prepared by an agricultural engineer, particularly where costs of construction will be substantial. However, simple but effective waterspreading systems are found in some primitive regions, that have long been used both for crop production on limited areas, and for forage production. On well-designed systems, increased forage production has varied from three- to ten-fold where several natural floodings occur yearly.

c. Terracing to retain water on the land is feasible under some conditions. As in the case of waterspreading, runoff water is intercepted in the stream-bed, and is directed to a series of terraces that are stair-stepped down the slope. Dikes at terrace borders direct the flow across the slope to the entrance of the next terrace, and thence from terrace to terrace down slope. The design of such a system calls for technical expertise, and is warranted only where both the rainfall pattern and the soil type are such that increased production will exceed the cost when prorated over a period of years. Well-established sod of forage grasses and legumes should require very little maintenance effort, when the system has been established. This may be an important means of providing supplemental feed for livestock, that is not available otherwise.

6, <u>Introducing superior forage species on rangelands and other permanent grasslands to improve forage yields and nutritive values.</u>

a. <u>Adapted grasses and legumes for different rainfall zones.</u> The species of forage grasses and legumes now present in rangelands and other permanent grasslands are those native to the region, that have survived under conditions of overgrazing and competition with unpalatable and woody types of plants. Restoration of indigenous useful forages maybe fostered by better control of stocking rates, periodic resting of areas to permit natural seeding and seedling establishment; supplemented by positive methods of reducing undesired vegetation. These methods, while useful, do not exploit the opportunities for introducing superior forage species from other regions with similar climates and soils, that have proven to have outstanding values under similar types of land use.

The opportunity to establish productive forage legumes along with additional adapted forage grasses gives unique significance to the practice of introducing new species in rangelands and other permanent grasslands. Perennial forage legumes have substantial potential for adding to the protein and mineral content of the forages, and also contribute strongly to residual soil nitrogen that stimulates grass growth. Field experience in various other tropical countries has demonstrated substantial improvements above native forage, by these means. The following superior forage grasses and legumes have promise for the tropics and subtropics: (See appendix tables for information on forage species.)

(1) For dry regions having 10 to 25 inches (250-625 mm.) yearly rainfall.

	Common Name	Botanical Name
(a) Forage legumes	Dwarf koa	Desmanthus virgatus
	Leucaena	Leucaena leucocephala
	Lucerne	Medicago sativa
	Stylo	Stylosanthes guyanensis
	Townsville Lucerne	Stylosanthes humilis
(b) Forage grasses	Birdwood grass	Cenchrus sitegerus
	Buffel grass	Cenchrus ciliaris
	Bluepanic grass	Panicum antidotale
	Love grass, Weeping	Eragrostis curvula
	Love grass, Lehmann	Eragrostis lehmannania
	Makarikari grass	Panicum coloratum makarikariense
	Yellow bluestem	Bothriocloa ischaemum

(2) For subhumid regions having 30 to 40 inches (750-1000 mm.) yearly rainfall.

	Common Name	Botanical Name
(a) Forage legumes	Centro	Centrosema pubescens
	Glycine	Glycine wightii
	Greenleaf	Desmodium intortum
	Lotononis	Lotononis bainesii
	Phasey bean	Macroptilium lathyroides
	Silverleaf desmodium	Desmodium uncinatum
	Siratro	Macroptilium atropurpureum
	Stylo	Stylosanthes guyanensis
(b) Forage grasses	Alabang grass	Dicanthium caricosum
	Angelton grass	Dicanthium aristatum
	Bermuda grass	Cynodon dactylon
	Carib grass	Eriochloa polystachya
	Dallis grass	Paspalum dilatatum
	Guinea grass	Panicum maximum
	Harding grass	Phalaris tuberosa stenoptera
	Molasses grass	Melinis minutiflora
	Pigeon grass	Setaria sphacelata
	Plicatulum grass	Paspalum plicatulum
	Rhodes grass	Chloris gyana
	Scrobic grass	Paspalum commersonii

(3) For humid regions with 40 or more inches (1000 mm.) yearly rainfall.

	Common Name	Botanical Name
(a) Forage legumes	Calopo	Calopogonium mucunoides
	Centro	Centrosema pubescens
	Lablab	Lablab purpureus
	Silverleaf desmodium	Desmodium uncinatum
	Siratro	Macroptilium atropurpureum
(b) Forage grasses - Propagated by seed	Alabang grass	Dicanthium caricosum
	Angleton grass	Dicanthium aristatum
	Bahia grass	Paspalum notatum
	Carib grass	Eriochloa polystachya
	Molasses grass	Melinis minutiflora
(c) Forage grasses - Propagated vegetatively	African star grass	Cynodon plectostachys
	Cynodon hybrids	Cynodon spp. (Bermuda grass hybrids)
	Elephant grass	Pennisetum purpureum
	Imperial grass	Axonopus scoparius
	Kikuyu grass	Pennisetum clandestinum
	Palisade grass	Brachiaria brizantha
	Pangola grass	Digitaria decumbens
	Para grass	Brachiaria mutica
	Signal grass	Brachiaria decumbens

7. Correcting mineral deficiencies in soils of rangelands and other permanent grasslands.

There are two points of view in dealing with soil nutrient deficiencies: (1) the deficiencies affecting plant growth, and (2) those that affect performance of livestock. The simple production of more forage is useful where its nutritive content meets animal needs. However, there is good evidence that some plants may make substantial growth as to dry matter, but of such low content of protein and essential minerals that the feed has limited nutritive value. This situation is widespread on both dry ranges and humid pasture.

a. Low protein forage. Much standing dry forage on dry grazing lands is so low in protein content (6% or less) that the energy feed constituents cannot be utilized beyond the available protein, even though eaten and passed through the animals digestive tract. The fostering of forage legumes in grazing lands, where feasible, is the most efficient way of supplying the necessary nitrogen (made available through root nodules) for stimulating growth of associated grasses, as well as for meeting the protein needs of grazing livestock. The alternative to fostering growth of legumes in grazing lands is to provide supplemental protein concentrate feeds particularly to the breeding herd and young stock. Increasing legumes in the forage is the preferred method in most situations.

b. Mineral deficiencies in soils of rangelands in semi-arid and subhumid regions. Phosphorus is widely deficient in such soils, and consequently in the forages grown on them. This deficiency may be great enough to hamper growth of legumes, even though most tropical forage legumes have stronger "feeding power" for soil phosphorus than temperate zone forage legumes. The magnitude of the soil phosphorus deficiency should be evaluated when introduction of new legumes in grasslands is contemplated. It may be necessary to apply phosphate fertilizer in preparation for seeding such legumes. Wherever the phosphorus content of forage is deficient for livestock, it may be necesary to supply supplemental phosphorus in a mineral mix (with salt) as a positive measure. This can meet livestock needs, in an inexpensive way even though the need for phosphorus by legume forages is not met.

In humid regions deficiencies in soil calcium, magnesium, potassium and sulfur are often found, and these adversely affect growth of forage legumes, as well as the performance of grazing livestock. In general, soil amendments are needed to correct these deficiencies so that legumes can be grown successfully, and these will also more nearly meet nutritional needs of livestock grazing on such forage. Low grade forage (wiry grasses and weeds) will grown on soils deficient in these minerals, but nutritive values of such forage are insufficient to support breeding stock and young animals even when total feed volume appears adequate. Fortunately, for virtually all soils (except some sands) in the semi-arid and subhumid regions, calcium, magnesium, potassium and sulfur are adequate for both forage plant growth and for grazing livestock.

Trace element deficiencies are not uncommon in tropical and subtropical soils, both in regions of limited rainfall, and in humid regions. These deficiencies may involve only one, or several "trace" elements. These elements are required in very small amounts by both plants and animals, which accounts for the term "trace" elements. The elements are boron, zinc, molybdenum, copper, manganese, and iron. To these, must be added cobalt which is a requirement for animals, but not for forage plants. The correction of these deficiencies for livestock is easily accomplished by including small amounts of all of them in a salt-mineral mixture. However, when these deficiencies affect plant production, it becomes highly desirable to identify the specific soil groups in which individual deficiencies occur, and to develop practices to correct them. An example is provided in Australia where a large region that was quite unproductive responded quickly to a few grams of molybdenum per hectare, to produce abundant growth of a nutritious forage legume.

The identification of trace element deficiencies and development of practical methods for their correction is closely tied-in to the establishment and growth of legumes. Forage legume species differ in their ability to extract trace elements from soils. At least one legume species is capable of extracting copper from a deficient soil, and will succeed when others fail.

Because the general knowledge on the occurrence of trace element deficiencies in soils of the tropics and subtropics is still fragmentary, it would be desirable to mark this as a fruitful area for investigation wherever forage legumes are unthrifty. The differences between the capabilities of different legume forages to extract trace elements from the soil, also needs more study to enable better matching of legume with kinds of soils. Fortunately, when the nutritional needs of forage legumes have been met, the mineral needs of livestock feeding on them also will be less critical. The exception is cobalt which is uniquely required by livestock, and must be supplied whenever deficient.

8. Preparations for introducing superior forage species in grazing lands.

The introduction of superior forage grasses and legumes that are adapted to specific ecological zones offers great promise, when accompanied by other improved management practices. The simple broadcasting of seed on unprepared land is not a dependable means of improving forage production. However, there have been notable successes in various regions when the situation is carefully surveyed and practical preparations are made.

a. Control of brush and trees. Wherever the grazing lands (rangelands or other permanent grasslands) are overgrown with trees, brush and other unpalatable vegetation, the reduction of this growth is necessary to provide opportunity for new seedings to become established. Practical methods might consist of (1) controlled burning under favorable conditions just prior to the rainy season, (2) use of selective herbicides applied as sprays or granules at seasons when the offending species are vulnerable, and (3) hand or machine grubbing. Any taller growing undesirable species should be reduced, so that adequate sunlight will reach the forage seedlings, and to reduce water consumption by the useless species.

b. Mineral requirements of forage species. The ability of the forage species being introduced, to meet their nutrient requirements from the soils present on areas to be seeded, should be considered. Particular attention must be given to the mineral needs of the seeded legumes. The legumes have more specific needs than the grasses, and the presence of legumes will provide nitrogen for the grasses, as well as increase the nutritive value of the forage. Some legume species are known to have strong "feeding power" for slowly available major nutrients (phosphate, calcium, magnesium, potassium, sulfur), and for the "trace elements" (zinc, molybdenum, boron, copper, iron, manganese). Chemical testing of soils to detect any deficiencies is easily done, and such tests have already been made on some major soil groups. Since the application of fertilizers and soil amendments may be quite expensive, it is important to learn which soil nutrients are actually in deficient supply.

For many situations, the mineral nutrient needs of legumes seeded in grasslands may be satisfied by the convenient and inexpensive practice of "pelleting" the seed by adding small amounts of deficient mineral nutrients to an adhesive and mixing this with legume seed just before planting. Such pelleting is compatible with inoculation of seed with the specific strains of nodule-forming bacteria that are needed to make the legume plants independent of soil nitrogen supply.*

*For more complete details on pellet[illegible] legume seed, see section B-5 in Technical Bulletin No. 12, "The C[illegible]ibution of Legumes to Continuously Productive Agricultural Systems f[illegible] the Tropics and Subtropics," published Jan. 1975 by Office of Agriculture, Technical Assistance Bureau, Agency for International Development, Washington, D. C. 20523.

On soils that may be markedly deficient in one or more mineral elements, such as often occurs in humid regions, it may be necessary and economically effective to broadcast the fertilizer and work it into the surface soil by some form of light tillage. For sub-humid (savanna) and semi-arid or semi-desert regions, phosphate is the most commonly deficient element. Where surface tillage is impractical, broadcasting the fertilizer on the ashes of burned areas before the onset of seasonal rains, may prove sufficient to establish and maintain forage legumes. Because of the variability of soils and climatic conditions in different regions, there is need to test the applicability of the optional methods on test areas before undertaking larger scale operations.

g. Seeding practices.

(1) All legume seed should be inoculated with the appropriate strain of root-nodule bacteria, just before planting. Seed suppliers normally are prepared to supply bacterial cultures for the species of legume seed being sold, together with instructions for treating the seed. Treated legume seed should be planted promptly. Where burning has been done, planting in the fresh ashes may provide sufficient coverage if rains occur soon thereafter. In more humid regions, seeding should be accompanied by light tillage so that seed will be covered by the next rain.

(2) A legume-grass mixture of species with compatible growth habits, adapted to similar rainfall zones, should be formulated (see appendix tables), and seed supplies brought to hand. Planting time is exceedingly important. The most favorable time is just at

the beginning of a season when rains normally occur, to foster prompt germination and rapid seedling establishment. Small seeded species require shallow planting. Larger seeded legume species require seed placement at 1 to 2 cm. depths to insure germination and seedling survival.

Since virtually all seeding of rangelands and other permanent grasslands in all soil and climatic zones involves non-arable lands, any tillage in conjunction with planting must be achieved through special means that are feasible under local conditions. Therefore, every effort should be made to take advantage of seedings made when moisture is adequate, on fresh ashes after burning, or any other means of placing seed so that germination and seedling establishment will be fostered. Legume seedlings are more sensitive than grasses to moisture deficiencies; and practices that insure legume establishment will almost surely be adequate for the grasses in the mixture. Should weather be unfavorable for the legumes, the grasses will probably survive.

d. Planting methods. Broadcast seedings of small amounts of seed, such as 5 to 10 kg. per hectare, require special care. The first step is to mix the seed with a large volume of a carrier substance, up to 20 volumes of carrier to 1 volume of seed. The carrier may be fine-texture plant material such as rice bran, or finely ground meal of a grain. A third choice might be screened, moist, fine-textured soil. Sand is not desirable, for it is too heavy. The seed and carrier should be well mixed just before planting; mixing the seed for each hectare separately. Broadcasting the mixture by hand calls for careful manipulation, and there should be preliminary practice using the carrier material without seed. Practice a sweeping motion, using the thumb and fingers to release small portions of a handful on the outward sweep and a small portion on the return sweep. There are small "whirlwind-type" broadcasting machines that are hand operated, and capable of adjustment to release metered amounts of seed. These inexpensive machines give reasonably uniform distribution.

The intent is to establish substantial propulations of the introduced species on the initial seeding. With careful management, these initial plants will seed and spread to thicken the cover of improved species in successive years.

9. Management of renovated grasslands.

There is no useful purpose in introducing superior forage species if the new plantings are not protected from overgrazing and other mismanagement that would decimate the new species. Since the total feed production and feed quality will be substantially improved on renovated grasslands, the herdsman does not suffer by providing adequate protection. The greater productivity should be evident in the first year, and improve much more in the following two years where successful introductions have been made. Some localized failures due to erratic rainfall or infertile soil areas may be expected, but these should not deter campaigns to introduce superior forage species.

The young growth made by introduced plants is highly palatable. All grazing of newly seeded areas should be prohibited until the new species have produced a crop of seed. Further protection need only be that provided by normal good management to maximize forage production on a continuing basis.

V. Measuring Productivity of Rangelands and Other Permanent Grasslands.

1. Estimating forage production during season of active growth.

Estimates of the forage production capacity of grazing lands are essential to guide the most effective grazing practices. These estimates may be in terms of actual forage produced annually per unit of land area, corrected to the amount that can safely be removed by grazing without depressing vigor of the forage species in the following growing season. The percentage of total forage that may be removed by grazing varies some with species and with climatalogical zones. When estimates have been made of total usable forage per hectare, per year, it is then feasible to predict the number of animal units that may be supported by the forage producing areas available.

The basic principle is to never permit grazing to remove so much of the tops of desirable forage plants that there is impairment in plant food manufacture and storage. This storage is necessary to maintain vigor and regenerative capacity in both root systems and top growth. The leaf area and roots must be fully functional during the remainder of the growing season after grazing terminates. The amount of top growth that can be safely used by grazing probably should not exceed 1/2 to 2/3 of the total growth made during the growing season.

With estimates of available forage at hand, it becomes necessary to determine whether the grazing herds must be supported for the entire year, or whether some or all of the livestock can be moved to other feed sources for part of the year. Such planning has in view the sustained maintenance of all stock, without prolonged periods of starvation that are common in many regions. Seasonal deprivation severely depresses productivity of the livestock, and wastes much of the forage they have consumed during the useful grazing period. These losses and wastes should be avoided by advance planning and implementation.

2. Methods of estimating available feed supplies.

a. Sampling the standing forage plant growth

An initial step is to estimate the equivalent air-dry weight of the forage grasses and legumes that are present on available grazing lands. This may be done by sampling, using small measured strips, each being about 10 meters long and 0.5 meter wide (total area = 5 square meters). There should be at least 20 ch strips randomly distributed over the range area so as to be representative of the grazing area. Twenty strips would amount to 100 square meters. For large range areas, the number of samples should be increased.

When the harvested forage on sample areas is air dry, determine the weight and express this in kilograms per hectare. Twenty samples is 1/100 of a hectare, and thus the total dry weight is multiplied by 100 to give an estimate of dry forage per hectare.

From the amoun air-dry forage required for meeting feed needs for animal support, it is then possible to determine the hectares of range land required per animal unit, to provide feed for 1 month, or 6 months, or a full year. This method may serve as the national basis for determining stocking rates of range land.

For example, if the forage yield from 20 representative samples totaled 1 kilogram, then each hectare should produce 500 kg of feed (on air-dry basis). Such a range area would require 4 hectares to produce enough feed to carry one bovine animal unit for 1 year, if this is the only feed available. Actually, many rangeland areas are less productive than this; and 15 to 20 hectares may be needed to support each bovine animal unit for a full year.

b. Supplemental feeds

In the event that supplemental feed may be provided in the dry season from crop by-products (stalks, vines, etc.), the yield of such feeds also should be estimated. Also, if standing forage on separate grazing lands will be available to carry ruminants through the dry season, such forage should be estimated, so that total forage supplies from all sources may be estimated for comparison with feed needs of all ruminants (cattle, sheep, goats) per year.

3. Predicting seasonal forage production on the basis of rainfall.

In semi-desert and subhumid regions where total rainfall fluctuates substantially from year to year, it is useful to determine the average plant growth response to greater or less rainfall than normal. For this purpose, it is necessary to compile records of forage growth made with rainfall experienced in the local region. When the seasonal response of plant growth in proportion to the amount of rainfall has once been estimated in terms of kilograms of forage per hectare, for different amounts of cumulative rainfall, predictions are possible as to feed resources to be expected for the season at hand. Predictions, at the close of the rainy season, made for the ensuing months of the dry season, can be estimated in time to make the necessary plans for adjustments in livestock numbers to be supported, either by use of reserved grazing lands, or by use of supplemental harvested feeds, or by sale or movement of livestock before serious weight losses or declining well-being of the herds and flocks occur.

VI. Estimating Feed Requirements of Ruminant Livestock in Tropical and Sub-Tropical Regions.

Precise information is generally lacking for a specific region, but general criteria may be formulated from fragmentary data in a few instances, supplemented with more compre..ensive evaluations from rangeland livestock in the dry temperate zone regions.

For convenience, guidelines as to nutrient requirements of ruminant livestock (particularly cattle, sheep and goats), may be expressed in daily and yearly feed requirements expressed in total dry weight of forages consumed, and in the animal needs for total digestible nutrients (TDN), and crude protein.

1. Feed requirements for cattle.

a. For mature cattle

	Total Dry Matter		Total Digestible Nutrients (T.D.N.)	Crude Protein
Feed maintenance requirement for animals weighing 300 kg. (average)	Daily kg.	Yearly kg.	Content pct.	Yearly kg.
	4.5-5.0	1700-1800	50%	100-110

b. For young cattle (1 to 3 years of age)

Reduce per animal feeds to 70% of mature animals, to support limited growth.

c. For lactating cows

Increase nutrient requirements above maintenance by 1/3 or more, depending on milk flow.

When feed allowances are deficient, for shorter or longer periods, livestock will lose weight in proportion to the extent of nutrient deficiencies. Regaining lost weight can only occur when feed supplies are more abundant than minimum maintenance requirements.

2. Feed requirements for sheep and goats

It is generally assumed that 5 sheep or 5 goats in tropical and sub-tropical regions have a feed equivalent to 1 fully grown bovine (beef) animal. Thus:

	Total Dry Matter		Total Digestible Nutrients (T.D.N.) Content	Crude Protein Yearly
	Daily kg.	Yearly kg.	pct.	kg.
Maintenance requirement per sheep or goat	0.9-1.0	320-330	50%	20-25

For growing lambs and kids (up to 1 year age); reduce per animal feeds to 70% of mature animals, to support growth.

For lactating females; increase feed supplies above maintenance by 1/3 or more, depending on milk flow.

Under deficient feed regimes, milk flow is curtailed or stopped, and weight losses occur. Regaining weight losses is possible only when feed supplies are more than adequate for body maintenance.

Sheep and goats have an advantage over cattle, in their use of browse plants (shrubs, bushes and other non-herbaceous vegetation) that are generally not consumed by cattle. The leaves and small branches of browse plants are richer in total digestible nutrients and in protein than mature grasses. Thus, seasonal deficiencies in total feed and digestible nutrients are less serious with sheep and goats than for cattle on dry range, because of these differences in grazing habits.

3. Feed values of edible forage plants.

Nutrient content (and feed value) of forage plants is determined by the content of digestible nutrients, by the protein component, and by the adequacy in supplies of essential mineral elements. Since mineral supplements may be provided separately from forages, it is convenient to use two principal factors in estimating feed value; total digestible nutrients (T.D.N.), and protein content.

In calculating available feed supplies for grazing livestock the following averages may be utilized in converting the yearly production of plant herbage into animal support.

Mature tropical grasses may be assumed to contain about 50% T.D.N., and 4.0 to 6.0% crude protein.

Perennial range legumes may be assumed to contain about 60% T.D.N., and 12 to 15% crude protein.

Browse plants generally are more nutritious than grasses, but less so than forage legumes.

The forage supply on rangelands tends to be deficient in protein content in the long dry seasons that are typical of rangelands; as well as being chronically inadequate in total amount of edible forage.

4. Relative feed values of growing forage plants on rangeland and pastures, and of mature plants

While the volume of forage per hectare is much smaller during the period of flush growth following the onset of rains, than is achieved at plant maturity, the nutritive value per kilogram of mature forage is much lower. When converted from fresh weight to the air dry basis, the relative nutritive values per kilo of dry weight may average as follows:

	Air-Dry Averages	
Type of Forage	Total Digestible Nutrients (T.D.N.)	Crude Protein
Rapidly growing immature forage	65%	10-15%
Mature forage plants	50%	4.5-5.5%

The immature nutritious forage permits good milk flow of lactating females, and growth of calves, lambs and kids. It also permits rapid recovery of weight losses of older animals that have survived the dry season when feed ratios were inadequate for sustained maintenance. However, the prudent herdsmen must recognize that this favorable season will be followed by a very long dry period when no new plant growth is made; and survival, or economic animal production must depend on standing dry forage reserved for this season, or on crop by-products, or on harvested and stored forages.

5. Feed value of crop by-products.

In many regions, the by-products of local crop production serve as supplemental feeds for livestock during the dry season when little or no plant growth is being made by rangeland forage grasses, legumes or browse plants. The amount of crop by-products that may be available, and their nutrient content are important factors in livestock enterprises, whether utilized by the farmers for their own livestock, or made available to non-farming herdsmen.

The following aspects of the nutritional value of representative types of crop products illustrated the significance of such feed types:

Type of Feed	Total Digestible Nutrients (T.D.N.)	Crude Protein Content
a. Stover (stalks & leaves) of millets, sorghum, and maize	50-55%	3 to 5%
b. Straw of cereal grains (wheat, barley, rice, etc.)	30-45%	3 to 5%
c. Vines of grain legumes (groundnuts, cowpeas, soybeans, etc.)	55-60%	10 to 20%
d. Other crops:		
sugar cane tops & leaves	55%	4.0%
cottonseed hulls & stems	45%	4.0%
e. Grass hays (mature)	50%	4 to 8%
Grass-legume hays	50-60%	10 to 15%

6. Balancing livestock numbers against total yearly feed supplies.

Falure to provide adequate livestock feed throughout the entire year, gravely reduces the possible income from any livestock enterprise. Growth and weight gains cease when feed supply is inadequate; and weight losses are regained very slowly when feeds are again more adequate. Reproduction is seriously reduced or prevented by seasonal starvation. Lactating females (cows, goats or sheep) quickly cease milk flow under deficient feed supplies, with adverse effects on growth and survival of suckling young animals, causing deprivation of farmer and herder families that depend on milk as a food.

There is no relief from the evil effects of deficient feed for livestock, to be gained by increasing livestock members. The most appropriate management of livestock enterprises is to adjust the size of livestock herds to the animal numbers that can be adequately sustained with available feed on a 12-month basis. When this principle is recognized, suitable livestock enterprises may become a major factor in fulfilling family food needs, and in providing dependable net incomes for marketable production that is surplus to family needs.

The yearly supply of livestock feed should include all available sources, including (a) grazing lands that are reserved for dry-season feed, (b) forages that have been harvested and stored during the plant growth season for feeding in dry seasons; (c) crop by-products that may be conserved and utilized in the dry-season, and (d) any local surplus feeds that may be purchased for feed supplements. Livestock production is most profitable when the number of animals to be fed is no greater than the feed supplies that are available. Various knowledgeable livestock experts have estimated that the potential for livestock profitability in the tropics and sub-tropics may be enormously increased by maintaining a balance between livestock numbers and available feeds. The choices of the manager include (1) greater efforts to increase feed supplies, or (2) disposal of excess animal units, to stay within the total feed potential. Profitability is not the result of total animal numbers, but of the performance of well-managed herds and flocks. Livestock offtake (live animals, meat and milk) often may be increased by 100% by application of known technology and practices that maximize use of natural resources to support livestock production.

VII. Conclusions

1. On the basis of experience in certain developed countries of the tropics and subtropics, there is justification for believing that very substantial increases in productivity of ruminant livestock is widely feasible, by application of known principles and practices in feed production, in livestock management, and in efficiency of marketing live animals or their products.

2. There appear to be important opportunities to improve the management of natural resources of land, climate and vegetation, when firm associations of lands with land users are arranged and legalized by government edicts. In regions where communal grazing of herds and flocks prevails, there should be an extension of responsibility for allocation of grazing rights by the village or tribal leaders, so that the livestock owners are entitled to prior and exclusive use of designated grazing lands. This would be similar to the allocations of croplands to families in village or tribal groups, which now is customary. In Moslem countries, there is ample precedent, stemming from the Koran, for communal control of grazing lands. With such control, the management and improvement of grazing lands become feasible, and profitable to the users.

3. The average feed requirements for growth and reproduction of different classes of livestock are rather well established. Also, methods for estimating the total forage produced on grazing lands have been established in some tropical and subtropical countries; and these are believed to be widely applicable. These criteria provide essential information

needed for rational management decisions and practices that should result in significant increases in productivity of livestock enterprises to the benefit of the individual herders and farmers, as well as to the economic viability of the nations.

4. Specific programs for particular ecological zones and regions of individual countries will be necessary to more adequately exploit feasible opportunities for enhanced productivity of livestock. These are essential for more complete and adequate utilization of these often neglected lands and forage resources, and to the welfare of the people that depend on their herds and flocks for subsistence and for incomes. The basis for change lies in the existing lands, flocks, and people; and extension of appropriate technical knowledge is a prerogative of national governments.

APPENDIX NO. 1

Perennial Forage Grasses for the Tropics and Subtropics

A. Species propagated by seed.

1. Alabang grass - Dicanthium caricosum
2. Angleton grass - Dicanthium aristatum
3. Bahia grass - Paspalum notatum
4. Bermuda grass - Cynodon dactylon
5. Birdwood grass - Cenchrus setigerus
6. Blue panic grass - Panicum antidotale
7. Buffel grass - Cenchrus ciliaris
8. Carib grass - Eriochloa polystachya
9. Dallis grass - Paspalum dilatatum
10. Green panic grass - Panicum maximum trichoglume
11. Guinea grass - Panicum maximum
12. Harding grass - Phalaris tuberosa, var. stenoptera
13. Love grass (weeping) - Eragrostis curvula
    (a. Boehr lovegrass - Eragrostis chloromelas)
    (b. Lehmann lovegrass - Eragrostis lehmanniana)
14. Makarikari grass - Panicum coloratum makarikariense
15. Molasses grass - Melinis minutiflora
16. Pigeon grass - Setaria sphacelata
17. Plicatulum grass - Paspalum plicatulum
18. Rhodes grass - Chloris gayana
19. Scrobic grass - Paspalum commersonii
20. Yellow bluestem - Bothriochloa ischaemum

APPENDIX NO. 1

Perennial Forage Grasses for the Tropics and Sub-Tropics (Continued)

B. Species propagated vegetatively*

21. African stargrass - Cynodon plectostachys

22. Cynodon Hybrids - Cynodon hybrids

23. Elephant grass (Napier grass) - Pennisetum purpureum

24. Imperial grass - Axonopus scoparius

25. Kikuyu grass - Pennisetum clandestinum

26. Palisade grass - Brachiaria brizantha

27. Pangola grass - Digitaria decumbens

28. Para grass - Brachiaria mutica

29. Signal grass - Brachiaria decumbens

* Usually propagated vegetatively from nurseries planted to seed.

APPENDIX NO. 2

Seed Characteristics and Adaptive Features of Forage Grasses

Grass Species	Seed Quality: Min. Germination %	Seed Quality: Min. Purity %	Seed Size Number per lb. (In thousands)	Seed Size Number per Kg. (In thousands)	Seeding Rate per Acre lbs.	Seeding Rate per Ha. Kg.	Minimum Yearly Rainfall in.	Minimum Yearly Rainfall mm.	Tolerance to Drought	Tolerance to Soil Water Logging
Alabang grass	34	23	*	*	18	20	40	1000	fair	fair
Angleton grass	34	23	*	*	18	20	40	1000	good	good
Bahia grass	50	70	150	336	4 to 6	4 to 7	50	1250	poor	good
Bermuda grass	20	80	1900	4000	6 to 8	7 to 9	30	750	good	poor
Birdwood grass	30	80	80	175	½ to 2	½ to 2	10	250	very good	poor
Blue panic grass	50	80	650	1430	½ to 3	½ to 3	20	500	very good	fair
Buffel grass	30	80	200	440	½ to 4	½ to 4	10	250	very good	poor
Carib grass	30	20	*	*	18	20	40	1000	poor	good
Dallis grass	50	70	220	485	6 to 10	7 to 11	35	875	fair	good
Green panic grass	35	60	880	1900	½ to 6	½ to 7	25	625	good	fair
Guinea grass	35	40	1100	2400	2 to 6	2 to 6	35	875	fair	fair
Harding grass	60	90	300	660	2 to 4	2 to 4	30	750	good	good
Love grass, weeping	80	90	1500	3300	½ to 1	½ to 1	10	250	very good	poor
Love grass, Lehmann	80	90	6800	14950	½ to ½	½ to 1	10	250	very good	poor
Makarikari grass	30	90	725	1600	1½ to 3	1½ to 3	20	500	very good	good
Molasses grass	30	(60)	6000	13200	2 to 4	2 to 4	40	1000	fair	fair
Pigeon grass	30	90	600	660	2 to 5	2 to 5	35	875	fair	good
Plicatulum grass	30	55	385	850	2 to 4	2 to 4	30	750	good	good
Rhodes grass	30	90	1750	3850	½ to 6	½ to 6	35	875	good	fair
Scrobic grass	30	95	170	375	2 to 5	2 to 5	35	875	fair	good
Yellow bluestem	20	25	1400	3000	1 to 2	1 to 2	20	500	good	poor

NOTE: figures in paranthases are estimates.

* Usually propagated vegetatively from nurseries planted to seed.

Appendix Table - 2

Seed Characteristics and Adaptive Features of Forage Grasses

Grass Species	Seed Quality: Min. Germination %	Seed Quality: Min. Purity %	Seed Size, Number per lb. (in thousands)	Seed Size, Number per Kg. (in thousands)	Seeding Rate per Acre lbs.	Seeding Rate per Ha. Kg.	Minimum Yearly Rainfall in.	Minimum Yearly Rainfall mm.	Tolerance to Drought	Tolerance to Soil Water Logging
Alabang grass	34	23	*	*	18	[illegible]0	40	1000	fair	fair
Angleton grass	34	23	*	*	18	20	40	1000	good	good
Bahia grass	50	70	150	336	4 to 6	4 to 7	50	1250	poor	good
Bermuda grass	20	80	1900	4000	6 to 8	7 to 9	30	750	good	poor
Birdwood grass	30	80	80	175	½ to 2	½ to 2	10	250	very good	poor
Blue panic grass	50	80	650	1430	½ to 3	½ to 3	20	500	very good	fair
Buffel grass	30	80	200	440	½ to 4	½ to 4	10	250	very good	poor
Carib grass	30	20	*	*	18	20	40	1000	poor	good
Dallis grass	50	70	220	485	6 to 10	7 to 11	35	875	fair	good
Green panic grass	35	60	880	1900	½ to 6	½ to 7	25	625	good	fair
Guinea grass	35	40	1100	2400	2 to 6	2 to 6	35	875	fair	fair
Harding grass	60	90	300	66[illegible]	[illegible] to 4	2 to 4	30	750	good	good
Love grass, weeping	80	90	1500	3300	½ to 1	½ to 1	10	250	very good	poor
Love grass, Lehmann	80	90	6800	14950	¼ to ½	½ to 1	10	250	very good	poor
Makarikari grass	30	90	725	1600	1½ to 3	1½ to 3	20	500	very good	good
Molasses grass	30	(60)	6000	13200	2 to 4	2 to 4	40	1000	fair	fair
Pigeon grass	30	90	600	660	2 to 5	2 to 5	35	875	fair	good
Plicatulum grass	30	55	385	850	2 to 4	2 to 4	30	750	good	good
Rhodes grass	30	90	1750	3850	½ to 6	½ to 6	35	875	good	fair
Scrobic grass	30	95	170	375	2 to 5	2 to 5	35	875	fair	good
Yellow bluestem	20	25	1400	3000	1 to 2	1 to 2	20	500	good	poor

NOTE: figures in parentheses are estimates.

* Usually propagated vegetatively from nurseries planted to seed.

APPENDIX NO. 3

Major Forage Legumes for the Tropics and Sub-Tropics

1. Calopo - Calopogonium mucunoides
2. Centro - Centrosema pubescens
3. Dwarf Koa - Desmanthus virgatus
4. Glycine - Glycine wightii (G. javanica)
5. Greenleaf desmodium - Desmodium intortum
6. Lablab - Lablab purpureus
7. Leucaena - Leucaena leucocephala
8. Lontononis - Lotononis baineseii
9. Lucerne - Medicago sativa
10. Phasey bean - Macroptilium lathyroides
11. Puero (kudzu) - Pueraria phaseoloides
12. Silverleaf desmodium - Desmodium uncinatum
13. Siratro - Macroptilium atropurpeum
14. Stylo - Stylosanthes guyanensis
15. Townsville lucerne - Stylosanthes humilis

The types of nodule-forming bacteria (Rhizobium species) on most of these species are genetically and physiologically different from those used most successfully on forage legume of temperate zones. Lucerne is an exception.

For a comprehensive list of named varieties of each species, see FAO publication, "Tropical Pastures: Grasses and Legumes." Rome 1971. These varieties (cultivars) often are ecotypes rather than true-breeding types, but have demonstrated adaptation to particular regions. Seed sources are listed.

APPENDIX NO. 4

Seed Characteristics and Adaptive
Features of Forage Legumes

Species	Approximate Seed Quality: Min. Germination	Min. Purity	Seed Size Number Seeds In thousands: lb.	Kg.	Seeding Rates: Acre	Ha.	Minimum Yearly Rainfall: in.	mm.	Tolerance to Drought	to Soil Water Logging
					lbs.	Kg.				
1. Calopo	85%	50%	33	73	1 to 3	1 to 3	50	1250	fair	fair
2. Centro	90	50	18	40	1 to 6	1 to 6	40	1000	fair	good
3. Dwarf Koa	(80)	(70)	(20)	(40)	(2)	(2)	20	500	good	poor
4. Greenleaf Desmodium	90	50	375	755	1 to 2	1 to 2	35	875	fair	good
5. Glycine	90	50	70	154	2 to 5	2 to 5	30	750	good	poor
6. Lablab	90	50	2½	5	5 to 20	5 to 20	40	1000	good	fair
7. Leucaena	90	50	12	26	4 to 6	4 to 6	25	625	good	poor
8. Lotononis	90	50	1600	3500	¼ to 1	¼ to 1	35	875	fair	good
9. Lucerne	90	80	200	440	½ to 5	½ to 5	25	625	good	poor
10. Phasey bean	90	70	56	125	1 to 3	1 to 3	30	750	good	good
11. Puero	90	50	37	81	1 to 3	1 to 3	50	1250	poor	good
12. Silverleaf Desmodium	90	50	95	210	1 to 3	1 to 3	40	1000	fair	fair
13. Siratro	90	50	36	79	1 to 3	1 to 3	40	1000	good	fair
14. Stylo	90	40	160	350	2 to 5	2 to 5	35	875	good	fair
15. Townsville lucerne	90	40	200	440	2 to 3	2 to 3	25	625	good	poor

APPENDIX NO. 5

"SOURCES OF SEED OF TROPICAL LEGUMES"

(Extracted from Appendix 4 of FAO book on Tropical Forage Legumes, by P.J. Skerman)

NOTE: Many of these seed sources also stock seed of Tropical & Sub-Tropical forage grasses.

ANGOLA

1. Divisao de Botanica e Ecologia
Instituto de Investigacao Agronomica
CP 406, Nova Lisbon
Angola

ARGENTINA

2. Division de Exploracion e Introduccion de Plantas (INTA)
Ministero de Agricultura
Buenos Aires

3. Instituto Nacional de Tecnologia Agropecuaria
Rivadavia 1349
Buenos Aires

4. Instituto Agrotecnico
Misiones, M-A
Buenos Aires

AUSTRALIA

5. CSIRO Division of Tropical Agronomy
Cunningham Laboratory
St. Lucia, Queensland 4067

6. Anderson's Seeds Ltd
Boundary
Brisbane, Queensland

7. Australian Estates Co. Ltd.
106-108 Creek St.
Brisbane, Queensland

8. Arthur Yates & Co. Pty. Ltd.
P.O. Box 42
West End, Brisbane
Queensland

9. A.W. Rasmussen Pty. Ltd.
Mackay, Queensland

10. Frank Sauer & Sons Pty. Ltd.
Tozer St.
Gympie, Queensland

11. Dalgety & New Zealand Loan
Eagle St, Brisbane
Queensland

12. State Produce Agency
Roma St, Brisbane
Queensland

13. J.H. Williams & Sons Pty. Ltd.
Murwillumbah, New South Wales

14. Wright, Stephenson & Co.
330 T. Kilda Rd
Melbourne

15. E.J. Eggins Pty. Ltd.
Lismore, New South Wales

16. The Producer's Cooperative Distributing Society Limited
Cribb St.,
Milton, Queensland

BARBADOS

17. Central Sugar Cane Breeding Station
Barbados

BRAZIL

18. Departamento de Producao Animal
Secretaria de Agricultura
Sao Paulo, S.P.

19. Estacao Experimantal de Forages
San Gabriel
Rio Grande do Sul

20. Instituto Pesquisas Experimentos
Agropecuario Centro-Sul
Seccao de Agrostologia
Caixa Postal 28, ZC-00
Rio de Janeiro

21. Instituto de Pesquisas IRI
Campinas
Sao Paulo

22. Instituto de Zootecnia
Universidad de Ceara
Fortaleza

23. Aracatuba
Casa da Agricultura
Sao Paulo

SRI LANKA

24. Agricultural Department
Peradenya
Sri Lanka

25. Anderson and Co.
Colombo

26. H.D. Constantine and Sons
GPO Box 378
Colombo

27. R.R. Johnson and Co.
Colombo

28. Central Agricultural Research Institute
Gonnoruva
Paradenya

COLOMBIA

29. Centro Nacional de Investigaciones Agropecuarias
"Diulio Ospina"
Medellin

30. Abadia y Jimenez
Bogota

31. Caja Agraria
Bogota

32. Proacal
Palmira, Valle

33. Programa de Forrajes
Instituto Colombiano Agropecuario (ICA)
Bogota

COSTA RICA

34. Estacion Experimental Los Diamantes
Ministerio de Agricultura
Guapiles

35. Granja Experimental El Alto
Ministerio de Agricultura
San Jose

36. Instituto Interamericano de Ciencias Agricolas (IICA)
Centro de Investigacion y Ensenanza Graduada
Turrialba

37. "El Semillero"
Luis Cruz B.
Aparatado 783
San Jose

CUBA

38. Estacion Experimental de Pastos y Forrajes
"Indio Huatey"
Matanzas

39. DAHOMEY

Centre de recherches agronomiques
IRAT
Niaouli (par Altogon)

40. EL SALVADOR

Estacion Agricola Experimental "San Andres"
La Libertad

FIJI

41. Director of Agriculture
Suva

FRANCE

42. Ets O. Genest et Cie
27 route de Venissieux
Lyon 8e

GHANA

43. Botanical Department
University of Ghana
Lagos

44. Council for Scientific and Industrial Research
P.O. Box 3785
Kumasi

45. Faculty of Agriculture
UST
Kumasi

46. Ministry of Food & Agriculture
Accra

47. Plant Introduction & Exploration
Crop Research Institute
Ghana Academy of Science
Burso

GUADELOUPE

48. Institut national de la recherche agronomique
Domaine Ductas
Petit Bourg

GUATEMALA

49. Buenavista Experimental Station
Esquirdila

GUYANA

50. Central Agricultural Station
Department of Agriculture
Georgetown

51. Botanic Gardens
P.O. Box 256
Georgetown 7A

HAITI

52. Departement de l'agriculture des ressources naturelles et du developpement rural
Damien, Port-au-Prince

HONG KONG

53. Department of Agriculture and Forestry
North Kowloon

INDIA

54. Agricultural College
Poona

55. Agricultural Research Institute
Coimbatore 3

56. Agricultural Research Institute
Chotagnapar, Ranchi
Bihar

57. Agricultural Research Service
Tridoanum, South Arcot

58. BAI
Bangalore

59. Deochanda Experiment Station
Deochanda

60. Division of Botany
Indian Agricultural Research Institute
New Delhi

61. Central Arid Zone Research Institute
Jodhpur

62. Economic Botanist
Institute for Agricultural Research
Jaipur

63. Indian Veterinary Research Institute
Isantnagar

64. Government Economic Botanist
Kanpur, Uttar Pradesh

65. National Seed Corporation Ltd.
F. 44 South Extension Park
King Road, New Delhi, 3

66. Madras Agriculture Department
Madras

67. Pratap Nursery Seed Stores
P.O Premnagar
Dehra Dun 6

INDONESIA

68. Institute for Agricultural Research
Bogor

ISRAEL

69. Plant Introduction Service
The Volcani Institute of Agricultural Research
P.O. Box 6, Beit Dagan

70. Hazera Seed Co.
P.O. Box 1565
Haifa

ITALY

71. Federazione Italiana dei Consorzi Agrari
Via Curtatone 3
Roma

IVORY COAST

72. Directeur des recherches
Office de la recherche scientifique d'Outre-Mer
BP Adropodoume
Abidjan

73. Institut d'enseignement et de recherches tropicales
Abidjan

JAMAICA

74. Experiment Station
Grove Place

KENYA

75. East African Agriculture & Forestry Organization
P.O. Box 34148
Nairobi

76. Kirchhoff's East Africa Ltd.
Box 30472
Nairobi

77. Kenya Seed Company
P.O. Box 553
Kitale

78. Kenya Farmers' Association
P.O. Box 35
Nakuru

79. Mackenzie Dalgety Ltd
P.O. Box 30345
Nairobi

80. Katumani Agricultural Research Station
P.O. Box 340
Machakos

81. Pasture Research Unit
National Agricultural Research Station
P.O. Box 450
Kitale

82. Research Station
Molo

MADAGASCAR

83. Station agronomique du Lac Alotra
IRAT, Lac Alotra

MALAYSIA

84. Federal Experiment Station
Penang

85. Pusat Penyelidikan Getan Tanan Malaya
(Rubber Research Institute of Malaya)
Petit Surat 150
Kuala Lumpur

86. Department of Agriculture
Kuala Lumpur

MALAWI

87. Agricultural Research Centre
P.O. Box 215
Lilongwe

88. Chitedze Agricultural Research Station
P.O. Box 158
Lilognwe

89. Makanga Experiment Station
P.O. Box 20
Chirono

MAURITUS

90. Department of Agriculture
Reduit

MEXICO

91. Campo Experimental
Cotaxtla
Vera Cruz

92. Instituto Nacional de Investigacion Agricola
Mexico City

NIGERIA

93. Institute for Agricultural Research
Ahmadu Bello University
P.O. Box 116, Samaru
Sheka Baria

94. Regional Research Station
Samaru
Zaria

95. West African Cocoa Research Institute
Ibadan

PAKISTAN

96. Agricultural College
Karachi

97. Ayub Agricultural Research Institute
Lyallpur

98. Department of Agriculture
Bangladesh, Dacca

99. Plant Introduction Officer
FACP
Karachi

100. Punjab Agricultural College
Lyallpur

101. Tandojam Agricultural College
Tandojam

PANAMA

102. John Fraser
Edif. CIA Panamena de eguros
3er. piso
Calle Richardc Arias
Apartado 4546
Panama 5

PAPUA - NEW GUINEA

103. Director of Agriculture
Department of Agriculture
Port Moresby

104. Highlands Agricultural Experiment Station
Aiyura

105. Lowlands Agricultural Experiment Station
Keravat, Rabaul
New Britain

106. Plant Introduction and Quarantine Station
Laloki, Port Moresby

PARAGUAY

107. Instituto Agronomico Nacional
Caacupi

PERU

108. Universidad Agraria La Molina
Lima

PUERTO RICO

109. Rio Piedras Estacion Experimental
Mayaguez

PHILIPPINES

110. Bureau of Plant Industry
Dept. of Agriculture & National Research
Manila

111. Bureau of Soils
Manila

112. College of Agriculture
University of Philippines
Manila

113. Economic Garden
Los Banos

114. Lamao Experiment Station
Lamao, Limay

115. National Forage Park
Rosario, La Union

RHODESIA

116. Department of Agriculture
Soil Conservation Service
Kasama, Southern Province

117. Dept. of Research & Specialist Services
Salisbury Research Station
Causeway, Salisbury

118. Gatooma Research Station
P.O. Box 396, Gatooma

119. Grassland Research Station
P.B. 701, Marandellas

120. Institute SAR
Ruibona
BP 167, Butare

121. Matopos Research Station
PB 19, Bulawayo

SENEGAL

122. Centre IRHO
Bambey

123. Department of Botany
Universite de Dakar
Dakar

124. Institut de recherches agricoles et de cultures vivrieres
Bambey

125. Laboratoire national d'elevage et des recherches veterinaires
Dakar Hann

SIERRA LEONE

126. Fourah Bay College
University of Sierra Leone
Mt. Aureol, Freetown

SINGAPORE

127. Hooglant & Co.
P.O. Box 245
Singapore

128. SOUTH AFRICA

128. Division of Plant and Seed Control
Dept. of Agricultural Technical Service
P.B. 179, Pretoria

129. Division of Crops and Pastures
Department of Agriculture
Pretoria

130. Gunson Seeds, South Africa (Pty,) Ltd.
P.O. Box 9861
Jonannesburg

131. Prinshof Experimental Station
Pretoria

132. Rietondale Grass Station
Pretoria

133. ASA Seeds (Pty) Ltd.
317-319 Main Reef Road
Johannesburg

134. Asgrow S.A. (Pty) Ltd
P.O. Box 2054
Pretoria

135. Bechuanaland Malt and Milling Co. (Pty) Ltd.
162 Vryburg

136. Cyclops Seed (Pty) Ltd.
Box 784
Pretoria

137. Delmas Koop Bpk.
P.O. Box 21
Delmas

138. Directo Produce & Seed Supplies (Pty) Ltd.
6 Pim St.
Newtown, Johannesburg

139. Distin Sagseeds (Pty) Ltd
104 Brae St.
Johannesburg

140. Eloff C. Mandla (Pty) Ltd
108 Brae St.
Newtown, Johannesburg

141. A. Ford & Company (Pty) Ltd
P.O. Box 5701
Johannesburg

142. Gouws & Gouws (Pty) Ltd
10 Jeppe St.
Newton, Johannesburg

143. S. Jaffe & Co. (Pty) Ltd.
65 Pretorious Street
Pretoria

144. Johs Levy
P.O. Box 120
Potchefstroom

145. Kaha & Kahn (Pty) Ltd.
46 Pim Street
N··ton, Johannesburg

146. Kingsbury & Co. (Pty) Ltd
42 Pim Street
Newton, Johannesburg

147. Lydenburg Voorspoed Koop
P.O. Box 17
Lydenburg

148. Magaliesberse Graankoop (Ltd)
P.O. Box 61
Brits

149. Marino Koop (Ltd)
P.O. Box 48
Zeerust

150. Maurice Flior & Co. (Pty)Ltd
Box 7176
Johannesburg

151. C. May and Co. (Pty) Ltd.
Box 4037
Johannesburg

152. Noord Transvaalse Koop (Ltd)
P.O. Box 29
Nylstroom

153. Noord-Westelike Koop
Landbou Mpy. Bpk.
P.O. Box 107
Lichtenburg

154. Potgietersrusse Tabakkoop Bpk.
P.O. Box 2
Potgietersrus

155. S.A. Seed Exchange (Coop.) Ltd.
P.O. Box 1781
Pretoria

156. Schmidt & Co. (Pty) Ltd
P.O. Box 9809
Johannesburg

157. Sentraal Westlike Koop Mpy. Bpk.
P.O. Box 98
Orkney

158. Suid-Westelike Transvaalse Landbou Koop
P.O. Box 5
Leeudoringstad

159. Vaalharts Landbou Koop Bpk.
P.O. Box 4
Hartswater

160. Voorspoed Saadhandelaars (Pty) Ltd.
151 Brae Strret
Newton, Johannesburg

161. F.R. Waring (Pty) Ltd
Box 2090
Johannesburg

162. West Rand Central Produce & Agric. Store (Pty) Ltd.
P.O. Box 414
Krugerdorp

THE SUDAN

163. Agricultural Research Div.
WadMedani

164. Kenana Research Station
Abu-Naama

165. Range & Pasture Research Dept.
Ministry of Agriculture
Khartoum

SURINAM

166. Lanboouw Proefst.
Paramaribo

SWAZILAND

167. Veld & Pasture Officer
Agricultural Research Statior
P.O. Box 4, Malkerns

TANZANIA

168. Agricultural Officer
Central Research Station
Ilonga, Kilosa

169. Coast Experiment Station
Chambezi

170. Pasture Research Station
Kongwa

171. Senior Research Officer
Coffee Research Station
Lyamungu

172. South Regional Research Centre
Nachingwea

173. Sisal Research Station
Mlingano

174. Western Research Centre
Ukiriguru

THAILAND

175. Department of Agriculture
Srisomrong Street
Bangkok

176. Department of Botany
Kasetsart University
Bangkok

177. Pakchong Forage Crops Station
Korat

178. Rubber Research Institute
Haadyai

TRINIDAD

179. Department of Agronomy
University of West Indies
St. Augustine

UGANDA

180. Cotton Research Station
Namulonge

181. Kawanda Experiment Station
Kawanda
Bugande District

182. Makerere University College
P.O. Box 7062
Kampala

183. Serere Experiment Station
P.O. Soroti
Uganda

UPPER VOLTA

184. IRAT
P.O. Box 596
Saria par Quagadougou

185. URUGUAY

185. Jardin Botanico
Montevideo

UNITED STATES

186. ALABAMA

Segrest Feed and Seed Co.
P.O. Box 338
Slocomb

187. ARIZONA

Advance Seed Co.
P.O. Box 6157
Phoenix

188. CALIFORNIA

F.M.C. Niagara Seeds
Box 3091
Modesto

189. FLORIDA

Everglades Branch Station
Fort Lauderdale

190. Florida Foundation Seed Producers Inc.
Florida Agricultural Experiment Stations
Gainesville, Florida

191. Indian River Research Station
Fort Pierce

GEORGIA

192. Georgia Experiment Station
Tifton

HAWAII

193. Agronomy and Soil Department
University of Hawaii
Honolulu

194. Hawaii Agricultural Experiment Station
RRI
Kapaa

195. College of Tropical Agriculture
University of Hawaii
Honolulu

ILLINOIS

196. Dekalb Seed Inc.
Sycamore Road
Dekalb

197. P.A.G. Division
W.R. Grace and Co.
Box 470, Aurora

198. *IOWA*

198. Pioneer Hybrid Corn Co.
1206 Mulberry Street
Des Moines

KANSAS

199. Frontier Hybrids Inc.
Scott City

LOUISIANA

200. Kalmbach-Buckett Co. Inc.
Shreveport

MARYLAND

201. USDA Crop Research Branch
Plant Introduction, Beltsville

MISSOURI

202. Rudy-Patrick Seed Co.
1212 West 8th Street
Kansas City 1

NORTH CAROLINA

203. McNair Seed Co.
Laurinburg

TEXAS

204. Paymaster Seed Co.
Star Route
Wildorado

205. Delta Inc.
Crosbyton

206. Taylor Evans Seed Co.
P.O. Box 480
Tulia

207. Lyndsey Seed Co.
Lubbock

VIRGIN ISLANDS

208. Kingshill St. Croix
Agricultural Institute

209. *VENEZUELA*

209. Centro de Investigaciones Agronomicas
Maracay

210. Servicio de Pastos y Forrajes
Facultad de Agronomia
Universidad del Zulia
Maracaibo

ZAIRE

211. Centre de recherche agrono-
mique
Yangambi, Kinshasa

212. Jardin d'essais d'eala
BP 278, Mondaka
Inkshasa

213. Station de recherches agrono-
miques
Nioka

ZAMBIA

214. Msekara Regional Experiment
Station
Fort Jameson

215. Mount Makulu Research Station
P.O. Box 7, Chilanga

216. Pasture Research Officer
Nisamfu Research Station
P.O. Box 55
Kasama

APPENDIX NO. 6

Sources of Rhizobium Cultures for Tropical Legumes

This list of names and addresses of organizations handling inoculants is necessarily incomplete but supplies information as to where inoculants can be obtained. Sources of inoculants for temperate legumes can be obtained from Dr. E. Hamatova, Department of Microbiology, Central Research Institute of Plant Production, Prague, Ruzyne, or Professor O.N. Allen, Department of Bacteriology, University of Wisconsin, Madison, Wisconsin 53706, U.S.A.

As more effective strains are developed, the present ones will be superseded and an up-to-date list is published from time to time in the *Rhizobium Newsletter* edited by Professor J.M. Vincent, Department of Microbiology, School of Biological Sciences, University of New South Wales, P.O. Box 1, Kensington, New South Wales, Australia. It is available to persons interested in using it, for a small charge.

ARGENTINA

Dr. Enrique Schiel
Intituto de Microbiologia e
Industrias Agropecuarias
Villa Udaondo, Castelar
F.C.N.D.F.S., Prov. de
Buenos Aires, Argentina
(on agar)

Roberto E. Halbinger
Quimica Industrial y Comercial
Tecnologia en Industrias
Agricola
H. Yrigoyen 571, Buenos Aires

Jose P. Radibak
Tamborini 3094
Buenos Aires, Argentina

Grace & Crawford Keen y Cia
San Martin 232
Buenos Aires,
Nitrasoil
Florida 622
Buenos Aires,

Instituto Agrotecnico
Avenida Las Heras 727,
Resistencia
Prov. del Chaco, Argentina
(on agar)

AUSTRALIA

Dr. R.A. Date
CSIRO Division of Tropical
Pastures
St. Lucia, Queenland 4067

Tropical Inoculants
1 Kneale St.
Holland Park
Queensland
(inoculants sold under the trade name of TROPICAL INOCULANTS)

Dr. R. Roughley
Biological and Chemical Research Institute
PMB 10, Tydalmere
New South Wales, 2116

Professor J.M. Vincent
School of Microbiology
University of New South Wales
P.O. Box 1, Kensington
New South Wales, 2033

D.J. Pulsford
Agricultural Laboratories
P.O. Box 8
Carlington St., Regent's Park New South Wales, 2143
(inoculants sold under the trade name of NOCULAID)

R. Daniels
Root Nodules Pty. Ltd
49 Chandos St., St. Leonards New South Wales, 2065
(inoculants sold under the trade name of NITROGERM)

The Head of the Department of Soil Service and Plant Nutrition
Institute of Agriculture
University of Western Australia
Nedlands, Western Austrslia, 6009

The Director
Dept. of Agriculture, Stock and Fisheries
Konedobu
Papua, New Guinea

BRAZIL

J.R. Jsrdim Freire, Ing. Agr.
Seccion de Microbiologia Agricola
Secretaria de Agricultura, Porto Alegre
Rio Grande del Sur

Instituto de Biologia y Pesquisas Tecnologicas
Casilla Postal 357
Curitiba, Parana

Laboratorio Leivas Leite S.A.
P.O. Box 91, Pelotas
Rio Grande del Sur

CHILE

Luis S. Longeri
Universidad de Concepcion, Dep. Microbiologis
Casilla 272, Concepcion
(inoculants distributed under the trade name of NITRO-FIX)

EAST AFRICA

The Kenya Seed Company
P.O. Box 553
Kitale, Kenya
(sole distributor of rhizobia for east Africa)

MEXICO

Dr. C.C. Casas
Escuela Nacional de Ciencias Biologicas
IPN Apartado Postsl 42-186
Mexico, D.F.
(inoculants distributed under the trade names of NITRAGIN and PAGADOR)

PERU

Ing. Agric. Rodolfo Vargas
Estacion Experimental Agricola de La Molina
Apartado 2791
Lima
American inoculants distributed as:
NODOGEN - Nodogen Laboratories, Princeton, Illinois, United States

NITRAGIN - The Nitragin Co. Inc., Milwaukee, Wisconsin 53209, United States

SOUTH AFRICA

Dr. B.W. Strydom
Dept. of Agricultural Technical Services
Plant Protection Research Institute
Agriculture Building
Beatrix St., Private Bag 134
Pretoria

S.A. Legume Inoculant Company (Pty) Ltd.
P.O. Box 248
Stellenbosch

URUGUAY

Dr. Carlos Batthyany
Laboratorio de Microbiologia de Suelo del M.G.A.
Ciudadela 1471
Montevideo

Laboratorios Dispert S.A.
Avenida Garibaldi 2797
Montevideo
(inoculants distributed under the trade name of NITRASOIL)

Esur Ltda.
Azara 3387
Montevideo
(inoculants distributed under the trade name of NITRUR)

UNITED STATES

Selected tropical-temperate inoculants

Plant Cultures
P.O. Box 284
Gainesville, Florida

Dr. U.M. Means
U.S. Soils Laboratory
Dept. of Agriculture
Beltsville, Maryland 20705

The Nitragin Company
3101 W. Custer Avenue
Station F, P.O. Box J
Milwaukee 9, Wisconsin
(inoculants sold under the trade name of NITRAGIN)

APPENDIX NO. 7

Additional publications dealing with livestock production and feed supplies, issued by:

OFFICE OF AGRICULTURE
DEVELOPMENT SUPPORT BUREAU
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C.

Technical Bulletin Series	
No. 1	Improved forages for tropical and sub-tropical regions, as feed for livestock. 1971.
No. 2	Guidelines for improving livestock production on rangelands. 1971.
No. 12	The contribution of legumes to continuously productive agricultural systems for the tropics and sub-tropics. 1975.
No. 13	Seeded forages for grazing and for harvested feeds in the tropics and sub-tropics. 1975.
No. 14	Characteristics of economically important food and forage legumes, and forage grasses for the tropics and sub-tropics. 1975.
No. 19	Combined crop/livestock farming systems for developing countries of the tropics and sub-tropics. 1976.
No. 20	Providing forages for ruminant livestock during dry seasons in the tropics and sub-tropics. 1977.

AGRICULTURE TECHNOLOGY FOR DEVELOPING COUNTRIES

Technical Series Bulletin No. 25

Leucaena leucocephala: an excellent feed for livestock

September 1980

Office of Agriculture
TECHNICAL ASSISTANCE BUREAU
AGENCY FOR INTERNATIONAL DEVELOPMENT
Washington, D.C. 20523

Leucaena leucoceopala: an excellent feed for livestock

Prepared by: Michael D. Benge

DIVISION OF RENEWABLE NATURAL RESOURCES
AGRO-FORESTATION

Office of Agriculture
Development Support Bureau
Agency for International Development
Washington, D.C. 20523

PREFACE

In 1976 near Batangas City in the Philippines, I stood and marveled at the canopy of feathery Leucaena foilage towering over my head as high as a two-story building. It was hard to believe that a year before the site had been open wasteland!

Because of such performance the leguminous tree, Leucaena leucocephala, long disdained as a nuisance weed, now promises to become one of the most valuable crops for the world's less developed countries.

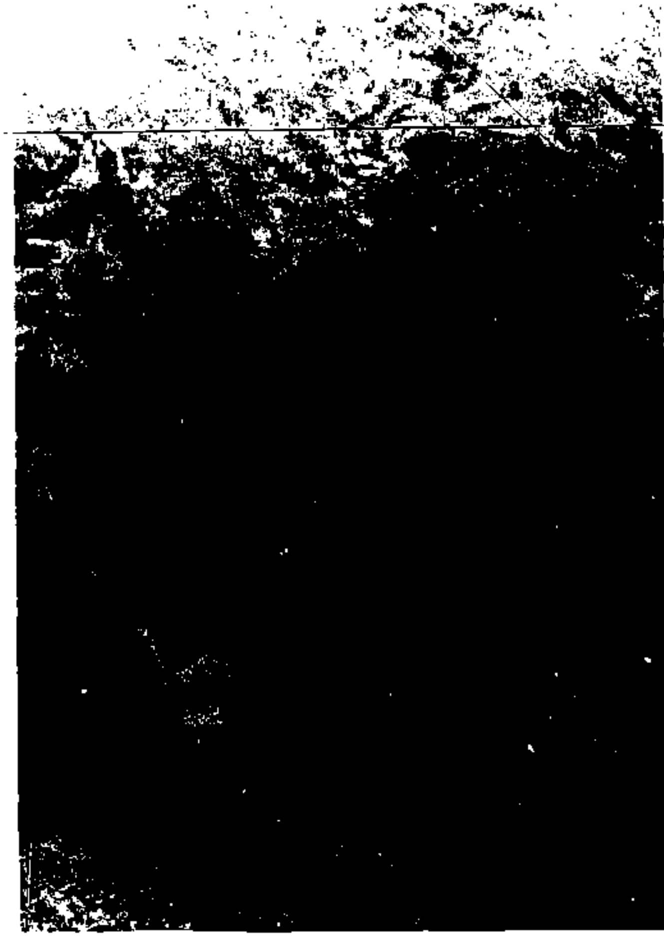
Depending on variety, Leucaena is either a tall tree or a branchy bush. It can be used for timber, firewood, fiberboard, paper, forage, fertilizer, landscaping, soil reclamation, shading for sun-sensitive crops, windbreaks and firebreaks as well as for dye, mucilage, jewelry and even human food. Moreover, Leucaena seems adapted to many soils too barren for conventional crops and it is one of the fastest growing plants measured. On top of all that, it obtains its own nitrogen fertilizer from air, survives drought, tolerates the salt of costal areas and has a high resistance to pests and diseases.

Truly, Leucaena seems to be a "tree of life"!

Noel

Noel D. Vietmeyer
Professional Associate
Board on Science and Technology
for International Development
National Academy of Sciences
Washington, D.C. 20418

Leucaena leucocephala, an excellent feed for livestock: it can be planted and managed in a variety of systems, such as in balanced pasture-forage systems [above (see page 8)] or in hedgerows to control erosion in fields or as a windbreak, fence or boundry marker around the house or field [below (see pp. 6, 9, & 10)].



In the seasonally dry tropics there are vast scattered areas where recurring dry seasons preclude shallow-rooted perennial forage grasses and pasture legumes. For these areas, an excellent management system is Leucaena planted at a spacing of 1 m. by 1 m. and allowed to grow until it reaches a 10 cm (4 in.) base diameter, or approximately 1½ years, before cutting back [above left]. The trees are then cut to a stump height of 1 m. and allowed to coppice (regrow). The foilage is then cut every three months. The 1½ year period before cutting allows the growth of a long taproot. This enables Leucaena to maintain a high rate of production even during the critical dry season months when other forage sources have dried up and become unpalatable [above right (see page 8)].

The abundant-lush growth of Leucaena, harvested in a cut-and-carry system (above), is fed to and relished by tethered livestock [below (see page 9)].

Leucaena leucocephala: an excellent feed for livestock

Introduction

Because there is an acute shortage of animal feed throughout the tropics, the need for high-protein forage and digestible nutrients is a chronic concern. Nowhere is the shortage more serious than in the seasonally dry tropics--vast scattered areas where recurring dry seasons inhibit the growth of shallow-rooted perennial forage grasses and pasture legumes. Pastures containing Leucaena leucocephala (Leucaena) are among the most productive in the tropics. Leucaena promises to become an especially useful forage source for the dry tropics. It can be harvested and carried fresh to animals, dried into leaf meal, fermented into silage, or animals can be allowed to browse the standing bushes. Whether it is young or mature, green, dry or ensiled, the Leucaena foliage is relished by livestock and by wildlife as well, particularly when green feeds are scarce. Succulent young Leucaena foliage is now used in various parts of the tropics to feed cattle, water buffalo, and goats (19).

Leucaena is indigenous to Central America. The Mayans and the Zapotecs disseminated it throughout that region long before the arrival of the Europeans. It is theorized that Leucaena as an intercrop and erosion control barrier served as a principal source of nitrogen

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Article by Michael D. Benge, Office of Agriculture, Agro-forestation, Development Support Bureau, Agency for International Development, Washington, D.C. 20523.

fertilizer for corn, the staple food of both civilizations. Leucaena was so important to their agriculture that they recorded it in their pictographs. Mexico's fifth largest state, Oaxaca, derived its name from "hauxin," a pre-Columbian word meaning "the place where Leucaena grows."

Leucaena As Forage

As a forage crop, Leucaena has yielded as much as 20 metric tons (MT) of dry matter per hectare (ha) per year. In some areas, alfalfa may yield more green forage than Leucaena, but the nutritive value of green and dry Leucaena forage is equal or superior to that of alfalfa. Leucaena also is equivalent or superior to alfalfa in digestibility, and is markedly superior to alfalfa in percentage of protein, since the protein content of green Leucaena leaves generally exceeds 25%. The content of total digestible nutrients (TDN) is comparable, and Leucaena contains almost twice as much carotene (which provides vitamin A) as alfalfa. Dry Leucaena contains almost four timea as much protein as napier grass (Pennisetum purpureum). The pelletized leaves of Leucaena are in demand as an animal feed mix in non-tropical areas such as Japan and Europe (19).

Recent experiments have shown that improved breeds of cattle will gain as much as 1 kg in weight per day when fed a 100% ration of protein-rich Leucaena for a 3 month period prior to alaughter. Theae teata were conducted by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. The leaves of improved strains of Leucaena contain 23%-30% protein by dry weight. Cattle can consume a high intake of Leucaena for a period of four months without any adverse effects, a length of time ideal for the fattening of cattle prior to slaughter (12).

Adaptation

Leucaena is persistent, rugged, and thrives on the steepest, rockiest slopes where its roots penetrate deep into rock crevices. It withstands prolonged periods of drought [22 centimeters (cm) of rain/year] and does very well in areas having as little as 60 to 150 cm of rainfall per year. In contrast, alfalfa and other similar forage-pasture plants usually require the best and most arable lands for their growth--land needed to grow food crops for human consumption (19).

Leucaena has a vigorous taproot and limited lateral branches that angle downward. Roots are commonly 2/3 as deep as the tree is tall. With its deep-growing root system, Leucaena can obtain water and nutrients from soil strata which are not accessible to most other plants (6).

Leucaena is found at elevations as high as 1,500 meters (m.). Higher altitudes often mean lower temperatures, shorter days (and thus less light), and more acidic soils; conditions which do not enhance Leucaena's growth. Leucaena does not normally tolerate water-logged soils, although strains growing along canals in Thailand seem to have adapted (8).

Leucaena is a legume and Rhizobium, nitrogen fixing bacteria, live in symbiotic relationship in the plant root nodules enabling it to fix nitrogen from the air. Nitrogen is essential for the optimum growth of Leucaena as well as for other plants. Not all soils contain the correct strain nor the necessary amount of Rhizobia to ensure proper inoculation and growth of Leucaena. Therefore, Leucaena should be inoculated before planting (for detail see pp. 17 & 18).

Leucaena is generally found growing on neutral or alkaline soils and an acid-exuding strain of Rhizobium (31A3) is commonly associated with the plant. Characteristically, Leucaena does not thrive on highly acidic soils. However, research indicates that Leucaena may adapt to more acid soils if it is initially established with an alkaline-exuding Rhizobium (CB81) developed by CSIRO. Further research on the adaption of Leucaena to acid soils is being conducted at the Centro Investigacion Agricultura Technologies (CIAT).*

Leucaena has few serious enemies other than man who cuts it down; and monkeys which ravish the young pods. Other problems affecting Leucaena include the following: its roots will sometimes harbor soil fungi and young plants will damp-off in wet soils; weevils will attack the seeds, especially in the wet season or when the seeds are old (this problem is easily overcome by the use of insecticides); and isolated incidents of stem-borer damage to Leucaena branches have been reported.

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*Dr. Mark Hutton, former Chief, Division of Tropical Crops and Pastures, Cummingham Laboratory (CSIRO), is the principal researcher on the CB81 strain of Rhizobium and its use in the adaptation of Leucaena to acidic soils. Dr. Hutton can be contacted by writing him c/o Centro Internacional de Agricultura Tropical, Apartado Aero 6713, Cali, Columbia.

Also, animals will graze young plants to the ground, but Leucaena reasserts itself when grazing pressures are removed.

Plant Characteristics

In field trials conducted by the Pastures Division of the University of the Philippines at Los Banos (UPLB), an improved variety of Leucaena was used (cv Peru) and a yield of 18 MT of dried leaf meal/ha/yr was recorded (14). In other test plots, yields of 28 MT/ha were projected (6).

Leucaena is not wholly without fault as a tropical forage plant, as it contains a toxic alkaloid, mimosine (some varieties contain higher amounts than others). This may cause thyroid problems or other harmful side effects when excessive amounts of Leucaena forage are fed to animals over a sustained period of time. Ruminants can be fed a continuous ration containing 40% Leucaena by dry weight without suffering from the effects of mimosine toxicity. Non-ruminants generally will not tolerate rations that contain an excess of 5-10% Leucaena (dry weight). Mimosine toxicity symptoms will disappear after a short period of time and leave no residual effects when the animals are removed from the high level Leucaena diet. CSIRO in Australia has been working on the development of a low-level mimosine line of Leucaena which should soon be released (7).

Growing and finishing pigs can be fed rations containing as much as 20% Leucaena leaf meal (dry weight) provided that 0.4% ferrous sulfate is added to the ration, according to research conducted at UPLB (17). In the Philippines, pigs a often fed a diet composed of 100%

Leucaena one month prior to slaughter. This high intake causes the pig to loose its hair (bristles), thus alleviating the arduous task of removal.

Laying hens were fed a ration containing 10% Leucaena leaf meal (dry weight) and 0.2 to 0.4% ferrous sulfate supplement in similar experiments at UPLB. The hens showed no significant decrease in egg production compared to those fed on commercial rations. However, when the ration was increased to 20% of their total intake, egg production was reduced (18).

Leucaena leaf meal contains high amounts of carotene which provides the ration with vitamin A. A diet containing 4 to 6% Leucaena leaf meal restores health to chicks and pigs suffering from vitamin A deficiency. Also, carotene is a desirable additive to poultry rations because it enhances the yellow coloring of the egg yoke as well as the fat of the chickens.

Batangas beef is well known in the Philippines for its excellent quality and tenderness. It is obtained by force-feeding young calves in the "SUPAK" system of back-yard fattening, in which the ration contains a mixture of chopped Leucaena leaves, rice bran and water. The Leucaena for the ration comes from the hedgerows around the farmers' home lots, the Leucaena serving both as a fence and a source of forage.

Tests conducted at the Brackishwater Aquaculture Center (BAC) in Leganes, Ilo-ilo, Philippines concluded that bangus (milkfish), talapia, bass, and shrimp fed with Leucaena leaf meal grew faster and heavier than those not given the meal (13). Because Leucaena contains high amounts of protein, as well as large amounts of nitrogen-phosphorus-potassium (NPK), its leaves served not only as a fish food, but as a fertilizer for the pond, increasing plant growth and providing natural fish food.

Philippine farmers in Barrio Naalad, Naga, Cebu feed their goats a diet consisting only of Leucaena, banana and coconut leaves. The latter two have high cellulose and fiber content and contain few nutrients. One of the reasons Naalad farmers raise goats is to recycle Leucaena leaves for the production of high-nitrogen fertilizer which is then applied in a tobacco-onion-corn cropping system. High levels of Leucaena are also fed to their hogs and chickens. Research indicates that certain breeds of animals, as well as individual animals within a breed, are capable of ingesting greater amounts of Leucaena than others (3).

Recent research conducted in the Philippines and Hawaii by Dr. Raymond Jones*, CSIRO, indicates that some goats may develop bacteria in their rumen which breaks down the chemical compounds in mimosine, thus nullifying harmful side-effects. If this is so and these bacteria can be isolated and multiplied, it is possible that other ruminants can be injected with these bacteria which would enable them to consume a diet consisting of 100% Leucaena without suffering harmful side-effects.

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*Dr. Raymond J. Jones, Senior Principal Research Scientist, Davies Laboratory, Commonwealth Scientific and Industrial Research Organization, Private Mailbag P.O., Townsville, Queensland, Australia.

Pasture Systems and Management

Leucaena pastures, with their vigorous growth and high nutritive value, can support heavy stocking with livestock. They have demonstrated some of the highest carrying capacities of any tropical pastures. Leucaena pastures interplanted with Guinea grass (Panicum maximum) often carry up to 2.5 cows per ha (1 per acre). In favorable locations, Leucaena-grass pastures extend into dry seasons much longer than those with shallow-rooted forages, and when rains commence, Leucaena recovers rapidly so that animals can be restocked early. Leucaena pastures require little more care than grasses and continue to produce year after year, especially where soils are good (19). Planting systems can be varied to suit the terrain and specific conservation objectives.

BALANCED PASTURE-FORAGE SYSTEM--For prepared fields and planted pastures, it is desirable to interplant Leucaena with some sort of grass cover. A balanced pasture-forage system may be established by planting alternate bands of Leucaena and improved grasses/legumes with a Leucaena to grass ratio of 40:60 by area. Interplanting will keep the weed growth to a minimum, reduce erosion, increase ground water levels, add materially to the carrying capacity, and provide a more varied and better-balanced forage. The interplanted grasses will probably receive sufficient nutrients from the associated legume, therefore, little or no fertilization is required. Under a paired-row layout, two rows of Leucaena are planted about 1 m. apart with a 2 m. space between paired rows of Leucaena and an in-row spacing of 4 cm between plants. The grass should be planted 2 to 3 months after the seeding of Leucaena to permit free cultivation of inter-row spacing during the early stages of growth and also to give the slower-starting legume sufficient time to become well established. Guinea (Panicum maximum), Bermuda (Cynodon dactylon), Dallis (Paspalum dilatatum), Pangola (Digitaria decumbens), and Kenya Sheep (Brachiaria decumbens) grasses work well for such interplantings (2).

CUT AND CARRY FORAGE SYSTEM--For marginal and steep hillyland areas, as well as for extremely dry areas, another planting system is recommended. Giant varieties of Leucaena (K8, K28 or K67) are planted at a spacing of 1 m. by 1 m. and allowed to grow until they reach a 10 cm (4 inch) base diameter, or approximately 1 1/2 years, before cutting back. The trees are then cut to a stump height of 1 m. and allowed to coppice (regrow). The foilage is then cut every three months. The 1 1/2 year period before cutting allows the growth of a long taproot. It is this taproot, penetrating the water table, which enables the plant to draw on deep water resources during the dry season as well as tap substrata nutrien•s, thus increasing forage production. Production remains high even during the critical dry season months when other forage sources have dried up and become unpalatable. In addition, the deep roots help hold the soils. Improved grasses, such as Guatemala (Tripsacum laxum), can be planted in the spacing between the stumps for additional forage production. Guatemala grass is relatively shade tolerant and will flourish under this system. The lush forage growth can be cut and carried to a feed lot, dried for leaf meal, or browsed by cattle. The 1 m. x 1 m. spacing provides ample space for the passage of browsing cattle. However, Guatemala grass will not withstand heavy grazing.

As a pasture legume Leucaena requires careful management. Since it is exceptionally palatable, overgrazing will seriously impair the rapidity of recovery and subsequent productivity (17). It should be noted that Leucaena will grow into trees if neither grazed nor perodically cut.

Erosion Control

In areas where soil erosion is commonplace, well designed pasture forage systems can markedly reduce erosion rates. The use of Leucaena in cropping systems to effectively reduce soil erosion was demonstrated in an innovative farming system introduced in 1953 at the Alabang Soil Conservation Project, Alabang, Rizal, Philippines. The experiment site was severely eroded and devoid of organic matter, Exposed "adobe" stones were visible and the top soil was completely absent in parts of the experimental area. The land had a slope of 25% (a drop of 2 1/2 m. every 10 m.). Paired rows of Leucaena were planted on the contour, the rows were 10 cm apart and the in-row spacing was 4 cm between plants. The paired rows were spaced 1 m. apart throughout the cropping system. When the Leucaena reached a height of approximately 1 m.,it was cut back to 35 cm, and the trimmings were allowed to decompose between the rows. Tests indicated that 12.28 kg of nitrogen (equivalent to 68.4 kg of ammonium sulfate) was added to the soil for every ton of fresh material incorporated into the soil. In addition, the erosion on the plot with the Leucaena bands was only 2% of that which occurred on the control plot. The top soil on the Leucaena planted plot was improved physically, chemically, and biologically.

Leucaena not only builds soil fertility on marginal land, but it will suppress undesirable plants and grasses when planted at 1 m. x 1 m. spacing. Leucaena will suppress tenacious grasses, such as Imperata cylindrica and Saccharum spontanaum, as well as noxious weeds, such as

Chromolaena ordorota [L.]. In many pastures in the Philippines, it drastically reduces the cattle carrying capacity of the land. It is fatal when ingested in large amounts, and over an extended period, Chromolaena deposits a high concentration of nitrate in the soil which will act as a suppressant to plant species having low tolerance to high levels of nitrates (4). The former are tenacious grasses and often considered as weeds. These grasses are relatively low in nutrient content, however, and exude plant suppressants which retard the natural succession of more desirable grasses and other plant species. Nevertheless, Imperata is one of the main sources of pasture grass in many parts of Asia. Imperata requires frequent burning to burn off coarse stems and to promote the growth of new grass. This "firing" burns the organic matter in the soil, reduces soil fertility, breaks down the soil structure, and creates an environment for accelerated erosion and degradation by exposing the soil to the leaching rainfall and solar radiation.

Establishment Procedures

Two determinations must be made before undertaking the establishment or Leucaena pasture. One has to do with the nature of the soil, its mineral content, and the other concerns the method of planting. A soil analysis will determine if fertilizer application is necessary to obtain optimum plant growth. The land selected for Leucaena pasture establishment should be prepared according to the planting method chosen. The necessity for these early decisions is explained in the following paragraphs.

FERTILIZER REQUIREMENTS--Leucaena requires adequate levels of phosphate, potash and sulfur. High levels of magnesium and low calcium content in surface soils may cause retardation in the growth of Leucaena. Adequate levels of available trace elements--molybdenum and cobalt--are necessary for maximum efficiency of the nitrogen fixing bacteria (see INOCULATION pp. 14 & 15). Therefore, it is important that sufficient levels of these elements are available in soil in which Leucaena is to be grown. A soil test should be made on the site selected for the establishment of Leucaena prior to planting to determine the appropriate fertilizer that will be required to gain maximum growth.

SEED SELECTION--One kilogram of Leucaena seed would be sufficient to plant nine hectares of land at a spacing of 1m. x 1m., if 100% of the seeds germinated and all of the seedlings survived. It is almost impossible, however, to obtain these results under normal conditions. Scientific procedures should be followed when establishing Leucaena plantings so that maximum and uniform growth can be obtained. Leucaena seeds should therefore be selected according to size (large) and density (heavy). This can be done by using a "hardware screen" and separating the seeds by specific gravity.

It is recommended that the seeds be graded into four sizes which can be done by using th[illegible]e different sizes of hardware screen. If adequate amounts of s[illegible] are available, is is recommended that only the largest 50% of the seeds be used. This will give more uniform germination and growth rates as well as size. The germination percentage will be quite high and the seedlings more vigorous, which will markably reduce establishment costs. However, germination percentage will also depend upon how the seeds are handled and stored and if the seeds were properly scarified.

Generally, the largest seeds will be the heaviest unless the seed was not mature when picked, or damaged by disease or insects. Therefore, seed selection by specific gravity is optional. Mechanical devices are available for the selection of seed by specific gravity. However, they are rather expensive. A more simple method is separation in a salt solution. Salt can be added to water until the solution is thick enough to obtain the desired gradation. The lighter seeds will float to the top and a greater portion will surface as more salt is added. Rinse the seeds with fresh water after separation.

Recommended Leucaena Varieties

The genus Leucaena is diverse and to avoid confusion, the different varieties have been assigned numbers with the prefix "K." The growth characteristics of different varieties are often referred to as Hawaiian, Peruvian, Salvadorian, and "Hawaiian Giant"; however, these are not varieties and the use of these names adds to the confusion. Furthermore, the varities termed Peru, Peruvian, CV Peru and Peru (Cunningham) are all the same (6) (7).

Of the "Giant" varieties, K-8, K-28 and K-67 have shown the most promise in terms of growth rate and forage production, all of which are dual purpose--wood and forage. None of the varieties have been researched extensively to establish their specific growth differences. The K-8 variety is a sparse seed producer and may produce a little more wood; however, this has not been verified. The K-28 variety produces more seed than the K-8, but not as much as the K-67. The K-67 variety is a prolific seeder, therefore, it is excellent for programs which are large in scope and where a large amount of seed is needed. The K-67 variety may branch more than the other varieties. Another variety, the Peru (Cunningham), is often recommended as a good forage plant, but it will not produce large volumes of wood since it has bushy growth characteristics. In appropriate management systems, K-8, K-28 and K-67 varieties can equal the forage yield of Peru (Cunningham). However, these varieties will grow into trees if left unmanaged.

Seed Treatment

SCARIFICATION--Leucaena seeds must be scarified prior to planting to obtain maximum and uniform germination. Common methods are hot water, chemical and mechanical; the simplest being scarification by hot water (1)(2)(9). The easiest way to scarify by hot water is to:

> heat water to boiling point, remove from the heat and allow to cool for 1-2 minutes (instant coffee temperature). Place the seed in a container and pour the hot water over the seed; the volume of water should be twice the volume of the seed. Stir the seeds so that they are uniformly treated, allow the water to cool, and soak the seeds overnight.

STORAGE--Leucaena seed can be dried after they have been scarified. Either solar or oven drying is effective. As many as 97% of the seeds will germinate up to 11 months after scarification if they are properly dried and stored in air-tight containers and under conditions of low humidity (1). It is recommended that seeds not be scarified until just prior to planting.

INOCULATION--Nitrogen fixing bacteria, Rhizobia, live in symbiotic relationship with Leucaena, fixing nitrogen from the air. Nitrogen is essential for the optimum growth of Leucaena as well as other plants. Not all soils contain the correct strain nor the necessary amount of

Rhizobia to insure the proper inoculation and growth of Leucaena. Therefore, Leucaena seeds should be inoculated before planting. Leucaena generally grows in neutral or alkaline soils and an acid-exuding strain of Rhizobium (31A3) is associated commonly with the plant under these conditions. The Commonwealth Scientific and Industrial Organization (CSIRO) in Australia has developed a strain of Rhizobium (CB81), reported to be alkaline-exuding thus enabling Leucaena to grow in more acidic soils. In requesting Rhizobia strains, it is desirable to specify both the plant (Leucaena) and the pH of the soil in which it is to be grown.

Small quantities of the inoculum, CB81, may be obtained for research purposes from CSIRO, Davies Laboratory, Private Mail Bag P.O., Townsville, Queensland, Australia. Commercial and small quantities of 31A3 may be obtained from Dr. J. Burton, Nitragin Corp. 3101 West Cuater Ave., Milwaukee, Wisconsin 53209, U.S.A. Small experimental aamples of CB81 and 31A3 inoculums as well as information and training in Rhizobium production can be obtain form the University of Hawaii-NifTAL Project, P.O. Box "0," Paia, Hawaii 96779, U.S.A. Rhizobia inoculants are inexpensive. The Rhizobia should be stored at temperatures ranging from 0° to 7° Centigrade or 32° to 45° Fahrenheit, approximately the temperature of a refrigerator. Seeds are easily inoculated after scarification by sprinkling the damp seeds with a light coating of inoculum.

PELLETIZATION--If Leucaena is to be direct seeded, it is recommended that the seeds be pelletized (coated) with the appropriate fertilizers to overcome nutrient deficiencies during its establishment phase (5)(10)(15)(16). Each 4 kg of scarified seed should be wet with a 3% aqueous solution of a non-toxic stickler, cellophas (methyl ethyl cellulose). A high density of inoculum is then applied. The seeds are than coated by rolling them in a mixture consisting of 1 kg of finely ground rock phosphate to which 400 grams of molybdemum trioxide has been added. This amount of molybdenum is enough to last for five to seven years. Molybdenum is important in the promotion of nitrogen fixation by the Rhizobium nodules. In acid soils, lime also plays an important role. The Rhizobium strain recommended for acid soils is CB81 (alkali exuding) and 31A3 (acid exuding) for alkaline soils. The pelletization should be done just before planting and the pelletized seed refrigerated prior to use maintain Rhizobium viability.

Field Preparation

Field preparation will vary depending upon terrain, size of area to be planted, soil conditions, available equipment and establishment cost constraints.

1. Controlled burning is the most simple and inexpensive method of land clearing. However, this method has its limitations. There is an inherent danger that the fire could not be adequately controlled and result in damage to adjacent properites. In addition, a portion of the organic matter in the topsoil may be destroyed and some soil erosion may occur. Furthermore, fires endanger wildlife that live in these areas. Nevertheless, there are always certain trade-offs in any system. When ground cover is burnt the ash is a ready source of fertilizer. When burning grasses, such as _Imperata cylindrica_ and _Saccharum spontaneum_, it is recommended that the old grass is fired when new green growth is approximately 22 cm (8 in) high at the first part of the rainy season. This will help set back

new growth by draining stored energy from the grass roots. Seeds are dibbled directly into the ash. Herbicides have also been used to reduce weed (grass) competition in seed bed preparation.* However, this method only kills the grasses and the dead-dry grass poses a fire hazard to interplanted cr

2. Ring weeding is simply a method of hoeing or cutting down the weeds around the Leucaena seedling after it has been transplanted into the field. A circle, 1 m. in diameter, surrounding the plant, is cleared of weeds. It is necessary to do this 2 or 3 times before the Leucaena will reach a height so that it can compete with surrounding weeds.

3. Furrows are plowed (animal or tractor) in the field at desired spacings between rows and the seeds are simply dropped in the furrow and lightly covered with soil.

4. A more intensive method of field preparation is that which would be done as if preparing the field to plant corn. The seed is dibbled, broadcasted or drilled into the seedbed.

Propagation and Sowing Procedures

Leucaena is conventionally grown in polyethylene bags, other containers (bamboo tubes, cans, etc.), or grown in seedbeds and then transplanted to the field. However at times, direct seeding may be a more appropriate technology. There are advantages and disadvantages to both methods, but direct seeding is a much less expensive method of planting.

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*Oregon State University (under an A.I.D. contract) used a herbicide, glyphosate, to kill "giant perennial grasses" in land preparation. Corn and beans are then "dibbled" through the residual mulch. The mulch greatly reduces annual weeds and soil erosion, saving time and money in land preparation. It is felt that this system could be used in establishing Leucaena stands.

1. Conventional methods of propagating Leucaena include the use of:

(a) Polyethylene bags [3 in. dia. x 6 in. high (7.5 cm x 15 cm] are filled with fertile potting soil. In place of potting soil, a mixture of river silt, sand and manure (equal parts) is recommended. If chicken manure is used, then reduce the manure proportion to 1/6 of the total. The bags should be perforated bottom to prevent the soil from being waterlogged causing the plant plant "damping off." After scarification, the seeds should be planted at a depth of 1 in. (2.5 cm) and covered with soil.

The bags should be placed under 3/4 shade. The shade can be made easily from grass, palm fronds, bamboo, colored polyethlene or commercial shade screen. The seeds should germinate 3-5 days after planting. The newly sprouted seedlings should be kept under 3/4 shade for approximately 1 week, then 1/2 shade for one week and full light after 3 weeks. It is recommended that the seedlings be fertilized every two or three weeks by disolving a heaping tablespoon of chemical fertilizer (15-15-15) in 2 gallons (approx. 8 liters) of water. This is applied as a normal application of water. The seedlings should be transplanted no later than 40-45 days after emergence or at a height of 9 in. (22.5 cm). This will minimize root-curl in the bag. Root curl will deform the tap root, thus reducing depth penetration and limiting the amount of water and minerals available to the plant.

Leucaena should be transplanted at the beginning of the rainy season. The seedling should be removed from the plastic bag without root disturbance to reduce transplant shock. The seedling should be placed in a hole and soil filled in around the plant and lightly compressed by pressing down on the soil around the plant with the foot. The plant should be recessed approximately 1-2 in. (2.5-5 cm) below ground surface level to act as a catchment for rain water. Additional applications of fertilizer are recommended. At the time of transplanting, a time release chemical fertilizer, such as Mag-Amp, could be placed in the hole as a one-time application. While the application of fertilizer may not be necessary, it will optimize growth.

(b) The use of seedbeds is a common practice when propagating Leucaena. However, the author does not recommend this method because of injury to the roots (transplant shock) when the seedling is pulled or dug for transplanting. If circumstances necessitate the use of a seedbed, it is recommended that the seedbeds be trenched and filled with sand or humus and then bedded to provide adequate drainage and to minimize root damage when seedlings are lifted for transplanting. The seedbed should have a pH as near as neutral as possible. Seeds should be drilled at an approximate spacing of 1 1/2 in. (approx. 4 cm.) in-row and 10 in. (25 cm.) between rows. If thoroughly mixed with the soil, 10 grams of complete chemical fertilizer [N-P-K (15-15-15)] per square meter of surface should be adequate. Animal manure can be substituted.

PRUNING--When Leucaena is transplanted, the leaves should be stripped from the seedling, leaving only 2 or 3 of the topmost compound leaves. This reduces evapotranspiration and reduces dieback. A less desirable practice entails pruning the top portion of the seedling, leaving only the brown wood, and pruning tow-thirds of the tap root prior to transplant. However, pruning the top of the seedling will cause excessive branching, an undesirable development if the tree is to be harvested as a pole at the time it is cut back. Furthermore, the tap root of a great many legumes will not regenerate once pruned, and pruning causes transplant shock and growth retardation. The author has observed that once the tap root of Leucaena has been cut, it does not regenerate. In areas with a pronounced dry season, it is essential that Leucaena achieves maximum tap root development so that maximum subsurface water and nutrients are available for optimum forage yield (2).

2. Direct seeding greatly reduces the costs incurred in planting Leucaena by eliminating the nursery and transplanting operations. Emperical observations indicate that growth is optimized by eliminating transplant shock in the establishment phase, thus the plant reaches maturity in a shorter period of time. However, planting must coincide with the onset of the rainy season. When Leucaena is to be direct seeded, it is recommended that the seed first be pelletized prior to sowing (see: PELLETIZATION under Seed Treatment). However, when seed is dibbled in the AUGER HOLE method (see below) pelletization is unnecessary if the soil is fertile and the seed inoculated with Rhizobia.

(a) Dibbling is a simple method of direct seeding whereby a pointed stick is used to punch a hole in the ground into which 1-3 seeds are placed, then covered with dirt by a sweep of the foot. It is recommended that the seed be pelletized. This can be the most appropriate method of establishing a 1 m. by 1 m. Leucaena system. The efficiency of the dibble method could be increased by the use of a modified corn planter.*

AUGER HOLE method is when a hole is augered or bored into the ground (with a common soil sample auger) prior to the onset of the rainy season. The bore hole is 3 in. by 6 in. (7.5 cm by 15 cm) and the hole is filled with a fertile potting soil (previously described). Preferably, a time release fertilizer (such as Mag Amp) is added to the soil to provide continued fertilization to the plant while growing. After scarification and inoculation with Rhizobium the seed is dibbled into the hole at the onset of the rainy season.

(b) Seed can be drilled by using a simple mechanical hand seed drill*, by a tractor drawn seed drill (such as those used to plant peas, corn, etc.) or by simply dropping them into the furrow.

(c) Broadcasting can be done by a simple hand seed broadcaster*, by a more sophisticated commercial mechanical device or by aerial seeding. Aerial seeding would be the most efficient method of sowing large tracts of land (19).

"Giant" Leucaena, a lush, protein-rich livestock feed that thrives on marginal land, will multiply the carrying capacity of tropical pastures, thus intensifying livestock production and increasing farm income.

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*Blueprints of a corn planter, a simple seed broadcasting machine and a seed drill may be obtained from Volunteers in Technical Assistance (VITA), 3706 Rhode Island Ave., Mt. Ranier, MD 20822. The hand corn planter can be modified to accommodate the pelletized Leucaena seed by simply enlarging the outlets.

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COMBINED CROP/LIVESTOCK FARMING SYSTEMS

for

DEVELOPING COUNTRIES OF THE TROPICS AND SUB-TROPICS

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PREFACE

Developing countries should be encouraged to establish farming systems that provide a combination of crop production enterprises with livestock production enterprises. Each individual enterprise must be adapted to the local environmental conditions, but also must fit into a system that is feasible under the social and economic conditions that prevail. The advantages of well designed systems must be to improve the profitability for the practicing farmers and herdsmen.

Not only should each crop and livestock enterprise be field tested to prove its suitability but there should be pilot testing of combined systems to demonstrate their practicability and effects on net farm income. More dependable productivity and more stable incomes for farmers are essential to nations that are striving for self sufficiency in food production, both in quantity and nutritional quality. In most developing countries, meeting food goals by national production is superior to a continuing rise in food imports.

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OUTLINE

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   Land Resources and Livestock Populations

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   A. Providing nitrogen in the crop rotation
   B. Soil improvement for greater production
   C. Providing feed for livestock
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   E. Improved control of plant pests
   F. Feed supplies for work animals
   G. Effective use of non-arable lands associated with cropped lands
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   I. Animal products for human foods
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III. Facilitating the Successful Addition of Livestock Enterprises to Crop Farming Systems
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      1. Cultural practices
   G. Suitable credit for animal enterprises
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   I. Cautions on use of communal or open grazing lands

OUTLOOK

During the past decade, there has been a growing awareness of the deteriorating world food situation. We now know of the urgent need for massive efforts to increase agricultural productivity in scores of developing countries and simultaneously to raise the incomes of hundreds of millions of their farmers and other rural people. It is hoped that such efforts, if successful, will buy time for population growth rates to be reduced.

The bulk of the basic food supplies of the agrarian nations are produced by the many farmers with tiny landholdings, often in remote and isolated areas, plus those people in coastal areas who depend upon near-shore fisheries and aquaculture for a livelihood. For the most part, the gains in productivity and income of these rural people - the poorest of the poor - will require the development for and use by many farmers of new high-yielding, science-based crop and animal production systems tailored to the unique combination of soil, climate, biological, and economic conditions of every locality in every nation.*

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*Quotation from statement prepared by Dr. Sterling Wortman, Vice-President, Rockefeller Foundation for 2 Subcommittees of the U.S. House of Representatives, Sept. 23, 1975.
"The World Food Situation: A New Initiative."

COMBINED CROP/LIVESTOCK FARMING SYSTEMS FOR DEVELOPING COUNTRIES OF THE TROPICS AND SUB-TROPICS

I. INTRODUCTION

The production of adequate foods to achieve substantial self sufficiency has become a major concern of virtually all developing countries. The population growth has equalled or surpassed total food production in the latest decade, and there is little evidence that population growth will decline in the near future. Populations generally have increased 30 to 35 percent between 1963 and 1974, (Table No. 1). When food production is expressed on a per capita basis, Latin American has made slight progress, but Asian and African countries generally have lost ground (Table No. 2).

Benefits From Combined Systems

There is need to more fully utilize natural resources available to agriculture, including a substantial development of livestock enterprises in farming systems that are now largely devoted to the production of crops. In some regions where there are extensive natural grasslands, livestock are produced with little involvement in crop production. However, nearly all crop farmers have some livestock that contribute to family subsistence. The development of appropriate livestock enterprises on arahle land offers substantial opportunity for significant improvement in total food production and in profitability of farming systems. The benefits that may be derived from including livestock enterprises in farming systems of the tropics and sub-tropics may be summarized as follows:

Table No. 1.

HUMAN POPULATION
(in millions)

Region	1963	1974	Increase
USA and Canada	208	234	+12.5%
Mexico Central America Caribbean	74	106	+43.2%
South America	157	212	+35.0%
Asia*	1070	1395	+30.4%
Africa	289	384	+32.9%

*excluding Mainland China

Data from FAO Production Yearbook, 1974

Table No. 2

SELECTED ECONOMIC DATA FOR DEVELOPING COUNTRIES

	Latin America	Asia	Africa
1974 Per Capita Food Production (1961-65=100)	105%	97%	95%
Agricultural Land per capita (Arable plus grassland)	5.0 acres	1.0 acres	8.0 acres
Urban populations	56%	23%	18%
Rural Populations	44%	77%	82%
Total Population	273 million	1,212 million	300 million
Literacy rate	70%	35%	18%

Data from Economic Research Service, U.S. Depr. of Agriculture

1. More effective use of natural resources - climate, land and soil, and vegetation.

   a. Use of rainfall-deficient areas not suited to cropping,

   b. Use of associated non-arable lands and soils in humid regions.

   c. Use of lands remote from markets.

   d. Use of forages grown in crop rotations.

2. Conversion through feeding to livestock of crop residues and by-products to produce foodstuffs for human consumption.

3. Contributions to incomes and food supplies.

   a. Production of milk and milk products.

   b. Production and sale of meat animals.

   c. Providing animal power for crop farming.

4. Production of animal manures for application to land for improvement of soil productivity.

5. Contribution to soil conservation and sustained land productivity by use of forages grown in rotations to control erosion to control weeds and pests and to improve soil fertility, with animal enterprises providing the income from consumption of these forages.

6. Contribution of livestock enterprises through stabilization of seasonal and yearly food production, improvements of net farm income, better distribution of labor and power-requirements for production, thus supporting more profitable farming systems.

Crop and livestock enterprises should be mutually beneficial when they employ currently available technology. Heretofore, the production of grains and certain export crops have tended to monopolize the attention of both country governments and external assistance agencies. However, the current interest in over-all agricultural development with food production as a major factor has improved opportunities for exploiting the advantages of mixed farming systems.

Land Resources & Livestock Populations

The land resources and the livestock population in the developing countries are indicated in table 3. It should be noted that ruminant livestock (cattle, buffalo, sheep, goats and camels) have a dual role, being important both for utilizing natural grazing lands, and for combined crop/livestock farming. These ruminants produce milk, meat animals, and also supply animal power in many countries. Milk is produced by all classes of lactating ruminants; there are few "dairy" herds managed exclusively for milk production but widespread milk production in conjunction with meat production is normally feasible and profitable, and is a common practice in many developing countries.

Pigs and poultry (non-ruminants) are widely used in developing countries, supported largely by concentrate feeds and by-products. For family support, these animals generally consume by-products and kitchen wastes as scavengers of a variety of available feedstuffs that would otherwise be wasted; but for commercial enterprises, more substantial feed sources are required. Pig and poultry enterprises enjoy good markets, but feed costs often make them less profitable than enterprises

Table No. 3

Lands and Their Use by Livestock
Data from FAO Production Yearbook, 1974

A. Land Types and Uses, 1970-74

	So. Amer.	Asia*	Africa	Three Continents
	Millions of Hectares			TOTAL
Total Area	1,783	1,995	3,031	6.809
Arable lands (cropped)	89	350	211	650
(irrigated)	(6)	(76)	(8)	(90)
Permanent grasslands (1)	385	333	792	1,510

* not including Mainland China
(1) Most permanent grasslands are unsuited for cropping because of unfavorable climate or topographic or soil limitations. They must be utilized by ruminant livestock to support people and contribute to total food production.

B. Ruminant Livestock Population, 1974

		Millions of Animals		Three Continents
Type animal	So. Amer.	Asia	Africa	TOTAL
Cattle	207	289	148	644
Buffalo and Camels	-	30	12	42
Sheep and Goats	147	494	266	907
Total "Sheep Equivalents"	1,182	2,089	1,066	4.337

(One large animal equals 5 sheep. One goat equals 1 sheep)

C. Non-Ruminant Livestock (2), 1974

		Millions of Animals		
	So. Amer.	Asia	Africa	TOTAL
Pigs	50	56	7	113
Poultry	456	1,088	446	1,990

(2) Pigs and Poultry consume concentrate feeds, by-products, and crop products unsuited for human food.

Table No. 4

CLASSES OF FOODSTUFFS PRODUCED IN DEVELOPING COUNTRIES

A. Crop Foodstuffs for the Tropics and Subtropics

1. Cereal grains - 5 major species
2. Food grain legimes - 8 major species, 15 minor species
3. Oilseed crops - 5 major species
4. Root and Tuber crops - 5 major species
5. Plantain and Banana - 2 plant types - sweet and cooking types
6. Sugar crops - 3 major species
7. Vegetables - about 15 major species, many minor species
8. Fruits - 6 major species and many minor species
9. Other tree crops - 5 major species

(Collectively, one or more species of each group are grown extensively in every tropical and subtropical region) (except semi-desert zones):

B. Types of Livestock and Livestock food products

	Food Animals	Products
1.	Ruminants	(Utilization of grazing lands, harvested forages, and crop residues)
	Cattle, Buffalo, Camels	Meat, Milk, Animal Power
	Sheep, Goats	Meat, Milk
2.	Non-Ruminants	(Utilization of concentrate feeds and by-products)
	Pigs	Meat
	Poultry	Meat, Eggs.

based on ruminant types of livestock that subsist on forages and other cellulosic materials. Ruminant livestock enterprises are generally beneficial to crop production and provide opportunities for strengthening the farming system.

II. How livestock enterprises improve the profitability of farming systems

The following advantages in farming systems may be exploited by inclusion of livestock enterprises in farming systems.

a. Providing nitrogen in the crop rotation. Livestock enterprises permit the exploitation of forage legumes in the cropping systems and largely eliminate the need for nitrogen fertilizers. There is good field evidence that a well adapted perennial forage legume will contribute 100 to 200 pounds of nitrogen per acre to the soil for each year of growth; and this soil nitrogen will be released by normal decay of legume roots and nodules over a period of 2-3 subsequent years of crop production. The perennial legume seed must be inoculated with compatible root nodule bacteria at planting time. Inoculums are available, this procedure is simple and quite feasible for any farmer.

b. Soil improvement for greater production. The inclusion of a mixed planting of perennial forage grasses and legumes for a period of 2 or more years, followed by several years of cropping, is one of the most effective ways of controlling soil erosion on crop lands and of improving soil structure and permeability to rainfall. This is due to the mass of fibrous roots that the forage grasses produce, plus the deeper penetration of the forage legume root system. This mass of roots that the forage species produce in the soil, gradually decomposes in the years following plowing of the forage plantings, to contribute nitrogen to the subsequent crops, and to the addition of semi-permanent soil humus that makes the soil more mellow and productive.

c. Providing feed for livestock. The growth of perennial forage plants on each field for 2 or more years followed by a few years of cropping, is an integral part of a farming system that includes livestock enterprises. Such forage is easily managed to produce highly nutritious feed for ruminant livestock in the form of pasture, or feed cut and fed green, or grass silage, or hay. These forages should be harvested or grazed before or whenever the crop reaches the blooming or heading stage to be most nutritious. This use is fully compatible with benefits in soil improvement. The storage of forages for feeding livestock during long rain-deficient seasons is a badly needed practice in most developing countries, principally for milk production but also to support satisfactory reproduction and growth of meat animals.

d. Animal manures for enhancing soil productivity. The inclusion of ruminant livestock enterprises in mixed farming systems permits the collection of animal manures and spreading these on the land for incorporation in soil during land preparation for crop production. Manures are widely recognized as being strongly beneficial to crops when incorporated in the soil, but the supply is very small unless livestock enterprises are included in a substantial way in farming systems. In addition to suppling major nutrient elements (nitrogen, phosphate, potash, calcium and magnesium) manures are quite useful in providing "trace" elements in an available form. These trace elements are essential for crop growth, and one or more of these are often deficient in crop lands. They are; iron, zinc, manganese, copper, boron and molybdenum.

The benefits of manure applications to the soil extend through 2 or more seasons of cropping. The effective use of manures involves little or no purchased inputs, and the labor involved in obtaining benefits may be spread over periods when crop production has low labor requirements.

e. Improved control of plant pests. The inclusion of forage plantings in the farming system has important values not found in systems without livestock enterprises. There is a reduction in the abundance of insects pests, nematodes, plant diseases, and of weeds that attack crops, when there is a regular sequence of perennial forages for 2 or more years in a 5 to 6 year rotation.

These pests are naturally decimated during the periods when forages are grown on the fields, because of the absence of susceptible host plants.

f. Feed supplies for work animals. Draft animals have an important role on mixed farms since they enable a larger farm operation than would be possible with the farm work force. Also since energy is farm produced, this does not involve out of pocket expense and obviates the need for fossil fuels and sophisticated mechanization. A serious limiting factor in the successful use of animal power to supplement manpower in farming is the failure to supply suitable feed for work animals (oxen, buffalo, asses, etc.) so that they are strong enough to be effective, and to survive heavy work. The frequent complaint that work animals die during land preparation at the beginning of the cropping season is primarily caused by the state of starvation these animals are in at the end of the long dry season when there has been little forage for grazing and no harvested feed available.

The production of nutritious feed on fields allocated to forages would permit correction of this constraint. Sustained feeding of work animals at all seasons, with additional feed when worked heavily, is virtually impossible when forage plantings are not included as important components of farming systems.

g. Effective use of non-arable lands associated with cropped lands.

Combined farm systems are not limited solely to crop lands. Farmers using systems that include ruminant livestock enterprises may make effective use of associated or nearby lands that are non-arable (rough topography, stony, or shallow soil, lands subject to flooding, etc.). These lands may be improved for forage production by prudent management and thus enlarge the size of the farm. Whether grazed or harvested as forage, these lands should provide additional feed, which is the real basis for livestock enterprises. Roadsides, field borders, wet areas and, areas that have been allowed to grow up to brush may all be significant sources of feed.

h. Profitable use of crop residues and by-products. Livestock provide an excellent means of utilizing crop residues and by-products to add to total farm production. Vines, stalks and leaves, straw, chaff from winnowing grain, and other plant residues may be used for livestock feed. These plant products after being fed, may ultimately be returned to the soil as manure. In such form, they are more useful in maintaining soil fertility than when incorporated into the soil directly. The additional values come from the livestock to which they are fed. In addition to crop res ıes on the farm, locally available by-products from central processing plants (cotton gin waste, rice mills, banana packing sheds, groundnut processing, etc.) are important feed stuffs. Many of the products are now wasted and lost in developing countries.

i. Animal products for human foods. There is a widespread shortage of protein foods in nearly all less developed countries, and this may be greatly alleviated by the inclusion of livestock enterprises in farming systems. Meat, milk, and eggs are often preferred protein foods for man since they are not only palatable, but also rich in the types of essential amino acids that are chronically deficient in plant proteins. Ruminant livestock (cattle, buffalo, sheep, goats) are particularly beneficial since these animals convert forages and roughages into meat and milk. Ruminants produce these highly prized nutritious foods from plant materials that are otherwise useless to man as foodstuffs.

Milk production and sales that are continous through the year provide a cash flow to farmers that is critically needed to cover on-going farm expenditures in seasons when there are no crop/annual sales. Since meat animals (male animals and less productive females) are a separate source of income to milk production, these sales constitute still further diversification in income, as well as increasing total amount. Furthermore, the labor requirements for livestock enterprises are well distributed throughout the year and thus largely avoid adding to peak labor problems related to crop production.

III. Facilitating the successful addition of livestock enterprises to crop farming systems.

There are specific types of action that may be taken to exploit the benefits from mixed crop/livestock systems. It is probable that suitable government programs will be needed in conjunction with specific external assistance agents to avoid needless disappointment. The following actions are suggested so as to fully capitalize on local farming situations:

a. Information on costs and benefits. An important type of advance information is data on the probable cost/benefits related to the livestock component enterprises, and to the entire farming system. This may become available as a result of pilot programs to test the effectiveness of methods that appear promising on the basis of experience elsewhere. The determination of actual costs for each type of enterprise is urgently needed. In most countries, it will be necessary to conduct field tests to determine the most appropriate livestock enterprises, and then make reliable estimates of cost/benefits. In some countries, the equivalent of such estimates have been approximated by a very few individual aggressive farmers with considerable personal success; but government assistance doubtless would greatly expedite more adequate testing and subsequent adoption of the more promising practices.

b. Providing livestock feed during dry seasons. Since the production of herbaceous feeds (forages) during the growing season for harvest or for reserved grazing in the dry season is almost completely neglected in developing countries, there is great need to institute programs to demonstrate the feasibility of supplying feeds and the best methods for using these feeds. It has been estimated that adequate feeds during the dry season could easily double the productivity of existing livestock herds and flocks, and at low cost. Adequate feed supplies are basic to successful livestock enterprises. When feeds are inadequate, lactation stops, with severe effects on calves, lambs, and kids; there is prolonged cessation in breeding; the animals cease growth; and continued feed deprivation causes severe loss in animal weight. Most of these adverse effects are quite unnecessary if feasible sources of feed are exploited. The longer the normal dry season for a region, the greater is the need for providing dry season pastures, standing or stored forages to feed cattle, buffalo, sheep and goats until the next growing season occurs. This practice which is traditional in temperate zone winters, is equally important in tropical regions with dry seasons.

c. Technical assistance on effective use of feed stuffs. Much information has been assembled from laboratory analyses of feedstuffs as to their nutritive value. and of the nutritonal requirements of different classes of livestock, so that technical assistance now can be provided on how best to use the feeds that are currently available. It is feasible to summarize such information for local conditions, and make recommendations that individual growers may follow. It is often found that feed production practices can be changed to improve the nutritive value of a feed. In other situations, it may be found that relatively small and inexpensive additions of minerals (notably, phosphate), alone or with salt; or of a concentrated protein supplement, may greatly improve the feeding value of a local feedstuff. This type of technical information will greatly improve the productivity of livestock particularly those of small producers who need guidance.

d. Developing milk processing to greatly enlarge markets for local milk producers. Milk processing is needed to provide milk products that are safe and in marketable form. Also in certain developing countries, the production of milk for processing into condensed or evaporated milk, or to milk powder, and for butter and cheese has had great benefits on the profitability of farming. For success, there must be prompt daily collection of milk and prompt cooling at central stations enroute to processing plants. The final milk products may be stored and marketed through normal food channels, including exports. Private enterprise has been notably successful in some countries, but there doubtless are many situations where government intervention (in the beginning) would be essential for development of a milk processing industry. In addition, to stimulating dariy operations, this movement should substantially increase the supply of meat animals moving to market.

Where milk processing has made progress to date, and where there has not been a companion program to improve feed supplies and to more fully utilize information on balancing feed rations to improve production at relatively low cost, there are additional opportunities that should be exploited. In view of the tremendous unfulfilled demand for dairy products in developing countries, as shown by massive imports in virtually all of these, the outlook is very promising. A key element at first is the development of markets, and an adequate road system for daily milk collection.

e. Effective livestock husbandry. In general, farmers and herdsmen have a natural affection of their livestock, but they often lack basic knowledge of their animals requirements and how to satisfy these. These livestock producers need guidance on (1) feeds and animal nutrition, (2) the management of animals for reproduction and milk production, (3) the absolute necessity to provide sustained feeding during dry seasons for year-round animal growth an production, (4) the basic principles for prevention of disease, and (5) the development of markets for both milk and meat animals. Most of this guidance must come from government programs directed to the small producers. These are the types of information needed to make livestock enterprises major income producers in combined farming systems.

One of the greatest contributions that an external assistance agency might make to the agriculture of a developing country would be to counsel governments to give a high priority to combined farming systems and the livestock components of such systems. In this connection, policies are needed that favor field testing in producing areas, effective extension education programs, supplemented with innovative methods for farm credit that will serve such enterprises.

f. Perennial forage grasses and legumes in crop rotations to support livestock enterprises. The advantage of including forage legumes and grasses in crop rotations to improve soil productivity have been stated in a foregoing section. They are usually equally valuable in improving feed supplies for ruminant livestock enterprises. These plantings should persist for at least two years to produce the desired improvement in soil conditions. (see Table 5, pp. 19&20)

The attached list of forage grasses and legumes is preliminary in nature; based on the limited printed information available, As additonal experience is acquired on performance of species grown in mixtures and as components of farm rotations, the number of suitable grasses and legumes that perform well without becoming weed hazards should be enlarged. For example, *Brachiara decumbens* might be added as a useful grass, and *Desmodium distortum* as a forage legume. Some species may be useful in certain regions and not in others. The ultimate potential for perennial forages suited for inclusion in crop rotations will doubtless be greatly enlarged by research and experience.

It should be noted that the species shown in table 5 have been selected to avoid any possibility that they might become weeds. This is important so that subsequent crops will not have additional weed problems. An additional factor in effective use is to graze the crop or harvest it whenever the legume or grass begins to flower or produce heads. During the growing seasons, the forage should not be allowed to produce seed, since the digestibility of the feed declines rapidly after heading or blooming. However, forage will mature when left standing to be used as feed in the dry season.

Cultural practices for establishing perennial forage plantings should be adjusted so that seeding occurs at the beginning of the rainy season. This insures rapid seedling establishment and growth.

Seed mixtures should contain 2 species each of perennial grasses and legumes. The total amount of seed will range from 5 to 10 lbs. per acre (5 to 10 kg per hectare), with about equal weights of grasses and legume seed. Lighter seedings rates are suitable for regions of lesser rainfall, and heavier rates for regions of more abundant rainfall.

Fertilizer. Limited amounts of nitrogen fertilizer (or animal manures) may sometimes stimulate seedling establishment, but no further nitrogen is needed after the legumes are well established. Phosphate fertilizers will benefit the legumes particularly, and should be incorporated in the soil during seed bed preparation. Other fertilizer needs may be determined by soil testing or actual field trials, as used on crops of the rotation.

TABLE 5 - Perennial Tropical Forage Grasses and Legumes, Suited for Use in Crop Rotation to Maintain Soil Productivity, and to Support Livestock Enterprises.

A. For regions with 10 inches or more annual rainfall (250 mm. or more)

1. Grasses

Birdwood grass - Cenchrus setigerus

Buffel grass (short variety) - Cenchrus ciliaris

Love grass - Eragrostis curvula

B. For regions with 20 inches or more animal rainfall (500 mm or more)

1. Grasses (including those in section A)

Blue Panic grass - Panicum antidotale

Makarikari grass - Panicum coloratum makarikariense

2. Legumes

Dwarf Koa - Desmanthus virgatus

Townsville Lucerne - Stylosanthes humilis (cool season rainfall only)

C. For regions with 30 inches or more annual rainfall (750 mm or more)

1. Grasses (including those in preceding sections)

Harding grass - Phalaris tuberosa stenoptera

Plicatulum grass - Paspalum plicatulum

2. Legumes (including those in preceding sections)

Leucaena - Leucaena leucocephala

Lucerne - Medicago sativa

Phasey bean - Phaseolus lathyroides

TABLE 5 - (cont'd)

D. For regions with 35 inches or more annual rainfall (845 mm or more)

1. Grasses (including those in preceding sections)

   Pigeon grass - Setaria sphacelata

   Scrobic grass - Paspalum commersoni

2. Legumes (including those in preceding sections)

   Stylosanthes - Stylosanthes guyanensis

F. For regions with 40 inches or more annual rainfall (1000 mm or more)

1. Grasses (Including those in preceding sections)

   Alabang grass - Dicanthium caricosum

   Molasses grass - Melinis minutiflora

2. Legumes (including those in preceding sections)

   Lablab - Dolichos lablab

   Silverleaf desmodium - Desmodium uncinatum

Table No. 6

Perennial tropical forage grasses and legumes suitable for use in crop rotations to maintain soil productivity, and to support livestock enterprises

Plant Species	Minimum Seed Quality Standards: Germination %	Minimum Seed Quality Standards: Purity %	Seed Size (Thousands): per lb	Seed Size (Thousands): per kg	Seeding Rates: Acre	Seeding Rates: Ha	Minimum Yr. Rainfall: In.	Minimum Yr. Rainfall: mm	Tolerance: to drought	Tolerance: to soil water logging
A. Regions with 10 inches or more annual rainfall										
Grasses										
Birdwood grass	30%	80%	80	175	½- 2	½- 2	10	250	very good	poor
Buffel grass	30	80	200	440	½- 4	½- 4	10	250	very good	poor
Love grass	80	90	1500	3300	½- 1	½- 1	10	250	good	poor
B. Regions with 20 inches or more annual rainfall										
Grasses (including those in section A)										
Blue panic grass	50	80	650	1430	½- 3	½- 3	20	500	very good	fair
Makarikari grass	30	90	725	1600	1½- 3	1½-3	20	500	good	good
Legumes										
Dwarf koa	80	70	20	40	2	2	20	500	good	poor
Townsville lucerne (cool season rainfall only)	90	40	200	440	2- 3	2- 3	20	500	good	poor
C. Regions with 30 inches or more annual rainfall										
Grasses (including those in preceding sections)										
Harding grass	60	90	300	660	2- 4	2- 4	30	750	good	good
Plicatulum grass	30	55	385	850	2- 4	2- 4	30	750	good	good
Legumes (including those in preceding sections)										
Leucaena	90	50	12	26	4- 6	4- 6	30	750	good	good
Lucerne	90	80	200	440	½- 5	½- 5	30	750	good	poor
Phaseybean	90	70	56	125	1- 3	1- 3	30	750	good	good
D. Regions with 35 inches or more annual rainfall										
Grasses (including those in preceding sections)										
Pigeon grass	30	90	600	660	2- 5	2- 5	35	875	fair	good
Scrobic grass	30	95	170	375	2- 5	2- 5	35	875	fair	good
Legumes (including those in preceding sections)										
Stylosanthes	90	40	160	350	2- 5	2- 5	35	875	good	fair
E. Regions with 40 inches or more annual rainfall										
Grasses (including those in preceding sections)										
Alabang grass	34	23	-	-	18	20	40	1000	fair	fair
Molasses grass	30	60	6000	13000	2- 4	2- 4	40	1000	fair	fair
Legumes (including those in preceding sections)										
Lablab	90	50	2½	5	5-20	5-20	40	1000	good	fair
Silverleaf desmodium	90	50	95	[illegible]10	1- 3	1- 3	40	1000	fair	fair

For further information on these forage species, see Technical Series Bulletin No. 14, "Characteristics of Economically Important Food and Forage Legumes and Forage Grasses for the Tropics and Sub-Tropics", published by TA/AGR, U.S. Agency for International Development, Washington, D.C., 1975.

Since a single fertilization is made at planning time to support the forage crop for at least 2 years, the amount of fertilizer should be increased proportionately, particularly the phosphate fertilizer.

Inoculation of legume seed just before planting is highly essential. The legume inoculants must be composed of strains of root nodule bacteria that are compatible with the legume species being planted. The inoculation material is usually supplied as a black powdery material; and the rates of use are given on the container. Mixing is simple; the culture is sprinkled on slightly moisten seed, and well stirred so that every seed carries some of the inoculum. Treated seed should be planted promptly thereafter, and shallow tillage given to cover the seed lightly. The bacteria in the culture begin growth as the seed germinates, and will inoculate the legume roots at an early stage of growth.

Seed bed preparation should produce a well compacted pulverized soil surface, since the seeds are small and should not be planted too deeply. Light tillage after planting will provide sufficient coverage of seed.

Protect new plantings. The young plantings should normally be protected from all grazing or harvest until the grasses begin to produce heads or the legumes to produce flowers. After the first harvest, the fields may be grazed intermittently, or harvested whenever a new crop of grass heads or legume flowers occur. The greatest benefits to soil improvement, and the greatest yields of forage for livestock are achieved when regrowth is protected until blooming or headir occurs.

However, best performance takes place as to yields and forage quality when top growth is harvested promptly as these growth stages.

When forage plantings are grazed, it is important that the livestock be managed in a way that is compatible with good animal production, as well as fostering sustained forage plant vigor. Overgrazing and overstocking are self-defeating. These practices are unfortunately widespread, and they must be corrected by any feasible means because of adverse effects on productivity, and on profitability to the farmer. Desirable management practices for local conditions are simple and feasible, and these are easily transferrable to producers.

It should be noted that this bulletin does not deal with production of other forages on arable lands, that may be periodically cut and fed green to livestock. There are many such feedstuffs, but they do not fall within the scope of mixtures of perennial forages grown in crop rotations to: (a) improve the long-term productivity of arable lands, and (b) to provide nutritious feed for ruminant livestock. Some examples of such feedstuffs would include elephant grass grown with abundant water and supplemental nitrogen fertilizer for harvest every 60 days, sugar cane harvested whenever height of 3 to 4 feet is reached, berseen (a cool season annual) grown with irrigation or adequat rainfall for harvest every 30 to 45 days, sorghum-sudan hybrids grown as warm season annuals with periodic harvests, and others that may have good regional performance.

g. <u>Suitable credit for animal enterprises.</u> The small farmers who wish to develop livestock enterprises as part of the farming system require a different type of credit from that suitable for seasonable cropping. Livestock enterprises require the purchase of animals that will not be fully productive until they reach maturity and either begin production of milk or until meat animals can be marketed. Consequently, it is necessary to have longer term loans for livestock purchases and also for establishment of forage plantings and their maintenance for at least 2 years of production. Other needs may be the purchase of fencing materials and of machinery services for planting, and shelter for controlled animals. There may be need also for new facilities for the collection, storage and field application of manures, to capitalize on such beneficial opportunities.

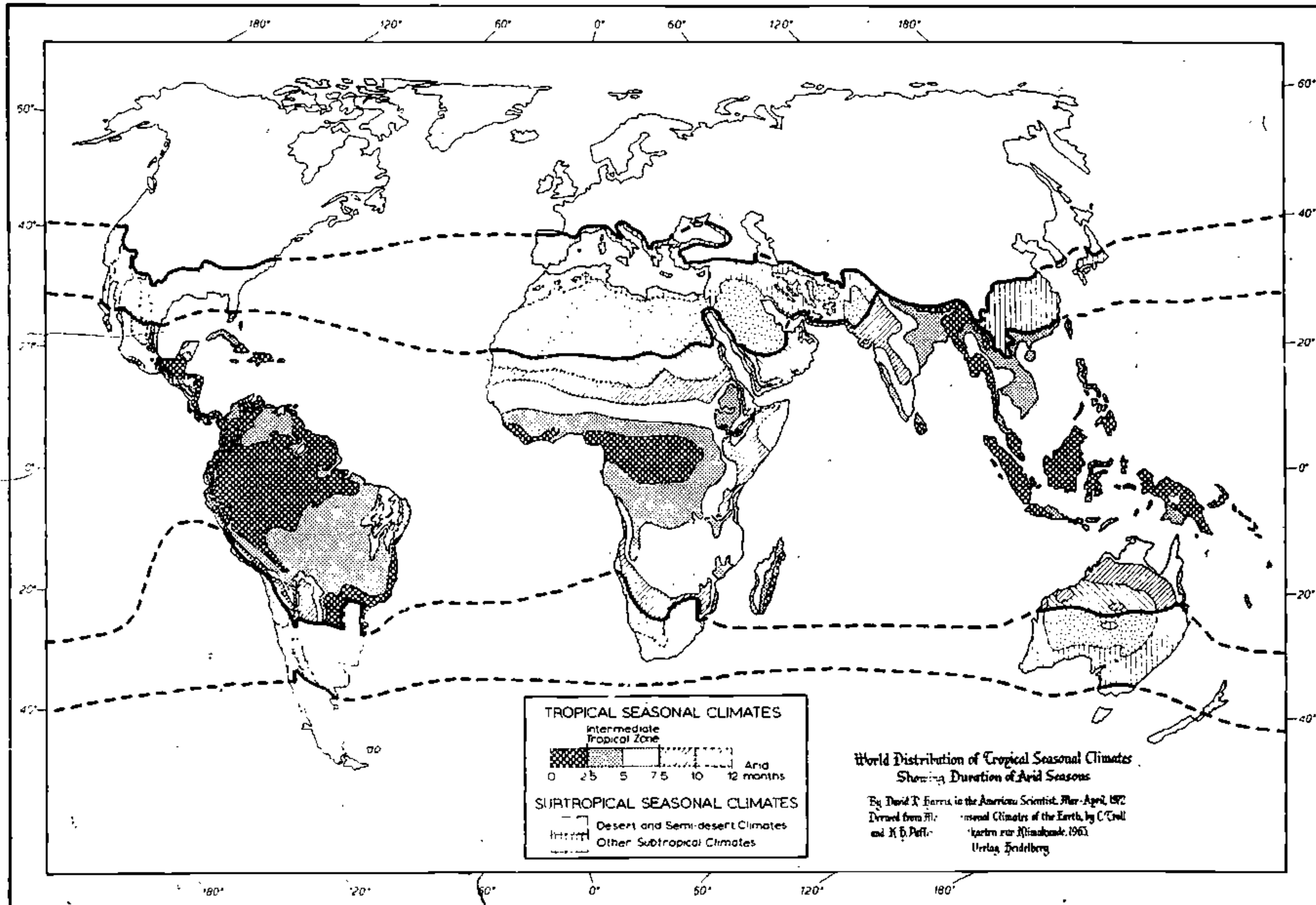
The Government may directly, or through farmer cooperatives, provide such credit to small farmers, on terms that are suitable to effective development of new animal enterprises by ᴐp farmers. An integral part of such credit may be the continuing counsel and guidance to the borrower on how best to use the credit for economic improvement. Without suitable credit and counsel, the advantages of combined crop/livestock farming systems may not be exploited successfully by the small farmers.

h. <u>Providing animal health care.</u> Any increase in numbers of livestock in a locality inevitably increases possibility of significant disease and animal health problems. To the extent that livestock of each farmer are restricted in movement to the boundaries of the farm and there is virtually no intermingling with communally managed herds, the increase in diseases may be minimal. However, a preventive program

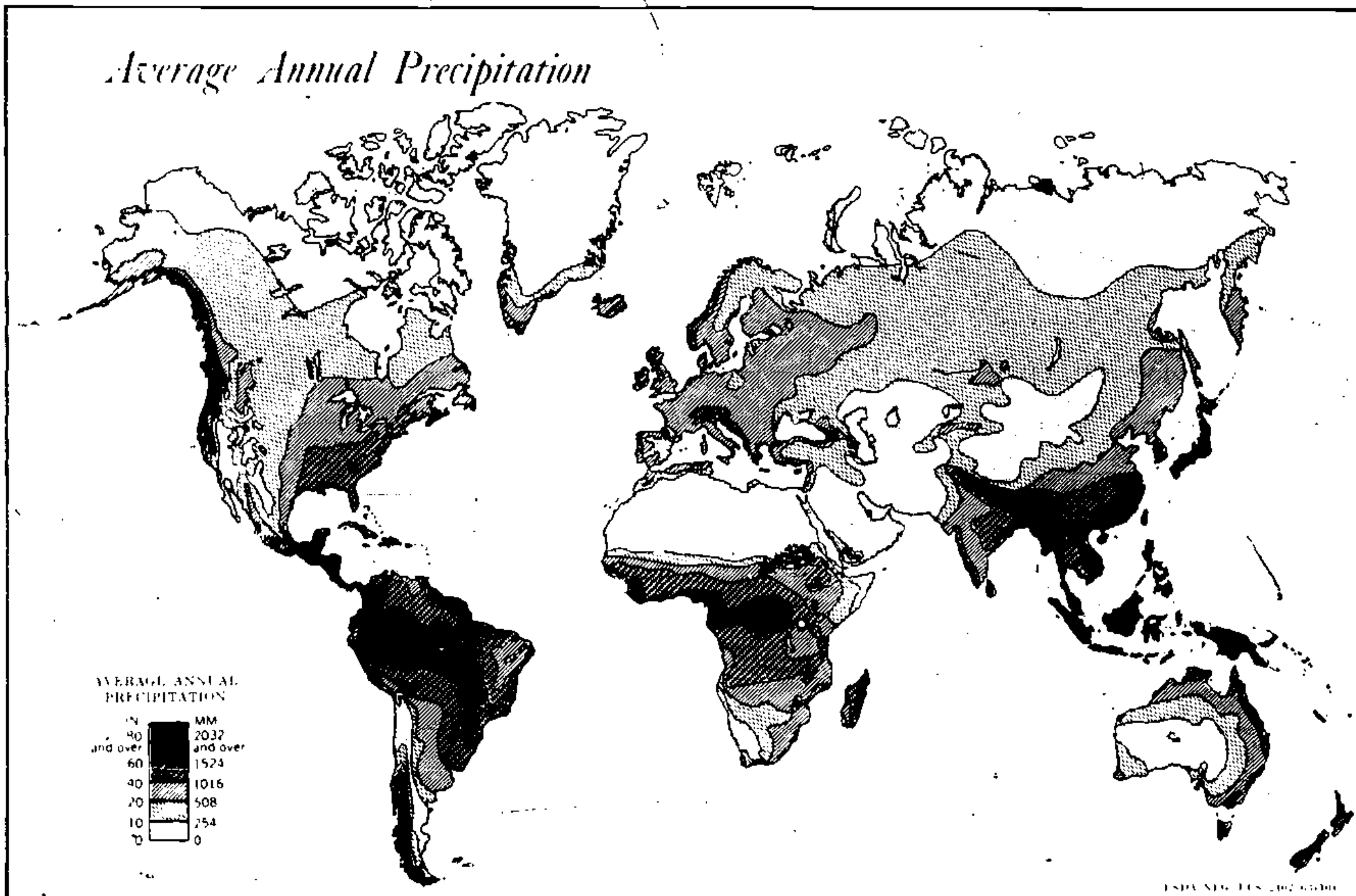
A particular problem must be solved in those regions where there are relatively large areas of public grazing lands in relation to crop lands. In those regions, there appear to be no alternatives to placing full responsibility for effective management of these grazing lands on the village leaders. These leaders should be counseled on the merits of controlled stocking rates, on the improvement of forage producing capacity of the lands by regulated grazing (such as rotation grazing, and protection of areas reserved for dry season feed), brush control, introduction of superior grasses and legumes, etc.). In some areas, village cooperatives may be developed to manage these open grazing lands. External assistance agencies generally have elected to remain aloof from such matters, but there would be merit in sensible development and management of open grazing lands in regions where they are extensive.

is the least expensive and most effective type of program for animal health control, and this requires the intervention of government in providing veterinary health services. In some situations, particularly after livestock enterprises have been widely adopted, farmer cooperatives may assume full responsibility for providing animal health services. But for initial introduction of such enterprises, crop farmers will need assistance. There are advantages in combining counsel and guidance on standard livestock management with technical assistance on disease control, since both types of aid are essential. However, the veterinarians may serve a larger region than the livestock management specialists, and be made available on call from the latter.

i. Cautions on use of communal or open grazing lands. Farm villages in much of Africa and the Near East make considerable use of communal or other open grazing lands. While the livestock are all individually family owned, the mixed herds of ruminants (cattle, buffalo, goats, sheep) are not segregated. Such common grazing lands do not occur in Latin America, and are absent in some other regions. There are serious problems in trying to develop livestock enterprises on individual farms, by using such open grazing. First, these open grazing lands are chronically overstocked, and are undependable sources of feed since no beneficial management practices for sustained feed production are invoked by the village leaders. Second, these communal herds as they grow in size, provide increasing dangers for spread of parasites and communicable livestock diseases throughout these herds. As individual farmers become more concerned and proficient in producing feed for their own livestock, they may decide to relinquish any use of open grazing lands.

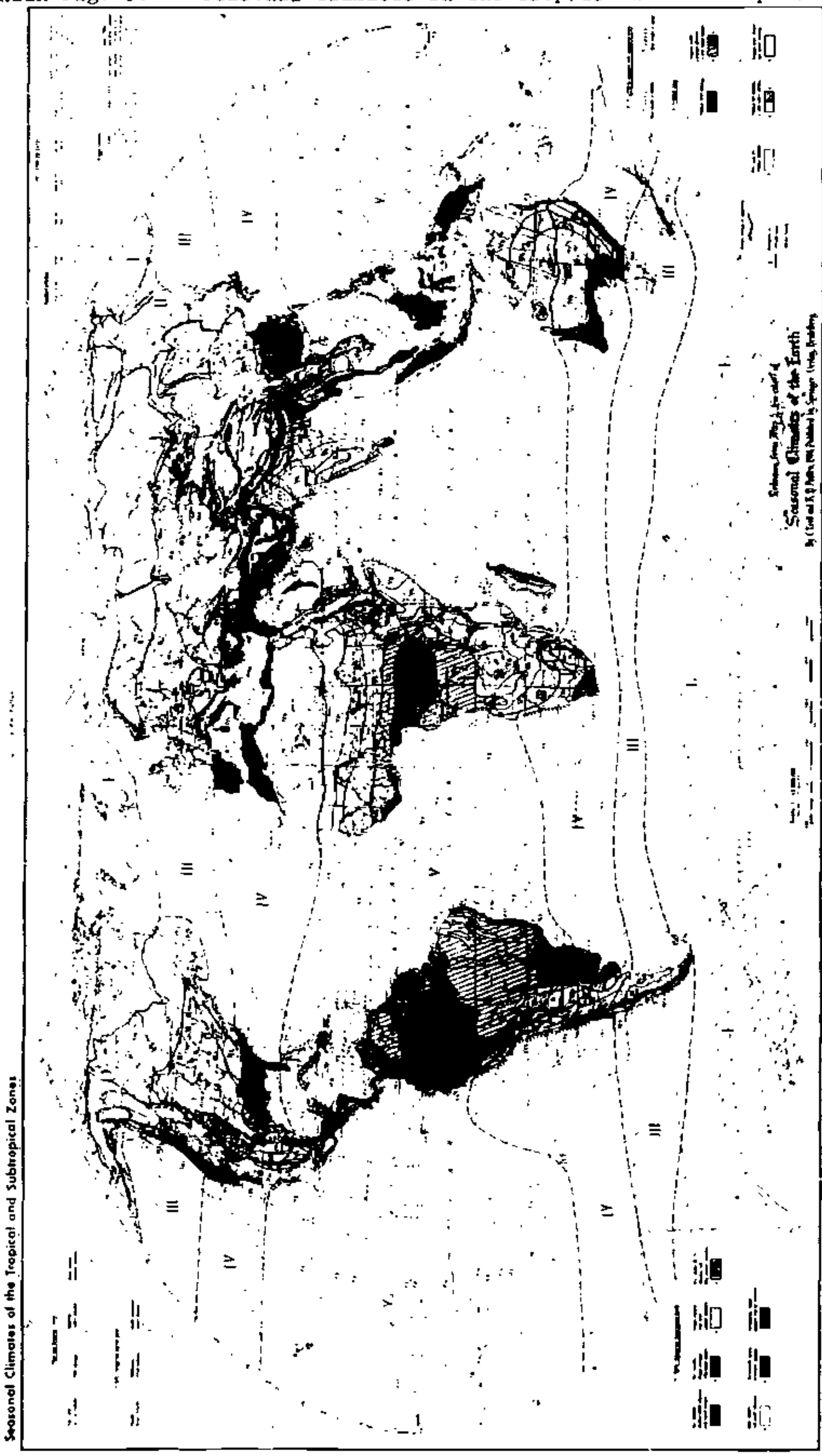


Appendix Fig. 1. "Duration of the Arid Seasons"



Appendix Fig. 2. "Average Annual Precipitation"

Appendix Fig. 3. "Seasonal Climates in the Tropics and Sub-Tropics"



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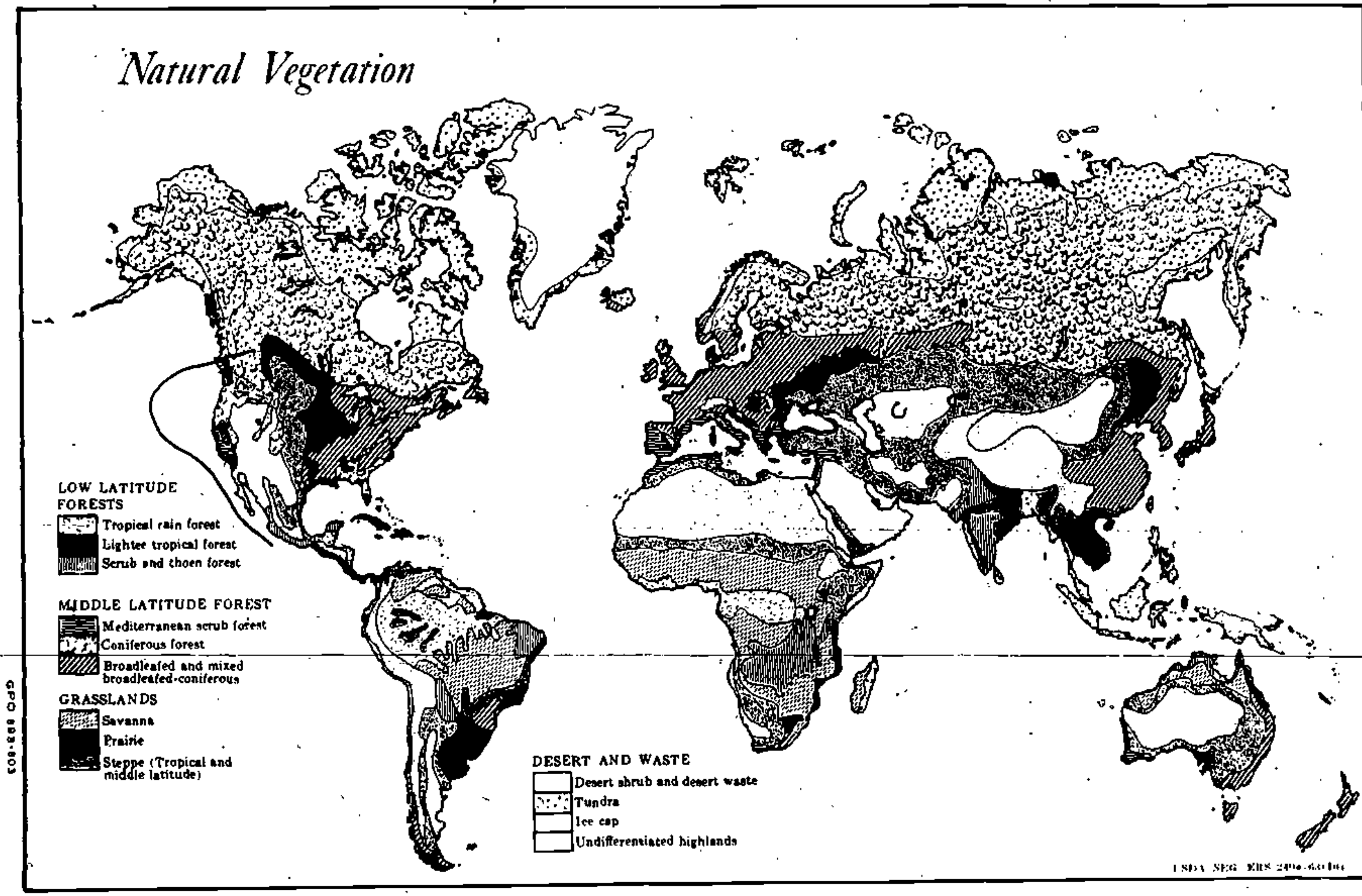

Appendix Fig. 4. "Natural Vegetation Zones"

Since 1961 when the Peace Corps was created, more than 80,000 U.S. citizens have served as Volunteers in developing countries, living and working among the people of the Third World as colleagues and co-workers. Today 6000 PCVs are involved in programs designed to help strengthen local capacity to address such fundamental concerns as food production, water supply, energy development, nutrition and health education and reforestation.

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