UTILIZATION OF LANDSAT IMAGERY FOR MAPPING VEGETATION ON THE MILLIONTH SCALE

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ABSTRACT

The United Nations Educational, Scientific and Cultural Organization (Unesco) has recently published a vegetation classification system. This system, based on the physiognomy of the vegetation, is designed to provide a comprehensive framework for the preparation of vegetation maps of any part of the world at scales of 1:1,000,000 or less. The utility of the system lies in the fact that optimal agricultural land uses are always related to the natural vegetation.

The system is designed for use with maps covering large areas. The large map area, however, poses a severe problem in uniform data collection, especially if large-scale imagery is employed as a mapping base. Since LANDSAT images have a basic utilization scale of 1:1,000,000, identical to that of the projected maps, they would serve as a uniform base for all parts of the world if they contained the information necessary to delimit vegetation formations.

To determine if the information content of the imagery is sufficient to permit mapping according to the Unesco classification, a series of test sites have been examined. These sites include examples from the humid tropics, arid and semi-arid subtropics and temperate zones. In every case the feasibility of this application of LANDSAT imagery has been verified. The agricultural significance of several sites is discussed to indicate how the vegetation maps may be interpreted for agricultural evaluation.

INTRODUCTION

In 1965 the Standing Committee on Classification and Mapping of Vegetation of the United Nations Educational, Scientific and Cultural Organization (Unesco) began consideration of a classification of vegetation. The Committee, composed of authorities from throughout the world, worked through the next decade to develop its classification. As published in its final form (ref. 1), this classification system is designed to provide a comprehensive framework for the preparation of vegetation maps of any part of the world at scales of 1:1,000,000 or less. Utilization of the system would result in the production of maps providing a solid basis for comparison of vegetation in all parts of the world.

The utility of such a system lies in the fact that optimal agricultural land uses are always related to the natural vegetation. Consequently, if successful production of a certain crop occurs in areas where ecological conditions produce a particular vegetation type, other parts of the world possessing the same vegetation type and, therefore, the same environment, will also be suited to the cultivation of that crop. As human populations continue to grow, it becomes ever more necessary to produce those crops best suited to each part of the Earth's surface to ensure the optimum availability of food and other agricultural commodities. This classification is therefore particularly relevant to large-area planning problems.

Prior to final publication of the system, field trials were conducted in Costa Rica by Küchler and Montoya Maquin (ref. 2). These trials established the feasibility of field classification of vegetation units under the system. Subsequently, Williams, et al. (ref. 3) mapped a small area in northeastern

Kansas. Although the map was published at a large scale (1:12,000), the feasibility of using the system was once again demonstrated. To date, no small scale map based on the Unesco classification has been published. Nevertheless, these results clearly indicate that the system is usable.

The classification is based upon physiognomic rather than floristic criteria. Physiognomy refers to the physical appearance or growth form of the vegetation while the floristic composition is the list of plant species which are present in a plant community. Although interconnected, physiognomy and flora are not identical. Thus, a given group of plant species may exhibit different physiognomies under different environmental conditions. For example, trees which form dense forests at lower elevations become reduced in size and tree density decreases near timberline. This changes the physiognomy of the vegetation from closed forests to open shrublands although the principal species are the same. On the other hand, different groups of plant species may exhibit identical physiognomies when growing under similar environmental conditions. This phenomenon has long been recognized in the wintergreen shrublands of California, the Mediterranean basin, southern Australia, South Africa, and Chile where the plants respond to the concentration of precipitation in the cool season. Because the Unesco classification is based upon physiognomy, it results in all such shrublands being assigned to a common class, accurately reflecting the comparability of environments in these areas (ref. 4).

The Unesco classification is an open-ended hierarchy with the formation as the basic unit of the system. As illustrated below, three levels exist above the formation. Although the definition is amplified in the text of the classification, the formation name is sufficient to inform the map reader that this

Classification Unit	Example
Formation Class	Closed Forest
Formation Subclass	Mainly evergreen forest
Formation Group	Tropical ombrophilous forest
Formation	Tropical ombrophilous swamp forest

example vegetation type is a forest, with tree crowns touching, composed of trees which are (1) broad-leaved; (2) evergreen; (3) grow in warm, very humid areas; and (4) are in permanently inundated localities. In preparing the classification the Committee designated some subformations, but the individual is free to add other subformations or further subdivisions and to augment the formation name with floristic data or significant local names of the vegetation type. The mapper might thus specify that his formation is locally known as chaparral in California and macchia in Italy.

Five formation classes have been designated by the Committee, encompassing all terrestrial and emergent aquatic vegetation known to occur. These formation classes are defined in the following manner (ref. 1).

Formation Class	Definition
Closed forest	Formed by trees at least 5 m tall with their crowns interlocking
Woodland	Composed of trees at least 5 m tall with crowns not usually touching but with a coverage of at least 40 percent.
Scrub	Mainly composed of woody plants 0.5 to 5 m tall.
Dwarf-scrub	Composed mainly of woody plants rarely exceeding 50 cm in height.
Herbaceous	Dominated by an herbaceous synusia and with woody plants not covering more than 40 percent of the area

Systems of subdivision used in each formation class are consistent within limits imposed by the characteristics of different plant growth forms and the range of naturally occurring vegetation types.

Cultural vegetation is treated as a separate and unique portion of the vegetation. Units of natural vegetation are used to infer ecologic conditions in cultivated and urbanized areas but such predicted areas are always distinctively indicated on the map.

Small-scale Mapping Methods

As detailed by Küchler (ref. 5), two basic methods exist for preparing small-scale vegetation maps. One of these methods is compilation. In compilation, all of the previously published vegetation maps of the study area are collected, common legend elements are extracted for a composite legend and the maps are compiled onto a common base. This method is feasible only if large- and medium-scale maps have previously been produced for the entire study area. Even then, substantial difficulties may arise because some maps may show floristic, others physiognomic, and still others ecologic classes and these legends may prove irreconcilable.

The second method of generating small scale vegetation maps is primary mapping. The principal components of this method are (1) acquisition of a set of aerial photographs, (2) delineation of vegetational boundaries apparent on these photos, and (3) a field survey to verify the boundaries and identify the vegetation units enclosed by these boundaries. In general, the products of primary mapping methods are considerably superior to products of compilation methods because of consistency of the legend classes.

Considering that the objective of the Unesco vegetation classification is to provide a basis for small-scale mapping and that the objective of small-scale maps is large-area coverage, primary mapping methods pose a serious problem. Areas suitable for inclusion on a single map sheet at the millionth scale may well be of the order of size of the state of Kansas, over 200,000 km^2. Over such an area, large scale imagery of uniform quality, scale, and date is rarely available. Even if such imagery were available, utilization poses a severe handling problem. Since each frame of 1:20,000 aerial photography represents a gain of approximately 5 km^2, about 40,000 frames of 9-inch format photography are required to cover the state. Nor is the standardly available imagery time-synchronous. In fact, the most current available set of photos for the state of Kansas have acquisition dates spanning a period of 16 years. The dollar cost and physical problems attendant on acquisition of a new set of images for such an area eliminate a special mission as a viable alternative. Since the actual surface area represented by the gain of one 1:20,000-scale photo will be portrayed by only 5 mm^2 on the finished map, most of the detail evident in the photo will have to be discarded during reduction. Acquisition of surface observations about all of the boundaries and types evident on the photo will represent large expenditures of wasted field effort. Further, the sheer mechanics of a 50 X scale reduction are costly and fraught with error potential.

In contrast to the problems of large-scale imagery specified above, LANDSAT images have a basic utilization scale of 1:1,000,000, identical to that of the projected maps. This scale effectively eliminates problems associated with reduction of the manuscript map and facilitates use of optimum current cartographic techniques. Parts of only 18 scenes are required to cover the state of Kansas, eliminating the aforementioned image handling problem. Although resolution is sufficient to record more detail than can be reasonably reproduced on the finished map, unnecessary detail has already been generalized out of the image by the acquisition process. The imagery provides a uniform mapping base for all parts of the world, thereby solving the difficulties of procuring a suitable base map.

Since it is evident that LANDSAT imagery would prove useful for vegetation mapping at the millionth scale, the remaining question must be whether the vegetational information contained in the images is that required for distinguishing formations as established in the Unesco classification.

MATERIALS AND METHODS

In order to test the feasibility of using LANDSAT Multispectral Scanner (MSS) imagery for vegetation mapping, a series of test sites was selected. These sites represent a wide range of physiognomic types, although they do not include every formation in the classification. Each test site was chosen on the basis of available MSS images and supporting data in either the form of direct observations by the authors or published maps and analyses of the vegetation amenable to use in the Unesco classification. The sites illustrated in this discussion are indicated on Figure 1, which also indicates several supplementary sites checked in the course of the investigation.

Color composite LANDSAT images were employed for interpretation of vegetation boundaries and the formations were determined by comparison with the supporting data. In addition, consideration was given to the image characteristics associated with each of the formations.

RESULTS

Results of this experiment are presented in the form of vegetation maps and annotated images which will serve to illustrate the detectability of various formations. The range of problems and potentials associated with small-scale vegetation mapping are indicated by Figure 2, which presents a vegetation map of a portion of the Western Highlands of Papua New Guinea together with the LANDSAT MSS image from which it was prepared. It should be noted that the image, although it exhibits the normal complement of colors, was prepared from bands 5 and 7 only. This was done because degradation of band 4 due to atmospheric scattering is extreme in very humid areas. Current experience indicates that loss of image sharpness (spatial resolution) due to incorporation of band 4 more than offsets any gain attributable to spectral differences between bands 4 and 5, as long as targets such as natural vegetation are under consideration. Except for the Papua New Guinea scenes, however, all composites used in this study are conventional combinations of bands 4, 5, and 7.

The basic relationships between image and map are readily apparent (Figure 2). However, a number of details deserve comment. Although boundaries between formations are often sharp, they are not always so. Two examples of this condition are apparent in the present illustration. One is the boundary between the Tropical Ombrophilous Submontane and Montane Forests. In some areas this boundary is clearly evident on the image whereas in other areas it is diffuse. Such diffuse boundaries, collectively termed transitions, are quite common in natural vegetation. In the present case, where the change in formation is associated with altitudinal changes, it is not surprising that transitions occur in areas of moderate regional slope while relatively abrupt boundaries are characteristic of more precipitous slopes. That a transition is occurring in this area is evident by the very gradual changes in color evident across the zone and the distinctness of the areas at opposite edges of the transition zone.

The second special boundary type is a mosaic such as that observed between the Tropical Ombrophilous Cloud Forest and Tropical Alpine Bunchgrass atop Mt. Giluwe. Here the two formations are physically discrete but are distributed in units of such a size that they cannot be shown as discrete mapping units. Rather, then, they are shown as mosaics of the formations of which the area's vegetation is composed.

The necessity for interpreting beyond color recognition is illustrated by comparison of sunlit and shadowed mountain slopes and of the two graminaceous formations. In the first case, the color shift within one formation due to directness of illumination is of the same order as the color shift between formations under constant illumination. In the second case, although colors of the Tropical Grassland and Tropical Alpine Bunchgrass are in some cases quite similar, topographic position readily establishes ecologic differences between these formations. In addition, it is quite evident from the case of the Tropical Grassland that subformational distinctions are possible. The pinker shades in this mapping unit are associated with vegetation composed of Phragmites karka (tall swamp reed) while the light blue sites are dominated by sedges and other grasses (ref. 6). In other cases, however, accuracy of subformational distinctions remain uncertain. Although the darker red areas within the Tropical Ombrophilous Montane Forest include all areas mapped by Saunders (ref. 7) in a class identifiable as the Microphyllous Subformation, substantial areas not mapped by Saunders exhibit identical image characteristics. Without further ground survey, a positive statement regarding the feasibility of subformation mapping in the forests of this region is not possible. On Mindoro Island, Philippines, however, the Needle-leaved Subformation of the Tropical Ombrophilous Submontane Forest is visually distinctive (ref. 8; Coiner, pers. obsv.).

As plotted on this map (Figure 2), cultivated land includes land under cultivation and those areas in various stages of regrowth. Since most agriculture in the highlands of Papua New Guinea occurs as shifting cultivation, a complex mixture of apparent vegetation types is to be expected and is, in fact, observed. Areas of cultivated land are classified according to their ecological zone. That is, the map color of each cultivated area reflects the apparent formation to which the area belongs. Distinctly different crops are cultivated depending upon the ecologic potential of the area.

In addition to shifting cultivation of subsistence crops, two crops are commercially important in the major highland valley in the northeastern part of the map area. These crops are coffee and Pyrethrum. Pyrethrum flowers yield a powerful contact insecticide now widely used in sprays. These crops are well-adapted to export and therefore desirable for cultivation in a developing region because of their capacity to generate foreign exchange.

The potential utility of preparing vegetation maps on the millionth scale is illustrated by comparison of Figure 2 with Figure 3A. The latter is a LANDSAT image of a valley lying further west in Papua New Guinea. Unlike the area included in Figure 2, no ground surveys of resources have yet been completed in this western valley. Comparison of the two scenes, however, demonstrate the general similarity of vegetation formations in the two valleys. The western valley should therefore prove suitable for further expansion of these agricultural industries.

Although striking similarities are evident, certain distinctive aspects of the vegetational formations on Mindoro Island, Philippines (Figure 3B) deserve comment. Unlike the Western Highlands of Papua New Guinea, where a sword grass (Miscanthus floridulus) regrowth predominates, extensive burning of forest on Mindoro has resulted in establishment of Imperata cylindrica (cogon, kunai) Tropical Grassland (Coiner, pers. obsv.). The lower elevations and coastal areas of Mindoro support two formations not evident at the higher elevations of the New Guinea sites, the Tropical Ombrophilous Lowland Forest and Mangrove Forest. Mangroves have proven visually unique on all images examined, irrespective of adjoining vegetation types.

Many forests include both deciduous and evergreen trees in varying proportions. Deciduocity may be associated with pronounced seasonality of either precipitation or temperature. Although color differences between the evergreen and deciduous Formation Subclasses are evident during the leaf season, distinctions ensuring recognition of the Formations are enhanced by selection of images which exhibit the deciduous forest in a non-leaf or partial leaf condition. The contrast between such images is amply illustrated by comparison of Figures 3C (12 July 1973) and 3D (15 October 1972). The Great Smoky Mountains of the southeastern United States have Evergreen Needle-leaved Forest with Conical Crowns at the highest elevations (ref. 9; Williams, pers. obsv.). This formation, dominated by spruce (Picea) and fir (Abies), retains the red color of living vegetation after deciduous leaf-fall has eliminated the red color of the Montane Cold-deciduous Forest, so designated to distinguish it from drought-deciduous forests, which replaces the Evergreen Forest at lower elevations. At still lower elevations, the deciduous forests are replaced by Cold-deciduous Broad-leaved Forest with Evergreen Needle-leaved Trees, with rounded crowns in this case. This mixed forest of deciduous and pine trees of the lower elevations of the Valley of East Tennessee has now been largely replaced by cropland and other human uses except in those localities too rugged for farming. In contrast, areas ecologically suited to the occurrence of deciduous forest in this region have remained forested because they are quite unsuited to cultivation due to topography and soils.

In sharp contrast to the heavily vegetated humid regions just examined, the vegetation of the interior of Western Australia (Figure 4A) is predominantly a Semideciduous Subdesert Shrubland. The mulga (Acacia aneura) and associated shrubs are facultatively deciduous. That is, they put out leaves whenever sufficient soil moisture is available to support growth and shed these leaves whenever the moisture supply drops below some minimum (ref. 10). Th's event may occur several times in a single year. At the time of image acquisition (30 November 197. ,, the shrubs were in leafless condition. Nevertheless, the shrublands are distinctive from the Medium-tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs, although the boundary between these formations is generally gradual because the only difference between the two formations i, shrub density. As the breakaways of the highlands are approached, large areas are nearly barren. Despite the inactive status of the vegetation of most of this region, formational distinctions are, then, feasible.

Representing a condition intermediate between the dense vegetation of the humid and sparse vegetation of the arid areas previously examined, northeastern Uganda illustrates conditions prevailing in a tropical savanna (ref. 11). Moisture supply varies greatly in this area, resulting in a distinctive vegetation pattern. Tropical Grassland composed of Cyperus papyrus occupies the permanent swamps of the major stream valleys. On sites having impeded drainage but not being permanently swampy, the Tropical Grassland is replaced by a Tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs. Much of the area covered by this vegetation type is subjected to frequent burning, as is readily evident on this image. Because of the heavy-textured soils under this formation, which cause the drainage to be impeded, the area is not suited to cultivation and is used only for grazing cattle. Variations in degree of vigor of the vegetation of this formation are indicated by color variations. The redder the vegetation, the more vigorous the growth but the less suitable the grazing because the wetter conditions producing the vigorous growth are indicative of conditions favoring hoof-and-mouth and rinderpest, both serious cattle disease problems in Uganda (ref. 12). On better drained sites, the density of trees increases and the vegetation becomes a Tall Grassland with a Deciduous Tree Synusia Covering 10-40 Percent. The boundary between this and the preceding formation defines the northeastern limit of cultivation in Uganda. At higher elevations on the slopes of Mt. Napak savannas yield to an Evergreen Needle-leaved Woodland with Rounded Crowns dominated by Juniperus procera and Podocarpus gracilior. This woodland is quite distinctive from forests of similar composition which occur elsewhere in Uganda because of the difference between the lighter and more mottled color associated with the woodland and the darker smoother color of the forest.

Although differing in detail, certain similarities are evident between the sites in Uganda and south-central Kansas (Figure 4C). This area, surrounded by cultivated land, is characterized by Medium Tall Grassland of Sod Grasses (ref. 13, Williams, pers. obsv.). Variation of plant density due to local topographic effects in this rugged area are evident. The plants are dormant on this image because it was acquired during a dry midsummer period and the native grasses grow actively only in the presence of suitable moisture supplies. In some parts of the area sand sage (Artemisia filifolia) is a common constituent of the vegetation, transforming the formation into a Medium Tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs. This formation is readily distinguished from the preceding one because of the continued active growth of the shrubs in contrast to the dormancy of the grasses. The canyons of this area contain dense stands of eastern red cedars (Juniperus virginiana) which form an Evergreen Needle-leaved Forest with Conical Crowns. Topographic position and the use of seasonal coverage permit ready distinction of the preceding formation from the Cold-deciduous Alluvial Forest composed entirely of phreatophytes on the major river floodplains. The intense infrared reflection of the forests in this area is indicative of the relatively abundant water supplies in the forested areas.

Examination of supplementary sites in Wyoming, northeast Kansas, New Jersey, the Amazon Basin, Patagonia, the Sudan, and northern Australia provide no data contravening the results discussed in this section.

DISCUSSION AND CONCLUSIONS

From the illustrated examples and other test sites examined, it has become evident that the formations of the Unesco vegetation classification can be satisfactorily distinguished on LANDSAT MSS images, especially when used as color composites and judiciously chosen as to season. The imagery may therefore be used as a mapping base for the preparation of vegetation maps on the millionth scale. This outcome was to be expected since the chief criteria used in preparing the classification were based on density and vigor of vegetation and seasonal variations in growth behavior. It is exactly these factors which affect the return of energy to the satellite in the wavelengths to which the Multi-spectral Scanner on LANDSAT is sensitive.

The potential value of maps of this type for large-area planning is illustrated by the example from the Western Highlands of Papua New Guinea. Analysis of the imagery indicates a significant potential for the expansion of production of valuable commercial crops into an area not previously used for this purpose. Such analyses may be accomplished by either of two related methods. The first of these, illustrated by the Papua New Guinea example, uses the concept of analogous areas, interpreted from LANDSAT data through comparative analysis of vegetation and landforms. The second method relies on knowledge of the suitability of various crop plants as substitutes for natural vegetation communities. Formations may serve to effectively indicate which crop or crops have the greatest production potential in any area or to localize the areas where ground surveys are required.

One other significant value of periodic satellite coverage is clearly illustrated by Figures 4D and 4E. Human activity is resulting in continuing changes in the distributional relationships of agricultural and natural vegetation. Recently, center pivot sprinkler irrigation has expanded rapidly in southwestern Kansas. Much of this expansion has occurred in areas of Medium Tall Grassland Consisting Mainly of Sod Grasses. The two LANDSAT images indicate the marked increase in cultivation which has occurred between September 1972 and July 1974. Another formation, Medium Tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs, is also present in this area. Few attempts to introduce irrigation into areas with this formation have been made and these attempts have met with limited success, indicating the general unsuitability of areas with this formation for irrigated cultivation agriculture. Utilization of repeated LANDSAT coverage then permits periodic updating of maps, both for monitoring affects of changing land use as well as the more or less striking changes attributable to droughts or other natural environmental variations.

In conclusion, this study has found LANDSAT MSS imagery suitable for the interpretation of vegetation communities at the formation level of the Unesco classification. The utility of LANDSAT data has been illustrated by a series of interpretations which produced vegetation formation identifications or maps similar to those expected from existing literature. LANDSAT data was employed to analyze natural vegetation at small scales for sites in the humid tropics, arid and semi-arid sub-tropics and temperate zones, attesting to the universal applicability of the data source when used in conjunction with the Unesco classification.

ACKNOWLEDGEMENTS

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LANDSAT Images Used

Frame Number	Acqu'sition Date	Quality	Cloud Cover (%)	Area
1026-00023	18 AUG 72	Excellent	10	Papua New Guinea
1027-00081	19 AUG 72	Good	30	Papua New Guinea
1081-01462	12 OCT 72	Good	20	Mindoro,Philippines
1084-15431	15 OCT 72	Excellent	10	Eastern Tennessee
1354-15431	12 JUL 73	Good	10	Eastern Tennessee
1130-01293	30 NOV 72	Good	0	Western Australia
1194-07284	2 FEB 73	Good	0	Uganda
1194-07291	2 FEB 73	Good	0	Uganda
1257-16464	6 APR 73	Good	0	South Central Kansas
1347-16455	5 JUL 73	Excellent	0	South Central Kansas
1103-17300	3 NOV 72	Good	10	Northwest Wyoming
1399-16332	26 AUG 73	Excellent	0	Northeast Kansas
1079-15131	10 OCT 72	Excellent	0	New Jersey
1008-13475	31 JUL 72	Good	0	Amazon Basin,Brazil
1008-13481	31 JUL 72	Good	0	Amazon Basin,Brazil
1237-13314	17 MAR 73	Good	10	Patagonia,Argentina
1108-07482	8 NOV 72	Good	0	Sudan
1020-01143	12 AUG 72	Good	40	Northern Australia
1061-16570	22 SEP 72	Excellent	0	Southwest Kansas
1709-16494	2 JUL 74	Good	20	Southwest Kansas

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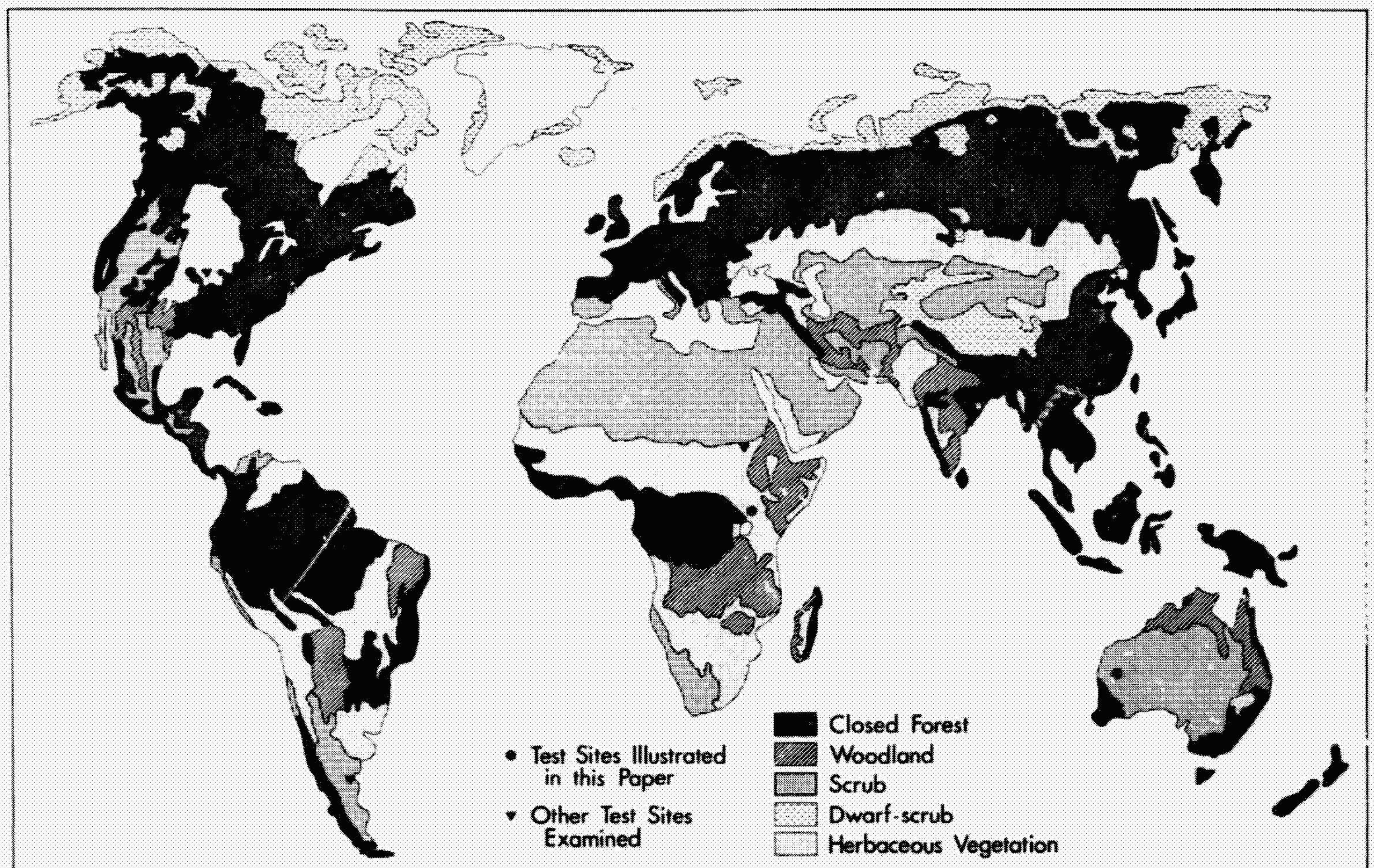

Figure 1. Location of test sites discussed in this paper with respect to the distribution of Formation Classes of natural vegetation. Vegetational data are after Sochava (ref. 14).

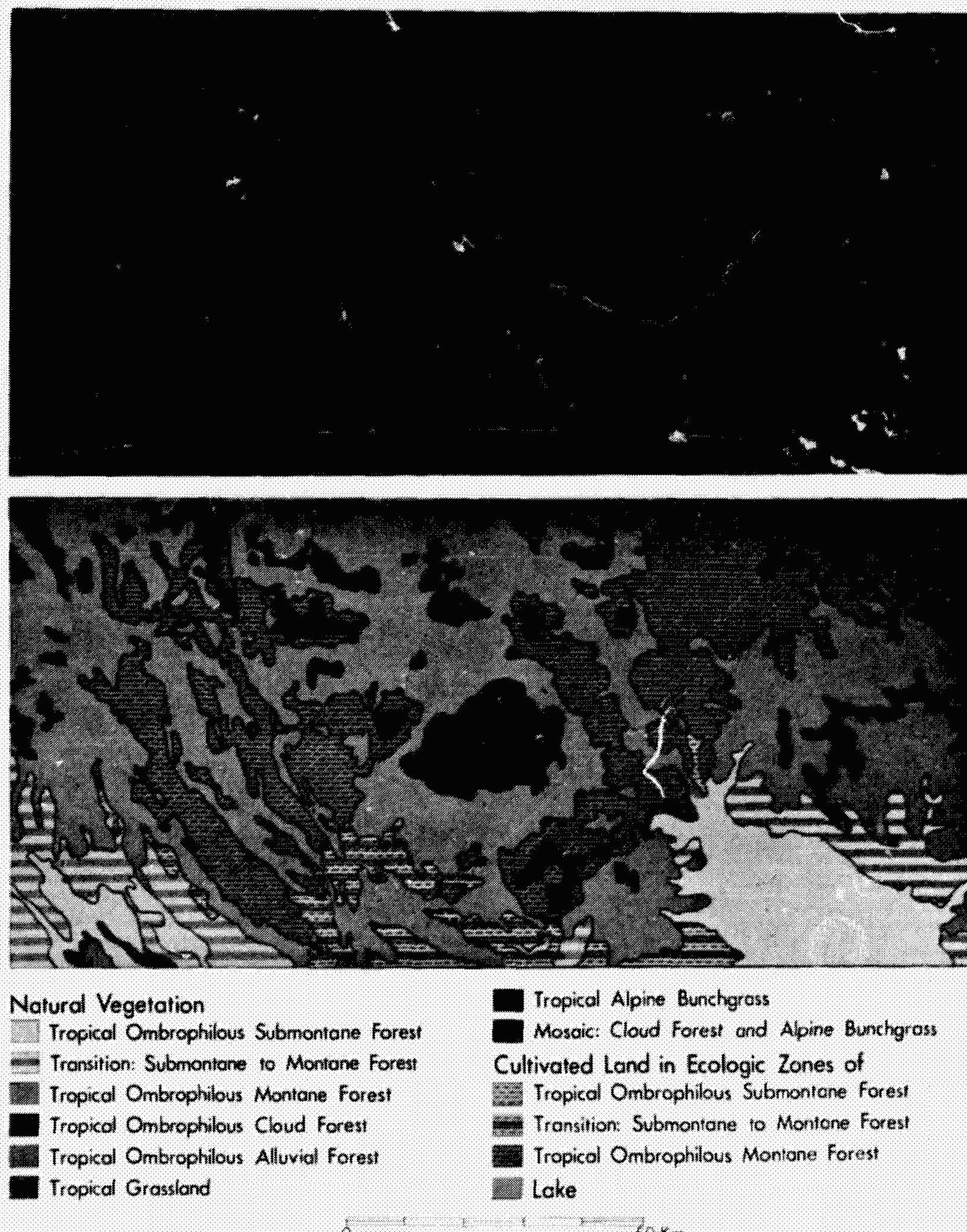

Figure 2. LANDSAT-1 image (1026-00023) of a portion of the Western Highlands of Papua New Guinea and the vegetation map prepared from this image according to the Unesco classification. It is evident by comparison of image and map that more detail is inherent in the image than may be reproduced on a map of this scale. Colors have been assigned to each cultivated area according to the apparent ecologic zone based on forest remnants and regrowth within the area.

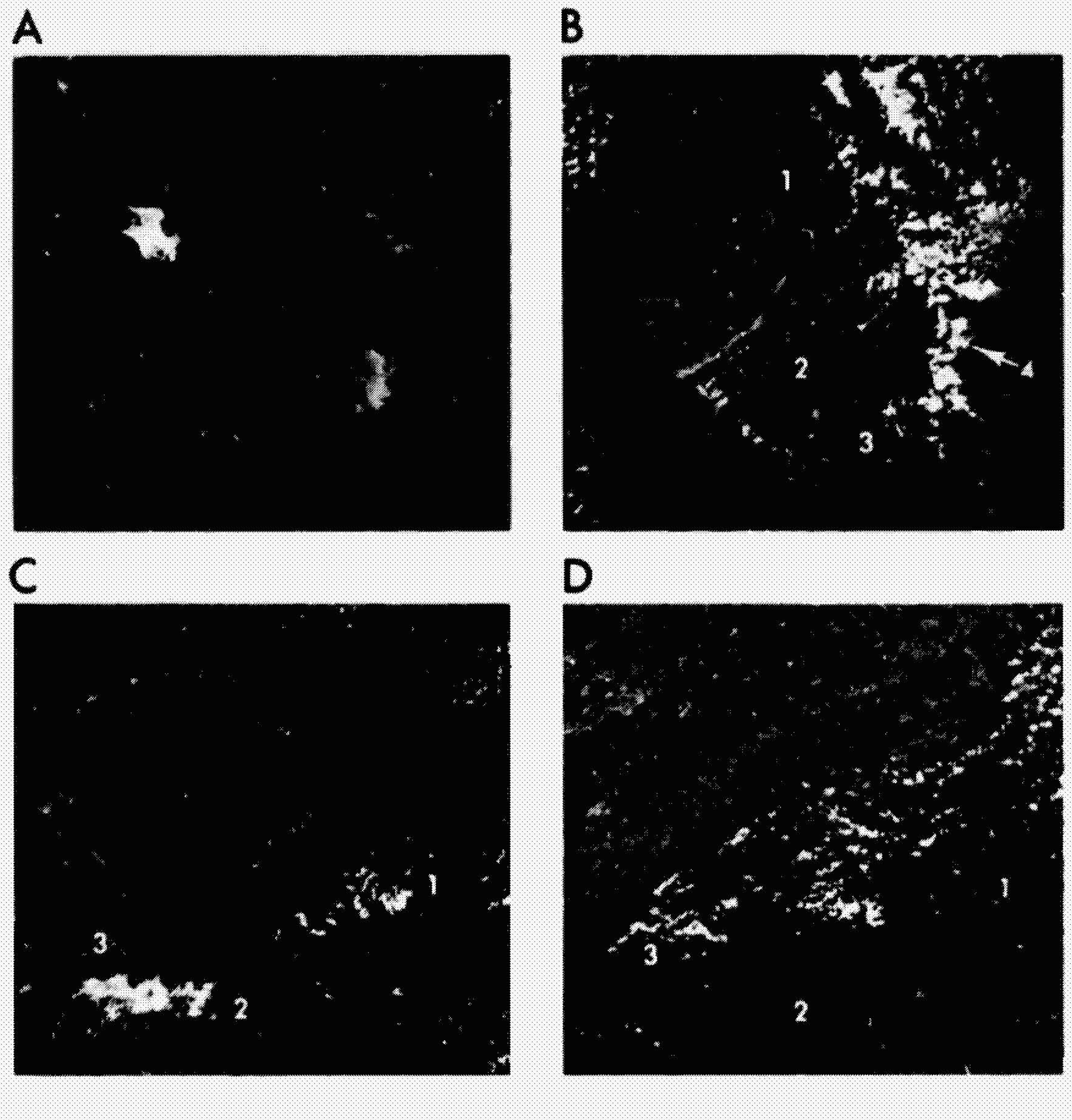

Figure 3. LANDSAT-1 images illustrative of other areas dominated by forest formations. A. Image (1027-00081) of another valley in the Western Highlands of Papua New Guinea, showing similar ecologic conditions to those on Figure 2. B. Image of Mindoro Island, Philippines (1081-014642) on which the following formations are annotated: 1) Tropical Grassland, 2) Needle-leaved evergreen subformation of the Tropical Ombrophilous Submontane Forest, 3) Tropical Ombrophilous Lowland Forest and 4) Mangrove Forest. C and D. Images showing seasonal contrast in the Great Smoky Mountains of the southeastern United States. Image C (1354-15431) was acquired 12 July 1973 while image D (1084-15431) was acquired 15 October 1972. Both frames are annotated as follows: 1) Evergreen Needle-leaved Forest with Conical Crowns, 2) Montane Cold-deciduous Forest, and 3) Cold-deciduous Broad-leaved Forest with Evergreen Needle-leaved Trees.

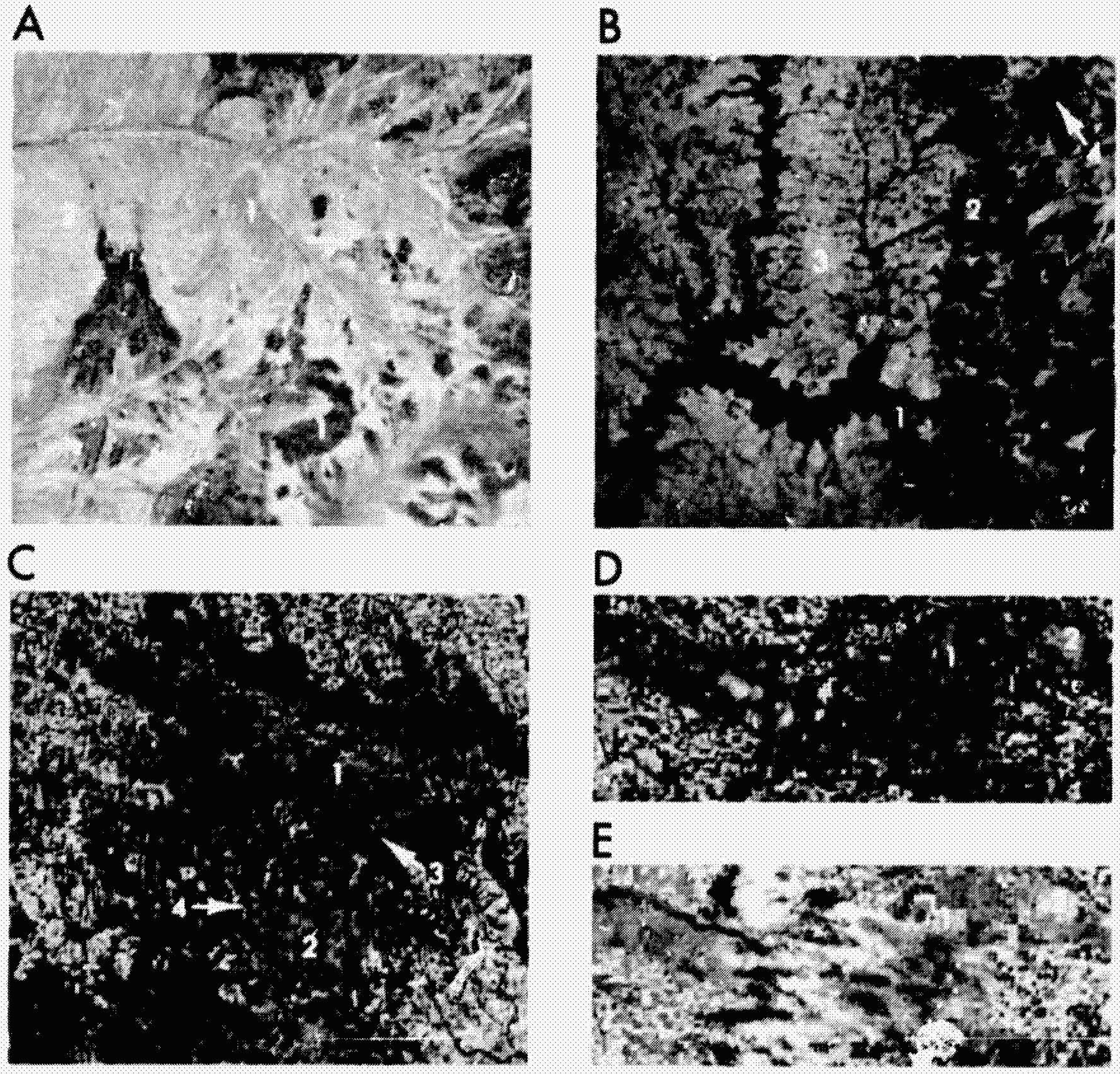

Figure 4. LANDSAT - 1 images illustrative of areas of predominantly scrub or herbaceous vegetation. A. Image (1130-01293) of interior Western Australia with the following annotations: 1) Semi-deciduous Subdesert Shrubland and 2) Medium-Tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs. B. Image (1194-07284) of northeastern Uganda annotated as follows: 1) Tropical Grassland, 2) Tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs, 3) Tall Grassland with a Deciduous Tree Synusia Covering 10-40 Percent and 4) Evergreen Needle-leaved Woodland with Rounded Crowns. C. Image (1347-16455) of south-central Kansas with the following types annotated: 1) Medium Tall Grassland of Sod Grasses, 2) Medium Tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs, 3) Evergreen Needle-leaved Forest with Conical Crowns, and 4) Cold-deciduous Alluvial Forest. D and E. This pair of images (1061-16570 and 1709-16494) of southwestern Kansas acquired in 1972 (D) and 1974 (E) illustrate replacement of a Medium Tall Grassland by sprinkler-irrigated cropland in the areas marked 1. Areas marked 2 are Medium Tall Grassland with a Synusia of Broad-leaved Deciduous Shrubs.