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Studies in Natural Resources

Woody Vegetation of the Serengeti National Park

DENNIS HERLOCKER

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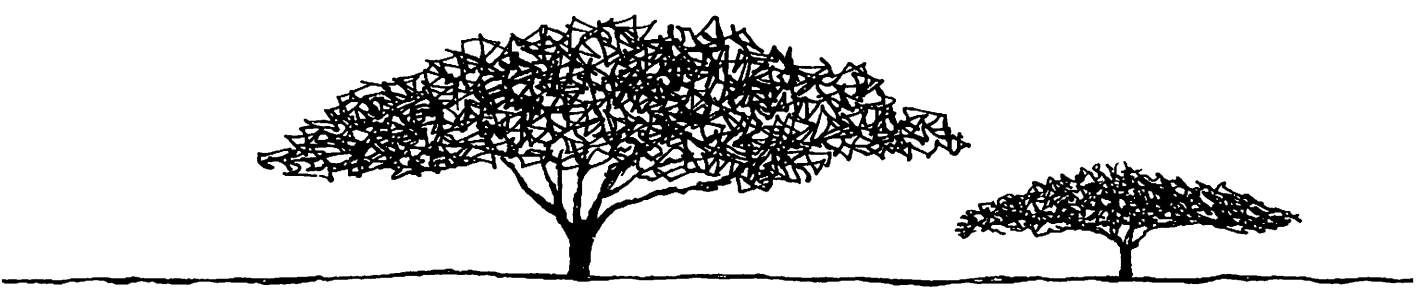

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These wishes of Caesar Kleberg are being carried out by scientists of The Texas Agricultural Experiment Station, a part of the Texas A&M University System. James G. Teer, holder of the Caesar Kleberg Chair of Wildlife Ecology and head of the Department of Wildlife and Fisheries Sciences at Texas A&M, directs the program.

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Woody Vegetation of the Serengeti National Park

BY DENNIS HERLOCKER

The Caesar Kleberg Research Program in Wildlife Ecology

and

Department of Range Science
The Texas Agricultural Experiment Station
The Texas A&M University System

This study, part of a research program dealing with the ecology of wooded areas of the Serengeti National Park, extended from 1969 to 1973 and was supported by the Caesar Kleberg Research Program in Wildlife Ecology at Texas A&M University.

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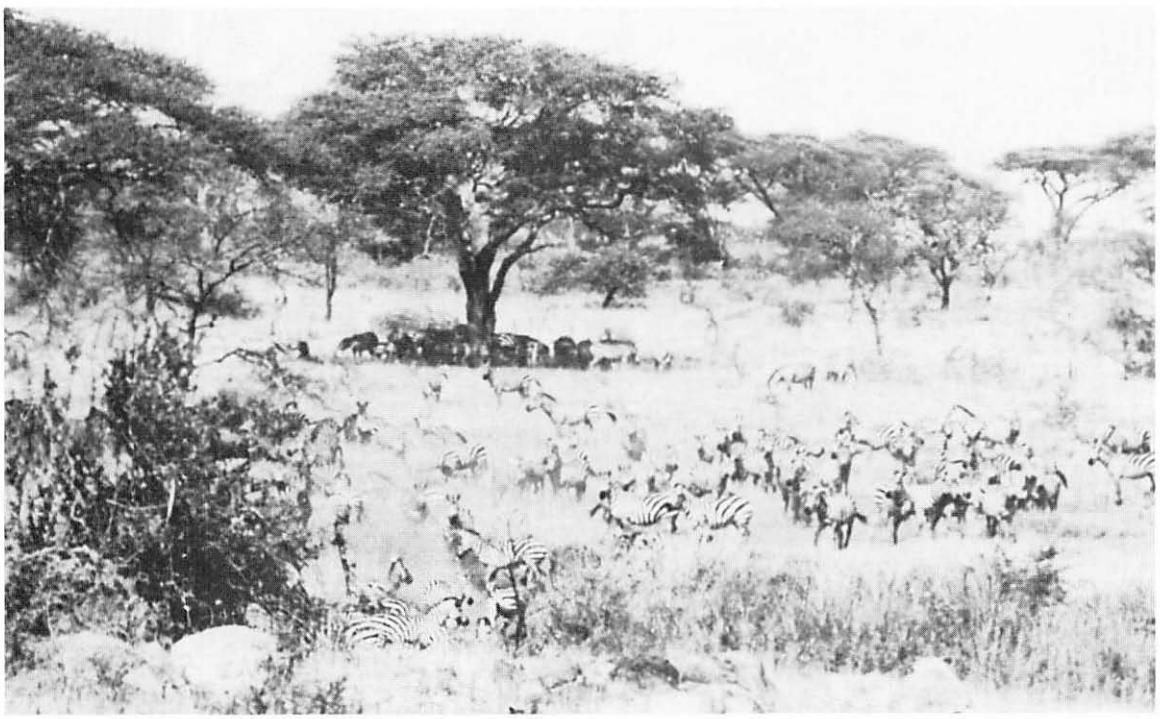

FRONTISPIECE. Herd of zebra at a waterhole near Seronera. *Albizia harveyi* and *Acacia tortilis* with a grass layer of *Panicum maximum* and *Digitaria macroblephara* occur throughout the area.

The Serengeti National Park, in North Central Tanzania, covers 12,950 square kilometers and is one of the largest national parks in the world. It is the central core area for a large and unique annual migration of wildebeest and zebra herds. However, these annual movements define a much larger area of 40,350 km², the Serengeti Ecosystem (Watson 1967, Norton-Griffiths 1972). Most of this ecosystem lies within areas, such as the Serengeti National Park, Maswa Game Reserve, Ngorongoro Conservation Area in Tanzania, and the Masai Mara Game Reserve in Kenya, which are protected from hunting and agronomic practices. The Serengeti Ecosystem affords an ideal opportunity for investigations of large numbers of biological populations and communities in a relatively natural state.

The Serengeti Research Institute (SRI), established in 1966 within the Serengeti National Park, has among its objectives the investigation of major aspects of the Serengeti Ecosystem and the assembling of ecological data in a form usable for both short and long-term management systems by the national park administration (SRI 1969). To achieve these objectives, the research scope of SRI was recently broadened from studies of behavior and population dynamics of large ungulates to include the environment. Additional emphasis is now placed on the vegetation portion of the biotic component of the ecosystem and its relationships with animals and with total abiotic environment.

The purpose of this research was a survey of the woody vegetation of the Serengeti National Park and construction of a vegetation map. The study contributes to the overall objectives of SRI. A plant community is the product of integration of all environmental forces (Kuchler 1967). Thus, a vegetation map reflects not only the plant communities of the total ecosystem, but also the environment. A vegetation map thus provides stratification of an important component of an ecosystem. This information is needed by all disciplines involved in ecosystem studies.

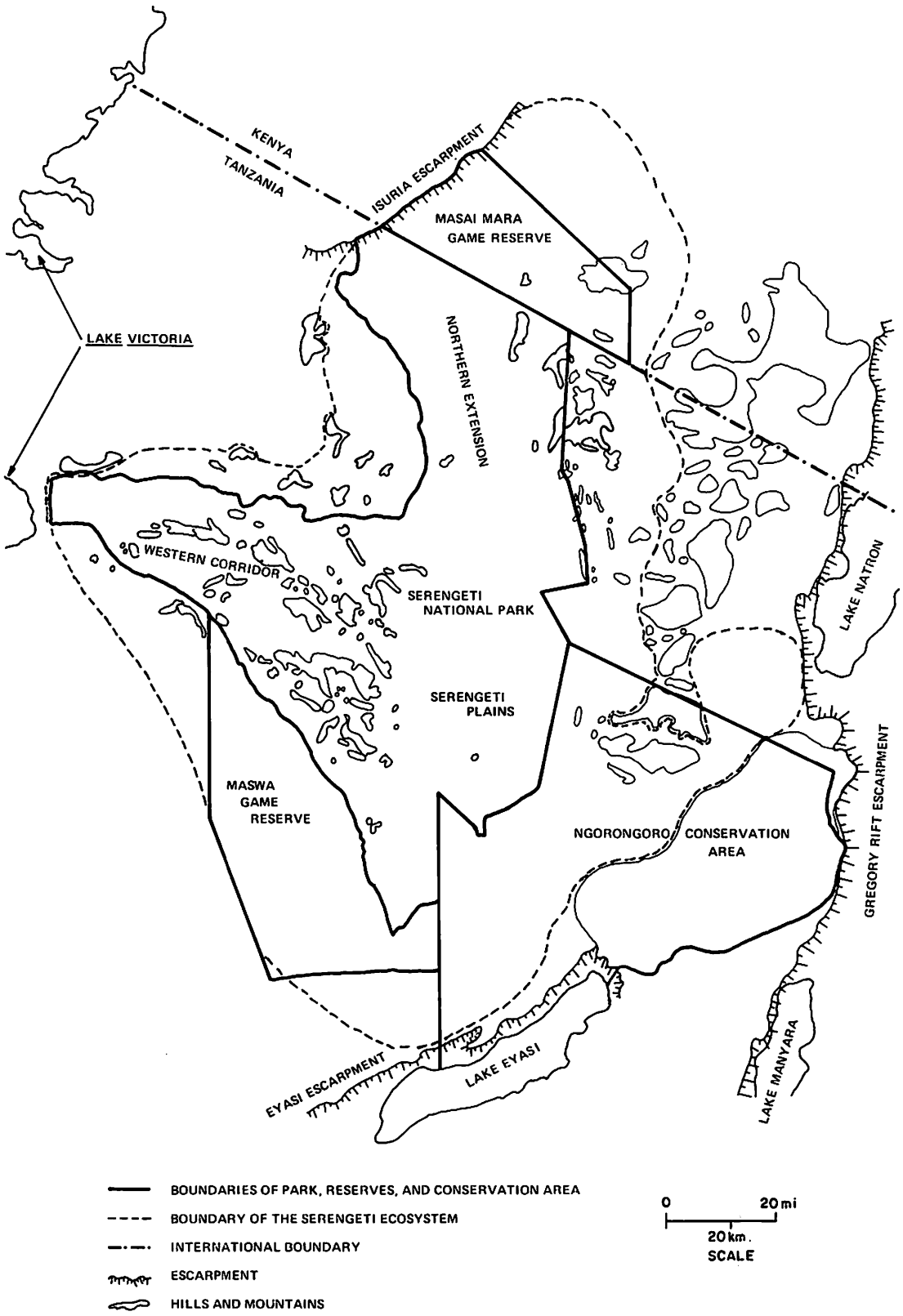

FIG. 1. Location map of the Serengeti National Park and surrounding area.

ENVIRONMENTAL FACTORS

Physiography and Geology

The Serengeti National Park lies between 1°28′ and 3°17′ south latitude and 33°50′ and 35°20′ east longitude in North Central Tanzania, East Africa. It touches Lake Victoria on the west and the Kenya-Tanzania border on the north (Fig. 1). The Park occupies a large upland area varying in elevation from 1,162 m at Lake Victoria to 1,860 m in the northeast.

Geologists of the Tanzania Mineral Resources Division have surveyed and mapped the geology of the Park (Pickering 1960, Naylor 1965, MacFarlane 1967, Thomas and Lounsberry 1967, MacFarlane 1968a and 1968b, Thomas 1968). Gerresheim (1971, 1974) mapped the landscape units of the Serengeti Ecosystem at several levels of generalization. The highest of these he termed "land regions" (Fig. 2), each having a common geological history and, possibly, a local climatic pattern. The criteria were characteristic patterns of land forms, geological structures, drainage, vegetation, soils, and human influence.

The woody vegetation of the Serengeti National Park occurs primarily on moderately rolling and dissected topography extending across the southwest and into the Northern Extension of the Park. This area has been subdivided by Gerresheim (1974) into several distinct land regions. Land regions 7 (Oseru), 8 (Siana-Loliondo), 10 (Ikoma), and 11 (Grumeti-Orangi) (Gerresheim 1974) make up the moderately rolling and dissected area between the Serengeti Plains and the Mara River in the Northern Extension. The area is underlain by quartzofelspathic gneiss in the northeast, granitic gneisses in the center, and granite in the west. Basic to acid Nyanzian lavas and tuffs occur in the southwest and north and undifferentiated soils in the northwest. Inselbergs (Fig. 3) are common where the underlying rock penetrates the surface. Land Region 17 (Simiyu) in the south of the Park, shows geological and topographical characteristics similar to the Northern Extension (MacFarlane 1967, 1968a, and 1968b, Thomas 1968, Gerresheim 1974). Several hills, oriented north-south, rise from 185 to 620 m above the surrounding countryside in Land Region 8 (Sianna-Loliondo) in the northeast of the Park.

An area of gently undulating topography and widely scattered drainage lines occurs between the Mara River and the Isuria Escarpment and Kenya Border. This area, Lamai Wedge, consists of Land Region 3 (Lamai-Lorogoti) in the northwest and is underlain by Neogene volcanics. Land Region 7 (Oseru), in the southwest, occurs over granites. The elevation averages about 1,425 m (MacFarlane 1968b, Gerresheim 1974).

Immediately west of the Serengeti Plains are a large number of hills and hill ranges in Land Region 13 (Musabi-Nyaroboro). These lie in a west-northwest direction and rise to about 1,612-2,015 m elevation, about 62-465 m above the surrounding land. Most of these hills are Bukoban Quartzites, siltstones and shales (Pickering 1960, Naylor 1965, MacFarlane 1967, Gerresheim 1974).

In Land Region 12 (Simiti-Dutwa) a range of hills extends westward from the Central Range for about 30 miles along the Grumeti-Mbalageti River divide. These are composed of Nyanzian banded ironstone and schist (MacFarlane 1967, Thomas and Lounsberry 1967). Elsewhere topography is level to gently rolling and little dissected. It supports both grassland and woodland vegetation. Bukoban sediments underlie the Musabi Plains. Soils derived from Nyanzian rocks occur on either side of the Simiti, Varichoro, and Nyakaromo Hills and extend southwest to the Kimamba Hills. Granitic rocks underlie most of the south and west of the area (MacFarlane 1967 and 1968b). Land Rerion 9 (Ndabaka-Ruana Plains) and 14 (Serengeti Plains) (Gerresheim 1974) are level to undulating grasslands of alluvial and aeolian (volcanic ash) origin, respectively. These land regions support only a small area of woodland vegetation (Thomas and Lounsberry 1967, MacFarlane 1968b).

Climate

Climatic data for the Serengeti National Park are limited mostly to monthly precipitation records. These data have been collected since 1962 from a network of storage gauges. A total of 62 gauges are presently in use. An analysis of these data by Norton-Griffiths *et al.* (in press) has shown a gradient of increasing mean annual precipitation extending across the Park from 500 mm/year in the southeast (Western Serengeti Plains) to 1,200 mm/year in the extreme northwest, a distance of about 137 km (Fig. 4). A dry season occurs throughout the Park from June to October, and a wet season from November to May. A second dry period may occur in January or February. Variability in precipitation from year to year is characteristically high. The highest variability is during the dry season and also in the drier portions of the Park. During

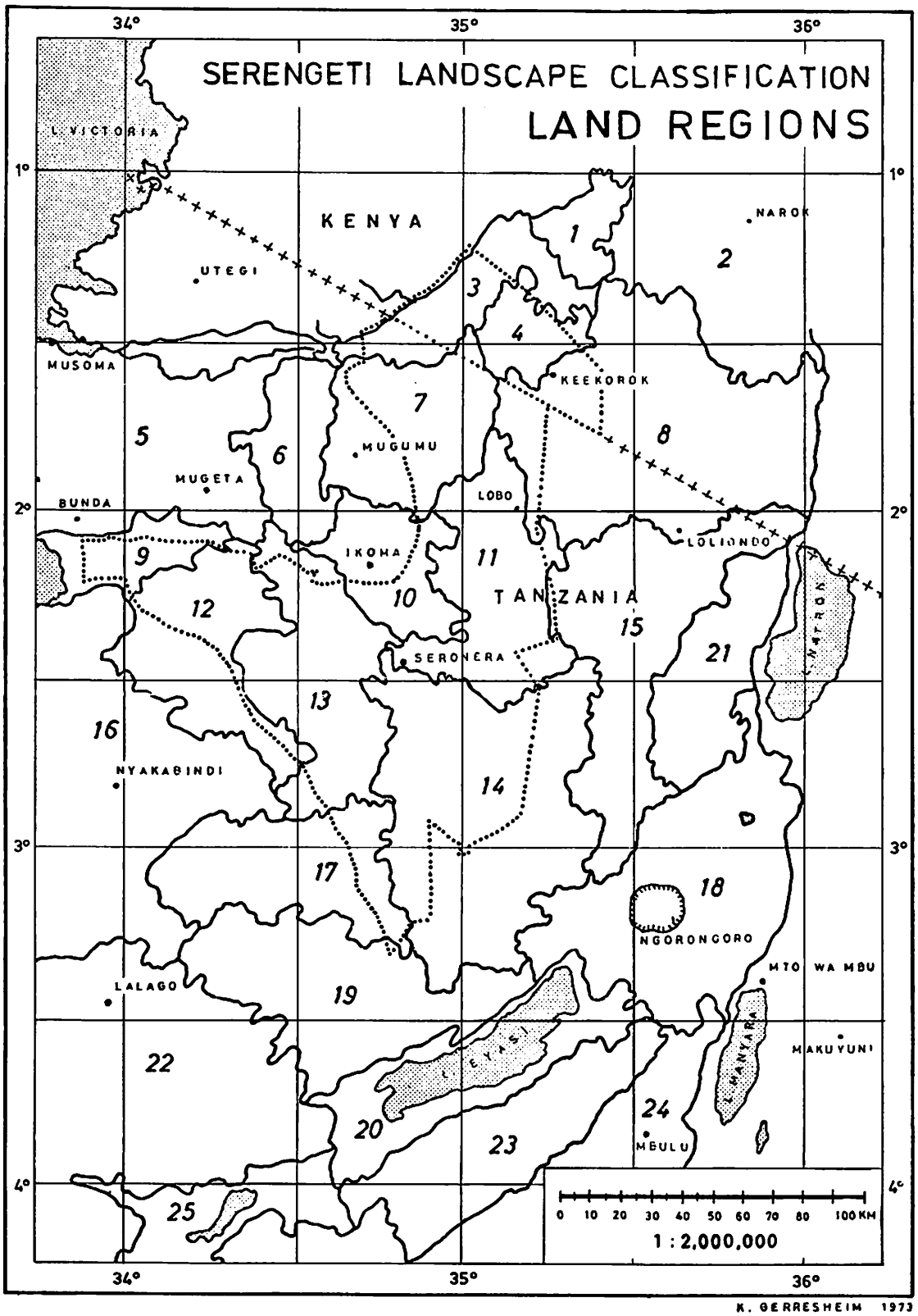

FIG. 2. Land regions of the Serengeti Ecosystem.

the dry season, precipitation may vary from 40 to over 60% (.05 level). Wet season variability seldom exceeds 40%, except in the southeast. In the more mesic north it is generally less than 40% (Norton-Griffiths *et al.*, in press).

Soils

Past investigations of extent and nature of soils in the Serengeti Park have largely been confined to the reconnaissance level. Most have as well been restricted to the grasslands in the east and west of the Park. (Grzimek and Grzimek 1960, Anderson and Talbot 1965).

Scott (1969) indicated six soil-topography associations within the Park. Four associations represented catenas containing from 2-5 soil types each, and the other two contained only one. Soils of the Serengeti Plains were shown to be generally well drained. Those elsewhere in the Park ranged from good to poor in drainage, depending upon catenary position.

Bell (1968) divided the soils into 5 groups. These were (1) black cotton clays associated with impeded drainage, (2) alluvial deposits on sites of existent or extinct drainage lines and lake beds, (3) calcareous volcanic soils (Serengeti Plains), (4) sandy soils formed from granite and basement sediments of Bukoban origin, and (5) lateritic soils formed from Precambrian ironstones and metavolcanic rocks.

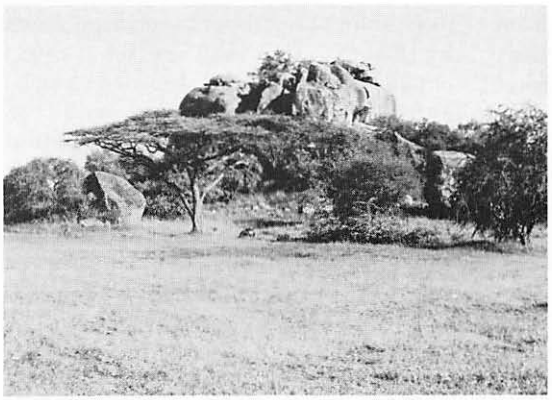

FIG. 3. A granitic inselberg (kopje) near Seronera. Tree species from left to right are *Commiphora trothae*, mature *Acacia tortilis* (flat top), young *A. tortilis* and *Commiphora trothae*.

Vegetation

Vegetation of the Park has also, in the past, largely been investigated at the reconnaissance level. Detailed studies have been restricted to the principal grassland areas (Anderson and Talbot 1965, Bell 1968, Braun 1972).

Gillman (1949) indicated two major physiognomic vegetation types: (1) wooded grassland and (2) ridge and slope grassland. Less extensive areas were valley grassland, bushland, thicket, and vegetation induced by native agriculture. Pratt *et al.* (1966) showed physiognomic units of (1) grassland and (2) wooded grassland and/or bushed grassland. Trapnell and Langdale-Brown (1969) divided the Park into grasslands, grasslands at low and medium altitudes, and savannah.

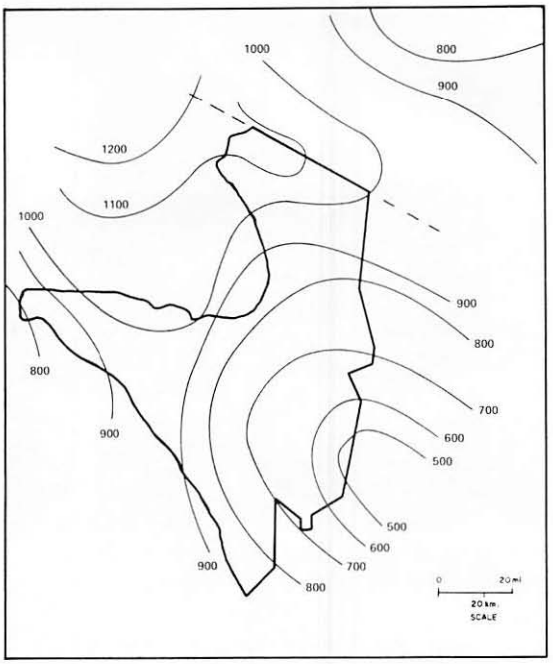

FIG. 4. Distribution of average annual precipitation (mm) over the Serengeti National Park.

The woody vegetation was described by Burtt (1942) as characteristically a thorn savannah with *Acacia drepanolobium*[1] and *A. seyal* var. *fistula* common on gray soils with hard pans and on black cracking clay of valleys. *Acacia tortilis* ssp. *spirocarpa* occurred on fan slopes of hard pan gray soils. In the west of the Park, *Acacia gerrardii* was found on thin soils of low hills of banded ironstone, dolomite, coarse schists, and granite. Other communities, dominated by *Ostryoderris stuhlmannii, Terminalia sericea* and *Combretum zeyheri* were reported on higher ground throughout the western portion of the Park.

Pearsall (1957) reported that hills west of the Serengeti Plains were characterized by a soil/vegetation catena with *Acacia-Commiphora-Balanites* bush on the tops. *Acacia tortilis* spp. *spirocarpa* occurred on the downwash slopes of red-brown soils with a covering of granitic

[1]Nomenclature follows that of the East African Herbarium, Nairobi, Kenya.

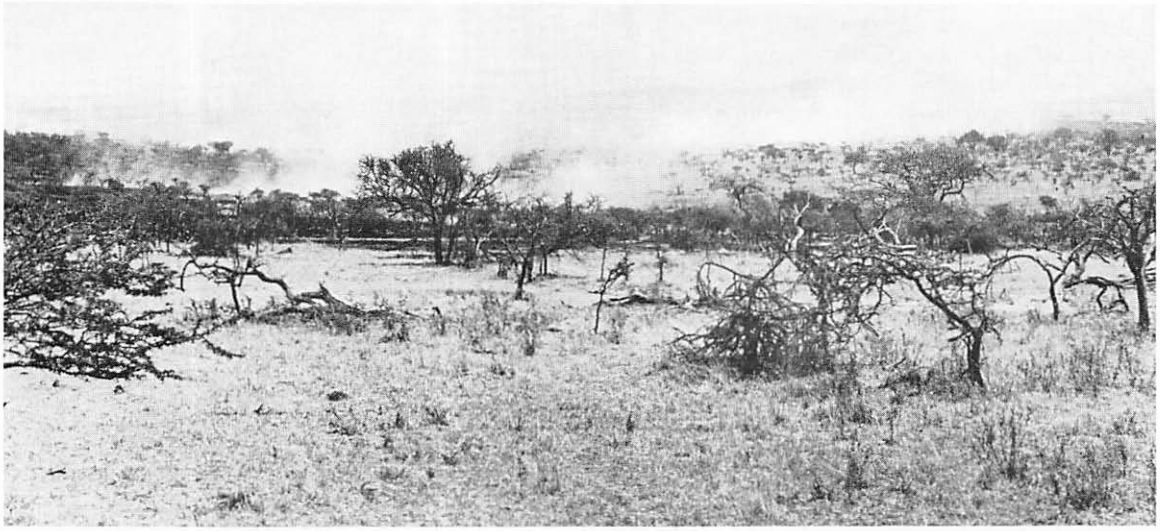

FIG. 5. Grass fire in *Acacia nilotica* Deciduous to Semi-Deciduous Thorn Tree Woodland in the Northern Extension. Nyamalumbwa Hills are in background.

sand, and *A. drepanolobium* grew on dark brown alkaline soils of the gentle lower slopes. Grasslands occurred on black cotton soils with underlying calcareous concretions.

Greenway (1962) divided the Park into grassland and woodland. Woodland was further divided into (1) forest, (2) springhead forest, (3) riverine forests, (4) open-to-closed woodland, (5) scattered tree grassland, (6) bushland, and (7) thickets, as well as inselberg and palm vegetation.

Watson and Bell (1969) delimited three vegetation types: Serengeti Plains (grassland), fine-leaved woodland (*Acacia-Commiphora* spp.), and broad-leaved woodland (*Combretum-Terminalia* spp.). Schaller (1972) delineated the boundaries of the *Combretum-Terminalia* community in the Northern Extension.

Human Influences

The semi-arid nature of the Park and high incidence of the tsetse fly (*Glossina* spp.), carrier of the sleeping sickness disease, has limited habitation of the wooded portion of the Park. The Serengeti Plains were used by pastoral Maasai who occasionally entered the wooded areas to visit water holes and salt licks or to raid agricultural peoples living west toward Lake Victoria. Principal use of the wooded areas seems to have been hunting (Gillman 1949, Pearsall 1957, Bell 1968, Fosbrooke 1968).

Establishment of the present boundaries of the Park during 1959-1968 resulted in the removal of all inhabitants. However, human occupation has increased considerably in past years in the areas immediately west and southwest of the Park boundaries. In some cases farms now lie directly adjacent to the Park (Bell 1968). Tourism also has increased within the Park (TNP 1968).

Fire

Dry season grass fires are a recurrent phenomenon throughout the Park (Watson 1967, Bell 1968). They usually originate either from centers of human habitation or from roads and tracks (Fig. 5). They also are set by pastoralists outside the Park and by transient poachers, honey hunters, and cattle raiders inside the Park. For some years, the Park Administration also has burned certain areas to create better game viewing or grazing conditions.

Bell (1968) reported that during 1962-1965, 30% of the Serengeti Ecological Unit (Ecosystem) was burned by grass fires each year. Data obtained from a continuation of this work by Herlocker and Norton-Griffiths (unpublished) indicates that from 1966-1972 the average for the Serengeti National Park was much higher.

METHODS

The area of woody vegetation within the Park is large, approximately 4,830 km^2. Thus, the approach used in mapping was at an extensive rather than intensive level. It was considered that, due to the lack of existing information on the vegetation, such an extensive approach would yield useful infornation on the distribution, nature, and environmental relationships of woody plant communities.

TABLE 1. CRITERIA AND DEFINITIONS OF VEGETATION UNITS AND SPECIES COMPOSITIONAL CLASSES.

VEGETATION UNITS

CLASSIFICATORY

UNIT	CRITERIA
Primary Physiognomic Category	Gross patterns of height, canopy cover, and vertical stratification of dominant plants.
Vegetation Type	Degree of leaf loss in dry season and growth form.
Species Type	Dominant tree and/or bush species.

NON-CLASSIFICATORY

UNIT	DEFINITION
Community	An abstraction of a vegetation unit at any level of generalization.
Stand	A concrete group of trees/shrubs of similar size, composition, and general appearance.
Mapping Unit	A unit of vegetation delineated on a map (or aerial photograph) for any purpose. The species type is the basic mapping unit in Fig. 8.

Initially, boundaries of mapping units (Table 1) were approximated by stereoscopically viewing vertical aerial photographs of the Park. The scale of these aerial photos was small (1:40,000-1:50,000), so the mapping units were necessarily broad, indicating major differences in topography and in general patterns of the woody vegetation.

The nature of the topography and physical character of the vegetation allowed relatively easy access, for sampling purposes, by 4-wheel drive vehicles for most of the year. Vegetation was sampled at systematic intervals along transects (Fig. 6). Where possible, transects were driven across stream lines and ridges in order to sample the greatest possible variation within a mapping unit (Fig. 7). At each point tree and/or bush species contributing at least 21% of the total density (trees/unit area) of the surrounding area were determined and recorded as dominants. This was a visual estimate; no measurements were taken. A visual estimate also was made of perennial canopy cover. This was based on both existing tree cover and regeneration potential. Each observation point was located and numbered consecutively on aerial photo-

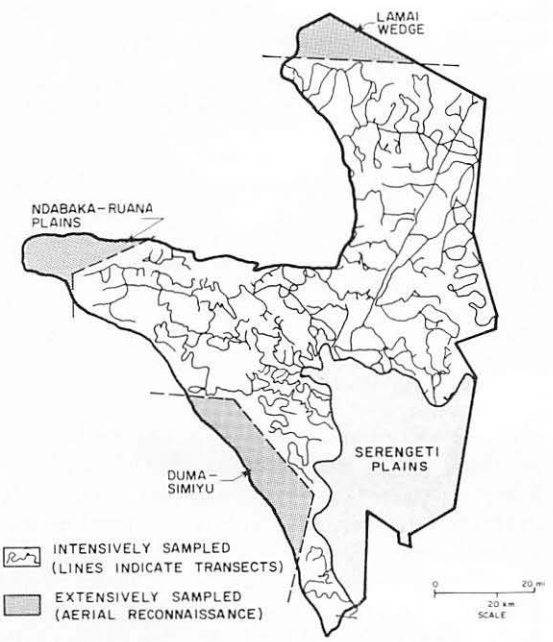

FIG. 6. Map of field transects driven and areas sampled from the air.

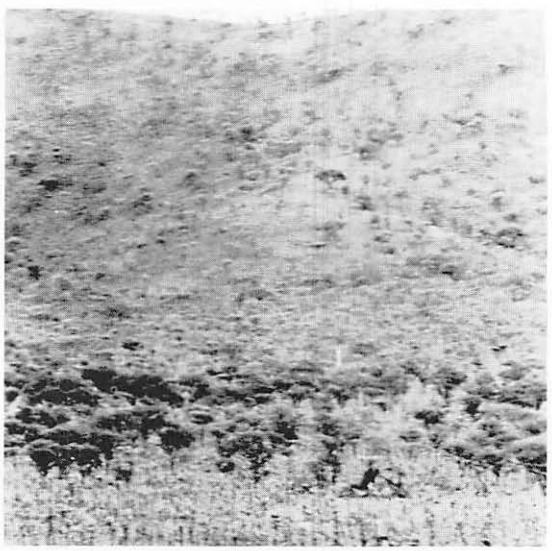

FIG. 7. Topographic variation of woody vegetation on Banagi Hill. Running from bottom to top the four zones are *Acacia drepanolobium*, *A. clavigera*/*A. drepanolobium*, *A. senegal*/*A. hockii*, and undifferentiated woodlands on rocky hills. (Photograph by J. D. Dodd)

TABLE 2. CLASSIFICATION OF THE VEGETATION INTO PRIMARY AND SECONDARY PHYSIOGNOMIC CATEGORIES.

Primary Physiognomic Categories	Vegetation Types	Specifications and Definitions
Forest		Tree cover with closed canopy of one or more strata > 7.5 m tall.
	*Evergreen Forest	Forest limited to riverine and springhead stands, mainly evergreen. Intermediate in character to upland evergreen moist and dry forests. Probably climatic climax.
	Woodland	Tree cover with one, or rarely two, discontinuous strata, minimum canopy cover 21%. Grasses and forbs dominate the ground cover. Grass fires are common.
	Semi-Deciduous Woodland	Woodland dominated by *Combretum* and *Terminalia* species with simple, entire leaves. Complete leaf loss only in driest years. Grass stratum to 2 m.
	Semi-Deciduous to Deciduous Thorn Tree Woodland	Woodland dominated by thorny *Acacia* and *Commiphora* spp. with bipinnate *(Acacia)* and trifoliate *(Commiphora)* leaves. Variable as to timing and degree of leaf loss. Grass stratum 0.5-1.5 m tall.
Wooded Grassland**		Trees conspicuous but scattered. Canopy cover < 21%. Grass fires are common.
	Semi-Deciduous Thorn Tree Wooded Grassland	Wooded grassland dominated by *Balanites aegyptiaca* on poorly drained black cotton clay soils.
Bushland		Upper stratum of woody plants of low stature and shrubby habit. Minimum canopy cover 21%.
	Evergreen to Semi-Deciduous Bushland	Principally evergreen bushland limited to relict stands in Northern Extension. Bush stratum to 8 m with scattered emergent trees to 12 m. Occasionally grades into evergreen forest. Probable climatic climax.
	Semi-Deciduous Bushland	Bushland on termite mounds in the western corridor with evergreen lower bush stratum and semi-deciduous emergent *Acacia-Commiphora* tree stratum.
	Deciduous Bushland	Bushland occurring on disturbed soil sites as a single stratum dominated exclusively by *Acacia mellifera*, definitely deciduous.
Inselberg Vegetation		A physiographic category indicating vegetation found on granitic or gneissic outcroppings. Physiognomic and compositional characteristics are highly variable.
Grassland		Land dominated by grasses and occasionally other herbs. Tree canopy cover < 2%.

* The term "Upland" indicates vegetation over 1,050 m elev. (Pratt et al. 1966). It is applicable to all vegetation categories as the entire park is above 1,050 meters.

** The woodland category is used if woody regeneration indicates a potential canopy cover > 21%.

graphs for future reference. Additional notes were made on associated plant species, vegetation physiognomy, soils, and topography. If necessary, mapping unit boundaries were corrected in the field. Dominants were determined by averaging the plant composition of the observation points in each mapping unit. Mapping units with similar combinations of dominants were grouped into a species type (Table 1). Mapping units not sampled in the field, but located within an area represented by a sample, were placed into a species type based on stereoscopically determined similarities in topographical detail, general vegetation physiognomy, and pattern.

Three areas of the Park — Ndabaka-Ruana Plains in the extreme west, Duma-Simiyu area in the southwest, and Lamai Wedge in the north (Fig. 6) — were not ground sampled. The pre-

liminary mapping units were transferred to 1:50,000 aerial photo mosaic sheets, and a sample of these was located in each region from a light aircraft. The dominant tree species were noted while flying at a low speed at a height of approximately 150 feet. Similarity of vegetation in the southwest and Lamai Wedge to that elsewhere in the Park allowed determination of dominants in these areas.

Vegetation classification was based upon a combination of subjectively determined physiognomic and floristic criteria (Tables 1 and 2) essentially following Pratt *et al.* (1966) and Herlocker and Dirschl (1972). Five primary physiognomic categories were recognized: forest, woodland, wooded grassland, bushland, and grassland. Inselberg vegetation, a physiographic category, was also recognized because of extreme variability in physiognomical and botanical characteristics. The primary categories were subdivided into vegetation types based upon a combination of seasonal leaf loss and growth form (Table 2). Vegetation types were subdivided according to dominant species into species types (Kuchler, 1967) (Tables 1 and 3). Primary physiognomic categories, vegetation types, and species types are based on progressively narrower physiognomical and compositional criteria and reflect progressively narrower ranges of environmental and habitat conditions.

MAP USES

This vegetation map (Fig. 8, inside back cover) is the first approximation in delineation and description of woody plant communities in the Serengeti National Park. It should be used as a guide to the understanding of the nature of woody vegetation of the Park and will require revision as knowledge of the vegetation and environment increases.

TABLE 3. CLASSIFICATION AND AREA OF VEGETATION TYPES.

VEGETATION TYPES	AREA (Km^2)	% OF TOTAL WOODY VEGETATION
Evergreen Forest		
Evergreen to Semi-Deciduous Bushland	240	2.9
Semi-Deciduous Bushland		
Deciduous Bushland	115	1.4
Semi-Deciduous Woodland	390	4.7
Semi-Deciduous Thorn Tree Wooded Grassland	225	2.7
Inselberg Vegetation	50	0.6
Deciduous to Semi-Deciduous Thorn Tree Woodland	7,260	87.7
TOTAL	8,280	100

The map is a stratification of the wooded portion of the Serengeti National Park into ecologically homogeneous units. The mapping units delineate areas capable of supporting the same kind of relatively stable community that is homogeneous as to dominants in all layers and biological potential. This is the habitat type of Daubenmire (1968) and, within the context of a land system, is essentially the land facet of Gerresheim (1971).

This vegetation map and Gerresheim's map (1974) of landscape units are therefore complementary stratifications into ecologically homogeneous units of a large portion of the Serengeti Ecosystem.

The vegetation map is simultaneously a stratification into homogeneous units — at different levels of generalization — of vegetation, primary productivity, phenological patterns, wildlife habitat, and soils.

PRINCIPAL VEGETATION UNITS

Semi-Deciduous to Deciduous Thorn Tree Woodland is the only vegetation type represented by more than one species type (Table 4). The other vegetation types contain only one species type, due to small areas and compositional simplicity or to an inadequate sample of more complex types. Therefore, no representative species types for the physiographically adjacent Evergreen Forest and Evergreen to Semi-Deciduous Bushland or for the Semi-Deciduous Bushland and Deciduous Bushland types were distinguished. Instead they have been grouped into two final mapping units.

Evergreen Forest

Evergreen Forest occurs on alluvial soils as narrow and often discontinuous riverine communities in the Mara River drainage in the Northern Extension and along the lower Grumeti, Orangi, and Mbalageti rivers in the Western Corridor (Fig. 9). In the Northern Extension it also occurs as small relicts scattered on deep sandy loam soils of broad ridge tops between Tabora and Wogakuria (Fig. 10) and at several large springheads. Evergreen Forest and Evergreen to Semi-Deciduous Bushland, with which it is closely associated throughout the north, cover 240 km^2 in area (Table 3).

Evergreen Forest has two vertical strata consisting of broad-leaved evergreen and often

TABLE 4. CLASSIFICATION AND AREA OF SPECIES TYPES.

Vegetation Types	Species Types	Area (Km^2)	% of Total Woody Vegetation
Evergreen Forest			
Evergreen to Semi-Deciduous Bushland		240	2.9
Semi-Deciduous Bushland			
Deciduous Bushland		115	1.4
	Acacia mellifera		
Semi-Deciduous Woodland			
	Combretum molle-Terminalia mollis	390	4.7
Semi-Deciduous Thorn Tree Wooded Grassland			
	Balanites Aegyptiaca	225	2.7
Inselberg Vegetation		50	0.6
Semi-Deciduous to Deciduous Thorn Tree Woodland			
	Acacia drepanolobium	1,375	16.6
	Acacia clavigera	955	11.5
	Acacia senegal-A. hockii	835	10.0
	Undifferentiated woodlands on Rocky Hills	695	8.4
	Commiphora trothae	460	5.6
	Acacia tortilis	405	4.9
	Acacia gerrardii	280	3.4
	Acacia nilotica	245	3.0
	Acacia seyal	230	2.8
	Acacia nilotica-A. hockii	220	2.7
	Acacia clavigera-A. gerrardii	165	2.0
	Acacia hockii	155	1.9
	Albizia harveyi-Acacia polyacantha-A. clavigera	135	1.6
	Acacia-clavigera-A. tortilis	135	1.6
	Acacia tortilis-Commiphora trothae	115	1.4
	Commiphora trothae-Acacia senegal	105	1.3
	Acacia clavigera-A. drepanolobium	100	1.2
	Acacia gerrardii-Bush clumps	90	1.1
	Acacia senegal	75	0.9
	Acacia clavigera-A. hockii	65	0.7
	Lonchocarpus eriocalyx-Acacia spp.	60	0.7
	Acacia xanthophloea	50	0.6
	Acacia clavigera-A. nilotica	40	0.5
	Acacia clavigera-Commiphora trothae	35	0.4
	Acacia drepanolobium-A. senegal	35	0.4
	Acacia clavigera-A. senegal-Commiphora trothae	35	0.4
	Commiphora trothae-Acacia drepanolobium	30	0.4
	Acacia gerrardii-A. nilotica	20	0.2
	Acacia clavigera-A. senegal	20	0.2
	Acacia clavigera-A. senegal-A. hockii	20	0.2
	Acacia drepanolobium-A. senegal-A. hockii	15	0.2
	Commiphora trothae-Acacia hockii	10	0.1
	Acacia tortilis-A. mellifera	10	0.1
	Acacia clavigera-A. tortilis-Commiphora trothae	10	0.1
	Acacia clavigera-A. gerrardii-A. nilotica	10	0.1
	Acacia sieberiana	10	0.1
	Acacia gerrardii-A. seyal	10	0.1
	Acacia nilotica-Combretum molle	10	0.1
Total		8,280	100

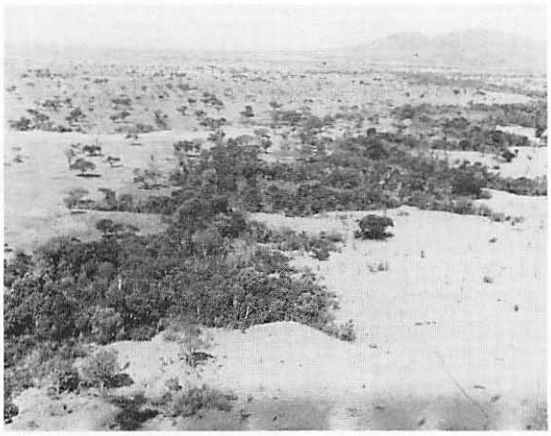

FIG. 9. Upland Evergreen Forest along the Grumeti River west of Kimareshe Hill. Wooded Grassland occurs on adjacent alluvial benches.

sclerophyllous woody species. The overstory canopy is moderately open to closed and varies from 12 to 28 m in height. In the Northern Extension several tree species are abundant in the overstory (Table 5), but *Diospyros asyssinica*, *Lecaniodiscus fraxinifolius*, and *Elaeodendron buchananii* appear most common. *Croton dichogamus* and *Teclea trichocarpa* dominate the bush stratum. *Setaria chevalieri*, a grass with characteristically broad leaves, is a constituent of the herbaceous stratum. The lower Grumeti, Orangi, and Mbalageti River communities were not sampled. However, some of the common woody species have been indicated by Greenway (1962) and Bell (1968) (Table 6).

TABLE 5. CHARACTERISTIC TREE AND BUSH SPECIES OF THE EVERGREEN FOREST VEGETATION TYPE.

OVERSTORY	UNDERSTORY
DOMINANT	
Diospyros abyssinica	*Capparis erythrocarpos*
Drypetes gerrardii	*Croton dichogamus*
Elaeodendron buchananii	*Teclea trichocarpa*
Lecaniodiscus fraxinifolius	
Suregada procera	
Teclea nobilis	
ASSOCIATE*	
Chaetacme aristata	*Acacia brevispica*
Euclea divinorum	*Carissa edulis*
Garcinia livingstonei	*Euclea schimperi*
Olea africana	*Phyllanthus sepialis*
Schrebera alata	*Scutia myrtina*
	Strychnos henningsii
	Teclea simplicifolia
	Turraea robusta

*A component comprising < 21% of the density of woody vegetation.

TABLE 6. CHARACTERISTIC TREE AND BUSH SPECIES OF THE EVERGREEN FOREST VEGETATION TYPE ALONG THE LOWER GRUMETI, ORANGI, AND MBALAGETI RIVERS.

OVERSTORY	UNDERSTORY
Aphania senegalensis	*Cordia goetzei*
Ekebergia sp.	*Cordia ovalis*
Fiscus sp.	*Crateva religiosa*
Garcinia livingstonei	*Erythroxylum fischeri*
Lecaniodiscus fraxinifolius	*Strychnos henningsii*
Tamarindus indica	
Ziziphus pubescens	

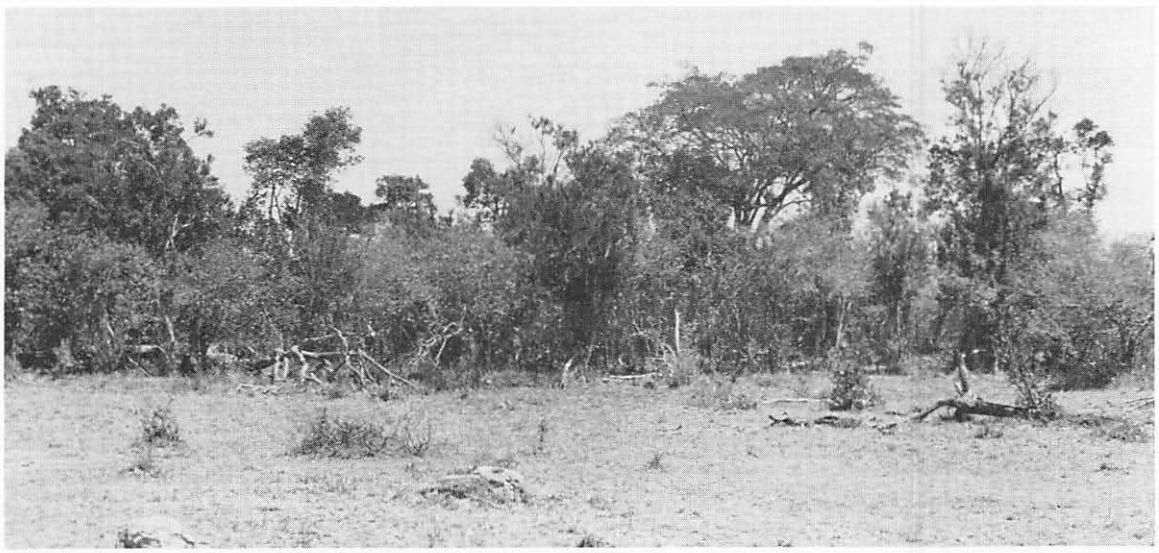

FIG. 10. Relict stand of Upland Evergreen Forest on ridge top in Northern Extension. Bush layer is dominated by *Croton dichogamus* and *Teclea trichocarpa*; the tree layer by *Olea africana* and *Diospyros abyssinica*.

FIG. 11. Evergreen Bushland on rock in Lamai Wedge. Dominant species are *Teclea trichocarpa*, *T. nobilis* and *Tarenna graveolens*.

This Vegetation Type is related to the Upland Evergreen Forest of Glover and Trump (1970), an association of the forest formation, in Narok District, Kenya. It is also similar to the vegetation found in the western *Diospyros* forest zone of Trapnell *et al.* (1969, 1970), a mainly semi-deciduous intermediate forest above the Isuria Escarpment to the north of the Park.

Evergreen Forest has a high water demand and is easily destroyed by burning. It therefore generally occurs on sites which provide a large amount of ground water and some protection against grass fires.

Evergreen Forest stands border directly on either bushland (sometimes grading gradually into it if edaphic and pyric conditions permit) or onto grassland or woodland. In the latter two cases the boundary is abrupt and shows little or no ecotonal transition, reflecting the impact of grass fires along the forest edge. The occurrence of a few small relict stands between Tabora and Wogakuria, on sites unprotected from fire and edaphically similar to those under the surrounding fire-adapted woodland vegetation, implies that Evergreen Forest was probably once the dominant vegetation type. Past distribution probably closely resembled the present occurrence of the surrounding *Combretum molle-Terminalia mollis* Species Type, which is apparently a fire-maintained successional community. A similar *Combretum* community (open hillside vegetation) was described by Glover and Trump (1970) as being successional to Evergreen Forest in Narok District.

Evergreen to Semi-Deciduous Bushland

This Vegetation Type occurs throughout the Park on several distinct physiographic sites: (1) on ridge tops, valley bottoms, and some intervening slopes throughout much of the Mara River drainage, (2) on rocky surfaces of hills in the northeast and southwest of the Park (Figs. 11 and 12), (3) along spring lines (seepage lines) between woodland on upper slopes and poorly drained grasslands on lower slopes throughout much of the north, and (4) on termite mounds mostly in the north (Fig. 13). It is distributed mainly as scattered relict stands of small to moderate size. Riverine stands occur where soils do not support Evergreen Forest.

Evergreen to Semi-Deciduous Bushland consists of a well-defined stratum of large bush and small tree species reaching 5 to 8 m in height. From this emerge scattered trees to

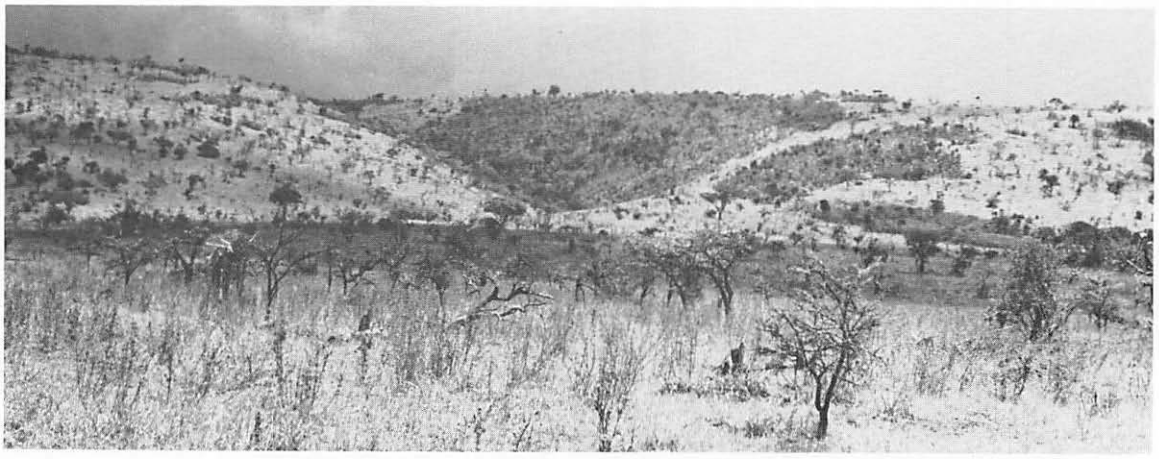

FIG. 12. Relict Semi-Deciduous Bushland on Nyamalumbwa Hills. Leafless *Croton dichogamus* appears light while the evergreen *Tarenna graveolens* shows as dark patches. Undifferentiated Woodlands of Rocky Hills (*Combretum-Acacia-Dombeya*), a successional community, occupy the remainder of the hillside. A stand of *Acacia gerrardii* is in foreground.

FIG. 13. Evergreen Bushland stands and single trees of *Acacia clavigera* and *Lannea stuhlmannii* on termite mounds in *Loudetia kagerensis-Themeda triandra* grassland near Ngirimi and Mara rivers.

about 9 to 12 m in height. The species of both strata generally have simple evergreen and sclerophyllous leaves. However, in the drier areas the deciduous nature of some species becomes apparent in the dry season (*Croton dichogamus* on Kuka Hill) and succulent genera such as *Aloe* and *Sansevieria* are more common.

Field sampling of this Vegetation Type was restricted primarily to the northwest sector of the Park. Here it apparently differs from the nearby Evergreen Forest chiefly in having fewer species, a lower bush layer, and fewer emergent trees. Botanical variability between stands is evident (Table 7).

This Vegetation Type is probably similar to the evergreen bushland formation which Glover and Trump (1970) show to be climax throughout much of Eastern Narok District. Trapnell *et al.* (1969, 1970) show much of this same area as supporting a potential climax of upland evergreen bushland vegetation. Trapnell and Langdale-Brown (1969) also describe an evergreen and semi-evergreen bushland and thicket type and note that it was once quite extensive throughout the Southwestern Kenya Highlands. The lion bush of Darling (1960) also appears similar.

The present widespread pattern of scattered small relict stands on a variety of physio-

TABLE 7. WOODY AND SUCCULENT SPECIES OF 3 EVERGREEN TO SEMI-DECIDUOUS BUSHLAND STANDS.

SPECIES	LOCATION		
	Mara River (Ngurimi)	Central Hill Range	Kenya Border
SPECIES	Clay Soils	Rocky Hill Slopes	Rocky Hill Tops
Acacia brevispica	X	X*	
Acacia mellifera ssp. *mellifera*		X	
Acalypha fruiticosa var. *villosa*		X	
Albizia petersiana	X		
Allophylus sp.	X		
Aloe sp.			X
Boscia angustifolia var. *corymbosa*		X	
Capparis erythrocarpos	X		
Cordia ovalis		X*	X
Croton dichogamus	X*		
Diospyros abyssinica	X		
Drypetes gerrardii	X		
Elaeodendron buchananii	X		
Euclea divinorum	X		
Euclea schimperi	X	X	X*
Euphorbia candelabrum			X
Grewia trichocarpa	X	X*	X
Haplocoelum foliolosum			X*
Lannea stuhlmannii		X	
Maytenus senegalensis		X	
Olea africana	X		
Pappea capensis		X	X
Phyllanthus sepialis		X	
Rhus natalensis			X
Sansevieria ehrenbergiana		X	
Scutia myrtina	X		
Strychnos henningsii	X		X
Tarenna graveolens		X*	X*
Teclea nobilis			X*
Teclea trichocarpa	X*		X*

*Dominant Species

FIG. 14. Evergreen to Semi-Deciduous Bushland near Mara River. The sharp bushland-grassland boundary reflects the impact of frequent grass fires.

graphic sites suggests that this type was once more extensive throughout the north of the Park and now exists only in localized fire-protected sites. The influence of fire is reflected in the characteristically abrupt boundaries of bushland stands with adjacent grassland and woodland vegetation (Fig. 14). The absence of an ecotone and the occasional occurrence of *Elaeodendron buchananii* trees, up to several hundred feet from the edge of bushland stands, indicates that edaphic characteristics are not necessarily the primary factors causing ecotones. The impact of grass fires was directly observed on several occasions where fire penetrated up to 7 m into bushland vegetation along fronts several hundred yards long. Stands in varying degrees of degradation are common throughout the north of the Park.

Elsewhere the boundary with grassland may be stable, as evidenced by occasional large woodland trees (*Acacia clavigera* spp. *usambarensis*) that are at least 50 years old, dominant in the surrounding woodlands, and found growing on the ecotone. Here, although the abruptness of the stand boundary remains evident, a small ecotone usually is found. This is characteristically composed of small coppicing bushes of *Euclea schimperi* with occasional regenerating *Elaeodendron buchananii* trees, both kept in this state by repeated burning.

Glover and Trump (1970) state that *Euclea schimperi* is often an indicator of past bushland and forest vegetation in Narok District. The previously mentioned ecotonal relationship with these vegetation types and occasional occurrence as abundant small coppicing bushes found among old stumps and relict plants of obvious bushland/forest origin corroborate this statement.

Evergreen to Semi-Deciduous Bushland and Evergreen Forest were probably once the dominant vegetation types throughout most of the Park along and north of the Grumeti-Mara River divide. The occurrence here of relict bushland stands in woodland dominated by *Acacia clavigera* and *A. gerrardii* indicates that the latter fire-resistant communities are successional. These *Acacia* woodlands have replaced Evergreen to Semi-Deciduous Bushland just as *Combretum molle-Terminalia mollis* woodland has replaced Evergreen Forest.

TABLE 8. CHARACTERISTIC TREE AND BUSH SPECIES OF THE SEMI-DECIDUOUS BUSHLAND VEGETATION TYPE.

OVERSTORY	UNDERSTORY
Acacia mellifera (dominant)	*Acacia brevispica*
Acacia clavigera	*Allophylus* sp.
Acacia polyacantha ssp. *campylacantha*	*Cadaba farinosa* ssp. *adenotricha*
Acacia tortilis	*Cissus* sp.
Commiphora sp.	*Cordia ovalis*
Commiphora trothae	*Grewia fallax*
Euphorbia candelabrum	*Grewia* sp.
	Salvadora persica
	Sansevieria ehrenbergiana

Semi-Deciduous Bushland

Semi-Deciduous Bushland occurs on termite mounds in grassland north of the lower Grumeti River and in the Ndabaka area. It consists of two strata. The lower stratum reaches 2 to 3 m in height, consists of several bush and succulent species, and is essentially evergreen in character. The overhead stratum, with *Acacia mellifera* the apparent dominant, consists of several tree species exhibiting variable height characteristics as well as degree of dry season leaf loss (Table 8). The boundary between Semi-Deciduous Bushland and Deciduous Bushland was inadequately determined, so both have been included as one mapping unit (115 km²).

Deciduous Bushland

Acacia mellifera Species Type

This is found as small, widely scattered stands throughout the hilly area west of Seronera and the region south of the Samsambe River (Fig. 8). There are no important associates.

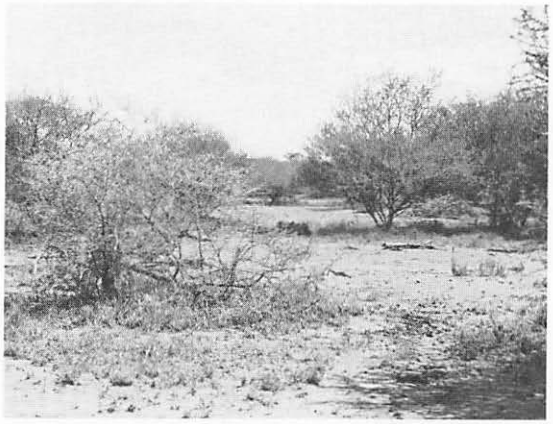

FIG. 15. *Acacia mellifera* Deciduous Bushland near Kimareshe Hill.

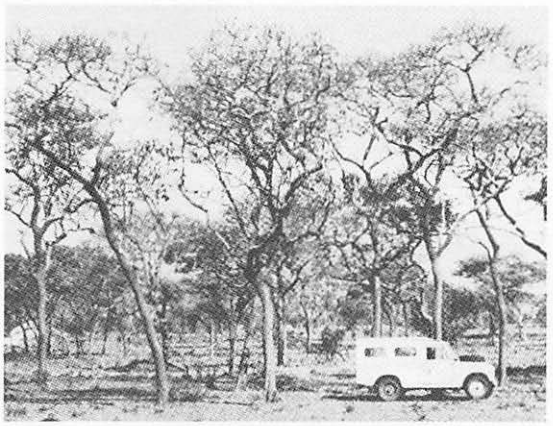

FIG. 16. *Terminalia mollis* Semi-Deciduous Woodland near Tabora.

TABLE 9. PRINCIPAL WOODY PLANT SPECIES OF THE *COMBRETUM MOLLE-TERMINALIA MOLLIS* SPECIES TYPE.

On Termite Mounds	Between Termite Mounds
Overstory	
Boscia angustifolia var. *corymbosa*	*Combretum molle*
Cussonia sp.	*Terminalia mollis*
Euphorbia candelabrum	
Ficus sp.	
Kigelia africana	
Lannea stuhlmannii	
Pappea capensis	
Parinari curatellifolia ssp. *curatellifolia*	
Understory	
Allophylus sp.	*Acacia hockii*
Carissa edulis	*Acacia nilotica* spp. *subalata*
Grewia trichocarpa	*Commiphora africana*
Lonchocarpus eriocalyx	*Gardenia jovis - tonantis*
Rhus natalensis	*Heeria reticulata*
	Maytenus senegalensis

Acacia mellifera is bush like when young, but takes on a more tree-like appearance as some of its basal branches are lost with age (Adams 1967). This Species Type is composed of a single low stratum of bush-like trees which exhibit a definite period of leaf loss in the dry season and grow to 3 to 6 m in height (Fig. 15).

Deciduous Bushland is closely associated with disturbed bare soil conditions caused by sheet and gully erosion or salt licks. *Acacia mellifera* has been shown to be a colonizer of disturbed soils in Uganda, where it often follows extensive overuse of land and indicates a regression from a more mesic plant community (Langdale-Brown *et al.* 1964).

Semi-Deciduous Woodland

Combretum molle-Terminalia mollis Species Type

This Species Type (Fig. 16) constitutes 390 km² (4.7%) of the woody vegetation in the Park. It is represented within the Serengeti National Park by *Combretum molle-Terminalia mollis* and occurs on deep to shallow loamy sand soils of ridge tops and upper slopes over a large area on either side of the Grumeti-Mara River divide in the northwest of the Park. Near the divide, topography is gentle and streamheads are shallow. A definite spring or seepage line, about midslope, divides the woodlands from grassy vegetation on poorly drained soils below (Fig. 17). As distance from the divide increases, the valleys are deeper, slopes steeper, seepage

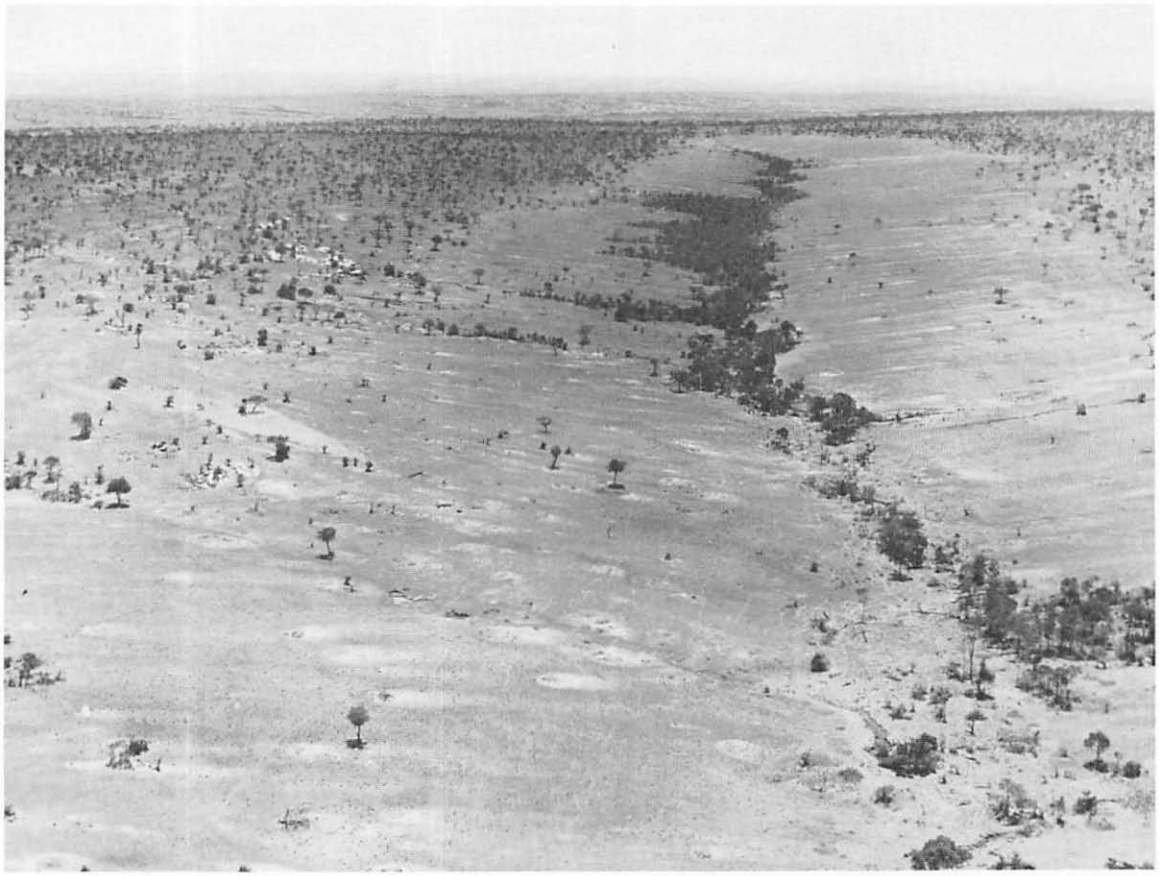

FIG. 17. Grumeti-Mara River divide east of Tabora. *Combretum molle-Terminalia mollis* Semi-Deciduous Woodland occupies ridgetops and *Themeda-Loudetia* drainage grasslands occur below. Eroding termite mounds show as white spots. Relict Upland Evergreen Forest follows the drainage line and, at lower right, degradation to grassland is occurring. (Photograph by H. F. Lamprey)

lines less distinct, and woodlands extend further downslope on shallower soils.

This Species Type consists of two principal strata. The open overstory is dominated by *Combretum molle* and *Terminalia mollis*, growing 10 and 13 m in height, respectively. *Combretum molle* is the more common, while *Terminalia mollis* is often restricted to small, scattered stands of pure composition. Both species are broadleaved and semi-deciduous. The understory is open and extends to 6 m in height. *Heeria reticulata*, an evergreen large bush or small tree with simple leaves, *Acacia nilotica* ssp. *subalata*, and *A. hockii*, deciduous thorn trees with small bipinnate leaves, are dominants (Table 9).

The lower stratum includes Evergreen to Semi-Deciduous Bushland clumps, which grow on termite mounds, found throughout the Species Type, as well as elsewhere in he north of the Park. The principal species are *Rhus natalensis* and *Grewia trichocarpa*. Emergent tree species such as *Lannea stuhlmannii* and *Sclerocarya birrea* commonly reach into the *Combretum-Terminalia* dominated overstory (Table 9). *Parinari curatellifolia* spp. *curatellifolia* and *Pappea capensis* are trees characteristically found on termite mounds along seepage lines. The lower stratum is composed of tall grasses, 1 to 2 m in height, including the genera *Diheteropogon*, *Hyparrhenia*, *Loudetia*, and *Themeda*. This statum experiences hot grass fires nearly every dry season.

The woody vegetation appears to have recently undergone considerable physiognomic changes. There is a definite absence of trees of either dominant species in the sapling to pole sizes. In addition, a zone of highly degraded woodland, from 1.5 to 6.5 km in width, lies along the eastern and northern boundary of the Species Type. In this zone, woody cover now occurs principally on termite mounds. Fallen medium-sized *Combretum molle* trees are common throughout the Species Type. Regenera-

tion of *Combretum molle* and *Acacia hockii* is common to abundant and is usually from well-developed root stalks and, occasionally, from tree stumps. However, growth into larger sizes is effectively suppressed by grass fires.

The persistance of regeneration indicates that the vegetation is adapted to the presence of grass fires, even though fire is currently suppressing further structural development in the Species Type. The *Combretum molle-Terminalia mollis* Species Type appears to be a fire-adapted, successional plant community to Evergreen Forest within the Serengeti National Park.

Semi-Deciduous to Deciduous Thorn Tree Woodland

This is the most important woody vegetation type in the Serengeti National Park in terms of area covered (7260 km² or 87.7% of all woody vegetation) and number of component species types (Table 4). It consists of a single low, open stratum of *Acacia* (bipinnate leaves) - *Commiphora* (trifoliate leaves) thorn trees extending 4 to 7 m in height. Exceptions are *Acacia tortilis*, *A. clavigera*, and *A. polyacantha*, which grow from 9 to 14 m tall, and *A. xanthophloea*, which reaches 18 to 22 m. Stands dominated by these latter species also may have closed canopies, especially in the sapling to pole sizes. An understory stratum, where present, consists of widely scattered single bushes or small groups of *Grewia fallax* and *Cordia ovalis*. There is a characteristic grassy stratum reaching from 0.5 to 1.5 m in height dominated by such species as *Digitaria macroblephara*, *Themeda triandra*, and *Eustachys paspaloides* on relatively well drained soils and *Pennisetum mezianum* on poorly drained soils. *Loudetia kagerensis* becomes important north of the Grumeti River in the Northern Extension. Much of this Vegetation Type is burned annually by dry season grass fires.

The timing and degree of leaf loss during the dry season vary widely between species and often between individuals of a species. There may be a clearly defined period of leaf loss throughout the dry season, as with *Commiphora trothae*, or this period may be shorter and occur much later in the dry season, as with *Acacia hockii*, or it may not occur at all, as in the case of *Acacia tortilis*. Leaf loss patterns of *Commiphora trothae* and *Acacia clavigera* appeared to be closely correlated with fluctuations in available soil moisture.

The Deciduous to Semi-Deciduous Thorn Tree Woodland Vegetation Type consists of 39 species types. The most important genus is *Acacia*, with 38 species types having one or more of 11 *Acacia* species as dominants and/or codominants.[2] Ten species types are dominated by a single *Acacia* species. These types account for 45.7% of the total woody vegetation in the Serengeti National Park (Table 4). This is indicative of the extent to which members of this genus have adapted to, and are a part of, the Serengeti Ecosystem. *Commiphora trothae* is the sole dominant of yet another species type.

Discussion of Deciduous to Semi-Deciduous Thorn Tree Woodlands will center principally on the species types having only one dominant tree species. An additional five species types will be discussed principally because of the large area occupied. These species types constitute 74.7% of the woody vegetation in the Serengeti National Park (Table 3).

Acacia nilotica Species Type

The *Acacia nilotica* Species Type occupies 245 km² of ridge tops and upper slopes immediately south of the Mara River in the northwest and throughout an extensive portion of the Grumeti River drainage in the north-central portion of the Park. (Table 4, Fig. 18). It also occurs as a narrow discontinuous strip at the base of the rocky scarp on the north face of the Nyaroboro Hills.

FIG. 18. Herd of buffalo in *Acacia gerrardii-A. nilotica* Deciduous to Semi-Deciduous Thorn Tree Woodland near Kuka Hill.

The dominant, *Acacia nilotica*, is a small tree with a wide, dense crown, growing from 3 to 7 m in height. *Acacia gerrardii* is the principal associate and possibly attains codominance locally in the northwest. *Commiphora africana* and *Acacia hockii* are important associates in

[2]Two or more species each contributing 21% or more to the density of an area are codominants.

the northeast, while *Acacia clavigera* is an associate throughout the center and south portion of the Species Type. *Combretum molle, Heeria reticulata,* and *Rhus natalensis* occur in the northwest (on termite mounds) and, to a lesser extent, in the north. Rocky outcrops are common throughout most of the Species Type. Wherever these are present, vegetation diversity increases significantly.

It is common to find stands of *Acacia nilotica* showing signs of recent degradation, with logs lying on the ground and an occasional standing dead tree. These are particularly obvious in the Grumeti River area and between it and the Grumeti-Mara River divide. Degradation seems to be selective, as small stands capping low hill tops are often heavily affected, while the surrounding *Acacia clavigera* vegetation on the slopes below shows little sign of damage.

Acacia gerrardii and *A. clavigera* occur as codominants with *A. nilotica* on a few low, gently sloped ridges on the Bologonja and between the Grumeti and Samsambe rivers. To the east *A. nilotica* forms a much larger species type with *A. hockii.*

Acacia nilotica-Acacia hockii Species Type

Samsambe and Grumeti rivers, Lobo Hill, and the Bologonja pipeline form the boundaries of the 220 km² area of this Species Type. It occupies a topographic position similar to the *Acacia nilotica* Species Type and shares the same principal species.

Acacia nilotica is the more common of the two dominant species. *Acacia clavigera, A. gerrardii, Commiphora trothae,* and *C. africana* are the principal associates. *Acacia senegal, A. drepanolobium, Combretum molle,* and *Heeria reticulata* are common. *Acacia gerrardii,* occurring in many stands, is associaed more often with *A. nilotica* than with *A. hockii.* This relationship, also occurring in the *Acacia nilotica* Species Type, suggests that *A. nilotica* overlaps in environmental requirements with both *A. gerrardii* and *A. hockii.*

This Species Type is the southern limit for distribution of *Combretum molle* and *Heeria reticulata* except on rocky hills and inselbergs. They occur as regeneration.

Acacia hockii Species Type

Acacia hockii, a small tree growing 3 to 5 m in height, is a codominant in several species types in the Park. It is the exclusive dominant over only 155 km² (Table 4) including (1) a small area between the Mara River and the Kenya border, (2) both sides of the Samsambe River

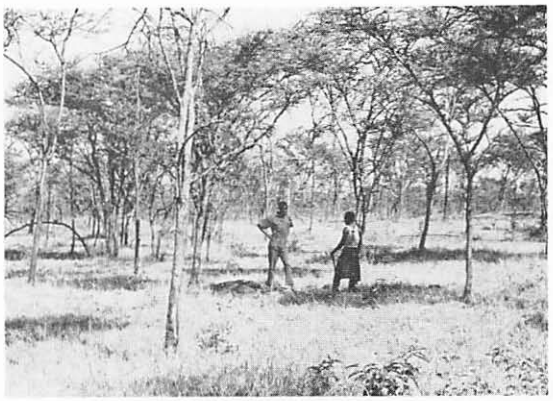

FIG. 19. *Acacia senegal-A. hockii* Deciduous to Semi-Deciduous Thorn Tree Woodland on footslope of Banagi Hill. The grass layer is dominated by *Digitaria macroblephara* and *Panicum maximum.*

west of the pipeline, (3) several small stands scattered among the hills west of Seronera, and (4) an area between the Grumeti River and Bwananuke Hill.

Acacia senegal-Acacia hockii Species Type

This large Species Type occurs on ridge tops and lower slopes over approximately 835 km² of gently to moderately rolling topography between the Samsambe and Seronera rivers. Within the Park it is bordered on the east and north by species types dominated by *Commiphora trothae, Acacia nilotica,* and *A. hockii.*

Acacia senegal and *A. hockii* may each be locally dominant or may occur together as codominants (Fig. 19). *Acacia senegal* dominates the majority of stands throughout the Species Type and is especially abundant in the southwest. *Acacia hockii* is more often dominant in the northeast and is common in the northwest and southeast. *Acacia clavigera, Commiphora trothae,* and *Ormocarpum trichocarpum* are important associates in the west and are common elsewhere. *Acacia drepanolobium, A. nilotica,* and *A. tortilis* (in particular, *A. tortilis* regeneration) commonly occur.

Acacia senegal Species Type

Acacia senegal, which is 3 to 5 m in height, exclusively dominates only a few small stands (75 km²) scattered throughout the hills west of Seronera and in the Nyamuma area along the Mbalageti River. These occur on rocky soils, either on low, small hills or in discontinuous narrow bands at the base of larger hills immediately above the *Acacia clavigera* Species Type. *Acacia clavigera* and *A. hockii* are the principal associates, while *A. tortilis, A. drepanolobium, Balanites aegyptiaca,* and *Commiphora trothae* are common.

Acacia senegal also is a codominant in three principal species types: (1) *A. drepanolobium-A. senegal*, (2) *Commiphora trothae-A. senegal*, and (3) *A. clavigera-A. senegal-C. trothae*. *Acacia drepanolobium* and *A. hockii* are the principal associates in the latter two species types, respectively.

Acacia gerrardii Species Type

Acacia gerrardii generally grows from 3 to 5 m in height (Fig. 20) and is the dominant tree species over an area of 280 km², mostly in the north of the Park (Table 4). It is most extensive in the northeast of the Park where it occurs on ridge tops and upper slopes. It apparently forms a fire-induced successional community to Evergreen to Semi-Deciduous Bushland. Evidence of vegetation change is abundant and characterized by the common occurrence of bushland relicts and by recent degradation of many successional *A. gerrardii* stands.

FIG. 20. *Acacia gerrardii* Deciduous to Semi-Deciduous Thorn Tree Wooded Grassland in Lamai Wedge. Grass understory is *Themeda triandra*.

FIG. 21. Mature stand of *Acacia clavigera* Deciduous to Semi-Deciduous Thorn Tree Woodland near Banagi. Grass layer is dominated by *Sporobolus fimbriatus*.

Acacia nilotica, *A. clavigera*, *A. hockii*, and *Commiphora africana* are important associates of the Species Type. *Boscia angustifolia* var. *corymbosa*, *Balanites aegyptiaca*, *Lannea stuhlmannii*, and *Lippia-Lantana* ssp. are common. *Boscia angustifolia* is more abundant here than elsewhere in the Park.

The *Acacia gerrardii* Species Type is found also on poorly drained clay soils of lower ridge slopes throughout the Mara-Mchonjo area in the northwest of the Park. *Rhus natalensis* and *Combretum molle* are common associates on termite mounds and rock outcrops, respectively. In the Lamai Wedge, this Species Type occurs on poorly drained clay soils of gentle topography. Tree density and canopy cover are characteristic of a wooded grassland.

An extensive area of *Acacia gerrardii* mixed with clumps of bush (probably *Rhus natalensis*) occurs in the western Lamai Wedge. Scattered through the area are relict stands of Evergreen to Semi-Deciduous Bushland capping small, low, rocky hills. This underlines once again the successional relationship between *Acacia gerrardii* and Evergreen to Semi-Deciduous Bushland. Elsewhere within the Park *A. gerrardii* occurs occasionally on shallow, rocky soils, as in the Nyaroboro and Varichoro Hills. Also, it is locally dominant within the Northern Extension, with *Acacia clavigera* on lower slopes and along drainage lines and with *A. nilotica* upslope. It occasionally occurs with *Acacia seyal* and *A. drepanolobium* in the southwest of the Park.

Acacia clavigera Species Type

This Species Type is widespread throughout the Park, occurring on a variety of topographic sites over an area of 955 km² (Table 4). In the north, the *Acacia clavigera* Species Type occurs across the full amplitude of ridge and slope topography (Kogatende), on termite mounds in grassland (Ngurimi), ridge tops and upper slopes (between Wogakuria and the Nyamalumbwa Hills), upper and middle slopes (north of the Grumeti River), and footslopes[3] and valley bottoms (along the south of the Grumeti River). In the south and southwest, it occurs principally on colluvial footslopes at the base of steep, rocky hills and on tops and upper slopes of lower and more gently sloped hills. It is occasionally found in the Western Corridor growing on termite mounds in grassland. These occur in lines at right angles to the contour. Occurrence of this Species Type locally in the

[3]Footslopes are colluvial in origin and intermediate in slope between adjacent hills and lower lying land.

Banagi-Nyabogati mine area seems unrelated to topographic characteristics, but is likely controlled by soil parent material.

Acacia clavigera grows from 8 to 12 m in height. It typically forms even-aged stands with dense canopies which restrict growth and abundance of most other woody plants (Fig. 21). Extensive areas of *Acacia clavigera* in the Western Corridor do not have trees in the small sapling and pole classes. However, the characteristic structure throughout much of the Northern Extension shows few pole-size and mature trees.

Few other tree species are abundant within the *Acacia clavigera* Species Type. Some relatively common associates are *Acacia gerrardii*, throughout the north and, occasionally, in the corridor and the Nyaroboro and Varichoro Hills; *A. hockii*, in the southwest; and *Commiphora trothae* throughout the west, southwest, and, occasionally, east. *Acacia polyacantha* is a codominant on footslopes of the Handajega-Simiti Hills. Other associates species are *Balanites aegyptiaca*, *Grewia fallax*, *Acacia tortilis*, and *A. senegal*.

Acacia clavigera is a codominant with *Commiphora trothae* on ridge tops south of the Simiyu River and in local areas along the Mbalageti River near Nyamuma. The *Acacia clavigera-A. hockii* Species Type occurs extensively on gently sloped and somewhat raised land southwest of the Itonjo Hills and occasionally elsewhere in the Park. The *Acacia clavigera-A. tortilis* Species Type is common on alluvial benches along the Samsambe, Rokari, and Orangi rivers. Elsewhere, *Acacia gerrardii*, *A. drepanolobium*, *A. senegal*, and *A. nilotica* combine with *A. clavigera* to form other distinct species types.

Most codominant species also are exclusive dominants of species types physiographically closely associated with the *Acacia clavigera* Species Type. Species types dominated only by *Acacia hockii*, *A. nilotica*, *A. senegal*, and *A. tortilis*, when present, always occur just above *A. clavigera* in the topographic sequence of vegetation. *Acacia drepanolobium* and *A. gerrardii* always occur downslope. This indicates that the environmental factors under which *Acacia clavigera* exerts exclusive dominance are intermediate to those favoring the two foregoing groups, and a relationship based on soil drainage is implied.

Acacia drepanolobium Species Type

This Species Type occupies 1375 km² of the Park, principally in the west, southwest, and south (Table 4). It occurs on level to gently sloping topography of plains, wide river valleys, and footslopes at the base of rocky hills. In parts of the Northern Extension it commonly occurs as a major species type on valley bottoms and adjacent lower slopes. In all cases the soils are either imperfectly or poorly drained. It is common to find stands of standing dead trees of *Acacia drepanolobium*. This implies the effect of some short term but extreme variation in edaphic conditions, such as waterlogging.

No other tree and bush species are even moderately abundant (Fig. 22). *Acacia drepanolobium*, characterized by galls at the base of thorns, grows from 1 to 8 m in height and is most closely associated with *Balanites aegyptiaca* in the western corridor. *Balanites aegyptiaca* occurs as widely but evenly spaced individuals, overtopping *Acacia drepanolobium* by at least 3 m. *Acacia tortilis* and *Commiphora trothae* are locally common in the Western Corridor south of the Grumeti River.

Acacia drepanolobium is a codominant in three species types of moderate extent in the Park's Northern Extension. It occurs with *Commiphora trothae* on ridges and slopes north of the Ngare Nanyuki and with *Acacia clavigera* and *A. gerrardii* in narrow valley bottoms between Ngelek and Kuka Hills. It is also found with *Acacia senegal* on a long, low, rocky ridge extending north from the Nyabogati River. This latter Species Type is closely associated with a specific geological substratum — chlorite and mica schists of Nyanzian acid volcanics and metasediments (MacFarlane 1968a). It is also the only occurrence of *Acacia drepanolobium* not obviously associated with imperfectly drained soils.

FIG. 22. *Acacia drepanolobium* Deciduous to Semi-Deciduous Thorn Tree Woodland near Nyaraswiga Hill. The grass layer is dominated by *Digitaria macroblephara* and *Pennisetum mezianum*.

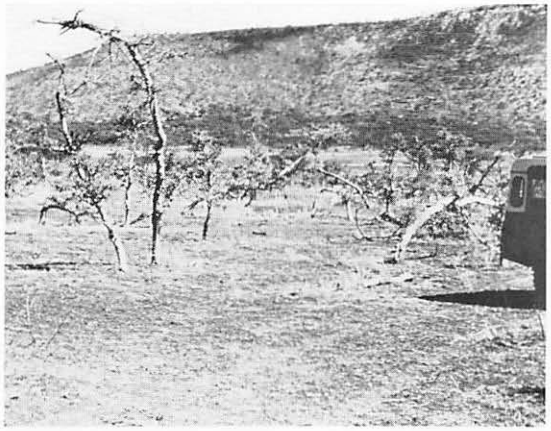

FIG. 23. *Acacia seyal* Deciduous to Semi-Deciduous Thorn Tree Woodland. This is the characteristic growth form in the Park.

FIG. 24. Characteristic *Acacia seyal* stand on Ndabaka Plain. These stands are even-aged in structure and atypical in growth form.

Acacia seyal Species Type

The *Acacia seyal* Species Type covers 230 km², occurring principally throughout the southwest and west of the Park. Distribution is limited in the Park north of Banagi. This Species Type occurs on poorly drained heavy clay soils of plains, sumps, and some drainage lines. Black cotton clay soils which crack in the dry season are characteristic of these areas. Stands of *Acacia seyal* are remarkably pure in composition, and *Balanites aegyptiaca* is the only associate of importance. *Acacia seyal* is seldom found as a component of other species types.

Acacia seyal grows from 4 to 6 m in height, has a small crown, smooth yellow to greenish-yellow bark, and whitish galls at the base of the thorns. It also has an odd growth habit in that the trees often bend in a permanent, near prone or sharply leaning position. Stands composed of such trees can often be easily recognized at a distance from the pattern created by many stems leaning at all angles and directions (Fig. 23).

Dense, even-aged stands occur on the Ndabaka Plains, a situation differing from the uneven-aged stands found elsewhere in the Park (Fig. 24). As with *Acacia drepanolobium*, *Acacia seyal* stands apparently tend to be adversely affected by local changes in edaphic conditions, probably related to drainage, and may disappear and reappear suddenly.

Acacia xanthophloea Species Type

This Species Type is small in area (50 km²) and localized in distribution (Table 4). Occurrence is limited to a few riverine stands along the edge of the Serengeti Plains — principally the upper Seronera, Ngare Nanyuki, Mbalageti, and Simiyu rivers and tributaries.

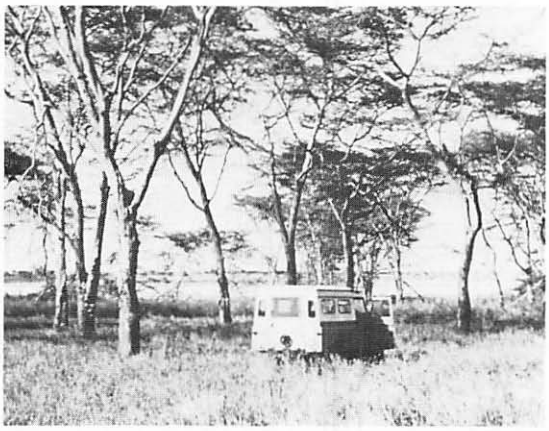

FIG. 25. Mature *Acacia xanthophloea* Semi-Deciduous Thorn Tree Woodland growing along the Seronera River.

Stands are dominated by the yellow barked *Acacia xanthophloea* which grows from 19 to 22 m in height (Fig. 25). Some characteristic, but not abundant, associated tree species are *Vangueria acutiloba*, *Hyphaene ventricosa*, and *Acacia kirkii* var. *intermedia* at stream edges; *Kigelia africana*, and *Acacia sieberiana* var. *sieberiana*. A bush layer of *Aspilia mossambicensis*, *Phyllanthus sepialis*, and *Pluchea ovalis* generally occurs under open *Acacia xanthophloea* stands. *Pluchea ovalis* is associated with saline soils (Glover and Trump 1970).

Acacia sieberiana Species Type

This Species Type is of limited extent (10 km²) and occupies many of the small, shallow drainage lines upstream from *Acacia xanthophloea* along the Bolojoro and Mongobiti rivers in the Western Corridor. Occasionally it occurs as open stands on higher ground, such as those near the Ngare Nanyuki track in the Wandamu

FIG. 26. Mature *Acacia tortilis*, with *Digitaria macroblephara-Microchloa kunthii* grass layer, on edge of Serengeti Plains.

drainage. *Acacia sieberiana* grows to 12 m in height, has a large, full crown and yellow-brown scaly bark. Associated tree species are *Balanites aegyptiaca*, *Kigelia africana*, *Acacia albida*, and *Gardenia* sp.

***Acacia tortilis* Species Type**

A Species Type dominated by *Acacia tortilis* covers an area of 405 km² of the Park (Table 4) and occurs on several distinct topographic sites. These are (1) tops and slopes of gently rolling plains (perimeter of the Serengeti Plains and Grumechen area), (2) gently sloped valley bottoms (Orangi River drainage north of Grumechen), (3) alluvial benches beside major streams (such as the Orangi, Nyabogati, upper Mbalageti, Magongo, and Simiyu rivers), (4) raised levees (Ndabaka Plains), and (5) colluvial footslopes of occasional rocky hills in the Central Range west of Seronera. There is no obvious topographic relationship common to these sites. It is inferred that soil parent material is the factor controlling occurrence of this Species Type in the Park.

Acacia tortilis grows from 9 to 14 m in height and is characterized by a wide, often flat crown, which may reach 21 m in diameter (Fig. 26).

The principal associates of *Acacia tortilis*, on riverside benches, are *Acacia clavigera*, *Commiphora trothae*, and *Albizia harveyi*. Bushland clumps composed of *Cordia ovalis*, *Salvadora persica*, and *Acacia mellifera* are common on the lower Orangi River. *Commiphora trothae*, *Acacia senegal*, and *A. drepanolobium* are common associates in the east with *Commiphora trothae* most common on hilltops. Elsewhere, *Commiphora trothae* and *Balanites aegyptiaca* are the principal associates, and *Acacia clavigera* and *A. hockii* are common.

Acacia tortilis is a codominant in a species type with *Commiphora trothae* south of the Simiyu River on ridge tops and, in the Grumechen area, on gentle hill slopes. It also occurs with *Acacia hockii* in a few scattered stands west of Seronera.

Regeneration of *Acacia tortilis* appears localized and sparse. In the Grumechen area, for instance, regeneration is almost totally absent. On the hilltops, *A. tortilis* stands are degenerating due to death of old, mature trees. Aerial photographs taken in 1958 show many more trees than now exist. With limited regeneration these woodlands have become essentially wooded grassland and, in some areas, grass-

land. Throughout the Park there is a definite absence of *A. tortilis* in the sapling to pole sizes.

Albizia harveyi-Acacia polyacantha-Acacia clavigera Species Type

This is a wooded grassland to woodland species type found on 135 km² of alluvial soil along the lower Grumeti, Mbalageti, and Duma rivers and a few tributaries (Table 4). In appearance, the flaky barked *Albizia harveyi* resembles many *Acacia* species but lacks thorns. The thorns of *Acacia polyacantha* are strong, black, and recurved. Visually, both species differ from *Acacia clavigera* in having generally flat crowns. All three species grow from 16 to 19 m in height.

Acacia tortilis is a common associate throughout, and *Borassus aethiopum* stands are characteristic along the Bolojoro and Mongobiti streams and along tributaries of the Mbalageti River east of Handajega. Dense stands of low-growing *Ormocarpum trichocarpum* and *Dichrostachys cinerea* are commonly scattered throughout the community.

Commiphora trothae Species Type

This Species Type (460 km²) dominates an extensive area north of the Serengeti Plains and along the eastern boundary of the Park to Longossa Mountain. It also occurs in less extensive stands between the Nyamuma and Ndoho Plains, in the upper Mbalageti Valley (including colluvial soils at the base of the northern face of the Nyaroboro Hills), and south of the Itonjo Hills.

FIG. 27. *Commiphora trothae* Deciduous to Semi-Deciduous Thorn Tree Woodland. The rounded crown, trifoliate leaves and stubby, knarled bole make this species easily distinguishable.

Commiphora trothae (Fig. 27) has a full rounded crown, spines, and trifoliate leaves. It grows 5 to 7 m in height. *Commiphora trothae* occurs on well-drained soils of ridge tops and slopes of gently to moderately rolling topography. These soils have been derived from granite or granitic gneisses, and rock outcrops are common. *Acacia tortilis, A. clavigera, A. senegal,* and *A. hockii* are the most important associates throughout the Species Type. *Commiphora africana* is common north of the Bololedi River. *Acacia tortilis* and *A. senegal* are common in the east and, with *A. hockii,* south of the Itonjo Hills. *Acacia clavigera, A. senegal, A. hockii,* and *A. drepanolobium* are common in the upper Mbalageti River area, occasionally in open, wooded grassland communities. *A. tortilis* and *A. clavigera* occur in the Nyamuma area.

Lonchocarpus eriocalyx-Acacia spp. Species Type

This Species Type covers 60 km² in area (Table 4) and is characteristic of many of the rocky hill sites west and southwest of Seronera. *Commiphora trothae, Acacia senegal, A. gerrardii, A. clavigera,* and *Lonchocarpus eriocalyx* are the most abundant species. They may occur as heterogeneous or relatively pure stands within the mosaic forming the Species Type. *Lonchocarpus eriocalyx* differs from *Acacia* spp. by its broader leaves. It is the more apparent component of the Species Type.

Additional investigation of the Undifferentiated Woodlands on Rocky Hills may show *Lonchocarpus eriocalyx-Acacia* spp. to be more extensive than shown by the present boundaries of the Species Type.

Undifferentiated Woodland on Rocky Hills Species Type

This Species Type consists of 695 km² (Table 4) of rocky hills, often with steep slopes. Elevations range from 62 to 465 m above the surrounding countryside. Few observations were made of vegetation on these hills. However, the species composition appears highly variable, probably reflecting a parallel variability in edaphic and physiographic conditions.

Varying combinations of *Acacia hockii, A. senegal, A. drepanolobium, A. clavigera,*

FIG. 28. *Balanites aegyptiaca* Semi-Deciduous Thorn Tree Wooded Grassland between Moru kopjes and Nyaroboro Hill.

A. nilotica, and *A. gerrardii* characterize most of the hills. However, *Combretum molle*, *Dombeya rotundifolia*, *Heeria reticulata*, and *Rhus natalensis* are common in the north in association with scattered relict stands of Evergreen to Semi-Deciduous Bushland (Fig. 11). A similar vegetation pattern occasionally occurs in the southwest, but the relict stands of Evergreen to Semi-Deciduous Bushland are fewer and more localized. *Acacia polyacantha* is locally dominant on a few small hills around Kiti Hill.

Semi-Deciduous Thorn Tree Wooded Grassland

Balanites aegyptiaca Species Type

This Species Type consists of 225 km² and is the sole representative of its vegetation type (Fig. 28). This is most extensive between Moru Kopjes and the Nyaroboro Hills and throughout much of the Lamai Wedge. It characteristically consists of widely but evenly spaced single trees of *Balanites aegyptiaca* scattered throughout medium grassland on level sites. Heavy, dark, cracking clays are closely associated with this Species Type, implying a strong edaphic influence.

Balanites aegyptiaca differs from other thorn trees in the Park in having bifoliate leaflets occurring two to a petiole. It has deeply fissured bark and grows from 8 to 11 m in height. It generally forms pure stands. *Acacia sieberiana*, *A. seyal*, and *A. albida* are common, but seldom numerous. Other species of limited occurrence are *Acacia drepanolobium*, *A. clavigera*, *Kigelia africana*, and *Grewia fallax*.

Inselberg Vegetation Type

Outcroppings of granite and gneiss, called inselbergs (Fig. 3), are particularly common throughout the Serengeti Plains, the Northern Extension south of the Mara River, and the Simiyu region. They range from isolated small, barely exposed rock surfaces at ground level to closely grouped clusters of large rocks up to 20 m high occurring over areas as large as 60 km². They commonly consist of a core of bare rocks surrounded by colluvium in various stages of weathering. A wide range of ecological niches are available. Vegetation of inselbergs is botanically and physiognomically heterogeneous. It is distinct from the vegetation of the surrounding plains and woodlands and often varies widely between inselbergs (Table 10). Woody vegetation is usually present, although it may be a minor component on some inselbergs, such as those in the eastern Serengeti Plains. Because of heterogeneity, a great deal more study will be required before the vegetation of these inselbergs is adequately described.

TABLE 10. WOODY PLANT SPECIES COLLECTED AND IDENTIFIED FROM TWO INSELBERGS 30 km APART AT THE WESTERN EDGE OF THE SERENGETI PLAINS.

SPECIES	LOCATION	
TREES		
Acacia tortilis	X	
Albizia harveyi	X	
Commiphora eminii		X
Commiphora trothae	X	X
Commiphora merkeri		X
Ficus thonningii	X	
Sclerocarya birrea	X	X
Teclea simplicifolia		X
BUSHES & FORBS		
Allophylus rubifolius	X	X
Asparagus falcatus	X	X
Capparis tomentosa	X	X
Cordia ovalis		X
Dichrostachys cinerea	X	
Grewia fallax	X	
Grewia trichocarpa	X	X
Hibiscus lunarifolius		X
Hoslundia opposita		X
Iboza sp.		X
Lannea stuhlmannii	X	
Maerua triphylla		X
Pavetta assimilis		X
Phyllanthus sepialis		X
Turraea fischeri		

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