CANADIAN INTERNATIONAL DEVELOPMENT AGENCY

Jamaica: Trees for Tomorrow Project
Phase II

ECOLOGICAL LAND CLASSIFICATION FOR FOREST MANAGEMENT AND CONSERVATION IN JAMAICA

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ACRONYMS

AEZ	Agro-ecological Zoning
ALES	Automated Land Evaluation System
CRIES	Comprehensive Resource Inventory and Evaluation System
DI	Degradation Index
DOS	Directorate of Overseas Surveys (UK)
ELC	Ecological Land Classification
FAO	Food and Agriculture Organisation of the United Nations
FCC	Fertility Capability Classification
FD	Forestry Department
GIS	Geographic Information System
HAP	Hillside Agriculture Project
ICEC	International Classification of Ecological Communities
JAMGIS	Jamaica Geographic Information Systems
JAMPLES	Jamaica Physical Land Evaluation System
LC	Land Conditions/Characteristics
LCC	Land Capability Classification
LESA	Land Evaluation and Site Assessment
LI	Land Index
LICJ	Land Information Council of Jamaica
LQ	Land Qualities
LUR	Land Use Requirement
LUT	Land Utilisation Types
RPPD	Rural Physical Planning Division (now called Rural Physical Planning Unit)
TNC	The Nature Conservancy
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USA	United States of America
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
UWI	University of the West Indies
WOFOST	Simulation Model of Crop Production (Centre for World Food Studies, Netherlands)

1.0 INTRODUCTION

In 1998, a draft version of this document was written with the objective of:

- establishing a methodology for undertaking a biophysical/ecological inventory for Jamaica;
- mapping woody vegetation types of Jamaica; and
- planning of potential land use for forestry in a pilot watershed management unit, namely the Buff Bay/Pencar.

The present document begins with a review of the land use/cover and land classification schemes used in Jamaica in the past several decades. These schemes are mainly oriented for use in agriculture development and soil conservation on steep lands. The document then describes a new ecological land classification scheme developed for use in the management and conservation of forests, and forestry development in Jamaica. This land classification scheme was tested in the biophysical inventory and mapping of forest lands in Buff Bay/Pencar watershed management unit. It has since been used by the Forestry Department for the biophysical inventories and woody vegetation mappings of the Rio Minho and the Martha Brae (including Cockpit Country Forest Reserve) watershed management units and the proposed Dolphin Head national park.

2.0 WOODY VEGETATION COVER CLASSIFICATION

Classification systems of vegetation and land cover are based on vegetation structure and/or on vegetation function. The main purposes for the classification of land cover and vegetation types are for use in planning agriculture development, in forest management and/or ecosystem conservation.

According to Jordan (1993), one problem in understanding the limitations of tropical forests is that most vegetation classification systems are based on structure. Successful forest management depends more on forest function than on structure. Where structure reflects function, management practices based upon a structure classification is satisfactory. This is the case when moisture is a critical factor in classification, eg, forest trees, steppe/savanna grasses and desert vegetation. However, structure does not always reflect function and it is notably true in the case of tropical forests (Jordan 1993).

The following classification systems of vegetation types are in use (Wadsworth 1997) at the regional level, comprising tropical America and the Caribbean islands[1]:

> Beard system (1944, 1955): classification based on physiognomic approach (community structure-habitat), showing each vegetation formation like a profile diagram (climax stage).
> Holdridge system (1967): classification of world climates, using annual precipitation and bio-temperature, into life zones and designates each with the name of a vegetative formation.
> UNESCO system (1973): comprehensive classification based on environmental variables and forest structure.

2.1 Bioclimatic Types

At the global scale, a correlation is often made between climate and vegetation types. The Holdridge system is the only scheme based entirely on climate. Recently, a new climatic framework for the worldwide classification of the tropical woody vegetation types was proposed in which the bioclimatic types are defined on annual rainfall, seasonality and mean temperature of the coldest month (Blasco *et al*. 2000). Unfortunately, these schemes for broad forest classification often are of little help to the practicing tropical forester who is concerned with management of local tracts of forest (Jordan 1993).

2.2 Woody Vegetation Formations

Within each bioclimatic type, Blasco *et al*. (2000) propose a second level, called forest formation which is defined on forest structure and physiognomy. The Beard system (1944, 1955) is based upon floristics, physiognomy and habitat, with the chief emphasis on physiognomy, following as

[1] Classification systems of forest types have also been proposed by Barbour (1942) and Stehlé (1945) for tropical America and the Caribbean islands respectively.

far as possible the method and nomenclature of Burtt Davy (1938)[2]. The UNESCO system (1973) integrates climatic, physiognomic and structural parameters to classify vegetation worldwide. In order to make an assessment of conservation priorities in Latin America and the Caribbean, Dinerstein *et al*. (1995) proposed another hierarchical classification of terrestrial ecosystems which incorporates a second hierarchical level called "habitat types" defined by the climate regime, general structure, and major ecological processes, with flora showing similar structure and life history.

Swabey (1949) proposed an outline for the first classification of Jamaican vegetation which was based on Burtt Davy's (1938) classification system of tropical woody vegetation types. Asprey and Robbins (1953) developed the first comprehensive description of the Jamaican vegetation communities based on the Beard (1944) classification system of tropical American vegetation types. A synthesis of Jamaican woody vegetation formations, using these and the Holdridge classification systems, is presented in Table 1. A comparison of the Beard, Asprey *et al*. and Holdridge systems was first conducted by Gray and Symes (1972) during the first national forest inventory in Jamaica.

[2] The Burtt-Davy's classification system (1938) was an attempt to correlate the nomenclature and to harmonise the classification of tropical woody vegetation types based on Schimper's, Warming's, Chipp's and Champion's nomenclature and classification systems of vegetation.

Table 1. Classification of Jamaican woody vegetation formations using the Beard, Swabey, Asprey *et al*. and Holdridge systems

Climax vegetation types (Beard 1944, 1955)	Vegetation types (Swabey 1949)	Vegetation communities (Asprey and Robbins 1953) (Loveless and Asprey 1957) (Asprey and Loveless 1958)	Life zones (Holdridge 1967)
OPTIMAL FORMATION			
Rain forest		No equivalent	Tropical wet forest
SEASONAL FORMATIONS			
Evergreen seasonal forest	Lower montane rain forest	Wet limestone forest	Premontane wet forest Tropical moist forest Premontane moist forest
Semi-evergreen seasonal forest	Limestone woodland	Dry limestone scrub forest	Tropical dry forest
Thorn woodland		Thorn scrub	Tropical very dry forest
Cactus scrub		Cactus-thorn scrub	Tropical very dry forest
DRY EVERGREEN FORMATIONS			
Dry evergreen woodland	Littoral woodland	Littoral evergreen bushland	Tropical dry forest
Dry evergreen thicket	Strand vegetation	Dry evergreen thicket	Tropical very dry forest
Dry evergreen bushland		Evergreen bushland	Tropical very dry forest
		Cactus scrub	Tropical very dry forest
MONTANE FORMATIONS			
Lower montane rain forest	Lower montane rain forest	Lower montane rain forest	Premontane rain forest
Montane rain forest	Upper montane rain forest	Montane mist forest	Premontane rain forest Premontane wet forest
Montane thicket		No equivalent	
Elfin woodland	Elfin woodland	Elfin woodland	Premontane rain forest
No equivalent		Montane sclerophyll	Premontane wet forest
SWAMP FORMATIONS			
Herbaceous swamp	Grass and reed swamps	Herbaceous swamp	Tropical very dry forest (1)
Mangrove forest	Mangrove	Mangrove woodland	Tropical very dry forest Tropical dry forest
SEASONAL SWAMP FORMATIONS			
Seasonal swamp forest	Fresh water swamp forest	Marsh forest	Tropical dry forest (1)
Seasonal swamp woodland		Palm-sedge marsh	Tropical dry forest (1)
(1) Sometimes occurs in other life zones.			

This second step of classification into woody vegetation formation is a good aid to strengthen or correct the broader systems of classification and are a necessary precursor to land use planning and management. Classification into woody vegetation formation is useful for mapping and description of large tracts of forest at the regional and sub-regional scale (Wadsworth 1997, Blasco *et al*. 2000), eg, the Caribbean and Greater Antilles forests, nevertheless, it is still of little use to the forester charged with managing a particular tract of forest.

2.3 Woody Vegetation Communities

This third level of the classification, corresponding to the Beard (1955) association[3], is mainly defined on floristic composition and varies more with soil than with climate. For example, the description of woody vegetation communities can include the main species associations along

[3] According to Beard (1955), the "association level" should be identified by a floristic name (eg, *Selaginella* association), while the "formation level" and the "formation-series level" should bear a physiognomic name (eg, upper montane rain forest) and a habitat name (eg, montane formation) respectively.

the creek to the ridge. The forest unit at this level can be small enough to be useful for forest management (Jordan, 1993).

Grubb and Tanner (1976) give a good example of the relationships between the forest type and soil for the montane forests of the Port Royal and Blue and John Crow Mountains of Jamaica. They described 10 forest types: Mor Ridge forest, Mull Ridge forest, Very Wet Ridge forest, Wet Slope forest, Gully forest, High Altitude forest, Dry Slope forest, Dry Limestone Scrub forest, Wet Limestone forest (lower) and Wet Limestone forest (upper). The description of each forest type is arranged under the headings: climate, geology and soils, floristics, forest structure and function.

Following Asprey and Robbins' work on Jamaican vegetation in 1953, other vegetation studies concerning important Jamaican ecosystems were carried out, including:

- vegetation on bauxite soils (Howard and Proctor 1957a, 1957b);
- dry limestone vegetation (Loveless and Asprey 1957, Asprey and Loveless 1958, Adams and du Quesnay 1970, Kapos 1986);
- upland wetland (bog) vegetation (Proctor 1970);
- montane forests (Grubb and Tanner 1976, Tanner 1986);
- mesic limestone vegetation (Proctor 1986a);
- wet limestone forests (Kelly 1986)
- wetland vegetation (Coke *et al*. 1982, Proctor 1986b);
- limestone forests (Kelly *et al*. 1988)
- reef island vegetation (Stoddart and Fosberg 1991); and
- high altitude forests (Iremonger 1992).

In 1992, Grossman *et al.* saw the need to update and expand Asprey and Robbins' classification (1953) and developed a new detailed classification scheme for the Jamaican natural communities and modified vegetation. Their scheme, called The Nature Conservancy (TNC) classification, is based on the UNESCO (1973) classification approach (Table 2). Muchoney *et al*. (1994) applied this new classification scheme to the vegetation description of the Blue and John Crow Mountains National Park. As shown in Table 2, the forest type identified as I.A.3a(1)(b) is interpreted as follows:

class I	closed forest
subclass I.A	non-wetland forest
group I.A.3	upper montane rain forest
formation I.A.3a	upper montane rain forest over shale
association I.A.3a(1)	typical association
variant I.A.3a(1)(b)	*Selaginella* variant of the typical association

The last two steps (association, variant) are based on the floristic characteristics of the stand.

Table 2. Classification of Jamaican vegetation communities according to UNESCO/TNC system

I CLOSED FORESTS
I.A NON-WETLAND FORESTS
I.A.1 Lowland rain forest
I.A.2 Lower montane rain forest
I.A.2a Lower montane rain forest over limestone
I.A.2b Lower montane rain forest over shale
I.A.2b(1) Typical variant
I.A.2b(2) Gully variant
I.A.2b(3) Transitional variant
I.A.2c Modified lower montane rain forest
I.A.3 Upper montane rain forest
I.A.3a Upper montane rain forest over shale
I.A.3a(1) Typical association
I.A.3a(1)(a) Typical variant of the Typical association
I.A.3a(1)(b) *Selaginella* variant of the Typical association
I.A.3a(2) Mor ridge forest type
I.A.3a(3) High altitude scrub forest
I.A.3b Upper montane rain forest over limestone
I.A.3b(1) Typical variant
I.A.3b(2) Edaphic variant
I.A.3b(3) Blue Mountains variant
I.A.3c Modified upper montane rain forest
I.A.4 Evergreen seasonal forest
I.A.4a Mesic forest over limestone
I.A.4b Modified mesic forest over limestone
I.A.5 Dry semi-evergreen forest
I.A.5a Dry semi-evergreen forest over limestone
I.A.5b Modified dry semi-evergreen forest over limestone
I.A.6 Commercial forest plantations
I.A.6a Pine plantations
I.A.6b Broadleaved timber plantations
I.A.6c Biomass plantations
I.B WETLAND FORESTS
I.B.1 Swamp forest
I.B.1a Swamp forest
I.B.1b Riparian forest
I.B.1c Modified swamp forest
I.B.2 Mangrove forest
I.B.2a Mangrove forest
I.B.2b Modified mangrove forest
II WOODLANDS (Open stands of trees)
II.A NON-WETLAND WOODLANDS
II.A.1 Strand woodland
II.A.2 Modified strand woodland
II.A.3 Plantation woodlands
II.A.3a Citrus grove
II.A.3b Coconut palm plantation
II.B WETLAND WOODLANDS
II.B.1 Palm woodland
III SCRUBS (Shrublands or thickets)
III.A NON-WETLAND SCRUBS
III.A.1 Dry semi-evergreen thicket over limestone
III.A.2 Thorn scrubs
III.A.2a Partly deciduous thorn thicket
III.A.2b Cactus thorn scrub
III.A.3 Upper montane thicket complex over limestone
III.A.4 Modified hill and montane scrub
III.A.4a Bamboo variant
III.A.4b *Hedychium* variant
III.A.4c *Polygonum chinense* variant
III.A.4d *Rubus* variant
III.A.4e Tree fern brake
III.A.5 Mixed subsistence agriculture with dwellings
III.A.6 Commercial shrub plantations
III.A.6a Coffee plantations
III.A.6b Pawpaw plantations
III.B WETLAND SCRUBS
III.B.1 Mangrove scrub
IV HERBACEOUS FORMATIONS
IV.A NON-WETLAND HERBACEOUS COMMUNITIES
IV.A.1 Montane summit savanna
IV.A.2 Fern-dominated sward
IV.A.3 Anthropogenic graminoid-dominated sward
IV.A.4 Commercial non-wetland herbaceous crops
IV.A.4a Sugar cane field
IV.A.4b Banana plantation
IV.B WETLAND HERBACEOUS COMMUNITIES
IV.B.1 Freshwater herbaceous wetlands
IV.B.1a Freshwater mudflat
IV.B.1b Sedge savanna
IV.B.1c Riparian swale
IV.B.1c(1) Graminoid-dominated riparian swale
IV.B.1c(2) Fern-dominated riparian swale
IV.B.1d Rice padi
IV.B.2 Brackish-water herbaceous wetlands
IV.B.2a Estuarine mudflat
IV.B.2b Herbaceous salt marsh
V SPARSELY VEGETATED FORMATIONS
V.A LIMESTONE PAVEMENT VEGETATION
V.B PIONEER BEACH VEGETATION
V.C CLIFFS AND LANDSLIDES
V.C.1 Seed plants and ferns predominant
V.C.2 Lichens and bryophytes predominant
V.D ROCK RUBBLE AND WALLS
V.D.1 Rock rubble
V.D.2 Rocky wall vegetation
VI AQUATIC FORMATIONS (freshwater)
VI.A FREE-FLOATING NON-ROOTED FRESH WATER COMMUNITIES
VI.B ROOTED FLOATING-LEAF COMMUNITIES
VI.C ROOTED UNDERWATER COMMUNITIES
VI.D NON-ROOTED UNDERWATER COMMUNITIES
VII OTHER LAND COVER TYPES
VII.A NATURAL TYPES
VII.A.1 Bare rock
VII.A.2 Bare sand
VII.A.3 Water
VII.B URBAN / INDUSTRIAL TYPES
VII.B.1 Residential / Business
VII.B.2 Industrial
VII.B.3 Transportation / Communication

In 1999 TNC and other USA agencies, through the Caribbean Atlas Project, developed a new vegetation classification scheme to standardise the over 20 vegetation classification systems used on individual islands in the region. The new classification scheme is based on the International Classification of Ecological Communities (ICEC) system which is a modified version of the UNESCO (1973) worldwide framework for classifying vegetation at coarse scales using the physiognomic characteristics of vegetation (structure). The ICEC adds finer levels of classification incorporating floristic characteristics of vegetation. The first five levels consisting of class, subclass, group, subgroup, and formation hierarchically separate vegetation types according to physiognomic differences. The two lowest levels in the classification, alliance and association, incorporate floristic information (Areces-Mallea *et al*. 1999). Li *et al.* (2000), using the Forestry Department-Trees for Tomorrow Project delineation of the 1998 satellite images, applied this Caribbean vegetation classification using only physiognomic classes to produce a new map of the Jamaican vegetation.

The woody vegetation communities classification step is useful in designing management strategies because foresters are usually primarily interested in species. At present, accurate maps of Jamaican woody vegetation communities, describing the species composition and the dendrometric characteristics, are available only for the Buff Bay/Pencar watershed management unit and the Dolphin Head area.

2.4 Forest Site Quality Curves

The site quality or site index is an expression of the average productivity of a specific land area for growing forest trees. The common way of expressing relative site quality is to have three to five site classes, such as Site I, Site II, Site III, Site IV and Site V, indicating comparative productive capacity in descending order. This classification for forest management of a specific land area is traditionally done on the basis of forest volume and height, or more often on height alone, at a fixed age. The site quality classification of forest lands is frequently used to predict the productivity of forest plantations or natural forests, usually relatively homogeneous conifer stands, in temperate regions. Forest land classification according to the site quality or site index system, except for plantations, can be highly misleading when applied to tropical rain forests, because the structure frequently does not reflect function (Jordan 1993).

In Jamaica, two sets of site index curves are available for forest plantations in Central and Eastern regions (Table 3). These are the site index curves for Caribbean pine (Johnson *et al*. 1981) and Blue mahoe (Jacyna 1981). In the same two regions, Liegel *et al*. (1991) carried out a study in Caribbean pine plantations, using the landform and soil characteristics, to explain the growth and to confirm the existing site index curves.

Table 3. Caribbean pine and Blue mahoe site index curves for Jamaica

Site index curves	Caribbean pine (15 years)	Blue mahoe (30 years)
Site quality 1	35 m^3 /ha/year	6.0 m^3 /ha/year
Site quality 2	30 m^3 /ha/year	3.6 m^3 /ha/year
Site quality 3	25 m^3 /ha/year	1.3 m^3 /ha/year
Site quality 4	20 m^3 /ha/year	
Site quality 5	15 m^3 /ha/year	

2.5 Forest Successional Stages

The functional classification of forests can be based on the successional stage or on the nutrient status (Jordan 1993). The successional stage is a common forest classification system that is based on function. Woody vegetation communities that invade recently abandoned agricultural land, pasture or forest gaps are usually called "secondary successional forests", "secondary forests" or "pioneer forests". They have several functional characteristics that differentiate them from mature woody vegetation communities, often called "climax forests".

Budowski (1965) divided neotropical forest succession into four stages, ie, pioneer forest (regeneration), early (young) secondary forest, late (mature) secondary forest and climax (primary) forest (Table 4). From a forestry perspective, the functional characteristics of early successional species make them relatively easy to manage (Jordan 1993). The selection of a silvicultural system, such as enrichment planting, improvement felling or selective harvesting is often based on the forest successional stage.

The new land classification approach of Jamaica's Forestry Department uses the forest successional stage system to classify forest cover at 1:15 000 scale (see section 5 for a full description). The successional stage or growth stage of the forest stand is indirectly determined by the average height of the canopy obtained by photo-interpretation, ie, each forest type is characterised by a height class as follows:

- < 6 metres (pioneer)
- 7-15 metres (early secondary)
- 16-24 metres (late secondary)
- 25 metres (climax)

The coverage percentage of the dominant and co-dominant tree crowns, or density class, and the disturbance/origin indicators are also estimated by photo-interpretation for each forest type (Forestry Department 2002). The average height of tropical mountain forests is generally lower than tropical lowland forests and is the reason for the differences between the height classes used in Jamaica, which is mainly covered by the hill/mountain forest types, and the height classes listed in Table 4 for forest successional stages.

Table 4. Classification of neotropical forest based on succesionnal stage

Characteristics	Pioneer	Early secondary	Late secondary	Climax
Age of communities observed (years)	1-3	5-15	20-50	> 100
Height (m)	5-8	12-20	20-30 some reaching 50	30-45 some up to 60
Number of woody species	Few, 1-5	Few, 1-10	30-60	Up to 100 or a little more
Floristic composition of dominants	Euphorbiaceae, *Cecropia*, *Ochroma*, *Trema*	*Ochroma*, *Cecropia*, *Trema*, *Heliocarpus*, most frequent	Mixture, many Meliaceae, Bombacaceae, Tiliaceae	Mixture, except on edaphic association
Natural distribution of dominants	Very wide	Very wide	Wide, includes drier regions	Usually restricted, endemics frequent
Number of strata	1, very dense	2, well differentiated	3, increasingly difficult to discern with age	4-5, difficult to discern
Upper canopy	Homogeneous, dense	Verticillate branching, thin horizontal crowns	Heterogeneous, includes very wide crowns	Many variable shapes of crowns
Lower stratum	Dense, tangled	Dense, large herbaceous species frequent	Relatively scarce, includes tolerant species	Scarce, with tolerant species
Growth	Very fast	Very fast	Dominants fast, others slow	Slow or very slow
Life span, dominants	Very short, less than 10 years	Short, 10-25 years	Usually 40-100 years, some more	Very long, 100-1000, some probably more
Tolerance to shade, dominants	Very intolerant	Very intolerant	Tolerant to juvenile stage, later intolerant	Tolerant, except in adult stage
Regeneration of dominants	Very scarce	Practically absent	Absent or abundant with large mortality in early years	Fairly abundant
Dissemination of seeds of dominants	Birds, bats, wind	Wind, birds, bats	Wind principally	Gravity, mammals, rodents, birds
Wood and stem, dominants	Very light, small diameters	Very light, diameters below 60 cm	Light to medium hard, some very large stems	Hard and heavy, includes large stems
Size of seed, or fruits dispersed	Small	Small	Small to medium	Large
Viability of seeds	Long, latent in soil	Long, latent in soil	Short to medium	Short
Leaves of dominants	Evergreen	Evergreen	Many deciduous	Evergreen
Epiphytes	Absent	Few	Many in number, but few species	Many species and life forms
Vines	Abundant, herbaceous, but few species	Abundant, herbaceous, but few species	Abundant, but few of them large	Abundant, includes very large woody species
Shrubs	Many, but few species	Relatively abundant but few species	Few	Few in number but many species
Grasses	Abundant	Abundant or scarce	Scarce	Scarce
Source: Budowski 1965.				

3.0 LAND USE CLASSIFICATION

There is a fundamental distinction between land cover and land use. According to Young (1998), land cover is a simple observational fact of what is there and refers to the natural or planted vegetation or human constructions (non-vegetated land, eg, buildings, etc.) that cover the earth's surface. Land use refers to the human activities which are directly related to the land, that is, making use of its resources and having an impact upon it, eg, crop production, pulpwood plantation, residential settlement, etc.

Confusion between the two exists because land cover and land use are often closely related. In practice, land cover is widely employed to diagnose its use, whether from ground or aerial survey (Young 1998). It is easy to guess the uses of grassland cover and built-up sites, but for forest cover, this is more difficult. For example, the forest can be used for wood production, watershed protection, grazing, hunting, nature conservation, recreation, etc. For practical reasons, a classification system incorporating both land use and land cover is often defined for the interpretation of remote sensing data (Young 1998). Data aquired by questionnaires to farmers or from forest plot samples refers mainly to use because the use of land is directly observable on the ground, whereas data from satellite imagery relates more to cover.

In 1958, the Directorate of Overseas Surveys (DOS) produced the first 1:50 000 imperial scale topographic map series of Jamaica based on 1954 aerial photographs. The series included a broad land use study and mapping. Adolphus (1968) carried out the first detailed land use study for Jamaica using the 1954 aerial photographs and new 1961 aerial photographs coverage. The Adolphus study was the basis of the projected changes in land use distribution between 1961 and 1990 published in the *1970-1990 National Physical Plan for Jamaica* and the land use map published in the first *National Atlas of Jamaica* (Town Planning Department 1971a, 1971b).

The country's second land use study and mapping were carried out for the UNDP/FAO national forest inventory project (Gray and Symes 1972) based on the interpretation of 1968 aerial photographs. The third land use study and mapping for Jamaica were produced by the Comprehensive Resource Inventory and Evaluation System (CRIES) Project (1982) using the interpretation of 1979-80 aerial photographs. In 1985 the Rural Physical Planning Division (RPPD) produced a new map updating the CRIES land use study (RPPD 1988) based on interpretation of new 1985 aerial photograph coverage. Table 5 shows a comparison of these four land use classificaion systems. In the second issue of the *National Atlas of Jamaica*, the Town Planning Department (1989) published a new island-wide land use map.

The objectives of the UNDP/FAO (1972) and CRIES/RPPD (1982, 1988) land use classifications were very different. As can be seen in Table 5, the assessment of forest and other wooded land is more detailed in the UNDP/FAO land use classification system, while the CRIES/RPPD land use classification system presents a larger number of classes for non-forest land assessment.

Within the framework of the Trees for Tomorrow Project, the Forestry Department (1999) carried out the most recent land use/cover study, using 1989 and 1998 LANDSAT^{TM} imagery with the objective of estimating the deforestation rate in Jamaica. A supervised classification system was used and over 100 locations island-wide were visited for “ground truthing” purposes (and photographed) and the coordinates taken by GPS for verification purposes. Aerial photographs (1991-92 1:15 000 colour and 1999 1:40 000 B&W) were also used to verify seven large blocks which were very difficult to interpret because of clouds and shadows (Evelyn and Camirand 2000). The 1998 land use/cover colour map was published in the *National Forest Management and Conservation Plan for Jamaica* (Forestry Department 2001a). The description of the land use/cover classification system, used by the Forestry Department and Trees for Tomorrow Project is discussed in detail in section 5.

Table 5. Comparison of land use classification systems existing in Jamaica before 1990

Adolphus 1968 (1)	Gray and Symes 1972 (2)	CRIES 1982 (3)	RPPD 1988 (4)
Forest / Other wooded land			
Dense woodland	Broadleaved natural forest	Deciduous (mixture of various broadleaf species)	Deciduous
Scrub woodland	Scrub forest	Brush (low grazing deciduous type trees)	Brush
Open woodland	Temporarily unstocked forest		Deciduous forest / Non-commercial
Mangrove swamp	Mangroves	Wetlands coastal	Wetlands coastal
Forest plantation	Man-made forest - Conifer	Coniferous (and broad-leaved evergreens)	Coniferous
	Man-made forest - Broadleaved		
Lowland scrub	Bamboo	Brush (low grazing deciduous type trees)	Brush
	Savanna		
	Other wooded areas		
Agricultural land			
Tobacco	Crops	Tobacco	Tobacco
			Tobacco fields not currently in production
Rice Other crops		Intensive mixed	Intensive mixed agriculture
		Extensive mixed	Extensive mixed agriculture
			Vegetable production
			Fish farming
			Fish ponds not currently in production
Small mixed farm Cleared land	Crops mixed with forest and fruit trees	Mixed coconuts and forest	Mixed coconuts and forest
			Mixed coconuts and improved pasture
		Mixed bananas and forest	Mixed bananas and forest
			Food forest
Sugar	Plantations	Sugar cane	Sugar cane
			Sugar cane fields currently not in production
			Abandoned sugar cane fields
Banana		Bananas	Bananas
Coconut		Coconuts	Coconuts
		Mixed bananas and coconuts	Mixed bananas and coconuts
Citrus		Orchards	Orchards
Small mixed farm		Orchards	Pimento
			Pimento and pasture
			Coffee
Other land types			
Unproductive land	Barren land	Bare sand / rock	Bare sand / rock
			Eroded areas
Salinas			Saline areas
Grassland	Natural range lands and grasslands	Improved pasture	Improved pasture
		Unimproved pasture	Unimproved pasture
		Unimproved pasture limited by slope	Grassland on steep slopes
			Grassland on less steep slopes
Marsh / Swamp	Swamps	Wetlands coastal	Wetlands coastal
		Wetlands non-coastal	Wetlands non-coastal
			Wetlands non-coastal saline
Settlement	Urban, industrial and communications areas	Urban residential	Urban residential
			Other urban features
		Rural residential	Rural residential
		Industrial / Commercial / Institutional	Industrial / Commercial / Institutional
		Resort development	Resort development
Mining	Other areas	Surface mining	Surface strip mining / Bauxite
			Surface strip mining / Limestone
			Other surface mining
Water	Water area	Lakes	Lakes
		Rivers	Rivers

(1) Interpretation of aerial photographs 1954 (B & W 1:50000) and 1961 (B & W 1:25000) for mapping at 1:50000 scale.
(2) Interpretation of aerial photographs (1968 B & W 1:25000 and 1:50000) for mapping at 1:50000 and 1:12500 (forest plantations) scales.
(3) Interpretation of aerial photographs (1979-1980 B & W 1:50000) for mapping at 1:50000 scale.
(4) Interpretation of aerial photographs (1985 B & W 1:50000) and update of CRIES land use study. Mapping at 1:50000 scale (RPPD 1986).

4.0 LAND CLASSIFICATION

Two of the most widely used approaches to classifying land with respect to its potential for land use are the USDA land capability classification system (Klingebiel and Montgomery 1961) and the FAO land evaluation framework (FAO 1976). Both take into account the risk of soil erosion. The two approaches are used internationally and have been adapted for different countries in the world

Other methods of land classification have been developed to evaluate the capability or suitability of the land to general or specific uses. These methods or groups of methods are the USBR land suitability for irrigation, soil survey interpretations, parametric indices (Storie index, land index, productivity index, etc.), yield estimates, soil potential ratings, agro-ecological zoning, fertility capability soil classification system, the LESA system, integral land evaluation, crop growth models and land evaluation/use computer packages such as WOFOST and ALES (van Diepen *et al*. 1991, Rossiter 1994).

4.1 Land Capability Classification

The USDA land capability classification (LCC) system is the best-known example of interpretative groupings of soils and the one most widely used and adapted. Klingebiel (1958) first described the system which was officially published a few years later by Klingebiel and Montgomery in 1961. Eight capability classes denoted by roman numerals I to VIII forms the highest level and are distinguished on the basis of the range of alternative uses, with priority for arable crops. The second level, capability subclass, is defined on the basis of major limitations and is denoted by one or more letters, eg, “e” for erosion hazard. The third level, capability unit, is identified by a number, eg, 1, 2, etc. and is a division of the subclass nearly identical in its management requirements. The degree and general type of limitations are the same as in a subclass, but important management differences exist, e.g. a LCC = IIIe1.

There is no standard procedure to account for the separate effect of each soil factor, and economic factors such as distance to market, kinds of roads and size of parcels are not explicitly used in the LCC system (van Diepen *et al*. 1991). According to Rossiter (1994), the LCC system presents two major problems:

- as already noted by van Diepen *et al*. (1991) the LCC system completely ignores the economic factors; and
- the land is not evaluated for specific uses.

The LCC system is useful for conservation farm planning and for grouping soil survey map units into general management groups.

In Jamaica, the first capability grouping of soils was described by Steele *et al.* (1954). The grouping, based on 24 groups combining geological substrate, drainage, soil depth, and texture, and 6 categories of degree of slope, yielded 60 significant “capability units”. Later these capability units were classified according to the former system of the USDA (before LCC system) in which the suitability of the land for mechanised agriculture was of prime importance.

The resulting land classification system for Jamaica, using 7 capability classes and 4 subclasses, differs in some details from the USDA capability system (Table 6). The Steele *et al*. system was adopted by the Regional Research Centre of the Imperial College of Tropical Agriculture (now University of the West Indies) and the description and capability classification of soils for Jamaica were published in a series of 13 "soil and land use surveys" (Imperial College of Tropical Agriculture-UWI 1958-1970). The soil maps from these 13 soil and land use surveys were digitised by the CRIES Project (1982), using a new set of symbols for the soil type complexes, and proposed an extrapolation of existing soil classification called soil type associations for forest reserves not covered by the Imperial College of Tropical Agriculture-UWI studies.

Table 6. Jamaican land capability classification system (1958-70)

Land capability class		**Most intensive suitable use**
I	Slopes (0^o - 5^o) of good soils	Suitable for cultivation (tillage) with no limitations
II	Mainly slopes (5^o - 10^o) of good soils	Suitable for cultivation (tillage) with moderate limitations
III	Mainly slopes (10^o - 20^o), some gentler slopes of less favourable soils	Suitable for cultivation (tillage) with strong limitations
IV	Mainly slopes (20^o - 30^o), some slopes (10^o - 20^o)	Suitable for tree crops, grasses and very limited cultivation
V	Mainly slopes (20^o - 30^o) and slopes (> 30^o)	Not suitable for cultivation, but suitable for planted forest, tree crops or improved grass
VI	Mainly steep rocky land or dry climate	Not suitable for cultivation, suitable for poor forest
VII	Rock, outcrops, riverwash, etc.	Little or no productive use
Land capability subclass (Secondary limiting factors)		
e	Slope / Erosion risk	
w	Excess water / Poor natural drainage	
s	Shallow or droughty soil	
c	Low annual rainfall / Long dry season	

During the period 1958 to 1970 soil and land use surveys used 12 capability soil groups, eg, IIc, IIIe, etc. based on the combinations of land capability classes and subclasses for Jamaican soils (Table 6). In 1971 the Town Planning Department proposed a new grouping which included a class V which was deemed unsuitable soils for agricultural purposes and which used only 3 subclasses (e, w, c), for mapping the agricultural land capability of Jamaican soils (Map 14, *National Atlas of Jamaica*, Town Planning Department 1971b). The omitted subclass "s", indicating shallow or droughty soil, is probably included in the subclass "e", ie, the soil is often shallow on steep slopes.

In the second version of the *National Atlas of Jamaica*, the Town Planning Department (1989) returned to the original Jamaican land capability classification system of 7 classes to produce an agricultural land suitability map at the national level (Map 11, *National Atlas of Jamaica 1989*). Based on CRIES/RPPD Project results, one subclass was added to refine the water limiting factor. The subclass "w" is redefined to indicate only the excess water characteristic or susceptibility to flooding. The new subclass "d" identifies unfavourable soil conditions of salinity, poor workability and poor drainage (Table 7).

Table 7. Generalised capability classification of Jamaican land for agricultural purposes

<table>
<tr><th colspan="2">1971</th><th colspan="2">1989</th></tr>
<tr><th>Class</th><th>Agricultural land capability</th><th>Class</th><th>Agricultural land suitability</th></tr>
<tr><td>I</td><td>Level with deep fertile soil and no limitations on agricultural use</td><td>I</td><td>Land suitable for cultivation with almost no limitation</td></tr>
<tr><td>IIc</td><td>Suitable for cultivation with moderate limitation of dry climate (irrigation required)</td><td rowspan="2">II</td><td rowspan="2">Land suitable for cultivation with moderate limitations (climate, salinity, poor drainage).
(mainly IIcd)</td></tr>
<tr><td>IIw</td><td>Suitable for cultivation with moderate limitation of imperfect drainage</td></tr>
<tr><td>IIIw</td><td>Suitable for cultivation with strong limitation of drainage (swamp)</td><td rowspan="3">III</td><td rowspan="3">Land suitable for cultivation with strong limitations (swamp, shallow and rocky soils, slope).
(mainly IIIs and IIIse)</td></tr>
<tr><td>IIIe</td><td>Suitable for cultivation with strong limitation of susceptibility to erosion</td></tr>
<tr><td>III / IVe</td><td>Combination of classes III and IVe</td></tr>
<tr><td>IV</td><td>Marginal for cultivation but suitable for tree crops or pasture</td><td rowspan="3">IV</td><td rowspan="3">Land suitable for tree crops, pasture and very limited cultivation.
(mainly IV and IVse)</td></tr>
<tr><td>IVe</td><td>Marginal for cultivation and susceptible to erosion but suitable for tree crops</td></tr>
<tr><td>IVe / V</td><td>Combination of classes IVe and V</td></tr>
<tr><td rowspan="3">V</td><td rowspan="3">Not suitable for cultivation and should remain in natural vegetation</td><td>V</td><td>Land not suitable for cultivation but for planted forest and tree crops</td></tr>
<tr><td>VI</td><td>Land not suitable for cultivation but suitable for poor forest</td></tr>
<tr><td>VII</td><td>Land with little or no productive use</td></tr>
</table>

According to Gumbs (1997), the relevance of a land capability classification system based on the USDA capability classification to the Caribbean is questionable because:

- complete mechanisation is not possible due to the size of farm, topography and sometimes crop type; and
- manual cultivation is often the only practical and suitable form of land management on most hillsides.

With such a system, all moderately to steeply sloping land is mapped as suitable only for non-arable uses. For many areas in developing countries, including Jamaica, the land capability classification as mapped does not correspond to actual land use, and an attempt to apply the mapped land capability would be completely unrealistic (Young 1989).

4.2 Soil Potential Rating for Crop Production

The soil potential rating for production of different crops is a method of land capability or suitability classification for more specific uses. In 1982 the CRIES Project developed and presented a nationally consistent resource data base, incorporating soils data, current land use/cover, and an agricultural production potential ratings (land capability) system at the parish and national levels.

The CRIES Project (1982) classified Jamaican soils into 24 “Crop Potential Groups” in order to assess the potential of soils for production of 15 traditional crops grown in Jamaica. These groups were developed on the basis of the recommended crops for each soil type presented in the 13 *Soil and Land Use Surveys* published by the Imperial College of Tropical Agriculture-UWI (1958-1970) for Jamaica, and the recommendations from the *Soil Technical Guide Sheets* for the 72 major Jamaican soil types (Hewitt 1964). A production potential rating of high, medium or low was attributed to each soil to produce a specific crop. The 24 crop potential groups and the production potential ratings are presented in Table 8 below. A crop potential group, numbered between 1 to 24, corresponds to each of the 176 primary Jamaican soil types, eg, Bonnygate Stony Loam soil type (no. 77), classified “Vs” according to the agricultural land capability classification (1971), is rated “9” for the potential crop production indicating high for wood production and medium for coffee/food trees production.

Table 8. Soil potential rating system for crop production

Crop Potential Group	SUGAR CANE	BANANAS	FOOD CROPS	VEGETABLES	IMPROVED PASTURE	TOBACCO	PINEAPPLES	CITRUS	COCONUT	COFFEE	CACAO	FOOD TREES	TIMBER	NATURAL FOREST	RICE
1	M	L	M	L	H	M	M	H	L	L	L	M	L	L	L
2	H	L	M	L	H	L	L	L	L	L	L	M	L	L	H
3	H	H	H	H	M	M	L	H	H	M	L	M	M	L	L
4	H	L	H	H	H	L	L	M	L	L	L	M	L	L	L
5	M	L	M	L	H	L	M	M	L	H	M	H	M	L	L
6	L	L	L	L	H	L	L	L	L	L	L	M	M	L	L
7	H	M	H	L	M	M	H	M	M	M	H	H	M	L	L
8	L	L	M	L	H	L	L	M	L	M	L	H	M	L	L
9	L	L	L	L	L	L	L	L	L	M	L	M	H	H	L
10	L	L	M	M	H	L	M	H	L	M	L	M	M	L	L
11	L	L	M	M	H	L	L	L	L	M	L	M	M	L	L
12	M	L	M	L	H	M	L	L	L	L	L	L	L	L	L
13	M	L	L	L	M	L	L	L	L	L	L	L	M	L	H
14	L	L	L	L	M	L	L	L	H	L	L	M	L	L	L
15	L	L	L	M	M	L	L	L	M	M	M	H	M	L	L
16	L	L	M	L	M	L	L	L	L	H	L	H	M	L	L
17	L	L	L	L	M	L	L	L	M	M	L	M	H	H	L
18	H	L	M	L	H	L	L	H	L	L	H	M	L	L	L
19	H	M	H	H	H	L	L	L	L	M	L	M	M	L	L
20	L	L	M	L	M	L	L	M	L	H	H	H	H	H	L
21	H	L	L	L	H	L	L	L	L	L	L	L	L	L	L
22	L	L	L	L	M	L	L	M	L	M	M	H	H	M	L
23	L	L	L	H	L	L	L	L	L	L	L	L	L	L	M
24	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

Rating: (H) High (M) Medium (L) Low

4.3 Land Evaluation Approach

Beek and Bennena (1972) developed a flexible land evaluation methodology which meets planning requirements much better than the USDA LCC system. FAO has adopted the main points of this methodology for application in all its development projects. It published a synthesis of the approaches to land classification in 1974 and the framework for land evaluation in 1976 (Zonneveld 1988). The FAO framework for land evaluation sets out basic concepts, principles, and procedures for land evaluation that are universally valid, applicable in any part of the world and at any level, from global to single farm (FAO 1976). The framework concepts have drawn heavily on the American experience in land classification and soil survey interpretation, in combination with experience gained from integrated surveys (van Diepen *et al*. 1991).

Within the framework a series of guidelines have been proposed for the 4 main land utilisation types (LUT):

- rainfed agriculture (FAO 1983);
- forestry (FAO 1984);
- irrigated agriculture (FAO 1985; and
- extensive grazing (FAO 1991).

Siderius (1986) proposed land evaluation guidelines specifically for land use planning and soil conservation on steep lands. The framework evaluation procedures comprise the following six activities:

1. Selection of relevant kinds of land use and their requirements (LUR);
2. Description of land unit characteristics (LC) and assessment of land qualities (LQ);
3. Matching: comparison of land use requirements with land qualities for each land use on each mapped land unit;
4. Provisional suitability classification;
5. Economic and social analysis; and
6. Final suitability classification (4 levels: order/class/subclass/unit).

The FAO approach, with its emphasis on specifying land utilisation types in detail, provides a more flexible approach to land use planning than that of the LCC method. The approach, matching land and land use, permits the adaptation of a form of land use in such a way that it may become applicable on land to which it was originally unsuited (Young 1989).

All lands are divided into two suitability orders according to whether the land is suitable or not for a given LUT where S = suitable and N = not suitable. The suitability class indicates the degree of suitability in each order, that is:

S1 = suitable
S2 = moderately suitable
S3 = marginally suitable
N1 = unsuitable for economic reasons but otherwise marginally suitable
N2 = unsuitable for physical reasons

Suitability subclasses, indicated by a letter, are divisions of suitability classes which indicate the nature of the limitations that make the land less than completely suitable, for example:

S3e = marginally suitable because of erosion hazard (e), or
S3w = marginally suitable because of wetness (w)

Suitability units, designated by numbers within the subclasses, eg, S3e-3, are intended to be managed similarly, where the number 3 indicates the level of management requirements.

Within the framework of the Jamaican land-reform programme (First Rural Development Project), a simplified version of the FAO land evaluation approach was tested and proposed to determine relevant and promising land use alternatives and related minimum farm sizes for the development plan of new smallholder settlement schemes (Andriesse and Scholten 1983). The procedures comprised the four following steps:

1. Definition of LUTs in terms of their output, level of management and related inputs;
2. Quantification of the inputs and outputs per LUT and determination of a maximum productivity per hectare;
3. Matching the specific requirements of each LUT (LUR) with the physical land conditions/ characteristics (LC); and
4. Determination of a minimum farm sizes for the individual LUT based on the productivity per hectare for each land capability class.

The land capability classes were defined in terms of "productivity unit (PU)" related to limitations per land utilisation type, eg, family-operated citrus orchard farming (LUT = Oc) with stoniness limitation (Oc IIs) (Table 9). The weakest part of this methodology is the determination of productivity per hectare for each LUT which is largely based on assumptions because research data and farm records are often limited in developing countries, including Jamaica (Andriesse and Scholten 1983).

Table 9. Land evaluation using productivity ratings and limitations per land utilisation type

Land capability class		Limitations	
I	Productivity 100-91% of the calculated maximum	No limitation	Land utilisation type (LUT) without limitation
II	Productivity 90-81% of the calculated maximum	Slight limitation	LUT with 1 limitation: slope (e), effective soil depth (d), stoniness (s), rock outcrops (r), flooding (f) or soil acidity (a)
III	Productivity 80-71% of the calculated maximum	Moderate limitation(s)	LUT with 1 limitation or combination: (1 major + 1 or more minor limitation, or 2 or more equally intensive limitations)
IV	Productivity 70-61% of the calculated maximum	Severe limitation(s)	LUT with 1 limitation or combination: (1 major + 1 or more minor limitation, or 2 or more equally intensive limitations)
V	Productivity 60-51% of the calculated maximum	Very severe limitation(s)	LUT with 1 limitation or combination: (1 major + 1 or more minor limitation, or 2 or more equally intensive limitations)
VI	Productivity < 50% of the calculated maximum	Extreme limitation(s)	LUT with 1 limitation or combination: (1 major + 1 or more minor limitation, or 2 or more equally intensive limitations)

The Jamaican land evaluation approach shown in Table 9 is classed a "land suitability system" because the assessment is for a particular use (LUT) and not an assessment of the potential of land for a range of specified uses. However, as with all national land evaluation systems in the world adapted from the USDA LCC (land capability) and the FAO framework (land suitability), it is often difficult to satisfactorily fit and classify a national system within one of these two categories of land classification schemes. Valentine (1986) suggests the use of grouping terms "land susceptibility" or "land possibility" classifications.

4.4 Treatment-oriented Land Capability Classification

The USDA LCC classes I to III, ie, slope gradients below 20 degrees, can be used for sustainable crop cultivation. Other land capability classification systems were specifically proposed to be applicable for sustainable use of hilly marginal lands. A treatment-oriented land capability scheme should permit marginal lands (classes IV to VII) to be used, through the introduction of suitable crop and soil conservation practices. Hudson (1977) and Gumbs (1997) have proposed treatment-oriented land capability classification guidelines, including soil management practices, for the humid tropics and the Caribbean countries respectively (Table 10).

Table 10. Land capability classification systems including soil management practices

Land class	Max. slope (degrees) (%)	Max. soil depth (cm)	Conservation treatment / practice	Land use / cropping system
HUMID TROPICS (1)				
1	7° (12%)		0-2° (Contour cultivation) 2-7° (Channel terraces)	Any
2	15° (27%)	100	Bench terraces	Any
3	20° (36%)	50	Step terraces	Close-cover crops, semi-perennials
4	25° (47%)	50	Step terraces, hillside ditches	Tree crops with ground cover
5	33° (65%)	25	Orchard terraces, platforms	Tree crops with ground cover (no cultivation)
6	>33° (>65%)		None	Forest only
CARIBBEAN COUNTRIES (2)				
1	0-4° (0-7%)		Good crop husbandry, contour farming	Best lands for intensive annual production, mechanized monocropping
2	4-10° (7-18%)		Vegetative barriers, hillside ditches	Good for intensive annual crop production, mixed cropping on erodible fragile soils
3	10-20° (18-36%)		Storm water diversion and downhill drains, vegetative barriers, hillside ditches, mulching, mini-terraces, narrow ridges and furrows	Semi-permanent crops, annual crops suitably intercropped with semi-permanent or permanent crops
4	20-30° (36-58%)		Hillside ditches, reversed sloping narrow terrace, tree basins especially at the higher slopes, relay cropping of food crops	Permanent crops, fruit trees in pure stands with grass ground cover, mixed with food crop on the less fragile soils, agroforestry
5	30-45° (58-100%)		Full ground cover always, soil conservation measures in association with agroforestry depending on crop mix	Production forest, agroforestry on the less fragile soils (forest species and permanent fruit trees only)
6	> 45° (> 100%)		Full ground cover always	Forest for watershed protection

Source: (1) HUDSON 1977, (2) GUMBS 1997.

In Jamaica, a treatment-oriented land capability scheme, developed under a UNDP/FAO project, has been proposed by Sheng (1971). The scheme was tested at the Smithfield experimental field plots and used with satisfactory results for the Kenilworth Property, the Lucea/Cabaritta watershed, the Cave River and Pindar River projects (Sheng 1984).

The scheme proposed by Sheng is practical and easy to understand. Lands are classified directly by their most intensive uses rather than in numerical classes. In comparison with previous schemes used in Jamaica (see section 4.1), the proposed scheme classified lands into whether they are cultivable and then by conservation treatments required (Sheng 1971, 1975). The lands are divided mainly according to degree of slope and soil depth although stoniness, wetness and gully dissection are also considered. Each class of land has recommendations for several soil conservation measures for erosion control (Table 11).

Table 11. Treatment-oriented land capability classification scheme especially for hilly watersheds

Slope / Soil depth	1 Gentle sloping (< 7°) (12%)	2 Moderate sloping (7° - 15°) (12%-27%)	3 Strongly sloping (15° - 20°) (27%-36%)	4 Very strongly sloping (20° - 25°) (36%-47%)	5 Steep (25° - 30°) (47%-58%)	6 Very steep (> 30°) (>58%)
Deep (D) (>36 in.) (>90 cm)	C1	C2	C3	C4	FT	F
Moderately deep (MD) (20-36 in.) (50-90 cm)	C1	C2	C3	C4 P	FT F	F
Shallow (S) (8-20 in.) (20-50 cm)	C1	C2 P	C3 P	P	F	F
Very shallow (VS) (<8 in.) (<20 cm)	C1 P	P	P	P	F	F

C1: Cultivable land; requiring no, or few, intensive conservation measures, e.g. contour cultivation, strip cropping, vegetative barrier, rock barrier and in larger farms, broad base terraces.

C2: Cultivable land; needing more intensive conservation, e.g. bench terracing, hexagon, mini-convertible terracing for the convenience of four wheel tractor farming; the conservation treatments can be done by medium sized machines such as bulldozer D5 or D6.

C3: Cultivable land; needing bench terracing and mini-convertible terracing on deep soil and hillside ditching, individual basin on less deep soil; mechanisation is limited to small tractor or walking tractor because of the steepness of the slope; terracing can be done by a smaller machine such as a D4.

C4: Cultivable land; all the necessary treatments are likely to be done by manual labour; cultivation is to be practised by walking tractor and hand labour.

P: Pasture, improved and managed; rotational grazing is recommended for all kinds of slope.

FT: Food trees or fruit trees; orchard terracing is the main treatment supplemented with contour planting, diversion ditching and mulching; because of steepness of the slopes, interspaces should be kept in permanent grass cover.

F: Forest land.

Two land utilisation types "AF = agroforestry" and "PF = protection forest" and two slope classes (30°-40° or 58%-84%) and (>40° or >84%) were later added to the scheme by the RPPD (Sheng 1984). In this way, the 1984 version of the Sheng's treatment-oriented land capability classification scheme parallels the Gumbs (1997) guidelines for Caribbean countries and the Michaelsen (1977) scheme proposed for the marginal hilly lands of Honduras.

Sheng's land classification scheme is another mixed system combining land unit characteristics (slope gradient and soil depth), the particular land utilisation type (LUT) and including soil conservation treatments for each LUT according to the land unit class (slope gradient and soil depth).

The "physical structures approach" of soil conservation recommended in the Sheng's land classification scheme is labour intensive and necessitates the use of machinery to carry out the soil treatments, ie, the use of earth, or in some cases concrete, structures to buils bench terraces or other physical structures on farmland. This approach proved unsustainable for two basic reasons:

- the cost of construction; and,
- inadequate maintenance (UNEP/FAO 1994).

More recently Jamaica and other Caribbean countries have moved towards methods based on biological conservation (Gumbs 1997).

4.5 Landslide Hazard and Land Degradation Evaluation

The plains and interior lowlands of Jamaica are level to gently undulating, while over half of the island has steep slopes, ie, 58 perent with slope gradient of over 20º (> 36%). Cultivation has been known on slopes of more than 45º (> 100%). For these reasons, specific land evaluation systems have been defined to qualify the land according to landslide susceptibility and land degradation status.

The occurrence of landslides is not a random phenomenon but results from the presence of specific combinations of lithology, structure and geomorphology. The landslide related mass movements are triggered by excessive precipitation and/or earthquakes (Ahmad 1995). For the upper part of St. Andrew parish, Maharaj (1995) proposed a zoning of landslide hazard based on a multivariate statistical analysis of geological, geotechnical and geomorphological parameters (Table 12).

Table 12. Relative landslide susceptibility classification based on slope geological materials

Relative landslide susceptibility	Major types of slope geological materials
Very low (VL)	River alluvium, as well as white limestones and sandstones bedrock
Moderate (M)	Expansive clays to silty and gravelly sands with minor sandy gravels. Bedrock are clastic sediments, altered volcanic and intrusive igneous lithologies
Moderately high to high (M-H)	Expansive clays to clayey and gravelly sands and gravels. Bedrock are sandstones, mudrocks and intrusive igneous lithologies
Very high (H)	Expansive clays to silty sands and gravels. Bedrock are sandstones, mudrocks and intrusive igneous lithologies
Extremely high (E)	Old landslide deposits, clayey to gravelly soils with low plasticity fines

When a rigorous analysis of the land physical indicators is not possible, McGregor *et al*. (1998) suggested a "qualitative degradation index". The degradation index (DI) is defined as a rating system derived by means of rapid field assessment techniques. The individual land, vegetation and soil management characteristics are assessed individually and then arithmetically combined. The index is decomposed in factors, characteristics and ranks (Table 13).

Table 13. Qualitative land degradation rating system

Topographic factors		**Vegetation factors**	
Characteristic	**Rank**	**Characteristic**	**Rank**
Slope angle	1 - 5	Canopy cover (dominance value)	1 - 5
Over steepening / undercutting	1 - 5	Bare soil exposed	1 - 5
Slope length	1 - 5	Litter cover	1 - 5
Slope shortening	1 - 5	Litter distribution	1 - 5
Soil factors		Roots in soil	1 - 5
Characteristic	**Rank**	Root size	1 - 5
Soil texture	1 - 3	Distribution of roots	1 - 5
Consistency (plasticity)	1 - 3	General vegetation	1 - 5
Pulveresence (% non coalesced)	1 - 5	Vegetation quality	1 - 5
Stoniness	1 - 5	**Erosion factors**	
Stone size	1 - 5	**Characteristic**	**Rank**
Surface crusting	1 - 2	Sheet erosion	1 - 5
Depth of "A" horizon	1 - 5	Evidence of overland flow	1 - 4
Humus content	1 - 5	Tree root exposure	1 - 5
Moisture content	1 - 3	Erosion pedestals	1 - 5
pH	1 - 5	Lag gravel	1 - 5
Evidence of fire clearance	1 - 5	Colluvial deposits	1 - 4

Management factors	
Characteristic	**Rank**
Land use quality	1 - 5
Tillage methods	1 - 2
Manure	1 - 2
Conservation techniques	1 - 3
Efficiency of conservation	1 - 5
Upkeep / maintenance	1 - 5
Cultivation intensity	1 - 5
General crop health	1 - 3
Weed occurrence	1 - 5
Evidence of recent weeding	1 - 2

4.6 JAMPLES Land Evaluation System

During the first phase of the Comprehensive Resource Inventory and Evaluation System (CRIES) Project between 1980 to 1982 the main tasks were:

- transfer existing soil survey data (Imperial College of Tropical Agriculture-U.W.I. 1958-1970), land use data from 1979-80 aerial photographs and other information to a Geographical Information System (GIS); and,
- establish the first criteria for land evaluation.

Between 1982 to 1989, the CRIES system was developed and tested, resulting in the JAMGIS system (Jamaican Geographical Information System) and JAMPLES module (Jamaican Physical Land Evaluation System). The JAMGIS system stores the data on soils, including land use, and other factors of the environment. The JAMPLES module is a programme for calculating land suitability for specified uses (UNEP/FAO 1994). The database of JAMGIS consists of 23 data elements (layers) and 10 look-up tables of statistically-defined attributes or characteristics, eg, the layers are geology, hydrology, soils, land use (1979-1980 aerial photos), land use (1985 aerial photos), rainfall, evapo-transpiration, population density, etc. (Eyre 1989).

The JAMGIS/JAMPLES system was created and developed for a specific purpose in the planning of crop development zones, eg, coffee and cocoa projects, at the Rural Physical Planning Division. Nevertheless, Eyre (1989) suggested the potential applications for the system were numerous at the time of creation however two factors constrained the achievement of this potential:

- the facility was hosted by a division or sub-department of the Ministry of Agriculture that is fairly low in the Government's bureaucratic hierarchy; and
- the entire operation, ie, hardware, staffing and routine management, was project-oriented.

An additional constraint to wider application was that the system was installed on minicomputer creating problems of availability and easy transfer to a microcomputer form for other users (UNDP/FAO 1994).

Two major technical problems have been also mentioned by Eyre (1989). These are:

- the variability in the quality of data (and scale) which is very common in developing countries such as Jamaica; and,
- the omission of elevation contours data into the system.

Elevation data is a major factor affecting temperature, rainfall, evapo-transpiration and is essential for slope calculations to accurately evaluate erosion potential and determine crop suitability. This omission of elevation contours data is probably explained by the high cost required to digitise elevation contours from 1:12 500 imperial topographic maps, particularly in the case of a hilly country like Jamaica.

In 1989, the JAMGIS offered full service only to Ministry of Agriculture (Eyre 1989). By 1992 the JAMGIS and JAMPLES were fully operational being managed by RPPD and used by the Hillside Agriculture Project (HAP) (UNDP/FAO 1994). According to contemporary sources in 1998, the JAMGIS/JAMPLES system was not in full operation but was in the process of transferring the system to microcomputer hardware. The CRIES/RPPD digital soils/land use database and land evaluation system were early efforts to implement a GIS land information system in Jamaica. The creation of subsequent GIS oriented to data such as parish boundaries, roads, rivers, geology, bauxite company lands, land titles, etc. and recently, forestry data, has followed the first steps taken by JAMGIS/JAMPLES.

5.0 FORESTRY DEPARTMENT LAND CLASSIFICATION APPROACH

By 1988, it had become clear that project oriented land classification systems developed to date were inadequate to meet the needs of government departments involved with land management. Thus began the development of a more effective method of managing Jamaica's land information. The process of change towards an integrated land management system started with the Land Titling Project – Phase I (Centre for Property Studies 1998). The implementation strategy to develop an integrated land information network, linking all public sector land management agencies, involved the establishment of the Land Information Council of Jamaica (LICJ) in 1991, followed in 1994 by the publication of the green paper *Towards a Land Policy for Jamaica* and the adoption of the National Land Policy of Jamaica (Government of Jamaica 1996). Following the framework and standards established by the LICJ, the Forestry Department (FD) started its own Forest Land Databank and GIS Systems in 1998, with the assistance of the Canadian International Development Agency-funded Trees for Tomorrow Project – Phase II.

After a critical analysis of the woody vegetation, land use and land classification systems existing in Jamaica (as discussed in sections 2, 3 and 4), it was evident that none of these systems have the characteristics and capacity for classifying forests for forest management and conservation nor evaluation for forest development. The first step taken by the FD was the establishment of a standard methodology to classify forest land cover and potential land for forestry and to collect biophysical data in the forest reserves and other forested lands. This methodology was successfully tested in the Buff Bay/Pencar watershed management unit (Forestry Department 2000). The second step was the creation of a digital database/GIS to store the biophysical data, compilation of biophysical inventory results and production of a GIS mapping of forest land characteristics and related management activities[4]. The third step was the production of the biophysical inventory report and the forest management plan, including the 1:10 000 and 1:25 000 scales mapping of forest cover and related data for Buff Bay/Pencar WMU (Forestry Department 2001b, 2001c).

The FD approach, to carry out a biophysical inventory and classification of forest lands, evaluation of potential lands for forestry activities and mapping of the forest resources and activities at different scales, is based on existing information in Jamaica as detailed in the sections 2, 3 and 4, and on guidelines used internationally. These are:

- guidelines for inventory and land evaluation of tropical forest land (Touber *et al.* 1989);
- UNESCO guidelines for soil survey and land evaluation in ecological research (Breimer *et al.* 1986);
- guidelines for soil survey for forestry (Valentine 1986); and
- guidelines for land evaluation for forestry (FAO 1984).

An outline of broad guidelines for the biophysical land classification was proposed by Larsson (1972) specifically for Jamaica.

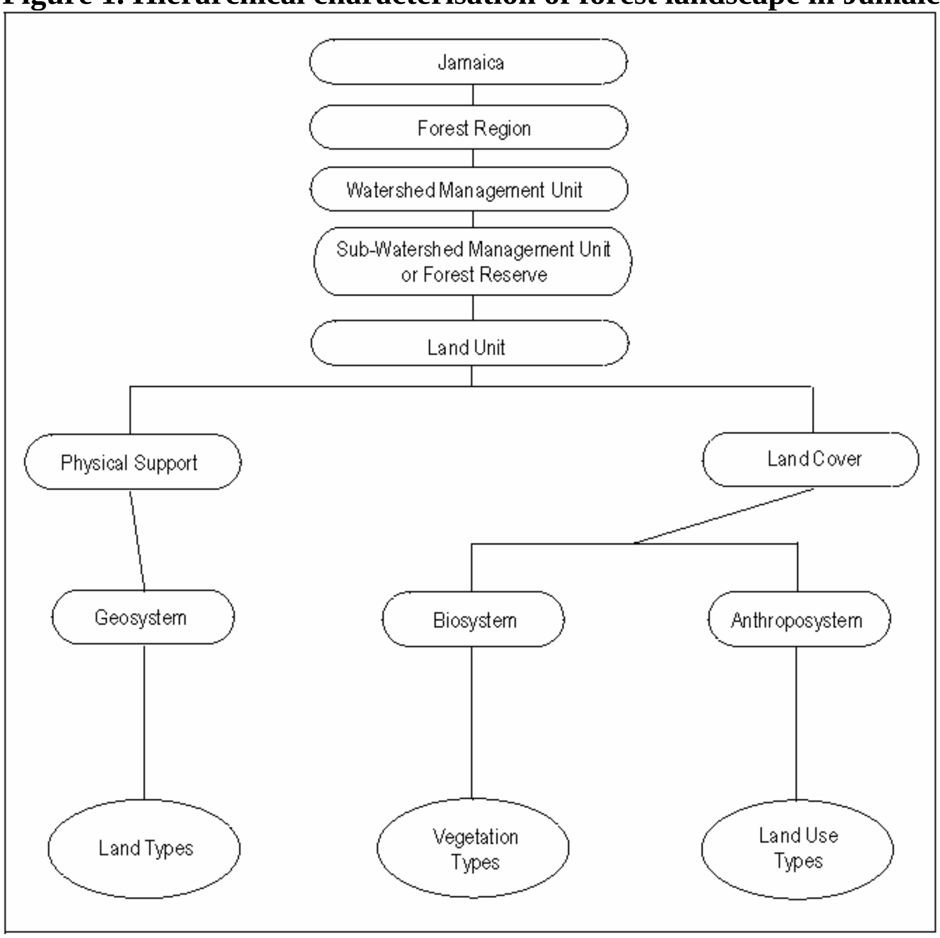
[4] The biophysical inventory data was compiled using "BPIprog" software and the maps produced using ESRI Arc-Info.

Historically, foresters have favoured the site classification system which is mainly characterised by vegetation types and species indicators (Cajander or Braun-Blanquet systems) and potential productivity (site index or site quality curves). With the addition of physical land parameters into site classification, the existing systems, often called biophysical or ecological land classification (ELC), combine classes of natural vegetation and land use with properties of the physical environment such as climate, geomorphology, soils, etc. (Sims *et al*. 1996). The ELC system is recommended to provide the spatially explicit framework needed during the ecological assessments (EAs) to address multiple issues and to monitor trends at different planning levels or scales (Bourgeron *et al*. 2001).

5.1 Planning Levels of Biophysical Inventory and Mapping of Forest Lands

A biophysical or ecological classification system of forest lands should work on different levels (or scales) in order to provide data and information for various planning horizons. A broad land and land use/cover classifications would suffice for island-wide planning of forestry activities, while more detailed and accurate data are necessary for a forest development plan at the watershed or subwatershed level The basis for the FD approach is a hierarchical characterisation of the forest landscape in Jamaica (Figure 1).

Figure 1. Hierarchical characterisation of forest landscape in Jamaica



Jamaica is divided into three forest regions (Eastern, Central and Western) and twenty six watershed management units, which units correspond approximately to the FD districts. The third sub-division is the sub-watershed management unit. The sub-watershed management unit boundaries are not precisely mapped, eg, the Buff Bay/Pencar watershed management unit actually includes 4 sub-watershed management units (Limbird *et al*. 1993, Forestry Department 2001c). The forest reserves within the watershed management unit could be used as third hierarchical forest landscape division. The fourth landscape sub-division is the land unit, characterised by climate and geomorphology (Figure 2).

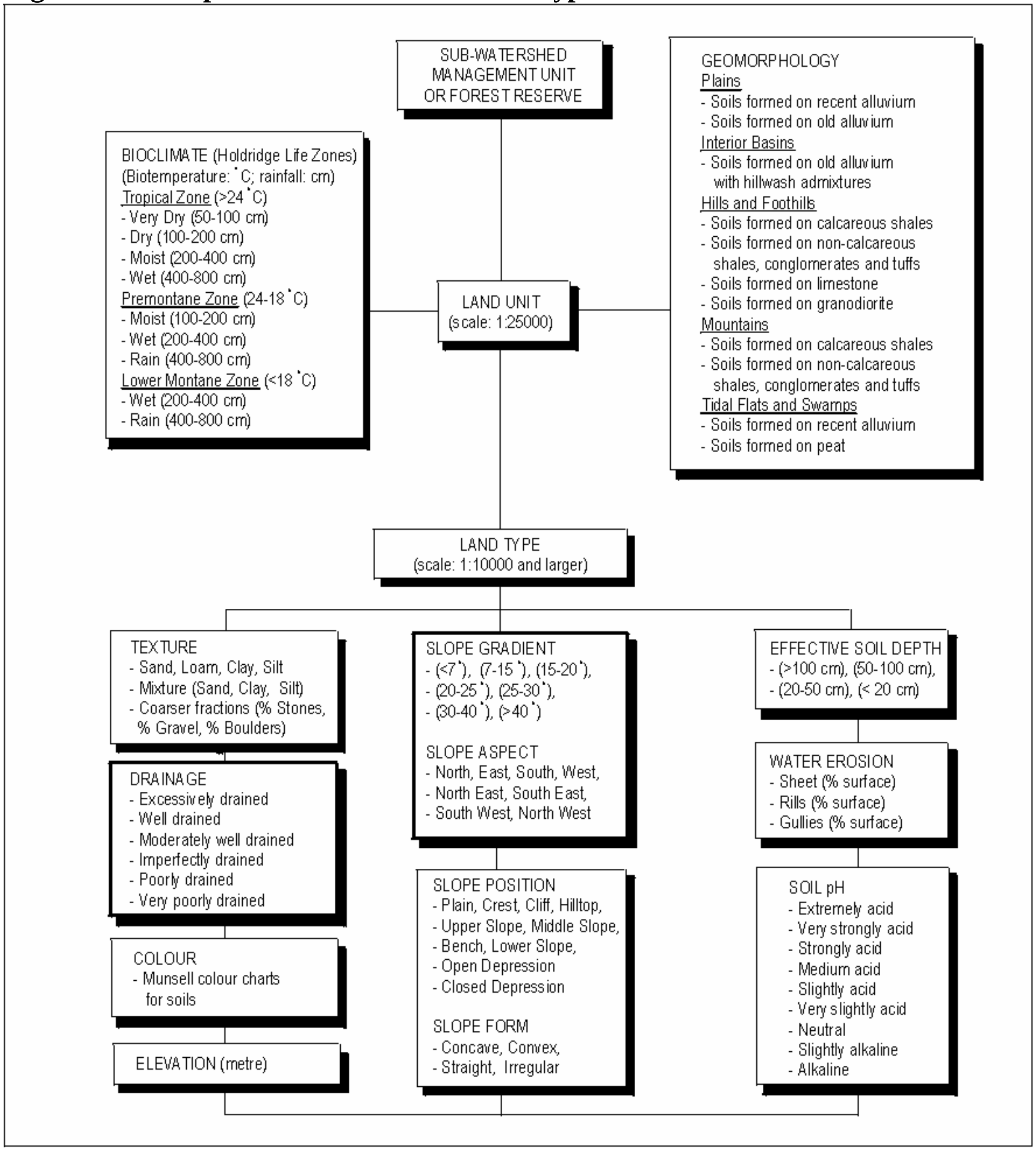
Three broad levels of biophysical inventory of forest lands are associated to the hierarchical forest landscape classification and are defined as follows:

Reconnaissance inventory: This level of inventory, based upon an exploratory investigation of the forest population and related parameters, corresponds to the broad nation-wide biophysical forest inventory. The information derived is primarily intended for preliminary management decisions. The inventory data are summarised on a regional or total area basis, for example the Jamaican forest regions or watershed management units (reconnaissance survey at scales 1:100 000 to 1:250 000).

Management inventory: This inventory represents a low intensity investigation of a large tract of forested area, for example forested areas in a sub-watershed management unit or forest reserve. The information produced is primarily intended for broad-based management decisions, allowable cut calculations and long range planning (semi-detailed survey at scales 1:25 000 to 1:10 000).

Operational inventory: An operational inventory is based upon an intensive investigation of a relatively small area. The information produced is primarily intended for use in short term or “operational” planning, eg, related to the harvesting of timber volumes within local cutting or logging units (detailed survey at scales larger than 1:10 000).

Figure 2. Description of land unit and land type classifications



5.2 Definitions of Land Unit and Land Type

Jamaica is divided into agro-climate zones which are characterised by the mean monthly potential evapo-transpiration, for example, R75 = 75% dependable rainfall. The classification is used in agriculture planning to select agricultural crops that will give the maximum yield for a particular zone, eg, the Buff Bay Pencar watershed management unit is divided into 6 agro-climate zones (Limbird *et al.* 1993). As with agricultural crops, forest tree growth is also a function of rainfall and temperature but the agro-climate zoning method is too specific towards agricultural production.

For forest conservation and management purposes, the first recommended level is to classify Jamaican land according to the Holdridge life zones system which indicates the potential natural vegetation of an area given its rainfall and bio-temperature, eg, the Buff Bay/Pencar watershed management unit includes 5 Holdridge life zones (Forestry Department 2001c).

The spatial distribution of soils and vegetation types is related to geomorphology which is the relation of landform, ie, physiography/altitude to geological structure, ie, parent material/rock (Figure 2). An example of the use of the geomorphologic land unit classification is given at the level of the Jamaican watershed and sub-watershed by Larsson (1972). The second recommended level is the use of geomorphologic land unit classification with the units broadly defined as follows[5]:

Plains: Elevation in general less than 60 metres; relief intensity less than 5 metres; slope gradients in general less than 5 percent; soils formed on recent alluvium or on old alluvium.

Interior basins: Elevation in general about 150 metres; relief intensity less than 10 metres; slope gradients in general 5 to 16 percent; soils formed on old alluvium with hillwash admixtures.

Hills and foothills: Elevation in general 60 to 800 metres; relief intensity up to 200 metres; slope gradients in general 16 to 50 percent; soils formed on calcareous shales or on non-calcareous shales, conglomerates and tuffs, or on limestone or on granodiorite.

Mountains: Elevation in general over 800 metres; relief intensity over 300 metres; slope gradients in general over 50 percent; in places steeply dissected; soils formed on calcareous shales or on non-calcareous shales, conglomerates and tuffs.

Tidal flats and swamps: Regularly flooded; slope gradients less than 1 percent; soils formed on recent alluvium or on peat.

The land type is the third level of land characterisation and is described by micro-relief (slope) and the physical soil parameters, and macro-relief as represented by the geomorphologic. Each Jamaican soil type description includes general soil information such as the texture of surface layer, parent material, root limiting layer, slope range, soil moisture, general fertility level, etc. (Imperial College of Tropical Agriculture/U.W.I. 1958 to 1970, Hewitt 1964). In each biophysical inventory at the level of the sample plot, the land type is characterised by detailed field measurement of the following parameters: elevation, slope gradient, slope aspect, slope position, slope form, soil texture, soil drainage, soil colour, effective soil depth, water erosion and soil pH (Figure 2)[6].

[5] Detailed description *in* Imperial College of Tropical Agriculture/ U.W.I. 1958 to 1970.
[6] Detailed methodology *in* Biophysical Inventory Manual, Forestry Department 2000.

Table 14 summarises the division of a sub-watershed management unit or forest reserve into land units which are characterised at three biophysical levels by the land type and the vegetation and land use type (Table 14).

Table 14. Biophysical levels of land unit characterisation

Level	Land type	Vegetation and land use type
1	Holdridge life zones	Climax vegetation and forest formations
2	Geomorphologic units	Forest communities and associations (Successional stages / Species associations)
3	Soil units	Cover density classes / Height classes / Disturbance and origin classes

5.3 Forest Cover and Land Use Type Classification

The basis of the FD's woody vegetation classification system is a hierarchical forest cover and land use type classification at 1:100 000 scale for national/regional level mapping and 1:10 000 scale for sub-watershed/forest reserve level mapping. At the broader scale, LANDSAT™ imagery is used for the interpretation and classification of forest cover and land use, verified by the establishment of a island-wide network of ground truthing points. Two coverages, showing the land use/cover for the years 1989 and 1998 respectively at 1:100 000 scale, are already available for the whole country (Forestry Department 1999).

At the detailed scale, forest cover and land use were interpreted and delineated at a preliminary level on the 1:15 000 scale 1991/92 colour aerial photographs. A biophysical inventory is being carried out in the field to collect the biophysical information based this preliminary interpretation. Afterwards, the 1:40 000 scale 1999 black and white aerial photographs coverage is used to finalise the preliminary interpretation, completed by the analysis of the recorded data from the biophysical sample plots.

The FD forest cover and land use type classification, used for mapping at 1:100 000 and 1:10 000 scales, follows the UNESCO international classification standards of vegetation (UNESCO 1973), and is based on The Nature Conservancy (TNC) classification of Jamaican vegetation communities (Grossman *et al*. 1992, Muchoney *et al*. 1994) and other woody vegetation and land use classifications used in Jamaica (see sections 2 and 3). The hierarchical classification system is presented in Figure 3 and definitions of the classes at 1:100 000 mapping scale are detailed in Table 15, including a comparison with the TNC and FAO classifications using LANDSAT™ imagery for the interpretation of forest cover and land use. The forest cover and land use types at the 1:10 000 mapping scale, including the criteria for interpretation on 1:15 000 scale colour aerial photographs, are described in the *Photo Interpretation Manual* (Forestry Department 2002).

Figure 3. Hierarchical classification system of forest cover and land use types

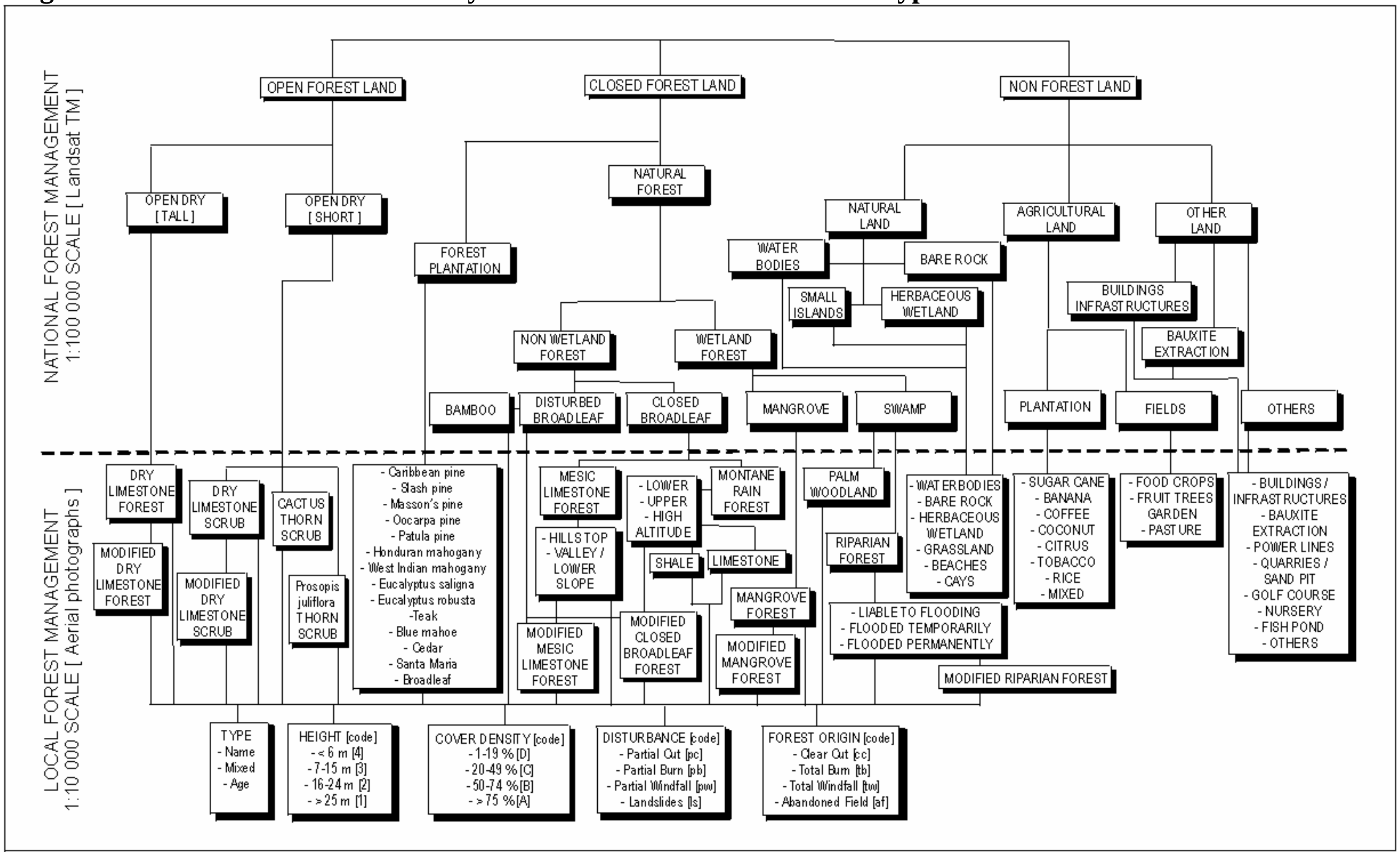


Table 15. Definitions of forest cover and land use types at 1:100000 mapping scale

FORESTRY DEPARTMENT CLASSES (Landsat TM; 1:100000 mapping scale)		CORRESPONDING	CORRESPONDING
TYPE (CODE)	**DEFINITION**	**TNC CLASSES (1)**	**FAO CLASSES (2)**
Forest Land Use/Cover (> 75 %, Minimum unit: 25 ha)			
Closed Broadleaf (PF)	Closed primary forest with broadleaf trees at least 5 m tall and crowns interlocking, with minimal human disturbance	Upper Montane Forest Lower Montane Forest Semi-evergreen Moist Broadleaf Forest (Natural Communities)	Undisturbed Closed Forest
Disturbed Broadleaf (SF)	Disturbed broadleaf forest with broadleaf trees at least 5 m tall and species-indicators of disturbance such as *Cecropia peltata* (trumpet tree)		Disturbed Closed Forest
Bamboo (BB)	*Bambusa vulgaris (* bamboo brakes) on the lower shale hills (disturbed forest)	Disturbed Natural Forest (Modified Communities)	Other Wooded Land
Tall Open Dry (WL)	Open natural woodland or forest with trees at least 5 m tall and crowns not in contact, in drier part of Jamaica with species-indicators such as *Bursera simaruba* (red birch)	Deciduous/Semi-deciduous Broadleaf Forest (Natural Communities)	Open Forest
Short Open Dry (SL)	Open scrub, shrub, bush or brushland with trees or shrubs 1-5 m tall and crowns not in contact, in drier part of Jamaica with species-indicators such as *Prosopis juliflora* (cashaw) or *Stenocereus hystrix* (columnar cactus)	Thorn Forest (Natural Communities)	Other Wooded Land
Swamp (SW)	Edaphic forest (soil waterlogging) with a single tree storey with species-indicators such as *Symphonia globulifera* (hog gum) and *Roystonea princeps* (royal palm)	Freshwater Swamp Forest (Natural Communities)	Disturbed Closed Forest
Mangrove (MG)	Edaphic forest (areas with brackish water) composed of trees with stilt roots or pneumatophores, species-indicators such as *Rhizophora mangle* (red mangrove)	Mangrove (Natural Communities)	Disturbed Closed Forest
Mixed Land Use/Cover			
Fields or Disturbed Broadleaf Forest and Pine Plantation (PP)	>50% fields or Disturbed Broadleaf forest; >25% Pine plantation	Forest Plantations (Modified Communities)	Plantations
Disturbed Broadleaf Forest and Fields (SC)	>50% Disturbed Broadleaf forest; >25% fields	Disturbed Natural Forest (Modified Communities)	75% Other Wooded Land 25% Other Land
Bamboo and Disturbed Broadleaf Forest (BF)	>50% bamboo; >25% Disturbed Broadleaf forest	Disturbed Natural Forest (Modified Communities)	Other Wooded Land
Bamboo and Fields (BC)	>50% bamboo; >25% fields	Disturbed Natural Forest (Modified Communities)	75% Other Wooded Land 25% Other Land
Fields and Disturbed Broadleaf Forest (CS)	>50% fields; >25% Disturbed Broadleaf forest	Disturbed Natural Forest (Modified Communities)	25% Other Wooded Land 75% Other Land
Bauxite Extraction and Disturbed Broadleaf Forest (BS)	>50% bauxite extraction; >25% Disturbed Broadleaf forest	Disturbed Natural Forest (Modified Communities)	25% Other Wooded Land 75% Other Land
Non Forest Land Use/Cover			
Plantations (PC)	Tree crops, shrub crops like sugar cane, bananas, citrus and coconuts	Non-forest Land Cover (Agriculture)	Other Land
Fields (FC)	Herbaceous crops, fallow, cultivated grass/legumes	Non-forest Land Cover (Agriculture)	Other Land
Herbaceous Wetland (HW)	Edaphic vegetation (soil waterlogging) with herbaceous plants	Non-forest Land Cover (Natural Communities)	Other Land
Water Bodies (WA)	Lakes, rivers	Water Bodies (Open Water)	Inland Water
Small Islands (SI)	Mostly sand/limestone, unvegetated small islands (cays)	Non-forest Land Cover (Natural Communities)	Other Land
Bare Rock (BR)	Bare sand/rock	Non-forest Land Cover (Natural Communities)	Other Land
Bauxite Extraction (BE)	Surface mining/bauxite	Non-forest Land Cover (Urban/Industrial)	Other Land
Buildings and Other Infrastructure (BA)	Buildings and other constructed features such as airstrips, quarries, etc.	Non-forest Land Cover (Urban Industrial)	Other Land
(1) Mapping types from Grossman, Iremonger and Muchoney (1992) and Muchoney, Iremonger and Wright (1994). (2) Guidelines from FAO (1998a, 1998b).			

5.4 Land Allocation for Forestry Development

As discussed in section 4, the existing land capability/suitability classification systems used in Jamaica are oriented to agricultural crop development, soil conservation, landslide risk, etc. Up to now, there has been no classification system which specifically uses a land capability/suitability approach with a forestry development orientation.

In 2001, the Forestry Department proposed a land capability/suitability classification system for forest management and conservation activities based on the slope gradient and the effective soil depth (Table 16). In fact, the use of the slope and soil depth variables reflects the two most important landform and soil parameters used in all prior proposals for a land capability classification system for Jamaica (Steele *et al*. 1954, Imperial College of Tropical Agriculture-U.W.I. 1958-1970, Sheng 1971).

Table 16. Guidelines for forest land use allocation

<table>
<tr><th rowspan="4">Soil Depth</th><th colspan="3">Slope</th></tr>
<tr><th>Gentle to Moderate Sloping</th><th>Strongly Sloping to Moderate Steep</th><th>Steep to Very Steep</th></tr>
<tr><th>1</th><th>2</th><th>3</th></tr>
<tr><td>[< 15^{o}] [< 27%]</td><td>[15^{o} - 30^{o}] [27% - 58%]</td><td>[> 30^{o}] [> 58%]</td></tr>
<tr><td>Deep (D)
[>100 cm]</td><td rowspan="2">FI(P) - C</td><td></td><td rowspan="2">FS - FP - AF</td></tr>
<tr><td>Moderately Deep (M)
[50-100 cm]</td><td>FI(P) - AF - C</td></tr>
<tr><td>Shallow (S)
[20-50 cm]</td><td>FI - AF - C</td><td>FI - AF - PA</td><td rowspan="2">FP</td></tr>
<tr><td>Very Shallow (V)
[<20 cm]</td><td>FS - AF - PA</td><td>FS - FP - AF</td></tr>
</table>

Potential Land Uses:

FI(P): Forest for industrial production, including intensive site preparation and plantation establishment; possible mechanisation.

FI: Forest for industrial production (e.g. selective cutting, enrichment planting, seeding and coppicing); possible mechanisation, but normally excluding intensive site preparation and plantation establishment.

FS: Selection forest for environmental protection and limited wood extraction: selective logging only, no clear-cutting, no road construction, no mechanised site preparation, no mechanised ground skidding.

FP: Protection forest for watershed management, ecosystem protection, and/or recreation: no road construction, no timber extraction.

AF: Agroforestry: trees or shrubs grown in association with herbaceous plants under an approved system involving soil conservation measures.

PA: Pastures.

C: Cultivable land.

Note:

In forest reserves, forest management areas, parks or protected areas:

(1) where the existing forest cover is Closed Broadleaf Forest, Mesic and Dry Limestone Forest or Mangrove Forest, use will be restricted to FP;

(2) where the existing forest cover is Modified Forest (Closed Broadleaf, Mesic and Dry Limestone or Mangrove), land will be retained as forest (i.e. FP, FS, FI or FI(P);

(3) where land is already under cultivation, pasture or agroforestry use, such uses may be permitted as specified in the table if warranted by local social, economic and environmental circumstances.

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