THE STRUCTURE AND COMPOSITION OF RIPARIAN VEGETATION IN TRINIDAD: A BASELINE FOR CONSERVATION AND RESTORATION

By

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To my Mom

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The structure and composition of riparian vegetation of 12 rivers in Trinidad were detailed, along with concurrent environmental and anthropogenic characteristics of the riparian zone and associated watershed. Cluster analysis, non-metric multi-dimensional scaling, and Spearman rank correlations were used to delineate riparian vegetation groups and indicator species, identify the most significant determinants of riparian vegetation groups and determine the most influential scale of variables. These data were used to develop a rapid assessment index to identify and prioritize riparian sites for conservation and restoration.

An approximate riparian zone width of 30 m was suggested for Trinidad and a list of 57 native riparian species generated. Of 36 randomly chosen sites, only nine were in forested areas. Fifteen were in abandoned agricultural estates. The others were in agricultural, grassland and developed areas. An exotic species, *Bambusa vulgaris,* had the highest tree importance value and another exotic, *Coffea* sp., had the highest ground flora coverage.

Nine major vegetation groups were identified and named according to dominant species, distribution and major determinants. These are *Justicia secunda-Eschweilera subglandulosa* (North Forest), *Mora excelsa-Bactris major* (South Forest), *Saccharum officinarum* (Agricultural), *Axonopus compressus* (Agricultural), *Justicia secunda* (Secondary Vegetation),

Flemingia strobilifera (Fire Influenced), *Sorghum* sp. (Weedy Species), *Acroceras zizanioides* (Native Grasses) and *Bambusa vulgaris* (Bamboo) groups. With the exception of canopy closure, form factor and geomorphology, the best predictors of riparian vegetation groups were anthropogenic variables like the degree of upland and riparian zone edaphic modification, fire, channel modification, distance from paved roads, land ownership and pollution. Out of a 4-level hierarchy of variables, Meso scale (reach level) variables were most important in explaining riparian vegetation patterns.

The rapid riparian index, which was developed, used eight variables to identify and prioritize sites for restoration and conservation. These included tree species richness, presence/absence of easily recognizable exotic and secondary vegetation species, and anthropogenic indicators like fire, channel modification and anthropogenic disturbance.

CHAPTER 1
INTRODUCTION

Current ecological paradigms emphasize interconnectivity between ecosystems and processes and patterns across both multiple scales and ecological gradients (Wiens 2002). Scales, gradients and interconnectivity are also factored into current natural resource management practices and ecosystem restoration strategies (Wissmar & Beschta 1998). These paradigms and management strategies are applicable to all terrestrial and aquatic ecosystems and are also relevant to terrestrial-aquatic interfaces such as riparian zones.

Riparian zones are transitional areas between terrestrial and freshwater systems. They include riverbanks and shores of ponds and lakes. Along riverbanks, riparian zones extend from the water's edge to the areas landward that either experience flooding or have elevated soil water levels. The importance of riparian zones lies in the fact that they connect aquatic and terrestrial ecosystems and also shape and influence them (Naiman et al. 2005).

Riparian zones influence terrestrial systems via nutrient inputs, for example, when animals feed in riparian areas and release waste material upland (Naiman & Rogers 1997). Riparian zones also influence aquatic systems by intercepting surface runoff and groundwater, which drain into rivers and ponds. Riparian plants absorb nutrients and pollutants, trap sediment and in so doing, buffer river water quality. Improved water quality benefits not only aquatic wildlife, but also humans using the site for recreation and water extraction (Peterjohn & Correll 1984; Darby 1999). In trapping and retaining sediment, riparian plants also strengthen riverbanks and reduce erosion (Anbumozhi et al. 2005). Riparian vegetation can provide food for aquatic fauna by contributing woody debris and other organic material to the river. Woody debris creates aquatic habitat by trapping sediment, reducing current velocity and forming pools (Darby 1999).

While riparian zones influence adjacent systems, their characteristics are also affected by adjacent terrestrial and aquatic systems. Riparian biotic composition, soil texture, soil nutrients, and spatial characteristics can vary, depending on river hydrological regime and terrestrial geomorphology. In particular, river channel depth, velocity and flooding regime can greatly impact riparian zones. Flooding facilitates riparian plant dispersal and replenishes soil nutrients (Naiman & Decamps 1997). Geomorphological factors include fine scale factors like channel slope and broader scale aspects like watershed size and shape. Geomorphology and hydrology often act in tandem; for instance, riparian zones on shallow riverbank gradients are more prone to flooding. Biological processes such as plant competition, herbivory and succession also shape riparian characteristics (Tabacchi et al. 1998).

In recent times, humans have started to exert greater influence on riparian zones via vegetation removal or alteration of hydrological regimes through dam construction or dredging. Such impacts on riparian areas can also be on a much broader scale, for example, through land use changes in the watershed that can change the volume, timing and chemical composition of water filtering through riparian zones (National Research Council 2002). At an even broader scale, riparian vegetation is controlled by regional climate (Lite et al. 2005).

Riparian zones are not only shaped by their lateral connections to adjacent ecosystems but also longitudinal connections and gradients. Riparian structure and function can change in response to downstream gradients in riverbank soil particle size (Mitsch & Gosselink 1993). Ecological gradients are also seen on a smaller scale, for example, a change in vegetation within the riparian zone due to decreasing moisture levels farther away from the river (Turner et al. 2004).

Riparian areas are important ecosystems in their own right. They are complex, dynamic systems with great heterogeneity and accompanying high levels of plant productivity and diversity (National Research Council 2002). Riparian zones are also important habitats and corridors for the movement of animals (Gregory et al. 1991). Given the important roles of riparian zones, there has been much emphasis on their management, conservation and restoration. Restoration is especially important as riparian areas are subject to high levels of human interference through settlement, agriculture, transportation and recreation (National Research Council 2002). To improve management, conservation and restoration, there must be a detailed understanding of riparian systems including the composition and structure of the vegetation and its determinants. Protection of riparian ecosystems in turn is critical for management of adjoining aquatic systems (Allan et al. 1997).

Past research has focused on hydrological and broad scale geomorphological controls of riparian vegetation. There has been less research on human influences on riparian vegetation and few interdisciplinary studies that incorporate the influence of both ecological and anthropogenic factors. Multiple scale studies are also lacking. While there is substantial information on temperate riparian systems and large tropical rivers, there are less data on riparian vegetation along narrow, short rivers found on tropical islands. In the Caribbean, there has been some riparian vegetation research in Puerto Rico. Heartsill-Scalley & Aide (2003) examined variations in vegetation composition and structure under varying land use conditions. However, the Puerto Rican literature has focused more on leaf litter decay and nutrient exchange between rivers and the riparian zone (Lodge et al. 1991; O'Connor et al. 2000) rather than analyses of composition and species distribution.

The overall goal of this study is to examine the structure, composition and determinants of riparian vegetation in Trinidad to provide a baseline for conservation and restoration of the island's riparian ecosystems. Trinidad, Republic of Trinidad and Tobago, is a Caribbean island just north of Venezuela. It is rich in biodiversity and natural resources, but is experiencing high levels of industrialization and environmental degradation due to its oil based economy (Water Resources Agency 2001). This study contributes to water resources and aquatic ecosystems management research in Trinidad carried out by the Life Sciences Department at the University of the West Indies (UWI). It provides riparian data that, in conjunction with ongoing water quality, aquatic ecology and land use studies, can form the basis for river management on the island. Additionally, this study will contribute to the limited information on riparian zones on the small, tropical islands of the Caribbean.

This study is divided into three main chapters. The following chapter (Chapter 2) describes vegetation and environmental conditions at 36 sites, along 12 rivers in Trinidad. An account of anthropogenic influences along the rivers is also provided as well as selected characteristics of the associated watershed. The field survey methodology is described and vegetation is characterized in terms of relative frequency, density, coverage, importance value, species richness and diversity. Comparisons are made to existing riparian vegetation literature from nearby countries, and there is a discussion of the vegetation within the context of the general flora of Trinidad.

The aim of Chapter 3 is to determine the relative importance of multi-scale hydrological, terrestrial (abiotic) and human influences on riparian vegetation composition and structure in Trinidad. Sites are grouped based on vegetation characteristics using cluster analysis and non-metric multi-dimensional scaling. Indicator species for each group are delineated and the most significant variables controlling the distribution of the vegetation groups are determined.

Chapter 4 utilizes information from Chapters 2 & 3 to develop and test an index to assess the biological integrity of riparian sites. The index also identifies and prioritizes potential riparian conservation and restoration sites.

Chapter 5 summarizes the study results and provides recommendations for future research. It also provides suggestions as to how this study can be integrated into environment management strategies in Trinidad.

CHAPTER 2
RIPARIAN VEGETATION ALONG 12 RIVERS IN TRINIDAD

Introduction

Riparian zones are found along banks of rivers and streams and are transition areas or ecotones between terrestrial and aquatic environments. They also influence the structure and functioning of adjacent ecosystems (Naiman et al. 2000). Riparian zones have high plant productivity due in part to high temperatures, light and moisture along riverbanks. High productivity is also linked to flooding along rivers (Tabacchi et al. 1998; Naiman et al. 2000). The flood pulse theory (Junk et al. 1989) refers to the lateral exchange between a river and its floodplain and the accompanying adaptations of the floodplain biota. The flood pulse results in a higher productivity level for both aquatic and riparian systems, as it facilitates nutrient exchange and waste product removal. Riparian systems also have high biotic diversity due to the wide variety of ecological niches associated with physical heterogeneity and heavy disturbance caused by flooding and river channel migration (Gregory et al. 1991; Naiman et al. 2000).

Riparian plants are tolerant of the harsh, dynamic conditions along riverbanks. They are adapted to flooding, shear stress due to high river velocity, and dry conditions during low river discharge. During periods of flooding, riparian soils can become anoxic, thus adaptations such as adventitious roots and aerenchyma root cells are common in riparian plant species. Plant zonation is also common, often in response to water table and flooding gradients (Naiman & Decamps 1997). Riparian zones also have a high abundance of exotic plant species due to their ability to adapt to harsh dynamic conditions and rapidly disperse along riparian corridors (Richardson et al. 2007).

Riparian vegetation provides food and habitat for terrestrial fauna. The plants also provide food, substrate and habitat for aquatic species when leaves, flowers, fruits and woody debris fall into steams. Riparian plants can influence the form and function of adjacent water bodies; for example, overhanging vegetation can reduce water temperature (Nagasaka & Nakamura 1999), and river discharge can be lowered through riparian plant evapotranspiration. Riparian zones also buffer the water quality of the adjacent river. This takes place when riparian plants trap sediment and pollutants and take up nutrients from surface and groundwater filtering into the stream. Riparian plant buffers are often created or maintained for water quality protection especially at sites used for recreation and water abstraction (Naiman & Decamps 1997).

Past riparian research has largely been carried out in temperate areas or along large tropical continental rivers. Baseline riparian inventories have been conducted throughout Europe, North America and South America, for example, Higler (1993), Nebel et al. (2001) and Holmes et al. (2004). Studies on riparian vegetation determinants have also been focused in these geographic areas, for example, Turner et al. (2004) working in Wisconsin and Sheridan & Spies (2005) in Oregon. Practical applications of riparian research have been devised by Bentrup (2004) working in Kansas to find appropriate sites for riparian buffers or Peterjohn & Correll (1984) who studied the ability of riparian buffers to absorb soil nitrates in Maryland.

Riparian ecological concepts have also been derived from tropical continental or temperate research. For example, Junk et al. (1989) developed the flood pulse theory in part by observing flooding along the Amazon River. Johnson & Lowe (1985) based their intra-riparian continuum concept on research conducted in the United States. This concept described variations in the spatial extent of the riparian community moving downstream due to changing geomorphology. Mitsch & Gosselink (1993) described a downstream change in riparian ecosystem structure and function in response to a downstream gradient in stream bank soil particle size, based on studies in Oregon and along the Mississippi River in the United States.

Tropical island riparian research is lacking in all aforementioned areas. Basic vegetation inventories are needed as well as data on environmental properties and anthropogenic influences on riparian vegetation. Riparian buffer research is lacking; hence, the water quality benefits of riparian zones are not fully exploited on tropical islands. Finally, the applicability of general riparian ecological concepts to the short narrow rivers of tropical islands is not known. In the Caribbean there has been limited riparian research in Puerto Rico, for example, Heartsill-Scalley & Aide (2003) who examined variations in vegetation composition and structure under varying land use conditions, and Lodge et al. (1991) who studied leaf litter decay and nutrient exchange in the riparian zone. However, research is lacking in other Caribbean islands, including Trinidad.

The goal of this chapter is to describe the structure and composition of riparian vegetation along 12 rivers in Trinidad. Apart from an account of the riparian plants, hydrological properties of the corresponding rivers are detailed as well as environmental and anthropogenic characteristics of the riparian zones. Selected properties of the associated watershed are also highlighted. This chapter provides baseline riparian vegetation, environmental and anthropogenic data for Trinidad. In turn, results can be used to study riparian vegetation determinants, incorporated into riparian water quality buffer research, used to inform conservation and restoration, and used to test and build on riparian ecological theories.

Methods

Study Area

Trinidad is the larger island of the Republic of Trinidad and Tobago (Figure 2-1). It is located between 10˚2' and 11˚2' N latitude and 60˚30' and 61˚50' W longitude, just off the coast of Venezuela (Berridge 1981). Trinidad is a 4826 km^2 continental island, sharing a similar geological profile and natural history with neighboring South American countries (Beard 1946). There are three mountain ranges on the island, namely the Northern, Central and Southern

Ranges. The highest point, Cerro del Aripo, is in the Northern Range at an elevation of 900 m. The Caroni Plain separates the Northern and Central Ranges, and the Naparima Plain separates the Central and Southern Ranges (Water Resources Agency 2001; Day & Chenoweth 2004) as seen in Figure 2-2. Ninety-nine percent of the island is made up of sedimentary and metamorphic rocks (Water Resources Agency 2001)

Trinidad has a seasonal, tropical climate. The dry season is from January to May and the rainy season from June to December. Total annual rainfall ranges from 3048 mm in the northeast of the island to 1524 mm in the northwest, southwest and small offshore islets. Mean annual temperature is 25˚C (Water Resources Agency 2001; Day & Chenoweth 2004)

The Water Resources Agency (2001) has designated 54 watersheds on the island. The major river systems are the Caroni, North Oropouche, South Oropouche, Navet and Ortoire. The Caroni River is the widest (30 m), and the Ortoire River is the deepest at 6 m (Phillip 1998). The mean width for 114 rivers sampled in Trinidad (Phillip 1998) was 5.96 m, and the mean depth was 0.49 m.

The total population of Trinidad and Tobago is approximately 1.25 million; however, only 4% of the people live in Tobago (Water Resources Agency 2001). In 1980, 45% of Trinidad was covered in forest decreasing to 34% in 1990 due to agriculture, housing and industry. However, given the country's current heavy rate of industrialization, much of the agricultural land has been abandoned and is experiencing secondary growth. This has resulted in increased forest cover of 60% in 2000 (Gibbes 2006).

Beard (1946) divided the island's vegetation into four climatic vegetation formations: the Seasonal, Dry Evergreen, Montane and Intermediate formations. He also designated Swamp and Marsh Edaphic formations. Each formation was further divided into groups of common structure and lifeforms called associations. Most of the island's vegetation falls under the Seasonal formation. The most widespread floristic association is the Evergreen Seasonal Forest association dominated by *Carapa guianensis* Aubl. (Crappo) and *Eschweilera subglandulosa* (Steud.) locally known as Guatecare.

Nelson (2004) also classified the vegetation of Trinidad and developed a hierarchical three-tier classification framework for the island. The first, the Ecoregion tier, roughly halved the island along a north-south axis based on potential evapotranspiration. The eastern half of the island was designated the Moist Forest Ecoregion and the western part was the Dry Forest Ecoregion (Figure 2-3). The two Ecoregions were then divided into nine lifezone tiers, and each was further divided into 13 landscape units. Nelson's (2004) landscape units approximate Beard's floristic association categories.

Neither Beard (1946) nor Nelson (2004) provided in-depth information on riparian vegetation in Trinidad. Beard (1946) wrote a substantial discussion of wetland floristic data, focusing on the Nariva freshwater swamp, a RAMSAR site in the eastern part of the island (Brown 2000). In terms of riparian vegetation; however, Beard (1946) only noted the presence of *Pterocarpus officinalis* Jacq. (Swamp Bloodwood) in stands at the mouth of the North Oropouche River.

River Selection

Twelve rivers were selected across Trinidad for study. Rivers and their associated catchments were delineated from a Geographic Information Systems (GIS) catchment layers obtained from the Department of Surveying and Land Information of the University of the West Indies (Figure 2-4). Past riparian studies have pointed to the importance of climate, geomorphology, and human activities in shaping structure and composition of riparian vegetation (Tabacchi et al. 1998; Turner et al. 2004; Williams & Wiser 2004; Lite et al. 2005). Hence, for this study in Trinidad, the 12 rivers were chosen to reflect rainfall conditions, geomorphology and level of human impact across the island.

Rainfall levels were represented by the Ecoregion Classification of Nelson (2004) as seen in Figure 2-3 that roughly halved the island along a north-south axis based on a potential evapotranspiration ratio of 0.75. Six catchments were chosen from the western Dry Ecoregion area and six from the eastern Wet Ecoregion (Figure 2-3). Catchments were further divided based on geomorphology, four were in the Northern Range (North Unit), four in the Caroni Plain/Central Range (Central Unit) and four in the Naparima Plain/Southern Range (South Unit) as seen in Figure 2-2.

The third criterion for catchment selection was level of human impact. Forest cover was used as a proxy for this parameter, where catchments with high forest cover were used as low human impact sites. Forest cover was initially delineated using a 1994 land use GIS layer with 50 land use categories, based on 1994 aerial photographs. Forest cover was calculated as the sum of the area of the following land use categories: 1. Forest 2. Scrub-Fire Burnt or Permanently Dwarfed Vegetation 3. Mangrove 4. Swamp, 5. Swamp and Forest and finally 6. Swamp Forest. Teak and Pine plantations were not included as forest, as timber plantations have a high level of human impact. Similarly, categories such as Broken Forest were not included as they implied human intervention. While the category Scrub-Fire Burnt or Permanently Dwarfed Vegetation suggests human interference, it was the only category that encompassed dry forest vegetation in Trinidad and was thus, included as a Forest category. Forest cover in each watershed in Trinidad is shown in Figure 2-5. Delineation between high and low human impact was based on a minimum of 40% forest cover in watersheds on the western half of the island. This cut off point was chosen to factor in high levels of human impact due to agriculture, industry and housing on the west of the island. By contrast, on the eastern part of the island, the cut off forest cover level was 60%, as this side of the island has greater forest cover (Table 2-1 & Figure 2-5).

Once all other criteria were met, adjacent watersheds were selected to ensure similar rainfall conditions. For the Northern Range sites, watersheds were only selected from south-facing slopes. While the Caparo watershed straddled both the Dry and Wet Ecoregions, it was used, as it was the only site in the western part of the island that had a relatively high forest cover of over 40%. Sites were plotted along tributaries that fell within the Dry Ecoregion portion of the watershed. Similarly, for the Poole watershed in the Wet Ecoregion, a portion of the watershed fell within the Dry Ecoregion and, as a result, tributaries from only the Wet Ecoregion component were used.

The 1994 land use map was used as the primary data source for watershed selection; however, a land use map developed by the Department of Surveying and Land Information at UWI based on 2001 Landsat images was used to corroborate forest cover levels (Chinchamee Unpublished Thesis). The high human impact catchments selected had lower levels of forest cover in both 1994 and 2001 (Table 2-1). Gibbes (2006) was not used to select watersheds, as data were not yet available during the site selection phase of this study.

Where the watershed consisted of a number of sub-watersheds, the longest river within the watershed was chosen. River length was based on the distance from the mouth of the river to the headwaters of the longest tributary.

Site Selection

Sites were selected to represent an upper, mid and lower reach point along each of the twelve rivers used in the study. The lower reach was selected as 10-30 % of river length from the river mouth, 40-60% of the length was designated the mid reach area, and 70-90% was considered the upper reach area. The lower reach segment was at least 1 km inland from the coastline to avoid tidal influence. Within each reach, five randomly chosen points were selected along the river. These were investigated for suitability and discarded if there were accessibility or safety issues. In summation, three sites were selected per river for a total of 36 sites across the 12 catchments (Figure 2-6). Sites were selected during 2006 and relocated in 2007 using GPS navigation.

Vegetation Data

Vegetation was surveyed between January and May of 2007 during the dry season to take advantage of accessibility afforded by low river discharge levels. Trees and ground flora were surveyed on one randomly chosen bank of each of the sites selected. Data were collected along three; 50 m transects running perpendicular to the river channel and spaced 50 m apart (Figure 2-7). A total of 108 transects were established. Three of the 108 transects were spaced more or less than 50 m apart to avoid steep slopes, tributaries or dense patches of thorny vegetation. In the case of the Caparo Lower Reach site (CAPL) all three transects were relocated 200 m downstream to avoid an active dredging operation during the time of sampling. Steep slopes at the North Oropouche Upper Reach Site (NORU) hampered access to the site; hence, the point was moved to an accessible location approximately 1 km upstream.

Each transect was divided into five contiguous 10 x 10 m blocks. All transects began at the water's edge and in the case of dry river channels, at the base of the riverbank. Block 1 was located closest to the river, and block 5 was at the end of the transect. The species and Diameter at Breast Height (DBH) of each tree (DBH> 10 cm) in each block was recorded. Plant samples were taken for identification and to serve as voucher specimens at the National Herbarium of Trinidad and Tobago (TRIN). In the case of multiple trunks, where the trunk forked below the DBH level, each trunk was measured and total DBH recorded. DBH was estimated where trunks could not be measured using DBH tape, for example, if they projected over the river channel.

For species such as *Bambusa vulgaris* L. (Bamboo) with numerous culms, the DBH of one representative culm was taken, and the number of culms in the bamboo stand was estimated to provide total DBH for the bamboo stand. Plants such as *Musa* sp. (Banana) were also included in the tree flora even though they were not woody. This was done as the trunks had a DBH> 10 cm, and functionally the plants exerted similar effects as woody species, for example, shading ground flora.

Ground flora plants (DBH<10 cm) were quantified by visual estimation within 2 x 2 m quadrats. Where plant percentage cover ranged from 5-100%, cover was estimated to the nearest 5%. Where plants covered less than 5% of the quadrat, estimation was to the nearest 1%. There was one ground flora quadrat per 10 x 10 m tree block, totaling five ground flora quadrats per transect and 15 per site (Figure 2-7).

Environmental and Anthropogenic Data

All environmental and anthropogenic variables examined are given in Table 2-2. In each 10 x 10 m transect block, data were collected for canopy closure, soil parameters, land use, distance from river and elevation relative to the river channel margin. Canopy closure was measured in the middle of the 2 x 2 m ground flora quadrats using a Spherical Crown Densiometer (Concave Model). Land use was recorded for each 10 m x 10 m block based on site observations. It was not logistically feasible to analyze soil samples from all three transects; hence, soil was only collected from the 50 m transect. Soil samples were collected from two depths, 0-30 cm and 30-60 cm from the middle of the 2 x 2 m quadrats. Thus, in total 10 soil samples were collected for each of the 36 sites. Slope was measured in each block and used to calculate elevation relative to the river channel margin. Relative elevation was used as a proxy for flooding magnitude following Chapin & Beschta (2002).

On a coarser scale, major land use for each of the 36 sites was designated based on the most common land use for the 15 (10 x 10 m) blocks. Other site level categorical data collected included evidence of recreation, fire, religious activities, drainage works, surface and groundwater abstraction, pollution, braiding, meandering and animal activity.

River hydrological parameters were also measured at each site including river velocity, channel depth, channel width, bankfull width, bank slope, bankfull depth and bank length. Velocity was measured using a flow meter (Global Water Flow Probe, model #FP101). Depth was measured with a meter rule for shallow rivers and a sonar depth sounder for the deeper rivers (HawkEye® Handheld Digital Depth Sounder). Five equally spaced readings of river velocity and depth were taken in a straight line across the river from each land transect (15 readings total). For South Oropouche Lower (SOUL) reach and North Oropouche Lower (NORL) reach, velocity and depth readings were only taken along one transect. This was due to sampling difficulties resulting from deep water and high river velocity, respectively. Velocity and depth were used to calculate discharge using the area velocity method, specifically the mean section method (Gregory & Walling 1973). Channel and bankfull width were measured using either a measuring tape or a LaserAce® Hypsometer. Bank slope and bank length were measured from the top of the bank to the water's edge. Bank was established as the point with the first major break in slope moving landward from the water margin. One reading was taken per transect for bankfull width, channel width, bank slope and bank length. Bank slope and bank length were used to calculate bank height relative to water level. This value was added to the greatest river depth for that specific transect to give a measure of total bankfull depth. Hydrological data for the three transects were averaged to provide one value for each of the 36 sites.

GIS and Map Data

While the aforementioned data were collected in the field, environmental and anthropogenic data were also derived using GIS layers and soil maps. Major soil type (per site) was obtained from soil maps of Trinidad and Tobago (Land Capability Survey 1971). Land ownership was obtained from topographic maps, (Lands and Surveys Department 1977) supplemented by interviews with residents in the area and information from Forestry Officers.

Catchment properties were derived from a 1994 GIS layer of watersheds in Trinidad, from the Department of Surveying and Land Information (UWI) in Trinidad. Catchment length was calculated using the most distant point method following Gregory & Walling (1973). Catchment shape was calculated using the form factor method following Horton (1932). Relief was designated using the relief ratio method following Schumm (1956).

Laboratory Analyses

Soils were analyzed for the parameters outlined in Table 2-2. Analyses were carried out by the Central Experiment Station (CES) in Centeno, Trinidad with the exception of soil particle size analyses that were done by the author at the Soil Science Laboratory at UWI in Trinidad. Methods of analysis followed Bartels (1996) &. Horwitz (2005). Three hundred and sixty samples were tested per parameter with 10% duplicate testing (36) samples. Soil particle size analysis was only carried out on samples from the 0-30 cm layer of each block; hence, only 180 samples were tested for this parameter.

Data Analyses

Species richness (combined number of tree and ground flora morphotypes) was calculated for each of the 36 sites and 12 catchments. Species richness was also calculated at a coarser scale on the island level, that is, on the basis of Ecoregion, geomorphology and level of human impact. The same calculations were performed for plant species diversity (Shannon Index).

Diversity and richness calculations were done using the DIVERSE program in the software package PRIMER (Plymouth Routines in Multivariate Ecological Research) Version 5.2.9. For these and all analyses described below, the questionable generic and species identifications were amalgamated with the genus or species they were most likely to be. Unidentified trees (UTs) and unidentified ground flora (UGs) were retained; however, as these were distinctly different morphotypes. Specimens identified to only the generic level were treated as separate morphotypes from specimens identified to species within that genus. While this may result in some overlap, it was felt that since the specimen could belong to any number of species within that genus, it should be treated separately. Specimens identified to family were treated in the same manner.

Trees were quantified in terms of Relative Coverage (Dominance), Relative Frequency, Relative Density and the cumulative Importance Value (Brower et al. 1990). Tree relative coverage was based on basal area. Ground flora was quantified in terms of relative coverage, that is, percentage cover in the quadrats.

Results

The following sections describe environmental, anthropogenic and vegetation characteristics of 36 sites along 12 rivers in Trinidad. River descriptions are arranged by geomorphological unit, then by Ecoregion and level of catchment human impact following the sampling regime described in Table 2-1.

Plant species found in this study are listed in Appendix A with appropriate nomenclature revisions and common names used in Trinidad. Questionable generic and species identifications are also included. In cases where a plant specimen could not be distinguished between two candidate sepcies, both possible species names were recognised. If identification to species was not possible, the genus was listed; if the genus could not be determined then the family was listed. Plants described as unidentified could not be identified to family. Unless otherwise stated, all subsequent details on characteristics and distributions of plants found in this study were based on Adams & Baksh-Comeau (Unpublished).

River Profiles

Caura

North Geomorphological Unit; Dry Ecoregion; Low Human Impact: Photographs of the lower Caura (CAUL), middle (CAUM) and upper (CAUU) reaches are seen in Appendix B. All three Caura sites had gravel in block 1 of transects. The highest elevation above the river channel margin of all sites (26.10 m) was in block 5 of the 100 m transect at CAUM, as seen in Table 2-3. *B. vulgaris* was common to all sites in the catchment.

CAUL was located next to a soccer field surrounded by businesses and industries. The site was classified as developed (DE) based on the presence of roads and concrete buildings (Table 2-4 & Appendix C). One transect ran along a rough gravel road. There were no species unique to CAUL, instead, weedy species like the grass *Cynodon dactylon* (L.) Pers. were present. *Axonopus compressus* (Sw.) P. Beauv (Savannah grass) covered the soccer field and was the most abundant ground flora species at the site. In terms of the tree flora, there was only a clump of *B. vulgaris* present, and as a result, eleven out of 15 blocks had 0% canopy closure (Appendix D).

CAUM was in a forested area next to an abandoned road. This site may have been cultivated in the past as suggested by the presence of the introduced cultivated species *Dipteryx odorata* (Aubl.) Willd. (Tonka Bean). However, the site was still classified as Forest (FO). CAUM had 25 species unique to this site. *Miconia punctata* (Desr.) D. Don ex DC. had the highest ground flora percentage cover, and *B. vulgaris* had the highest tree importance value. CAUU was a Government agroforestry site with mature fruit trees and timber tree saplings. It was classified as a SV site (Table 2-4) as there was heavy undergrowth under the timber and fruit trees, suggesting a lack of maintenance. Timber saplings included *Cordia alliodora* (Ruiz & Pav.) Oken and *Cedrela odorata* L., two of the nine species found only at this site. Fruit trees at the site included *Annona muricata* L. (Soursop), *Citrus* sp., *Manilkara zapota* (L.) P. Royen (Sapodilla) and *Syzygium malaccense* (L.) Merr. & L.M. Perry (Pomerac). *B. vulgaris* had the highest tree importance value at this site, and *Selaginella plana* (Desv. ex Poir.) Hieron. was the most abundant ground flora species. The highest percentage of gravel in the soil (63.98%) of all 180 blocks was found in a CAUU block 1 (Table 2-3 & Appendix E).

Arouca

North Geomorphological Unit; Dry Ecoregion; High Human Impact: Appendix B shows Photographs of the lower (AROL), middle (AROM) and upper (AROU) reaches of the Arouca river. All three sites studied were polluted and under private land ownership. A high level of human impact was evident in the well-developed road network in the catchment and two sites closest to paved roads were in this catchment. Overall, the catchment had 34% forest cover (Table 2-5). *Pueraria phaseoloides* (Roxb.) Benth. (Kudzu), a widely distributed weed, was the only plant common to all sites along the Arouca River.

AROL was sandwiched between a shopping mall and a number of large retention ponds. There was a well-maintained lawn between the riverbanks and the retention ponds and a highway crossing the river just south of the sample location. AROL was categorized as a developed site (DE) seen in Table 2-4. The river was dredged, and the riverbanks were covered in low-lying un-maintained grassy, weedy vegetation. There were nine plants found only at this site (Appendix F). They included *Ludwigia* sp. and *Cyperus surinamensis* Rottb. which are both associated with moist areas in Trinidad. *Sorghum* sp., an introduced grass had the greatest percentage coverage at the site. This site did not have any trees; hence, there was zero percentage canopy closure at all blocks at the site.

AROM was a relatively open, sunny, grassy area with fruit trees. It was classified as a SV site. There were houses uphill on both sides of the river, and the site was also used for recreation. AROM appeared to be a recently abandoned agricultural or un-maintained agricultural site with tree crops like *Persea americana* Mill. (Avocado), *Psidium guajava* L. (Guava), *Cocos nucifera* L. (Coconut) and *Mammea americana* L. (Mame Sepo). Sixteen of the plants including the aforementioned agricultural plants were restricted to AROM. Highest tree importance value belonged to another fruit tree *Mangifera indica* L. (Mango), and a sedge *Scleria melaleuca* Rchb. ex Schltdl. & Cham. was the most abundant ground flora species. Sample blocks at AROM had the lowest soil nitrogen and phosphate levels, <0.01 g kg^{-1} and 1 mg kg^{-1}, respectively; however, these values were shared with other sites.

Land use at AROU was classified as Secondary Vegetation/Abandoned Estate (SV) as it was a former cocoa (*Theobroma cacao* L.) and citrus (*Citrus* sp.) estate. The river ran parallel to a road, 5 m away. The steepest slope (-57°) of all 540 blocks in the study was at a block 1 site at AROU (Table 2-3). The lowest soil calcium level in all 36 sites was from a block at AROU (0.04 cmol kg^{-1}) seen in Table 2-3. Six plants were exclusive to this site, including two agricultural plants, *Annona squamosa* L. (Sugar Apple) and *Zingiber officinale* Roscoe (Ginger). The highest tree importance value belonged to *Cecropia peltata* L. (Bois Canot), which is common in disturbed areas. The most abundant ground flora species (highest percentage coverage) was *Pachystachys coccinea* (Aubl.) Nees, which is associated with cocoa estates and also riparian areas (Adams & Baksh-Comeau Unpublished).

North Oropouche

North Geomorphological Unit; Wet Ecoregion; Low Human Impact: The lower (NORL), middle (NORM) and upper (NORU) reaches of the North Oropouche river are shown in Appendix B. All sites in this catchment were on privately owned land (Table 2-4). There were no species in common amongst the three reaches.

NORL consisted of a strip of natural vegetation merging into an active cocoa estate with some secondary vegetation in between. Overall, the site was classified as SV, having the greatest number of sample blocks in the SV portion of the site. NORL was downstream of intensive sand and gravel quarrying operations, resulting in a sediment laden river and sand deposition on the riverbanks. As a result, the NORL block 1 soil sample had the highest sand content of 83.97%. This site also had the two highest soil silt percentages (70.72%) in block 5 followed by 67.16% in block 4. NORL also had the lowest soil pH of 3.81. The NORL river channel was braided, and the river had the highest discharge (6.42 m^3s^{-1}) of all sites (Table 2-3). *B. vulgaris* had the highest tree importance value, and *Pueraria phaseoloides* had the highest ground cover flora percentage coverage. There were five unique species at NORL, four of which were unidentified, but also *Eugenia monticola* (Sw.) DC, which is normally found in forested areas.

NORM was a heavily disturbed area just upstream of a major quarrying operation and downstream of an industrial site. The channel was braided like NORL. The lowest organic carbon value (<0.01 g kg^{-1}) was found in two blocks at NORM. However, this low value was also found at two other sites. NORM also had the highest soil pH value (8.19). There was a narrow strip of vegetation on the riverbank, beyond which there was a large burnt field resulting in a land classification of GR. *B. vulgaris* had the highest tree importance value, and *Panicum maximum* Jacq. had the highest percentage coverage in the ground flora. *P. maximum* was one of five species exclusive to this site; however, it should be noted that there were occurrences of

Panicum sp. at other sites, but at NORM, the plants bore flowers, which allowed identification to species level.

NORU consisted of a patch of native forest sandwiched between abandoned cocoa/coffee plantations. This patch of forest was perhaps retained, since the area was on a steep rocky outcrop as opposed to the flatter land on either side. The site was classified as FO. NORU had the greatest bankfull depth of 11.29 m and the steepest bank slope of -50.67°. It was one of the sites with <0.01 g kg^{-1} nitrogen levels and also had the lowest soil electroconductivity (EC) value of 0.013 mS cm^{-1}. *Hieronyma laxiflora* (Tul.) Müll. Arg., a forest species, had the highest importance value, and *Coffea* sp. had the highest ground flora percentage cover at this site. NORU had 25 unique species including *H. laxiflora, Ryania speciosa* Vahl, *Calophyllum lucidum* Benth. and the ground flora plant *Miconia nervosa* (Sm.) Triana. *R. speciosa, C. lucidum* and *M. nervosa* are normally found in moist forested areas. *Quiina cruegeriana* Griseb., which was found only at this site, has been previously reported in riparian areas, while *Psychotria capitata* Ruiz & Pav. has been noted in swampy areas. Another NORU exclusive species is *Chimarrhis cymosa* Jacq, which while not specifically reported in riparian areas, is commonly called Bois Riviere (River Wood). Four of the unique species at NORU were ferns including the tree fern *Cnemidaria spectabilis* (Kunze) R.M. Tryon, which has previously been reported near rivers.

Aripo

North Geomorphological Unit; Wet Ecoregion; High Human Impact: Appendix B shows Photographs of the lower (ARIL), middle (ARIM) and upper (ARIU) reaches of the Aripo river. This catchment had the highest basin relief of all 12 catchments, with the greatest difference between the highest and lowest points (787.4 m). It also had the highest relief ratio of 0.055, which is the ratio of basin relief to catchment length (Table 2-5). ARIM and ARIL had braided channels. All three sites had gravelly riverbeds; however, gravel was not found in the soil sampled at ARIL. All three Aripo sites had Justicia secunda Vahl and Spondias mombin L. The former is associated with moist shady areas in Trinidad, while S. mombin is an introduced, naturalized plant common in forests and swampy disturbed areas (Adams & Baksh-Comeau Unpublished).

ARIL was classified as grassland (GR) as seen in Table 2-4, due to limited tree cover, low canopy closure, and a dominance of vines, grasses and low-lying vegetation. The entire area was swampy and pitted with small ponds. ARIL had 36 plant species, of which six were found only at this site. These included *Cassia reticulata* Willd., *Hymenachne* sp., *Ludwigia peruviana* (L.) H. Hara and *Commelina erecta* L. (Watergrass), of which the latter three plants are associated with wet, moist, or riparian areas (Adams & Baksh-Comeau Unpublished). There were only two tree species at this site represented by one specimen of *Vismia laxiflora* Reichardt and four *Erythrina glauca* Willd. specimens. *E. glauca* is an introduced, naturalized plant in Trinidad. It is found in low-lying areas and is commonly called the Water Immortelle. A vine, *Ipomea* sp., had the highest ground flora percentage coverage at this site.

ARIM was classified as an agricultural site (AG), as it was located in a *Carica papaya* L. (Papaya) field. There was also a patch of secondary forest at this site at the 100 m transect. The river channel was modified by the insertion of large concrete columns to block water flow to create pools for bathing. This site was also downstream of a water abstraction point. Papaya was one of the 12 plants exclusive to the site, seven of which were weeds or agricultural plants. The highest tree importance value belonged to *Hura crepitans* L. (Sandbox), a typical secondary forest species, and the highest percentage coverage in the ground flora belonged to *Parthenium hysterophorus* L., a weedy species found under papaya plants at this site.

ARIU was a recreational area located downstream and downhill from a nature lodge. The site was crisscrossed by a number of tributaries and was the highest site in the study at 228.60 m above sea level (Table 2-3). The site was classified as forested (FO) as the majority of sample blocks at this site (9/15), had forest cover (Appendices 2 & 3). ARIU had the highest soil calcium level (26.69 cmol kg^{-1}) of all 360 soil samples collected across all sites (Table 2-3). This value was found at the 30-60 cm soil depth in block 4, the second to last landward block of the transect. The next seven highest calcium readings were also found at the ARIU, which also had 89 g kg^{-1}, the highest organic carbon level found in this study (Table 2-3). One sample block in ARIU also had the lowest phosphate level of 1 mg kg^{-1}; however, this value was shared with blocks at other sites.

ARIU had a strip of trees on the riverbank beyond which there were shallow ponds used for growing *Rorippa officinale* R.Br. (Watercress). *R. officinale* was one of the plant species unique to ARIU site (Appendix F). Only seven species were exclusive to this site including *Chrysothemis pulchella* (Donn) Decne, an ornamental plant normally associated with *T. cacao* (Cocoa) plantations. The highest tree importance vale at this site belonged to *Erythrina poeppigiana* (Walp.) O.F. Cook, an introduced, naturalized species normally associated with cocoa plantations. Also found at this site was the lycopod *Selaginella plana*, which had the highest ground flora percentage cover.

Caparo

Central Geomorphological Unit; Dry Ecoregion; Low Human Impact: Photographs of the lower (CAPL), middle (CAPM) and upper (CAPU) reaches are provided in Appendix B. The Caparo catchment had the smallest form factor of 0.17 (ratio of area to the square of catchment length). Overall, only five tree species were found across all three sites, and no species were common to the three sites.

CAPL was in a sugarcane (*Saccharum officinarum* L.) field; however, sugarcane was only found in transect blocks 4 and 5. The river channel was covered in aquatic vegetation. This site was classified as grassland (GR) seen in Table 2-4 as grasses and weeds such as *Malachra fasciata* Jacq. and *Dichanthium caricosum* (L.) A. Camus replaced the sugarcane closer to the river. The aforementioned species were two of five species unique to this site. The most abundant ground flora plant at CAPL was a grass only identified to the family level. There were no trees at CAPL resulting in a 0% canopy closure in all blocks at the site. During field visits, dredging was taking place upstream of the sampling area, and the existing riverbank morphology suggested that the site had been dredged the year before. CAPL had the widest bankfull width in the study (31.67 m). The two highest soil magnesium levels were in sample blocks at CAPL (8.34 cmol kg^{-1}) in the 30-60 cm soil depth level and 7.79 cmol kg^{-1} at the 0-30 cm depth.

CAPM was a SV site located about 300 m behind a house. There was a strip of trees within 40 m of the riverbank, beyond which a series of grass-covered fields extended to the house. The site had a high level of human traffic as indicated by well-worn trails and litter along the river. The area also appeared to be subject to fires as suggested by blackened tree trunks at the site. In terms of soil properties, CAPM had one sample block with <0.01 g kg^{-1} nitrogen, the lowest value shared with three other sites. CAPM was the only site in the study that had *Crudia glaberrima* (Steud.) J.F. Macbr. This species is found in swampy areas. Apart from *C. glaberrima*, five other species were restricted to this site. The highest importance value among the trees belonged to *Syzygium cumini* (L.) Skeels (Gulub Jamoon), an introduced, naturalized tree. *Flemingia strobilifera* (L.) R. Br. (Wild Hops) a weedy, introduced species had the highest ground flora coverage.

CAPU was an AG site located in a sugarcane field and like CAPL, dredging was taking place upstream during field sampling. There were six species unique to CAPU including two grasses *Echinochloa colona* (L.) Link and *Leptochloa virgata* (L.) P. Beauv. There was a clump of *B. vulgaris* Schrad. ex J.C. Wendl (Bamboo) in a block 1, but no other trees at this site. *Saccharum officinarum*. (Sugarcane) had the highest percentage coverage at this site.

Couva

Central Geomorphological Unit; Dry Ecoregion; High Human Impact: Photographs of all Couva sites are seen in Appendix B. The catchment had the lowest forest cover of all 12 catchments (17%) seen in Table 2-5 and all three sites in the catchment were polluted. All three sites had *B. vulgaris*, *F. strobilifera* and *J. secunda*.

COUL was located in a *S. officinarum* (Sugarcane) field; however, the river was deeply incised such that sugarcane was only found in blocks 4 and 5 of the transects. Blocks 1-3 had native forest species and heavy canopy cover, and as a result, the site was classified as FO (Table 2-4). Fires appear to be common at the site. Only three species were exclusive to COUL in this study, two were unidentified, but the third, *Machaerium tobagense* Urb. was a generalist species found throughout Trinidad. COUL had the highest total nitrogen level in the study, 36 g kg^{-1} found in blocks 3 and 4 (0-30 cm depth). *B. vulgaris* had the highest importance value at the site and *F. strobilifera* the highest ground flora percentage cover.

COUM was located within 60 m of a house and was classified as a SV site (Table 2-4). Vegetation transects extended to the lawn surrounding the house. There was evidence of fire at the site. There were six unique plants including the weedy species *Justicia pectoralis* Jacq. (Appendix F) and a cashew tree (*Anacardium occidentale* L.) in the house's backyard. The highest phosphate level in the study (151 mg kg^{-1}) was found at this site at a depth of 0-30 cm in block 3. Like COUL, *B. vulgaris* had the highest importance value at the site, and *F. strobilifera* (L.) R. Br. had the highest ground flora percentage cover.

COUU bordered an old cocoa estate and was classified as a SV site. There were three unique species at this site: *Gibasis geniculata* (Jacq.) Rohweder, *Ludwigia decurrens* Walter and *Priva lappulacea* (L.) Pers. Like the other Couva sites, *B. vulgaris* had the highest tree importance value, but *F. strobilifera* was replaced by *Pueraria phaseoloides* as the most abundant ground flora plant.

L'ebranche

Central Geomorphological Unit; Wet Ecoregion; Low Human Impact: Appendix B shows all the lower (LEBL), middle (LEBM) and upper (LEBU) reaches of the L'ebranche river. At 47.09 km^2, L'ebranche was the smallest catchment in the study and also, along with the Poole catchment, had the lowest maximum basin relief of 68 m (Table 2-5). Seven species were common to all three reaches. These included *Heliconia bihai/spatho-circinada, T. cacao, Spondias mombin, Tectaria* sp. *Cecropia peltata, Adiantum* sp. and Bignoniaceae 1. The L'ebranche catchment had the highest amount of *B. vulgaris* in the study, almost 46% of the total *B. vulgaris* basal area across all sites. There was no evidence of recreation, fire or human modification at any of the LEB sites (Table 2-4). While the catchment is characterized as low human impact with a forest cover of 63%, the three randomly chosen sites were in abandoned cocoa estates.

LEBL was situated 70 m from a major paved road. The site had <0.01 g kg^{-1} carbon in a block 1 sample, the lowest value for the study, also shared with blocks at three other sites. LEBL had *Cissus* sp., *Clidemia* sp. 2 and *Marsdenia macrophylla* (Humb. & Bonpl. ex Schult.) E. Fourn. and one unidentified species found only at this site. *B. vulgaris* had the highest importance value, and *H. bihai/spatho-circinada* had the highest ground flora percentage coverage. Like, LEBL, *B. vulgaris* had the highest importance value, and *H. bihai/spatho-circinada* had the highest percentage coverage

at LEBM. LEBM had two unidentified species and *Costus* sp. unique to that site. LEBM had two blocks with 1 mg kg^{-1}, the lowest soil phosphate level shared with three other sites.

Unlike the other two sites, LEBU had *Costus scaber* Ruiz & Pav. in greatest abundance in the ground flora and *Ficus maxima* Mill. with the highest tree importance value. *C. scaber* is found in disturbed, shady areas often in association with cocoa plantations. *F. maxima* is widespread across Trinidad. LEBU had eight species unique to that site including a seedling of *Pterocarpus officinalis*, a noted swamp species. The other seven unique species were all ground flora plants, in particular, vines like *Dioclea reflexa* Hook. f., and *Mikania scabra* DC. These were found along riparian transects and also on the dry river bed of LEBU. Other unique species such as *Drymonia serrulata* (Jacq.) Mart. and *Palicourea crocea* (Sw.) Roem. & Schult. are normally found in wet areas. *Passiflora serratodigitata* L. is found in moist disturbed areas, while *Lasiacis ligulata* Hitchc. & Chase is a known riparian plant.

Cumuto

Central Geomorphological Unit; Wet Ecoregion; High Human Impact: Photographs of the upper (CUMU) middle (CUMM) and lower (CUML) reaches are presented in Appendix B. All sites were on privately owned land. There were no recreational activities and no evidence of pollution or fire (Table 2-4). Two weeds, *Pueraria phaseoloides* and *Blechum pyramidatum* (Lam.) Urb. were found at all three sites along the river.

CUML was classified as SV for this study as it was an un-maintained agricultural estate. Agricultural trees at this site included *Citrus* sp., *Syzygium malaccense* and a timber species *Swietenia macrophylla* King (Mahogany). *S. macrophylla* was only found at CUML, as was the palm *Euterpe oleracea* Mart. and *Simarouba amara* Aubl. *E. oleracea* is common in low-lying moist areas, while *S. amara* is normally found in forested areas. Overall, six species were unique to this site. While not exclusive to CUML, *Bambusa vulgaris* had the highest importance value, while *Justicia secunda* had the greatest ground flora percentage cover at this site.

CUMM was a well-maintained agricultural area (AG). There were citrus trees and a closely cropped lawn under the trees. River morphology suggested past dredging at the site. Unique species consisted of four unidentified plants in addition to *Cyperus* sp. and *Ludwigia* sp. *Ludwigia* sp. is associated with moist areas in Trinidad. *Citrus* sp. had the highest importance value, and the lawn grass *Axonopus compressus* had the highest ground flora coverage.

CUMU had a dry riverbed. The site was forested, extending into an open agricultural area with tree crops and a ground cover of weedy vegetation. It was classified as AG as eight of the 15 sample blocks were in the agricultural area. There were six species found only at this site, including one tree *Zanthoxylum martinicense* (Lam.) DC and five ground flora plants. These unique ground flora species included a weed *Urera baccifera* (L.) Gaudich. ex Wedd and *Commelina diffusa* Burm. f. (Watergrass). *C. diffusa* is associated with moist and riparian areas in Trinidad. Like CUML, *J. secunda* had the highest ground percentage coverage and *B. vulgaris* the highest tree importance value.

Penal: South Geomorphological Unit; Dry Ecoregion; Low Human Impact

Photographs of the lower (PENL), middle (PENM) and upper (PENU) reaches are seen in Appendix B. Penal had the highest form factor of all catchments (1.83) due in part to its shortest catchment length (6.62 km). All three reaches had dry riverbeds and were on public land, as the river was located entirely in the Southern Watershed Reserve. *Bactris major* Jacq. and *Spondias mombin* were found at all three sites in this catchment. *B. major* is a clump-forming palm species and has been reported in swamp and riparian areas (Adams & Baksh-Comeau Unpublished).

There was evidence of hunting at all sites and abandoned marijuana plots (*Cannabis sativa* L.) at PENM and PENL. PENL was classified as a forested site (FO), as seen in Table 2-4. The highest importance value belonged to *Bravaisia integerrima* (Spreng.) Standl. (Jiggerwood), a tree found in wet forests in Trinidad, while the highest percentage coverage belonged to a vine *Paullinia leiocarpa* Griseb. There were 14 species unique to this site. These included *Bursera simaruba* (L.) Sarg., a dry forest species and also *Chionanthus compactus* Sw. and *Nectandra rectinervia* Meisn., two generalist tree species. Two other unique species were *Sansevieria hyacinthoides* (L.) locally known as Mother-in-law's Tongue, a ground flora plant, and the tree *Crescentia cujete* L. (Calabash), both introduced, cultivated species.

PENM was approximately 1.9 km away from a paved road, the site furthest away from a road. It was classified as a forested site. *Bactris major* had the highest percentage coverage in the ground flora and *Bravaisia integerrima* the highest importance value. There were nine species found only at PENM including the trees *Capparis baducca* L., found in wet forests in south Trinidad, and *Zanthoxylum microcarpum* Griseb. (Lepinet), another wet forest species, but not restricted to south Trinidad.

PENU had the shallowest bankfull depth in the study (0.84 m). The site was in a Teak plantation (*Tectona grandis* L. f.), and as it was the dry season, the teak trees had shed their leaves. As a result, 11 of the 15 sample blocks had canopy closures less than 20%. The teak plantation at PENU was categorized as AG, as it was a well-maintained monoculture with little undergrowth. *T. grandis* had the highest importance value and *Bactris major* the highest percentage coverage in the ground flora. *T. grandis* was only found at PENU, as were the trees *Diospyros inconstans* Jacq. and *Machaerium robiniifolium*, (DC.) Vogel. Both *D. inconstans* and *M. robiniifolium* are dry forest species.

South Oropouche

South Geomorphological Unit; Dry Ecoregion; High Human Impact: South Oropouche was the largest catchment in the study (438.67 km^2). There was evidence of fire and pollution at all sites. All reaches had *Acroceras zizanioides* (Kunth) Dandy and *Saccharum officinarum* (Sugarcane). Appendix B shows the lower (SOUL), middle (SOUM) and upper (SOUU) reaches of the river.

SOUL was located at a large, dredged, straightened canal, part of a network of canals in the South Oropouche watershed. Dredging and straightening at this site may have taken place more than 10 years ago, as there were mature trees in the dredged areas. The site was classified as SV, as it included sugarcane fields and fruit trees. There were houses within 80 m of the site. *S. officinarum* had the highest ground cover, and *Bambusa vulgaris* had the highest importance value. Seven unique species were found at this site including *Hymenachne amplexicaulis* (Rudge) Nees., *Imperata brasiliensis* Trin., *Urochloa mutica* (Forssk.) T.Q. Nguyen and *Terminalia catappa* L., *I. brasiliensis* is associated with fire prone areas. *H. amplexicaulis* is a known swamp and riparian species as is *U. mutica,* an introduced grass (Para Grass). The two highest soil EC levels were at SOUL (9.60 mS cm^{-1}) at the 30 cm level and 7.85 mS cm^{-1} at the 60 cm level, both in block 1 of the transect where soil was collected.

SOUM was at another dredged, straightened canal. The site was in a sugarcane field that was already burnt and harvested. There were only two tree specimens, and as a result 12 of 15 blocks had 0% canopy closure. A grass, *Eriochloa punctata* (L.) Desv. ex Ham, had the highest ground cover, and *Erythrina glauca* had the highest tree importance value. The other tree species present at the site was *Cordia collococca* L. The grass *Eriochloa punctata* is normally found in moist disturbed areas. The site did not have any unique species.

SOUU was not part of the canal system in the South Oropouche watershed. The site was in a burnt, harvested sugarcane field. At the time of sampling sugarcane had started re-sprouting to such an extent that it had the highest ground flora coverage. *Sapindus saponaria* L., a tree found in riparian areas, had the highest importance value. There were three unique species including *Paullinia pinnata* L., a moist forest ground flora species.

Moruga

South Geomorphological Unit; Wet Ecoregion; Low Human Impact: Photographs of the lower (MORL), middle (MORM), and upper reach (MORU) are seen in Appendix B. The Moruga catchment had an 84% forest cover value, the highest in the study. All three sites had *Costus scaber* and *Mora excelsa* Benth. in common. All three sites were classified as FO (Table 2-4) and had evidence of hunting and timber harvesting. They were located in the Victoria Mayaro Forest Reserve. Although it is a forest reserve, the area is also controlled by the National Petroleum Company of Trinidad and Tobago (PETROTRIN), and as such, was crisscrossed by access roads and pipelines.

MORL was approximately 1 km from a paved road. It was also at the lowest elevation in the study, 2.3 m above sea level. The lowest phosphate level recorded, 1 mg kg^{-1}, was found in two sample blocks at MORL, but this value was shared with blocks at five other sites. *Leptochloa* sp. was the most abundant plant in the ground flora, and *M. excelsa* had the highest importance value among the trees. Although *Leptochloa* sp. could not be identified to species, *Leptochloa longa* Griseb. has been noted in riparian areas. MORL had 15 species found only at this site, one of which, the tree *Mouriri rhizophorifolia* (DC.) Triana, is common in south Trinidad in forested and swampy areas. All other exclusive species were ground flora plants such as *Cleome gynandra* L., *Heliotropium angiospermum* Murray and *Lastreopsis effusa* (Sw.)

Tindale var divergens (Willd. Ex Schkuhr). These three species were either weedy or common in disturbed areas.

MORM was also located 2.3 m above sea level, the lowest in the study (Table 2-3). It was within 500 m of a road and 300 m of an oil pump. Eight of the 15, 10 x 10 m blocks had over 95% canopy closure, including three blocks with 100% canopy closure. Only five blocks in the entire study had 100% canopy closure, suggesting heavily shaded conditions at MORM. However, it should be noted that block 1 (closest to the river) in each transect at MORM had 0% canopy closure. MORM had the highest soil potassium values (21 cmol kg^{-1}) found in one block at the site but the lowest magnesium level (0.03 cmol kg^{-1}) found in another block at the 30-60 cm soil depth. Like MORL, *Mora excelsa* also had the highest importance value at this site, while the most abundant ground flora species was *Piper hispidum* Sw. *P. hispidum* is found in swampy areas. There were four unique species at this site including one tree *Terminalia dichotoma* G. Mey, which is found in forests in south Trinidad. While this tree is not noted to be a riparian or swamp species, the common name is Water Olivier. Two of the other three unique species were weedy species, namely *Cleome spinosa* Jacq. and *Wedelia trilobata* (L.) Hitchc.

M. excelsa had the highest tree importance value at MORU like the other two sites, but the most abundant ground flora plant was *Ischnosiphon arouma* (Aubl.) Körn., commonly called Tirite. This plant is common in low-lying moist forested areas. MORU had 11 species unique to this site including the tree *Crateva tapia* L., which is restricted to south Trinidad. Ground flora plants exclusive to this site included *Pavonia castaneifolia* A. St.-Hil. & Naudin and *Pharus latifolius* L., both found in moist areas, as well as the fern *Lomariopsis japurensis* (Mart.) J.Sm. and *Piresia sympodica* (Döll) Swallen, both noted riparian species.

Poole

South Geomorphological Unit; Wet Ecoregion; High Human Impact: Appendix B shows photographs of the lower (POOL), middle (POOM) and upper reaches (POOU) of the river. Poole had the longest catchment length of 32.70 km and the lowest relief ratio of 0.002. The catchment had 53% forest cover, and all three reaches were in abandoned cocoa and coffee estates. However, it should be noted that there were no cocoa plants collected within transects at POOL. There was river meandering at all three sites. All land was privately owned, and there were caimans (*Caiman crocodilus*) at POOL and POOM (Table 2-4). All three sites shared *Inga ingoides* (Rich.) Willd., *Coffea* sp., *Costus scaber*, and the ferns *Adiantum* sp. and *Tectaria* sp. *C. scaber* is associated with cocoa plantations, and *I. ingoides* is found in moist, disturbed areas.

While POOL was in a cocoa/coffee plantation, there was a patch of native vegetation in a steep part of the site. *Coffea* sp. had the highest ground flora coverage, and *Erythrina poeppigiana* had the highest importance value. Unique species at the site included *Myrcia splendens* (Sw.), found in moist forests, and *Buchenavia tetraphylla* (Aubl.) R.A. Howard DC. (Yellow Olivier), which was another forest species.

At POOM, *Heliconia bihai/spatho-circinada* had the highest ground flora coverage, and *Bambusa vulgaris* had the highest importance value in the tree flora. Unique species at POOM consisted of six unidentified species. POOM also had fruit trees, namely *Syzygium malaccense* and *Musa* sp. There was an active agriculture patch on the riverbank consisting of *Colocasia esculenta* (L.) Schott.

POOU had the narrowest channel width of 1.79 m. At this site, *Coffea* sp. had the highest ground flora, and *Pisonia cuspidata* Heimerl., a widespread species, had the highest importance value. Unique species included nine unidentified plants and one tree tentatively identified as

Xylosoma seemannii. *Ficus trigonata* L. and *Hypolytrum longifolium* (Rich.) Nees were also restricted to POOU. *H. longifolium* is found in moist, shady areas.

Summary of Environmental and Anthropogenic Characteristics of Riparian Zones

A total of six land use types were noted across the 36 sites. These were Developed (DE), water (WA), Secondary Vegetation (SV), Forest (FO), Agriculture (AG) and Grassland (GR). The only one instance of a WA site, was in block 5 of the AROL reach where the transect extended into a retention pond. The most commonly occurring land use was SV, found at 197 sample blocks, followed by FO at 142 blocks. Five of the seven blocks with 100% canopy closure blocks were in FO blocks. Of the 144 sample blocks with 0% canopy closure, 63 were agriculture blocks and 48 were grassland sample blocks. On a coarser scale, 15 of the 36 sites were classified as SV, seven were AG, nine were FO, four GR and one was DE. Seven of the SV sites were abandoned cocoa/coffee plantations. Agricultural sites were well-maintained, cultivated sites with little undergrowth and little canopy cover. They included papaya fields, citrus orchards and sugarcane fields. Five of the nine forested sites were in the South Geomorphological Unit.

Twenty-five of the 36 sites were on privately owned land. The public lands were in Forest Reserves, former State owned sugarcane estates or public recreational areas. None of the 36 sites had evidence of religious activities or groundwater abstraction. Twenty-one sites had evidence of recreational activities including hunting, fishing, bathing and camping. In particular, evidence of hunting was found at all Moruga sites in the Victoria Mayaro Forest Reserve in south Trinidad. Conspciuous fauna were present at nine sites including *Caiman crocodilus* (Caimans), *Alouatta seniculus* (Red Howler Monkey) sighted at LEBU and *Lontra longicaudis* (Otter) at ARIM. There were 22 polluted sites characterized by solid waste or a stench either in the riparian area or from the river. Twelve sites had evidence of fire.

The seven highest sites (elevation relative to sea level) were in the Northern Range. The four sample blocks with the highest elevation relative to the river channel were also in the Northern Range. The four steepest slopes across all blocks were in the Northern Range, all at block 1 sites on river channel margins. Five rivers had dry channel beds including, CUMU, LEBU, PENM, PENU and PENL. There was meandering at 14 sites and braided channels at four sites. There were no meandering river channels or dry riverbeds in the Northern Range. Twenty-three of the 36 sites had river discharges lower than 0.1 m^3, indicating near stagnant conditions. Only 10 of 36 sites and 17 of 180 blocks had gravel. Overall, the most common soil type was L'ebranche clay found at nine sites. This series is categorized as Aeric Tropaquepts under the USDA soil classification system and Dystric Gleysol under the FAO soil classification scheme (Paul 2001).

Summary of Plant Composition and Structure

Importance value, species richness and diversity

B. vulgaris had the highest basal area and subsequent relative coverage and importance value across all sites surveyed (total area=0.054 km^2) seen in Table 2-6. *Tectona grandis*, *Cecropia peltata* and *Theobroma cacao* followed in importance value. *B. vulgaris* was found at the greatest number of sites (15), giving rise to a relative frequency of 4.62%, whereas *Tectona grandis* was found only at one site with a relative frequency of 0.31%. *T. grandis* had the highest number of specimens (80), with a resulting relative density of 9.30%.

Among ground flora species, *Coffea* sp. had the highest relative coverage followed by the lycopod *Selaginella plana*, *J. secunda* and *Pueraria phaseoloides* (Table 2-7). *P. phaseoloides* was found at the greatest number of sites (18).

AROM had the highest overall species richness of all 36 sites (64) followed by NORU (60 species) and LEBU (58) species (Table 2-8). The lowest species richness was at SOUM, which had eight species. Both NORU and CAUM had the highest number of unique species (25), while CAUL had no unique species (Appendix F). Highest species diversity was at NORU, with a Shannon index value of 3.89, followed by LEBU and AROM, both with a value of 3.80. The lowest diversity (1.15) was at PENU. SOUM and SOUU also had low diversities of 1.48 and 2.1, respectively. Species richness and diversity per reach are provided in Table 2-8 along with most important tree species and ground flora plants with the highest percentage coverage. On a catchment basis, North Oropouche had the highest species richness (123), and South Oropouche had the lowest species richness of 43 species (See Table 2-9). The North Oropouche River also had the highest species diversity and the South Oropouche River the lowest (Table 2-10). In terms of geomorphological units, the North Unit had the highest species diversity (5.20) and the highest species richness (292 species) as seen in Table 2-11. The Wet Ecoregion had a higher species richness (351) and diversity (5.18) compared to 314 species and a diversity of 5.02 in the Dry Ecoregion. When combined, the six impacted catchments had a total species richness of 337 and diversity of 5.17, while the low impact catchments had a species richness of 323 and a diversity of 5.04 (Table 2-11).

Plant taxonomy

The Poaceae family had the most number of morphotypes (species and unidentified specimens) represented in the study (43). This was followed by Leguminosae (40), then Asteraceae and Rubiaceae, with 19 specimens each. *T. grandis* had the highest number of specimens (85) followed by *Mora excelsa* (73) and *B. vulgaris* (68). These numbers included both mature trees and seedlings of the species found in the ground flora. *P. phaseoloides* (Roxb.) Benth. had the next highest number of morphotyes (64). This is a ground flora species as is *Costus scaber*, which followed *P. phaseoloides* with 57 morphotyes.

Ninety-four plant families were identified across the island including eight fern families and one lycopod (Selaginellaceae). All other plants were angiosperms. Within the 94 plant families, there were 426 morphotypes, including family, generic and species level morphotypes as well as those morphotypes, with questionable identifications. These 426 morphotypes belonged to 330 species and 270 genera. The species list with plants identified to at least family level for all the sites surveyed is shown in Appendix A.

Twenty-eight of the species found are associated with rivers in Trinidad; 33 species have been previously found in swamps and six are found in both swamps and along rivers (Adams & Baksh-Comeau Unpublished). These species are highlighted in Table 2-12. Forty-nine plant species were introduced to Trinidad. These included agricultural crops, fruit trees, timber trees, forage grasses and ornamental plants. Only one of the plants found was endemic to Trinidad. This was *Philodendron krugii* Engl. found at the L'ebranche Upper Reach (LEBU), Aripo Upper Reach (ARIU) and Caura Upper Reach (CAUU) sites.

A total of 2894 plant specimens were found within the 36 study sites, distributed among 502 morphotypes. These specimens were sub-divided into 2034 ground flora specimens, 860 trees, and included 48 unidentified ground flora specimens (UG) and 36 unidentified tree (UT) morphotypes. All other specimens were identified to at least the family level.

Discussion

Anthropogenic Characteristics of Riparian Zones in Trinidad

Half of the catchments studied were categorized as having a low level of human impact based on forest cover (Table 2-1). However, of the 36 randomly chosen sites in the catchments, only nine were in forested areas. This could reflect the random site selection process, but it also may point to a high level of human interference along rivers in Trinidad. It may be that even in the less impacted catchments, riparian zones were preferred agricultural or settlement sites.

Riparian areas have traditionally been areas of high human interference worldwide especially for agriculture, settlement, transport and recreation (National Research Council 2002).

On a finer scale, human activity occurred in close proximity to the river margin at the sites. At agricultural sites, crops were found within the second block (10-20 m) of the 50 m transect, for example, *Saccharum officinarum* (Sugarcane) at the CAPU site. This may be due to, *inter alia*, an absence of national regulations regarding riparian setbacks or buffer zones, allowing agriculture, industry and housing to take place at the river's edge. The implication of human activity so close to the river channel margin is that vegetation collected during this study may be more reflective of land use practices and other human interference, than hydrological parameters, which are generally regarded as the major control on riparian vegetation composition and structure (Tabacchi et al. 1998). The relative importance of hydrological vs. anthropogenic variables will be explored further in Chapter 3. Apart from the direct replacement of riparian plants with agricultural crops, agricultural activity may also have indirect effects on vegetation. Sugarcane fields at SOUU and SOUM were sampled after fields were burnt, a practice that facilitates easier harvesting. At these agricultural sites, burning could also extend to non-cultivated riparian areas. Unplanned fires are also common in the dry season in Trinidad (Singh 2001) and may have altered plant species composition and structure at SV sites such as CAPM and POOU. Apart from agriculture, it appears that housing and urbanization may have also shaped riparian vegetation in Trinidad. For example, this was seen at CAUL, where roads and buildings replaced plants.

Past human activity may still be shaping riparian vegetation in Trinidad. Seven riparian sites were former cocoa plantations. In the case of the L'ebranche River, a low impact river (Table 2-1), all three reaches had abandoned cocoa plantations. Cocoa was an important agricultural crop in Trinidad during the early 20^{th} century, occupying approximately 90 000 hectares in 1917. The industry collapsed due to a combination of disease, unfavorable prices and competition from other countries (Bekele 2008). As a result, many estates were abandoned and are now secondary growth (SV) sites. The SV sites not only included abandoned cocoa estates, but also abandoned citrus fields at CUML and AROU. Agricultural abandonment is on the rise in Trinidad. Overall, the agricultural sector has been steadily declining and only contributed 0.6% to Trinidad's GDP in 2007 compared to a 62% contribution from the industrial sector (Central Intelligence Agency 2008).

Deliberate physical modification of sites could also have influenced the vegetation collected. At ARIM for instance, residents altered the riverbed to create pools for bathing. This could have also altered the flooding regime in this area and impacted riparian vegetation. At CAUM, there was direct plant removal for firewood and campsite construction. During sampling in 2007, dredging was taking place at CAPU and CAPL. Excavators deepened the river channel and cleared all vegetation within 20-30 m of the water margin. Sampling at these sites took place downstream of dredging activities, but based on the angular channel morphology and bare riverbank slopes at the actual transect points, it is likely that dredging took place at those points perhaps within the last 1-3 years. Regular channel modification could have resulted in the dominance of short lived or fast growing plant species at these riparian sites in response to continuous vegetation removal. Dredging is carried out regularly along rivers in Trinidad to reduce flooding in nearby settlements, but the absence of the normal flooding regime can alter riparian vegetation life history and distributional patterns (Freeman et al. 2003). Dredging can also block connections to backwaters and tributaries, again with possible changes in riparian plant species composition as well as riparian zone width and shape (Wissmar & Beschta 1998).

Forested sites were also not free from human impact. At FO sites along the Moruga River, there was evidence of hunting and timber harvesting. An oil pump was also located approximately 300 m from MORM. The PENM and PENL forest sites were close to skidder trails, and in the case of PENM, one of the vegetation transects bisected an abandoned marijuana field. Hunting trails, skidder trails and marijuana plots all resulted in direct removal of riparian vegetation at the sites studied. The high level of human impact at the study sites has implications for the selection of riparian reference systems for conservation purposes. This will be explored further in Chapter 3, but it should be noted here that there was evidence of either present or past human activities at all sites studied, thus, none can be regarded as pristine.

Environmental Characteristics of Riparian zones in Trinidad

Sampling was carried out during the dry season, thus the low discharges and dry riverbeds found were expected. For this reason, bankfull depth was also measured at each site to provide an indication of water levels during the rainy season. As was also expected, site elevation and slope values were highest along rivers of the Northern Range Geomorphological Unit. The soils parameters examined included chemical and physical variables that were likely to impact plant growth. Levels of the variables measured seemed generally to agree with typical values of major soil types found in the areas sampled (Brown & Bally 1968). The very high soil EC values at SOUL may be a sampling error. While estuarine areas were avoided in this study, SOUL may have been under tidal influence even though the site was more than 10 km away from the river mouth. High soil phosphates values at ARIM, may be linked to fertilizer application in the papaya field. High phosphates at COUM may be due to wastewater runoff from the house located uphill of the transects.

Generally speaking, riparian soil properties are shaped by both terrestrial and hydrological influences. Hydrology affects riparian soil through flooding and chemical exchange between the river channel and riparian zone via the hyporheic corridor (Boulton et al. 1998). However, sampling took place during the dry season when the rivers had low flow or stagnant pools. As a result, the influence of the hyporheic zone was probably minimal, especially as soil depths sampled were only 0-30 cm and 30-60 cm. It is likely; however, that past flooding events have influenced both physical and chemical properties of the soil. High sand levels at NORL, for instance, may be due to deposition of mined sand from farther upstream during past flooding events.

Riparian Plant Composition and Vegetation Types in Trinidad

There are about 2200 flowering plant species and 600 ferns recorded for Trinidad (Nelson 2004). During this study, 502 morphotypes were found, including 20 species of ferns and two lycopods. This is a relatively high number of species considering that the total sample area for all 36 sites was 0.054 km^2 compared to the total area of Trinidad, which is approximately 4800 km^2. High species richness is characteristic of riparian zones linked to great levels of physical heterogeneity and physical disturbance (Stanley 2001). The high number of species found during vegetation sampling may not only be linked to riparian characteristics, but also to variations in geomorphology and rainfall among sites. These possible variations were deliberately included in the sampling protocol to capture the range of potential riparian vegetation types. This will be analyzed in more detail in Chapter 3.

Typical riparian species for Trinidad will be designated after an examination of riparian environmental variables in Chapter 3. There is however, supporting information from herbarium records detailed in Adams & Baksh-Comeau (Unpublished), which identified possible riparian species, based on their distribution and growth habits. Table 2-12 highlights plant species from this study, which according to herbarium records, are associated with rivers and freshwater swamps in Trinidad. A number of species in Table 2-12 are weedy including *Commelina diffusa*, *C. erecta* and S*phenoclea zeylanica* Gaertn. Species such as *Spondias mombin*, *Acroceras zizanioides*, *Lasiacis ligulata* and *Renealmia alpinia* (Rottb.) are common in both riparian and disturbed areas. Weedy species were found along rivers even at forested sites, for example, *W. trilobata* found at MORM. Overall, 13 of the riparian species listed in Table 2-12 were grasses, including five introduced species.

Apart from herbarium records described in Adams & Comeau (Unpublished), there is some available literature on the geographic distribution of species collected in this study. For instance, Beard (1946) noted *Crudia glaberrima* (Steud.) J.F. Macbr. in swamp hollows and waterlogged areas around the Nariva freshwater swamp. *C. glaberrima* was found at CAPM in this study. *Pterocarpus officinalis*, which is also listed in Table 2-12, was found by Beard (1946) in large stands at the mouth of the North Oropouche river. However, in this study only one juvenile specimen was found at LEBU. Beard also noted the palms *Roystonea oleracea* (Jacq.) O.F. Cook and *Bactris major,* as well as the giant reed *Gynerium sagittatum* (Aubl.) P. Beauv. in what he classified as Palm Swamp vegetation. These were also found along rivers in this study along with *Lonchocarpus sericeus* (Poir.) Kunth ex DC., *Manilkara bidentata* (A. DC.) A. Chev., *Carapa guianensis* Aubl., *Virola surinamensis* (Rol. ex Rottb.) Warb. and *Calophyllum lucidum,* which Beard, (1946) also found in Palm Swamp vegetation.

Beard (1946) developed an in-depth classification of all vegetation in Trinidad. Nelson (2004) provided an update in 2004. Nelson (2004) landscape level vegetation groupings approximated Beard's associations. This discussion will focus more on Beard's work, as he provided more in-depth information about individual species distributions. Beard's vegetation type for each of the study sites is shown in Table 2-13. Twenty-three sites fell in the geographic range of Evergreen Seasonal Forest characterized by the *Carapa guianensis-Eschweilera* *subglandulosa* association. In the absence of removal and modification of Trinidad's natural vegetation, this association would cover most of the island. In this study, there were three forested (FO) sites found within the Evergreen Seasonal Forest geographic range, namely MORU, MORM and MORL. These fell specifically within the *Mora* faciation of Evergreen Seasonal Forest, which according to Beard (1946), consisted of almost monotypic stands of *Mora excelsa*. Other common species listed for this faciation were *C. guianensis*, *Swartzia pinnata* (Vahl) Willd. and *Brownea latifolia* Jacq. It was noted; however, that these species were found at less than 0.16 the density of *M. excelsa* (Beard 1946). Beard (1946) also found *Bactris major* and *Ischnosiphon arouma* in *Mora* forest understorey. All of the aforementioned species were found at the Moruga sites during this project, and *M. excelsa* did dominate both the tree and ground flora at these sites.

None of the other FO sites fell within the geographic range of Evergreen Seasonal Forest; however, there appeared to be some remnant forest species at some of the Abandoned Vegetation/Secondary Vegetation (SV) sites. For example, POOM had *Brownea latifolia* and POOU had *Pentaclethra macroloba* (Willd.) Kuntze, both common in Evergreen Seasonal Forest. These species may have been deliberately or accidentally retained during land clearing for agriculture, or have since reestablished at sites after agricultural abandonment.

According to Beard (1946), most of the Northern Range is covered in Lower Montane Forest. This forest type was characterized by *Licania ternatensis* Hook. f. ex Duss and *Byrsonima spicata* (Cav.) DC; however, none of these species were found in this study. At the Northern Range FO site CAUM, *Terminalia amazonia* (J.F. Gmel.) Exell, *Pouteria minutiflora* (Britton) Sandwith and *Hirtella racemosa* Lam. were identified. Beard (1946) noted these species in Lower Montane Forest but at lower densities than *L. ternatensis* and *B. spicata*. *T.*

amazonia was also found at two SV sites in the Northern Range. Another Lower Montane species *Chimarrhis cymosa* was found at the SV site NORU.

Sites PENU, PENM and PENL were located in Semi Evergreen forest, specifically, the *Bravaisia* faciation (Beard 1946). Beard (1946) noted the presence of the following species: *Bravaisia integerrima*, *Brosimum alicastrum* SW, Standl., *Hura crepitans*, various Inga sp., *Coccoloba venosa* L., *Brownea latifolia* and *Bursera simaruba.* These were also found during field sampling for this study. Beard (1946) also found *Symphonia globulifera* L. f., *V. surinamensis* and *Manicaria saccifera* Gaertn. along rivers in Trinidad. *S. globulifera* was not found in this study, but *V. surinamensis* was found at POOU, CAUM and NORL. *M. saccifera* was found at NORU. Adams & Comeau (Unpublished) also listed *V. surinamensis* as a riparian species. *Erythrina glauca* was noted as common in lowland swamps and along rivers in Trinidad by Feinsinger et al. (1982) and Adams & Baksh-Comeau (Unpublished). The latter also mentioned that *E. glauca* was introduced to Trinidad as a shade tree for lowland cocoa plantations and has since become naturalized and widespread along rivers. While no supporting documentation has been found, it is commonly known that *Bambusa vulgaris* is abundant along rivers in Trinidad, having been planted for riverbank stabilization (Forestry Division pers. comm.).

Of the 502 morphotypes collected, not all may be specific to riverbanks. *Carapa guianensis,* for instance, is a type species for Evergreen Seasonal Forest, the most common forest type in Trinidad (Beard 1946). *Manilkara bidentata* is abundant in Littoral Woodland along the coastline (Beard 1946). In addition, a number of agricultural plants were found at the study sites, the result of human influence, rather than naturally occurring patterns and processes.

Some species found in this study were also documented in riparian vegetation in the Caura River Basin, Bolivar State, in neighboring Venezuela (Rosales et al. 2003). Rosales et al. (2003) noted the presence of *Myrcia splendens* (Sw.) DC. and *Vismia* sp. at the river channel margin among the group of early successional riparian plants. *M. splendens* was only found at POOL in this study, but it was located in the transect block at the water's edge. *Vismia cayennensis* (Jacq.) Pers. was found at AROU in block 1, and *Vismia laxiflora* Reichardt was found at NORL in block 4 and ARIL in block 1. Rosales et al. (2003) also noted an abundance of ferns in the Caura River Basin, which they linked to high understory humidity. In addition, Rosales et al. (2003) found an abundance of vines and reeds in both disturbed riparian areas and areas with poor drainage. In this study, vines such as *Ipomea* sp., *Merremia umbellata* (L.) Hallier f. and the reed *G. sagittatum* were abundant at the swampy ARIL site.

Rosales et al. (2003) described a high incidence of palms like *Attalea maripa* (Aubl.) Mart, *Euterpe precatoria* and *Desmoncus* sp. in flooded forests of the Caura River Basin. All palms were found at riparian sites in Trinidad; however, *A. maripa* is more associated with disturbed, fire affected areas in this country (Adams & Baksh-Comeau Unpublished). Rosales et al. (2003) also found *Eschweilera subglandulosa*, *Schefflera morototoni* (Aubl.) Maguire, Steyerm. & Frodin and *Virola surinamensis.* All three were found in Trinidad in this study. They also noted that the riparian forest floor along the Caura River was comprised of the following genera: *Piper* sp., C*ostus* sp., *Heliconia* sp., *Renealmia* sp., *Eugenia* sp., *Tabermontana* sp., *Miconia* sp. and *Psychotria* sp. These were also found during this study (Appendix A). The apparent similarity in riparian flora between Trinidad and Venezuela, is in keeping with the strong floristic affinity between Trinidad and South America (Beard 1946)

From the above discussion, it is evident that common forest species are also found at riparian sites. Some specimens of *Brownea latifolia*, *C. guianensis*, *Eschweilera subglandulosa* and *Pentaclethra macroloba* were even found in block 1 of the transects at the water's edge. This may mean that these forest species can tolerate a wide range of conditions, or it may be that the riparian zone in Trinidad is very narrow allowing forest species to survive close to the river's edge.

Riparian Vegetation Structure

Bambusa vulgaris had the highest importance value of trees sampled. This is based largely on its high relative coverage value of 99.12%. The relative coverage values were due to the growth habit of *B. vulgaris,* which formed large stands where found. In the case of CAUU, there was a single cluster of 500 culms with an average DBH of 10 cm. *Tectona grandis* had the second highest importance value. It was only found at one site in a teak plantation but occurred there in very high numbers, as would be expected. *Spondias mombin* and *Theobroma cacao* had the 4th and 5th highest importance values of all the trees found. All of these species are introduced to Trinidad. *B. vulgaris* and *S. mombin* are widespread and naturalized in Trinidad, (Adams & Baksh-Comeau Unpublished), but the other two species appear to be limited to areas where they are planted.

The native species *Cecropia peltata* had the third highest importance value, and two other native species *Mora excelsa* and *Andira inermis* (W. Wright) Kunth ex DC. had the 6th and 7th highest values, respectively. The high importance value of *M. excelsa* was expected given its presence at sites that fall within the geographic range of the *Mora* faciation of Evergreen Seasonal Forest.

Exotic species such as *Coffea* sp. and *Pureraria phaseoloides* dominated the ground flora. *Coffea* sp. had the highest relative coverage value and was found at SV sites. *P. phaseoloides* is an exotic species found at SV and AG sites. Generally, it appears that exotic species are common and abundant at riparian sites in Trinidad. This will be explored further in Chapter 3.

Sites with the highest levels of richness and diversity appear to be SV areas. In particular, AROM is in the early stages of regeneration, and it may be that open conditions and relatively high light levels promote the growth of a high number of agricultural seedlings and weedy species. This in turn yielded high richness. It has been suggested that in some cases, high richness and diversity in riparian areas may be facilitated by an abundance of exotics (Naiman et al. 2000). This may be the case in Trinidad, where high species richness was found in the SV sites, which had a combination of native and introduced species.

The low diversity and richness sites were mostly agricultural areas where ground flora is heavily managed or removed. Sugarcane sites SOUU and SOUM were burnt as part of the harvesting process, and when the sites were sampled, regeneration of sugarcane and weeds had just begun. Even sites where sugarcane was not burnt, there was low richness and diversity due to the dominance of sugarcane. In the case of CUMM, the ground flora largely consisted of lawn grass (*Axonopus compressus*) which appeared to be regularly mowed.

Riparian Zone Delineation

Naiman et al. (2005) defined the riparian zone as the area extending from the water's edge to areas beyond the bank that either experience flooding or have elevated soil water levels. In this study vegetation was surveyed at each site along 50 m transects running from the water's edge perpendicular to the river channel. A 50 m vegetation transect length was used as this encompassed and exceeded the width of the flooded areas observed during preliminary site visits during the rainy seasons of 2005 and 2006.

While 50 m was the initial conservative estimate of riparian zone width, a revised width of 30 m is suggested for Trinidad based on riparian zone delineation factors such as height relative to surface water level, stream size, location in the watershed, and evidence of frequent erosion and deposition along the riverbanks as suggested by Naiman et al. (2005) and Drucker et al. (2008). While riparian zone width varied from site to site depending on the aforementioned factors, a 30 m cutoff included the range of possible riparian zone widths in Trinidad from small, narrow rivers in upper reaches to large wide rivers in lower reaches. The 30 m cutoff eliminated sample blocks 6 m above the channel margin, which were unlikely to be flooded or have elevated water tables even during higher discharges in the rainy season. Naiman et al. (2005) also suggested that the presence of wetland herbaceous flora was a good delineator of riparian zones. While this is the first in-depth study of riparian vegetation of Trinidad, a 30 m riparian zone included plants noted in Adams & Baksh-Comeau (Unpublished), as common along rivers and wetlands in Trinidad.

Riparian vegetation buffers are used in managing river water quality as explained earlier in this chapter. Mean riparian buffer width in the United States for streams >5 m wide was 28.1 m and the equivalent in Canada was 43.8 m (Lee & Smyth 2004). For streams less than or equal to 5 m in width the mean riparian buffer width was 21.8 m and 29.6 m for the United States and Canada, respectively (Lee & Smyth 2004). Wenger (1999) advocated a 30 m buffer as a good rule of thumb for riparian buffers for sediment retention. While there has been much work on determining suitable riparian buffer widths for river water quality, more recently researchers are focusing on protecting “active river areas” including riparian zones as part of overall river management schemes (Smith & Schiff 2008). For Trinidad this will include the 30 m riparian zone delineated

Summary

The baseline data in this chapter help fill the information gap on Caribbean island riparian zones. In general, riparian trends from research in North America, Europe and South America appear relevant to small islands like Trinidad. For example, high plant biodiversity and a prevalence of exotic species were noted in this study. Trinidad riparian zones are environmentally heterogenous and heavily impacted by anthropogenic influences as is the general pattern. It may be that anthropogenic influences are even more pronounced on small island settings due to limited land area. This study also recognizes a riparian zone width of 30 m for Trinidad, which can be used as the basis for establishing riparian buffers or “active river areas”.

Table 2-1. Rivers used in the study

Ecoregion	Level of human impact (based on 1994 land use data)	Geomorphological area	Catchment /River	Catchment forest cover in 1994 (%)	Catchment forest cover in 2001 (%)
Dry	High	Northern Range	Arouca	34	51
	(<40% forest cover)	Central Plain	Couva	17	22
		Southern Plain	South Oropouche	31	39
	Low	Northern Range	Caura	66	73
	(>40% forest cover)	Central Plain	Caparo	43	51
		Southern Plain	Penal (Grande Riviere River)	63	72
Wet	High	Northern Range	Aripo	54	66
	(<60% forest cover)	Central Plain	Cumuto	48	84
		Southern Plain	Poole	53	77
	Low	Northern Range	North Oropouche	75	95
	(>60% forest cover)	Central Plain	L'ebranche	62	86
		Southern Plain	Moruga	84	91

Table 2-2. Environmental and anthropogenic data collected

Variable category	Variable type	Variable
Anthropogenic	Metric	Percentage forest cover in watershed (1994 and 2001 data)
Anthropogenic	Metric	Distance from sample point to nearest paved road
Anthropogenic	Categorical	Land ownership: private vs. public
Anthropogenic	Categorical	Presence/absence of recreational activities
Anthropogenic	Categorical	Presence/absence of fire
Anthropogenic	Categorical	Presence/absence of cultural/religious activities
Anthropogenic	Categorical	Major land cover per reach
Anthropogenic	Categorical	Presence/absence of drainage works, for example, channelization or dredging
Anthropogenic	Categorical	Presence/absence of surface water abstraction.
Anthropogenic	Categorical	Presence/absence of groundwater abstraction.
Anthropogenic	Categorical	Presence/absence of maintenance, for example, clearing of the sides of the roads
Anthropogenic	Categorical	Evidence of pollution
Anthropogenic	Categorical	Land cover per 10 x 10 m transect block
Hydrological	Metric	Mean bankfull depth
Hydrological	Metric	Mean riverbank slope
Hydrological	Metric	Mean channel width
Hydrological	Metric	Mean bankfull width
Hydrological	Metric	Mean river velocity
Hydrological	Metric	Mean river discharge
Terrestrial	Metric	Catchment length
Terrestrial	Metric	Catchment shape
Terrestrial	Metric	Catchment relief
Terrestrial	Metric	Catchment area
Terrestrial	Categorical	Major soil type
Terrestrial	Metric	Elevation above sea level
Terrestrial	Categorical	Evidence of braiding
Terrestrial	Categorical	Evidence of meandering
Terrestrial	Categorical	Presence/absence of animal activities
Terrestrial	Metric	Distance of sample point from water's edge
Terrestrial	Metric	Riverbank length
Terrestrial	Metric	Elevation above water margin
Terrestrial	Metric	Slope
Terrestrial	Metric	Canopy closure
Terrestrial	Metric	Soil organic carbon content (0-30 cm and 30-60 cm)
Terrestrial	Metric	Soil total nitrogen (0-30 cm and 30-60 cm)
Terrestrial	Metric	Soil plant available phosphates (0-30 cm and 30-60 cm)
Terrestrial	Metric	Soil calcium (0-30 cm and 30-60 cm)
Terrestrial	Metric	Soil potassium (0-30 cm and 30-60 cm)
Terrestrial	Metric	Soil particle size (% sand, silt, clay and gravel) (0-30 cm only)
Terrestrial	Metric	Soil electroconductivity (EC) (0-30 cm and 30-60 cm)
Terrestrial	Metric	Soil magnesium (0-30 cm and 30-60 cm)

Table 2-3. Summary of block and site level metric data

	Maximum	Minimum	Mean
Elevation above sea level (m)	228.60	2.30	46.30
Discharge (m^3)	6.42	0.00	0.48
Bank slope	-14.00	-50.67	-28.85
Channel width (m)	24.36	1.79	5.99
Bankfull width (m)	31.67	5.20	15.97
Bankfull length (m)	2535.33	143.33	730.78
Bankfull depth (m)	11.29	0.84	3.91
Canopy closure (%)	100.00	0.16	59.28
Cumulative elevation (m)	26.10	-2.79	5.32
Slope	29.00	-57.00	-8.47
Distance from paved roads (m)	3000.00	5.00	403.14
Soil pH (30 cm)	8.19	3.81	5.76
Soil nitrogen (30 cm) (g kg^{-1})	36.00	0.20	4.67
Soil phosphates (30 cm) (mg kg^{-1})	151.00	1.00	11.73
Soil potassium (30 cm) (c mol kg^{-1})	0.21	0.01	0.04
Soil calcium (30 cm) (c mol kg^{-1})	26.01	0.32	7.55
Soil magnesium (30 cm) (c mol kg^{-1})	7.79	0.04	2.11
Soil electroconductivity (30 cm) (mS cm^{-1})	9.60	0.06	0.34
Soil organic carbon (30 cm) (g kg^{-1})	89.00	0.00	26.48
Soil pH (60 cm)	8.11	3.94	5.63
Soil nitrogen (60 cm) (g kg^{-1})	23.00	0.10	3.46
Soil phosphates (60 cm) (mg kg^{-1})	78.00	1.00	8.88
Soil potassium (60 cm) (c mol kg^{-1})	0.15	0.01	0.03
Soil calcium (60 cm) (c mol kg^{-1})	26.69	0.04	6.26
Soil magnesium (60 cm) (c mol kg^{-1})	8.34	0.03	1.90
Soil electroconductivity (60 cm) (mS cm^{-1})	7.85	0.01	0.25
Soil organic carbon (60 cm) (g kg^{-1})	48.00	0.00	16.98
Soil% clay	66.68	1.30	20.63
Soil% sand	83.97	3.10	38.86
Soil% silt	70.72	0.90	37.36
Soil% gravel	63.98	0.00	3.15

Table 2-4. Summary of site level categorical data

Site	Land use	Land use 50 -100 m	Land ownership	Hunting/ recreation activities	Cultural/ religious activities	Human modification of channel	Surface water Abstraction	Maintenance activities	Pollution	Animals	Fire
ARIL	GR	FO	PU	Y	N	N	N	N	N	N	N
ARIM	AG	AG	PR	Y	N	Y	Y	N	Y	Y	N
ARIU	FO	AG	PR	Y	N	Y	N	N	Y	N	N
AROL	GR	DE	PR	N	N	Y	N	Y	Y	N	N
AROM	SV	SV	PR	Y	N	N	N	N	Y	N	N
AROU	SV	SV	PR	Y	N	N	N	N	Y	N	N
CAPL	GR	AG	PU	N	N	Y	N	N	Y	N	Y
CAPM	SV	GR	PR	Y	N	Y	N	N	Y	Y	Y
CAPU	AG	AG	PR	N	N	Y	N	N	Y	N	Y
CAUL	DE	DE	PU	Y	N	Y	N	N	Y	N	Y
CAUM	FO	FO	PR	Y	N	N	N	N	Y	N	N
CAUU	SV	SV	PU	Y	N	N	N	N	N	N	N
COUL	FO	AG	PU	N	N	N	N	N	Y	N	Y
COUM	SV	DE	PR	N	N	N	N	N	Y	N	Y
COUU	SV	SV	PR	Y	N	N	N	N	Y	N	N
CUML	SV	SV	PR	N	N	N	N	N	N	Y	N
CUMM	AG	AG	PR	N	N	Y	N	N	N	N	N
CUMU	AG	AG	PR	N	N	N	N	N	N	N	N
LEBL	SV	SV	PR	N	N	N	N	Y	Y	N	N
LEBM	SV	SV	PR	N	N	N	N	N	Y	N	N
LEBU	SV	SV	PR	N	N	N	N	N	N	Y	N

ARI=Aripo, ARO=Arouca, CAP=Caparo, CAU=Caura, CUM=Cumuto, COU= Couva, LEB=L'ebranche, MOR=Moruga, NOR=North Oropouche, PEN=Penal, POO=Poole, SOU=South Oropouche, L=Lower Reach, M=Middle Reach, U=Upper Reach. DE=Developed (Buildings, roads, playgrounds present. Site may be landscaped.), SV=Secondary Vegetation (Evidence of past or present land conversion. Trees and remnant agricultural species may be present. No sign of active maintenance of the site), FO=Forest (No past or present human driven land conversion evident. Both trees and ground flora present. Natural bodies of water, for example, ponds may also be present), Ag=Agriculture (Agricultural crops present, active maintenance of site, for example, lawn mowing or weeding), GR=Grassland (No trees, no agriculture. Some ground cover present. No site maintenance, for example, lawn mowing evident). Y=Yes, N=No, PU=Public, PR=Private,

Table 2-4. Continued

Site	Land use	Land use 50 -100 m	Land ownership	Hunting/ recreation activities	Cultural/ religious activities	Human modification of channel	Surface water abstraction	Maintenance activities	Pollution	Animals	Fire
MORL	FO	FO	PU	Y	N	N	N	N	N	N	N
MORM	FO	FO	PU	Y	N	N	N	N	N	N	N
MORU	FO	FO	PU	Y	N	N	N	N	N	N	N
NORL	SV	AG	PR	Y	N	Y	N	N	Y	Y	N
NORM	GR	GR	PR	N	N	N	N	N	Y	N	Y
NORU	FO	FO	PR	Y	N	N	N	N	N	N	N
PENL	FO	FO	PU	Y	N	N	N	N	N	N	N
PENM	FO	FO	PU	Y	N	N	N	N	N	N	Y
PENU	AG	AG	PU	Y	N	N	N	N	N	N	Y
POOL	SV	FO	PR	Y	N	N	N	N	Y	Y	N
POOM	SV	SV	PR	Y	N	N	N	N	N	Y	N
POOU	SV	SV	PR	N	N	N	N	N	Y	Y	Y
SOUL	SV	DE	PR	Y	N	Y	N	N	Y	Y	Y
SOUM	AG	DE	PR	N	N	Y	N	N	Y	N	Y
SOUU	AG	AG	PR	N	N	N	N	N	Y	N	Y

ARI=Aripo, ARO=Arouca, CAP=Caparo, CAU=Caura, CUM=Cumuto, COU= Couva, LEB=L'ebranche, MOR=Moruga, NOR=North Oropouche, PEN=Penal, POO=Poole, SOU=South Oropouche, L=Lower Reach, M=Middle Reach, U=Upper Reach. DE=Developed (Buildings, roads, playgrounds present. Site may be landscaped.), SV=Secondary Vegetation (Evidence of past or present land conversion. Trees and remnant agricultural species may be present. No sign of active maintenance of the site), FO=Forest (No past or present human driven land conversion evident. Both trees and ground flora present. Natural bodies of water, for example, ponds may also be present), Ag=Agriculture (Agricultural crops present, active maintenance of site, for example, lawn mowing or weeding), GR=Grassland (No trees, no agriculture. Some grond cover present. No site maintenance, for example, lawn mowing evident). Y=Yes, N=No, PU=Public, PR=Private

Table 2-5. Catchment characteristics

Catchment	Maximum basin relief (m)	Catchment length (km)	Relief ratio (height/ length)	Area (km^2)	Form factor (area/length^2)	% forest cover (1994)	% forest cover (2001)
Aripo	787.40	14.39	0.055	52.68	0.25	53.85	66.19
Arouca	647.97	14.77	0.044	59.40	0.27	34.24	50.60
Caparo	73.15	24.07	0.003	96.72	0.17	43.24	50.90
Caura	647.97	14.06	0.046	48.49	0.25	65.85	72.80
Couva	88.39	18.52	0.005	193.32	0.56	16.51	22.20
Cumuto	85.34	17.47	0.005	86.57	0.28	47.75	83.60
L'ebranche	68.00	9.36	0.007	47.09	0.54	62.49	85.50
Moruga	245.67	18.32	0.013	237.36	0.71	83.82	90.60
North Oropouche	647.97	20.61	0.031	139.37	0.33	75.37	94.86
Penal	245.67	6.62	0.037	80.35	1.83	62.84	72.00
Poole	68.00	32.70	0.002	188.24	0.18	52.72	76.70
South Oropouche	162.73	25.07	0.006	438.67	0.70	30.60	38.87

Table 2-6. Relative Coverage, Density, Frequency and Importance Value (IV) of the Tree Species at all 36 sites

Species	Relative coverage (%)	Relative density (%)	Relative frequency (%)	IV (%)
Bambusa vulgaris Schrad. ex J.C. Wendl.	99.12	6.51	4.62	110.25
Tectona grandis L. f.	0.04	9.30	0.31	9.65
Cecropia peltata L.	0.02	4.42	4.31	8.75
Theobroma cacao L.	0.01	5.47	2.46	7.94
Spondias mombin L.	0.07	2.91	4.00	6.98
Mora excelsa Benth.	0.07	5.12	0.92	6.11
Andira inermis (W. Wright) Kunth ex DC.	0.03	2.56	1.85	4.43
Swartzia pinnata (Vahl) Willd.	0.02	2.79	1.54	4.35
Inga ingoides (Rich.) Willd.	0.01	2.09	1.85	3.95
Citrus sp.	0.00	1.86	1.85	3.71
Erythrina poeppigiana (Walp.) O.F. Cook	0.06	1.74	1.85	3.65
Erythrina glauca Willd.	0.02	1.16	1.85	3.03
Lonchocarpus sericeus (Poir.) Kunth ex DC.	0.02	1.16	1.85	3.03
Syzygium malaccense (L.) Merr. & L.M. Perry	0.01	1.28	1.54	2.82
Cordia collococca L.	0.01	1.51	1.23	2.75
Lonchocarpus heptaphyllus (Poir.) DC.	0.01	1.74	0.92	2.68
Hura crepitans L.	0.01	1.16	1.23	2.41
Guazuma ulmifolia Lam.	0.01	1.40	0.92	2.33
Brownea latifolia Jacq.	0.00	1.05	1.23	2.28
Musa sp.	0.00	1.63	0.62	2.25
Brosimum alicastrum SW.	0.00	0.93	1.23	2.16
Syzygium cumini (L.) Skeels	0.08	1.16	0.92	2.16

Only species with an importance value greater than 1% are listed. Species are listed in order of descending IV

Table 2-6. Continued

Species	Relative coverage (%)	Relative density (%)	Relative frequency (%)	IV (%)
Attalea maripa (Aubl.) Mart.	0.01	0.81	1.23	2.05
Cupania americana L.	0.00	0.81	1.23	2.05
Ochroma pyramidale (Cav. ex Lam.) Urb.	0.00	0.81	1.23	2.05
Bravaisia integerrima (Spreng.) Standl.	0.03	1.05	0.92	2.00
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	0.01	1.05	0.92	1.98
Sabal mauritiiformis (H. Karst.) Griseb. & H. Wendl.	0.00	1.05	0.92	1.97
Eschweilera subglandulosa (Steud. ex O. Berg) Miers	0.00	1.05	0.92	1.97
Casearia guianensis (Aubl.) Urb.	0.00	0.70	1.23	1.93
Roystonea oleracea (Jacq.) O.F. Cook	0.01	0.81	0.92	1.75
Mangifera indica L.	0.01	0.81	0.92	1.75
Sterculia pruriens (Aubl.) K. Schum.	0.01	0.81	0.92	1.74
Artocarpus altilis (Parkinson) Fosberg	0.01	0.81	0.92	1.74
Guarea guidonia (L.) Sleumer	0.00	0.70	0.92	1.63
Carica papaya L.	0.00	1.28	0.31	1.59
Ficus maxima Mill.	0.01	0.58	0.92	1.52
Castilla elastica Sessé ex Cerv.	0.00	0.58	0.92	1.51
Pisonia cuspidata Heimerl	0.01	1.16	0.31	1.48
Pachira insignis (Sw.) Sw. ex Savigny	0.01	0.81	0.62	1.44
Genipa americana L.	0.01	0.47	0.92	1.39
Chrysophyllum cainito L.	0.01	0.70	0.62	1.33
Rollinia exsucca (DC. ex Dunal) A. DC.	0.00	0.35	0.92	1.28
Zanthoxylum sp.	0.00	0.35	0.92	1.27

Only species with an importance value greater than 1% are listed. Species are listed in order of descending IV

Table 2-6. Continued

Species	Relative coverage (%)	Relative density (%)	Relative frequency (%)	IV (%)
Chrysophyllum argenteum Jacq.	0.00	0.35	0.92	1.27
Ficus broadwayi Urb.	0.00	0.58	0.62	1.20
Terminalia amazonia (J.F. Gmel.) Exell	0.00	0.58	0.62	1.20
Eugenia procera (Sw.) Poir.	0.00	0.58	0.62	1.20
Dipteryx odorata (Aubl.) Willd.	0.01	0.47	0.62	1.09
Virola surinamensis (Rol. ex Rottb.) Warb.	0.00	0.47	0.62	1.08
Carapa guianensis Aubl.	0.00	0.47	0.62	1.08
Swietenia macrophylla King	0.00	0.70	0.31	1.01

Only species with an importance value greater than 1% are listed. Species are listed in order of descending IV

Table 2-7. Species with the 20 highest relative coverage values in the ground flora.

Species	Relative coverage (%)
Coffea sp.	5.21
Selaginella plana (Desv. ex Poir.) Hieron.	3.46
Justicia secunda Vahl	3.44
Pueraria phaseoloides (Roxb.) Benth.	3.44
Heliconia bihai or *spatho-circinada*	3.39
Saccharum officinarum L.	3.16
Axonopus compressus (Sw.) P. Beauv.	3.00
Paspalum fasciculatum Willd. ex Flüggé	2.92
Mora excelsa Benth.	2.87
Costus scaber Ruiz & Pav.	2.27
Flemingia strobilifera (L.) R. Br.	2.12
Poaceae	2.10
Bactris major Jacq.	1.89
Scleria melaleuca Rchb. ex Schltdl. & Cham.	1.77
Sorghum sp.	1.55
Pachystachys coccinea (Aubl.) Nees	1.54
Dieffenbachia seguine (Jacq.) Schott	1.48
Blechum pyramidatum (Lam.) Urb.	1.21
Bambusa vulgaris Schrad. ex J.C. Wendl.	1.04
Cynodon dactylon (L.) Pers.	0.93

Table 2-8. Diversity, species richness, most important tree species and highest percentage cover ground flora species

Site	S	H'(loge)	Highest tree importance value	Highest percentage cover ground flora species
ARIL	36	3.09	*Erythrina glauca* Willd.	*Ipomea* sp.
ARIM	54	3.72	*Carica papaya* L.	*Parthenium hysterophorus* L.
ARIU	36	3.30	*Erythrina poeppigiana* (Walp.) O.F. Cook	*Selaginella plana* (Desv. ex Poir.) Hieron.
AROL	27	3.08	No trees	*Sorghum* sp.
AROM	64	3.79	*Mangifera indica* L.	*Scleria melaleuca* Rchb. ex Schltdl. & Cham.
AROU	42	3.29	*Cecropia peltata* L.	*Pachystachys coccinea* (Aubl.) Nees
CAPL	20	2.71	No trees	Poaceae
CAPM	26	2.90	*Syzygium cumini* (L.) Skeels	*Flemingia strobilifera* (L.) R. Br.
CAPU	26	2.86	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Saccharum officinarum* L.
CAUL	13	2.37	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Axonopus compressus* (Sw.) P. Beauv.
CAUM	52	3.67	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Attalea maripa* (Aubl.) Mart.
CAUU	35	3.26	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Selaginella plana* (Desv. ex Poir.) Hieron.
COUL	20	2.55	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Flemingia strobilifera* (L.) R. Br.
COUM	36	3.32	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Flemingia strobilifera* (L.) R. Br.
COUU	34	3.15	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Pueraria phaseoloides* (Roxb.) Benth.
CUML	43	3.44	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Justicia secunda* Vahl
CUMM	15	2.28	*Citrus* sp.	*Axonopus compressus* (Sw.) P. Beauv.
CUMU	41	3.56	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Justicia secunda* Vahl
LEBL	43	3.57	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Heliconia bihai or spatho-circinada*
LEBM	28	2.90	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Heliconia bihai or spatho-circinada*
LEBU	58	3.80	*Ficus maxima* Mill.	*Costus scaber* Ruiz & Pav.
MORL	47	3.43	*Mora excelsa* Benth.	*Leptochloa* sp.
MORM	33	2.83	*Mora excelsa* Benth.	*Mora excelsa* Benth.
MORU	32	2.80	*Mora excelsa* Benth.	*Mora excelsa* Benth.
NORL	48	3.66	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Pueraria phaseoloides* (Roxb.) Benth.
NORM	31	3.20	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Panicum maximum* Jacq.

ARI=Aripo, ARO=Arouca, CAP=Caparo, CAU=Caura, CUM=Cumuto, COU=Couva, LEB=L'ebranche, MOR=Moruga, NOR=North Oropouche, PEN=Penal, POO=Poole, SOU=South Oropouche, L=Lower Reach, M=Middle Reach, U=Upper Reach S=species richness H'(loge)= Diversity

Table 2-8. Continued

Site	S	H'(loge)	Highest tree importance value	Highest percentage cover ground flora species
NORU	60	3.89	*Hieronyma laxiflora* (Tul.) Müll. Arg.	*Coffea* sp.
PENL	37	3.25	*Bravaisia integerrima* (Spreng.) Standl.	*Paullinia leiocarpa* Griseb.
PENM	40	3.42	*Bravaisia integerrima* (Spreng.) Standl.	*Bactris major* Jacq.
PENU	13	1.15	*Tectona grandis* L. f.	*Bactris major* Jacq.
POOL	46	3.60	*Erythrina poeppigiana* (Walp.) O.F. Cook	*Coffea* sp.
POOM	38	3.29	*Bambusa vulgaris* Schrad. ex J.C. Wendl.	*Heliconia bihai or spatho-circinada*
POOU	43	3.42	*Pisonia cuspidata* Heimerl	*Coffea* sp.
SOUL	30	3.16	*Bambusa vulgaris* Schrad. ex J.C. Wendl.	*Saccharum officinarum* L.
SOUM	8	1.48	*Erythrina glauca* Willd.	Acroceras zizanioides (Kunth) Dandy
SOUU	14	2.10	*Sapindus saponaria* L. .	*Saccharum officinarum* L.

ARI=Aripo, ARO=Arouca, CAP=Caparo, CAU=Caura, CUM=Cumuto, COU=Couva, LEB=L'ebranche, MOR=Moruga, NOR=North Oropouche, PEN=Penal, POO=Poole, SOU=South Oropouche, L=Lower Reach, M=Middle Reach, U=Upper Reach S=species richness H'(loge)= Diversity

Table 2-9. Catchment species richness (trees and ground flora)

	Dry Ecoregion		Wet Ecoregion	
	Low Impact	High Impact	Low Impact	High Impact
Geomorphological Unit				
North	93 (Caura)	117 (Arouca)	123 (North Oropouche)	106 (Aripo)
Central	69 (Caparo)	62 (Couva)	93 (L'ebranche)	83 (Cumuto)
South	73 (Penal)	43 (South Oropouche)	95 (Moruga)	100 (Poole)

Table 2-10. Catchment species diversity (trees and ground flora).

	Dry Ecoregion		Wet Ecoregion	
	Low Impact	High Impact	Low Impact	High Impact
Geomorphological Unit				
North	4.23 (Caura)	4.37 (Arouca)	4.56 (North Oropouche)	4.29 (Aripo)
Central	3.72 (Caparo)	3.68 (Couva)	4.05 (L'ebranche)	4.02 (Cumuto)
South	3.35 (Penal)	3.16 (South Oropouche)	3.68 (Moruga)	4.16 (Poole)

Table 2-11. Richness and diversity by Geomorphological Unit, Ecoregion and Level of catchment human impact

	Species richness	Species diversity
North Geomorphological Unit	292	5.20
Central Unit	209	4.72
South Unit	228	4.66
Dry Ecoregion	314	5.02
Wet Ecoregion	351	5.18
High human impact	337	5.17
Low human impact	323	5.04

Table 2-12. Species found in this study, which are known to be associated with rivers or swamps according to Adams & Baksh-Comeau (Unpublished)

Species
Mimosa pigra L.
Pterolepis glomerata (Rottb.) Miq.
Combretum fruticosum (Loefl.) Stuntz
Lomariopsis japurensis (Mart.) J.Sm.
Acroceras zizanioides (Kunth) Dandy
Calathea lutea Schult.
Commelina diffusa Burm. f.
Commelina erecta L.
Cyclanthus bipartitus Poit
Cyperus luzulae (L.) Rottb. ex Retz.
Cyperus surinamensis Rottb.
Dichanthium caricosum (L.) A. Camus
Faramea occidentalis (L.) A. Rich
Gynerium sagittatum (Aubl.) P. Beauv.
Heliconia bihai (L.) L.
Hymenachne amplexicaulis (Rudge) Nees
Hymenocallis tubiflora Salisb.
Hypoderris brownii J.Sm.
Isertia parviflora Vahl
Justicia comata (L.) Lam.
Leptochloa ?longa
Pachystachys coccinea (Aubl.) Nees
Palicourea crocea (Sw.) Roem. & Schult.
Panicum ?frondescens
Paspalum fasciculatum Willd. ex Flüggé
Pennisetum purpureum Schumach.

Table 2-12. Continued

Species
Pharus latifolius L.
Phenax sonneratii (Poir.) Wedd.
Piper ?hispidum
Piper hispidum Sw.
Piresia sympodica (Döll) Swallen
Psychotria capitata Ruiz & Pav.
Renealmia alpinia (Rottb.) Maas
Spathiphyllum cannifolium Schott.
Thelypteris serrata (Cav.) Alston
Urochloa mutica (Forssk.) T.Q. Nguyen
Carapa guianensis Aubl.
Ficus yaponensis Desv
Lonchocarpus heptaphyllus (Poir.) DC.
Lonchocarpus sericeus (Poir.) Kunth ex DC.
Manilkara bidentata (A. DC.) A. Chev.
Mouriri rhizophorifolia (DC.) Triana
Pterocarpus officinalis Jacq.
Quiina cruegeriana Griseb.
Sapindus saponaria L.
Spondias mombin L.
Virola surinamensis (Rol. ex Rottb.) Warb.
Vismia cayennensis (Jacq.) Pers.
Bactris major Jacq.
Cnemidaria ?spectabilis
Lasiacis ligulata Hitchc. & Chase
Sphenoclea zeylanica Gaertn
Tripogandra serrulata (Vahl) Handlos

Table 2-13. General vegetation classification of the sites used in the study according to Beard (1946) and Nelson (2004)

Site	Beard's forest type	Nelson's landscape tier unit
ARIL	Evergreen Seasonal Forest	Evergreen Seasonal
ARIM	Lower Montane Rain Forest	Lower Montane
ARIU	Lower Montane Rain Forest	Lower Montane
AROL	Semi-evergreen Seasonal Forest	Semi Evergreen Seasonal
AROM	Lower Montane Rain Forest	Lower Montane
AROU	Lower Montane Rain Forest	Lower Montane
CAPL	Evergreen Seasonal Forest	Evergreen Seasonal
CAPM	Evergreen Seasonal Forest	Evergreen Seasonal
CAPU	Evergreen Seasonal Forest	Evergreen Seasonal
CAUL	Evergreen Seasonal Forest	Semi Evergreen Seasonal
CAUM	Lower Montane Rain Forest	Lower Montane
CAUU	Lower Montane Rain Forest	Lower Montane
COUL	Evergreen Seasonal Forest	Evergreen Seasonal
COUM	Evergreen Seasonal Forest	Evergreen Seasonal
COUU	Evergreen Seasonal Forest	Evergreen Seasonal
CUML	Evergreen Seasonal Forest	Evergreen Seasonal
CUMM	Evergreen Seasonal Forest	Evergreen Seasonal
CUMU	Evergreen Seasonal Forest	Evergreen Seasonal
LEBL	Evergreen Seasonal Forest	Evergreen Seasonal
LEBM	Evergreen Seasonal Forest	Evergreen Seasonal
LEBU	Evergreen Seasonal Forest	Evergreen Seasonal
MORL	Evergreen Seasonal Forest-Mora faciation	Evergreen Seasonal
MORM	Evergreen Seasonal Forest-Mora faciation	Evergreen Seasonal
MORU	Evergreen Seasonal Forest-Mora faciation	Evergreen Seasonal
NORL	Evergreen seasonal Forest	

ARI=Aripo, ARO=Arouca, CAP=Caparo, CAU=Caura, CUM=Cumuto, COU=Couva, LEB=L'ebranche, MOR=Moruga, NOR=North Oropouche, PEN=Penal, POO=Poole, SOU=South Oropouche, L=Lower Reach, M=Middle Reach, U=Upper Reach

Table 2-13. Continued

Site	Beard's forest type	Nelson's landscape tier unit
NORM	Evergreen seasonal Forest	Evergreen Seasonal
NORU	Lower Montane Rain Forest	Lower Montane
PENL	Semi- Evergreen Seasonal Forest-Bravasia faciation	Semi Evergreen Seasonal
PENM	Semi- Evergreen Seasonal Forest-Bravasia faciation	Semi Evergreen Seasonal
PENU	Semi- Evergreen Seasonal Forest-Bravasia faciation	Semi Evergreen Seasonal
POOL	Evergreen Seasonal Forest	Evergreen Seasonal
POOM	Evergreen Seasonal Forest	Evergreen Seasonal
POOU	Evergreen Seasonal Forest	Evergreen Seasonal
SOUL	Evergreen Seasonal Forest	Evergreen Seasonal
SOUM	Evergreen Seasonal Forest	Evergreen Seasonal
SOUU	Evergreen Seasonal Forest	Evergreen Seasonal

ARI=Aripo, ARO=Arouca, CAP=Caparo, CAU=Caura, CUM=Cumuto, COU=Couva, LEB=L'ebranche, MOR=Moruga, NOR=North Oropouche, PEN=Penal, POO=Poole, SOU=South Oropouche, L=Lower Reach, M=Middle Reach, U=Upper Reach

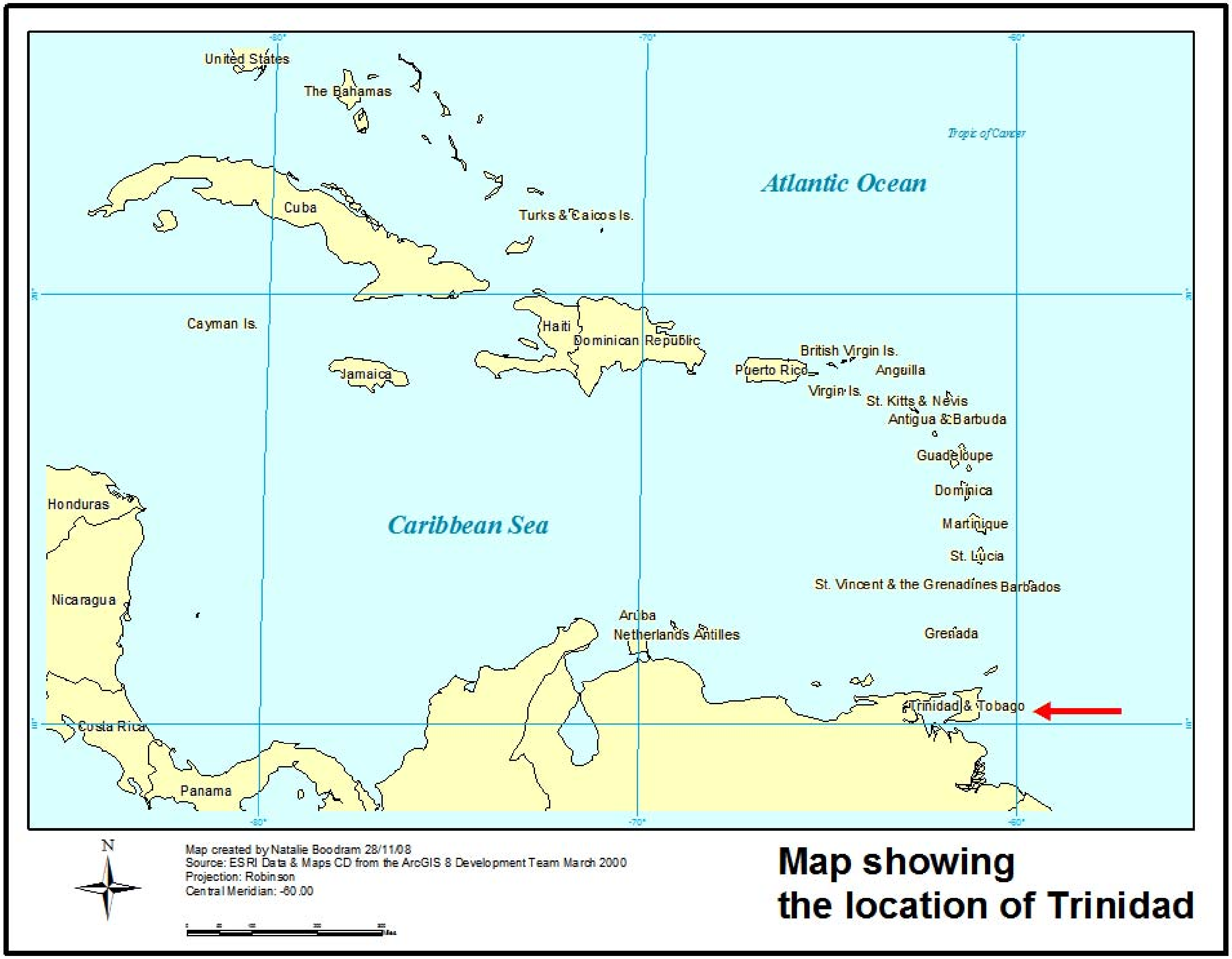

Figure 2-1. Trinidad, Republic of Trinidad and Tobago

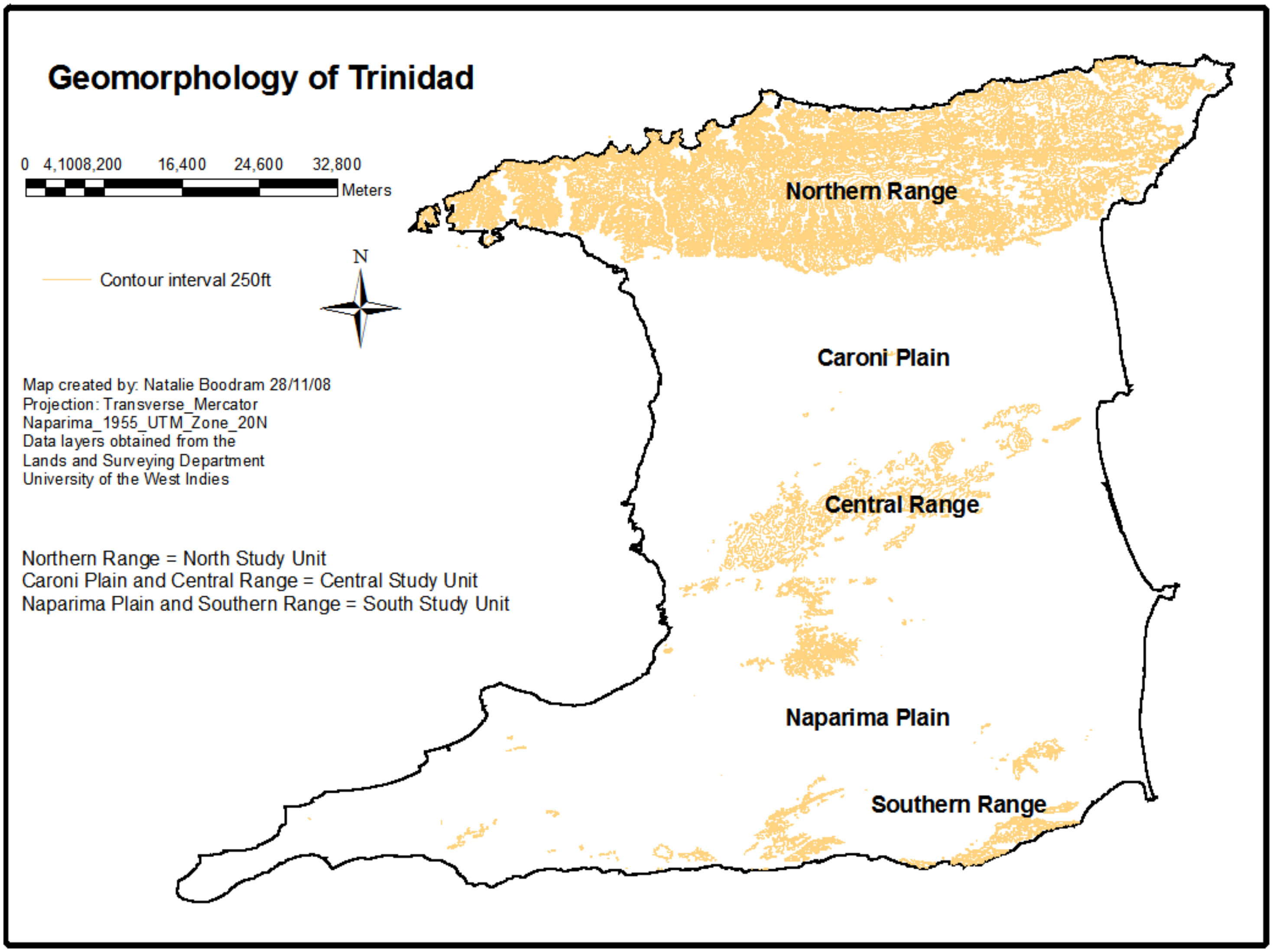

Figure 2-2. Geomorophological regions in Trinidad.

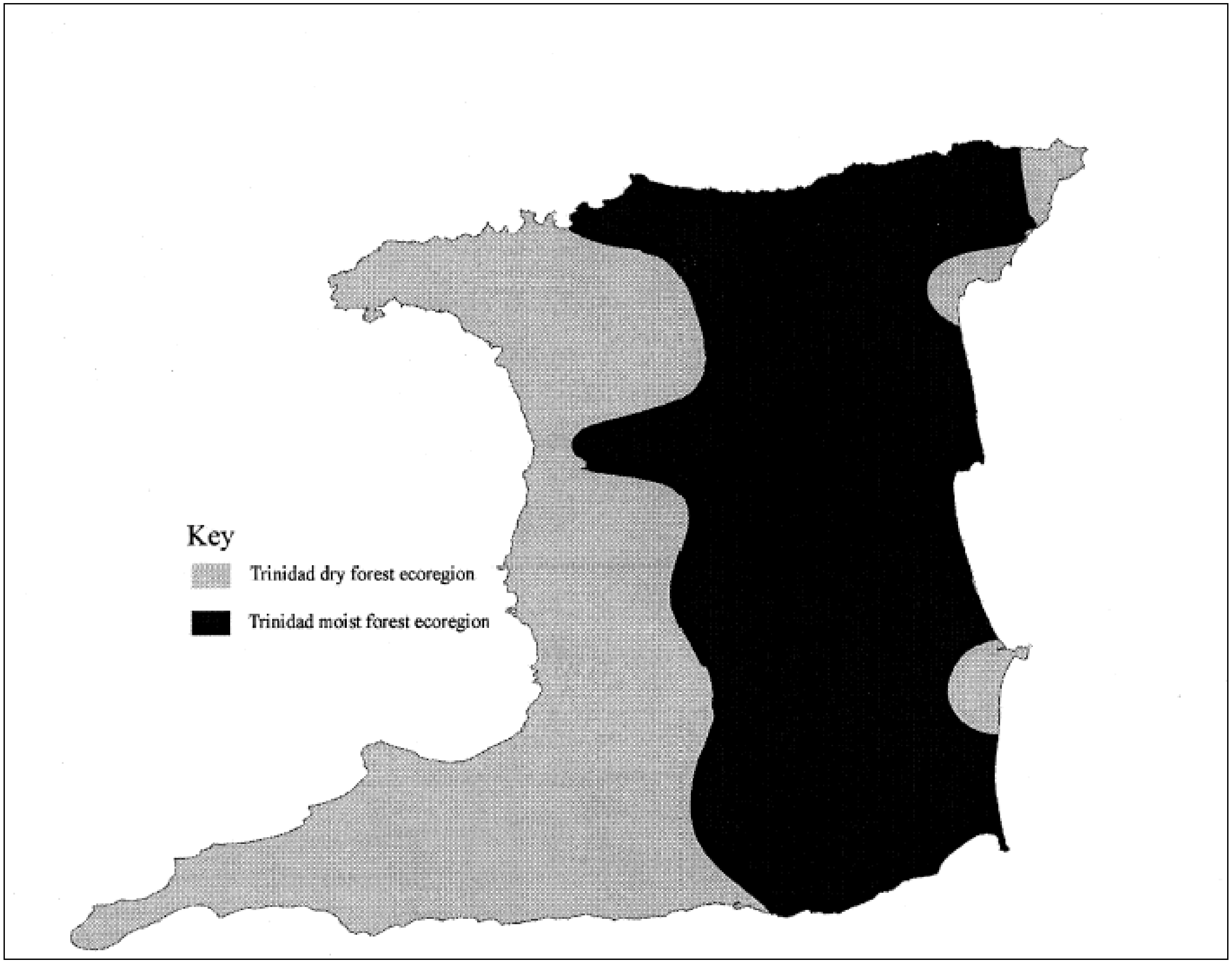

Figure 2-3. Trinidad Ecoregion Classification. Reprinted by permission from Nelson, H. P. 2004. *Tropical forest ecosystems of Trinidad: Ecological patterns and public perceptions.* Ph.D. (Figure 4 page 94). Thesis University of Wisconsin, Madison, WI, US.

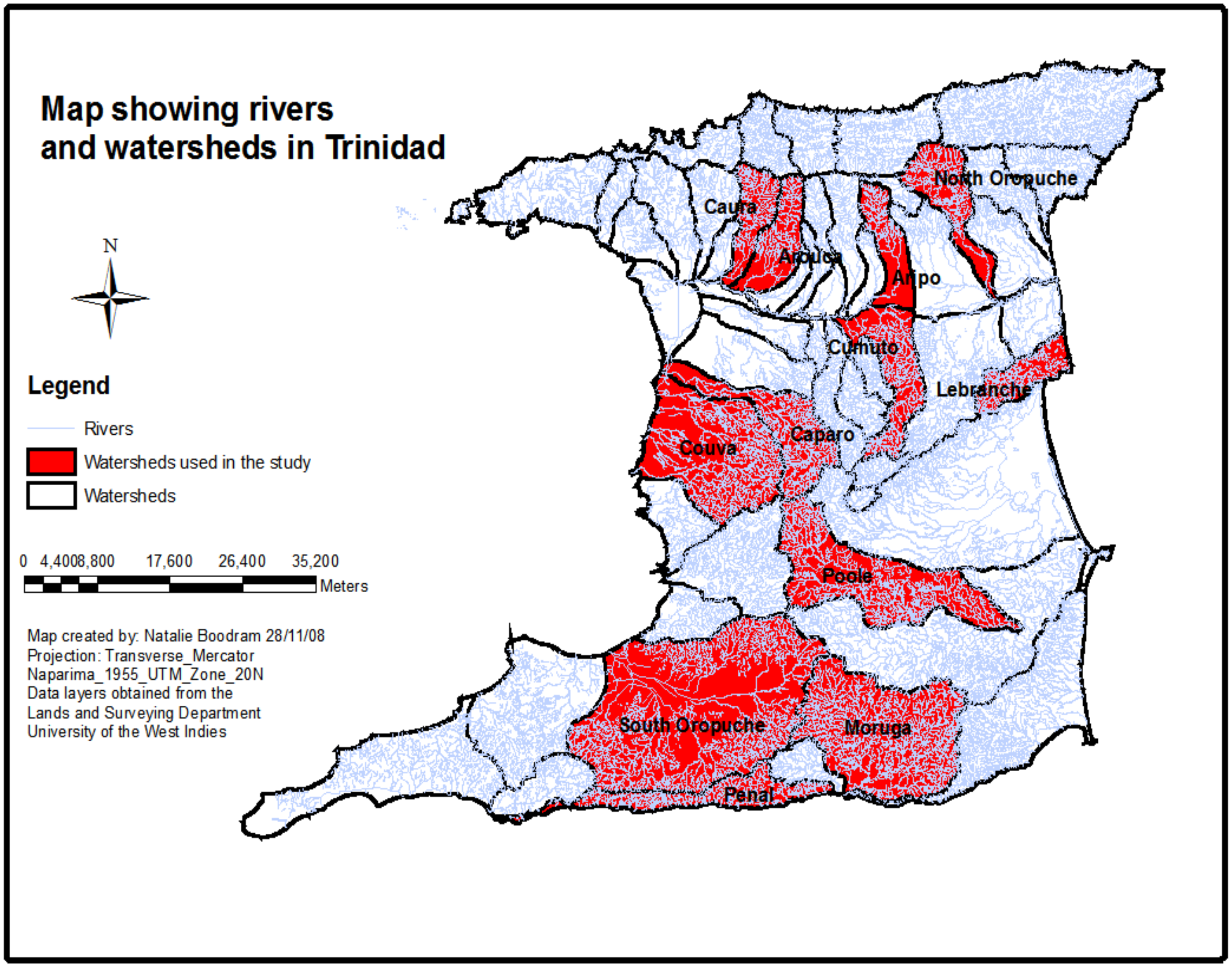

Figure 2-4. Rivers and watersheds

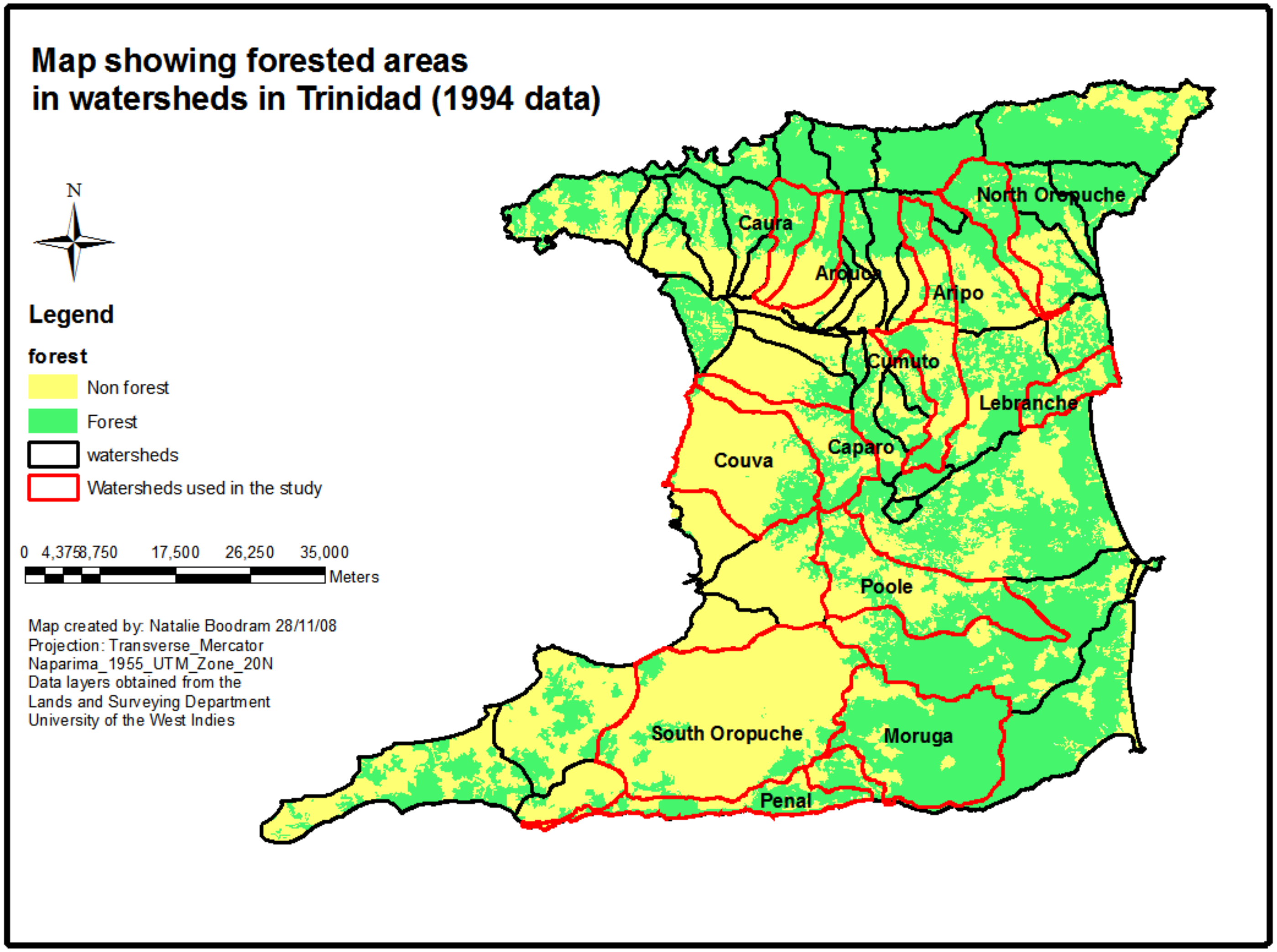

Figure 2-5 Watershed forest cover

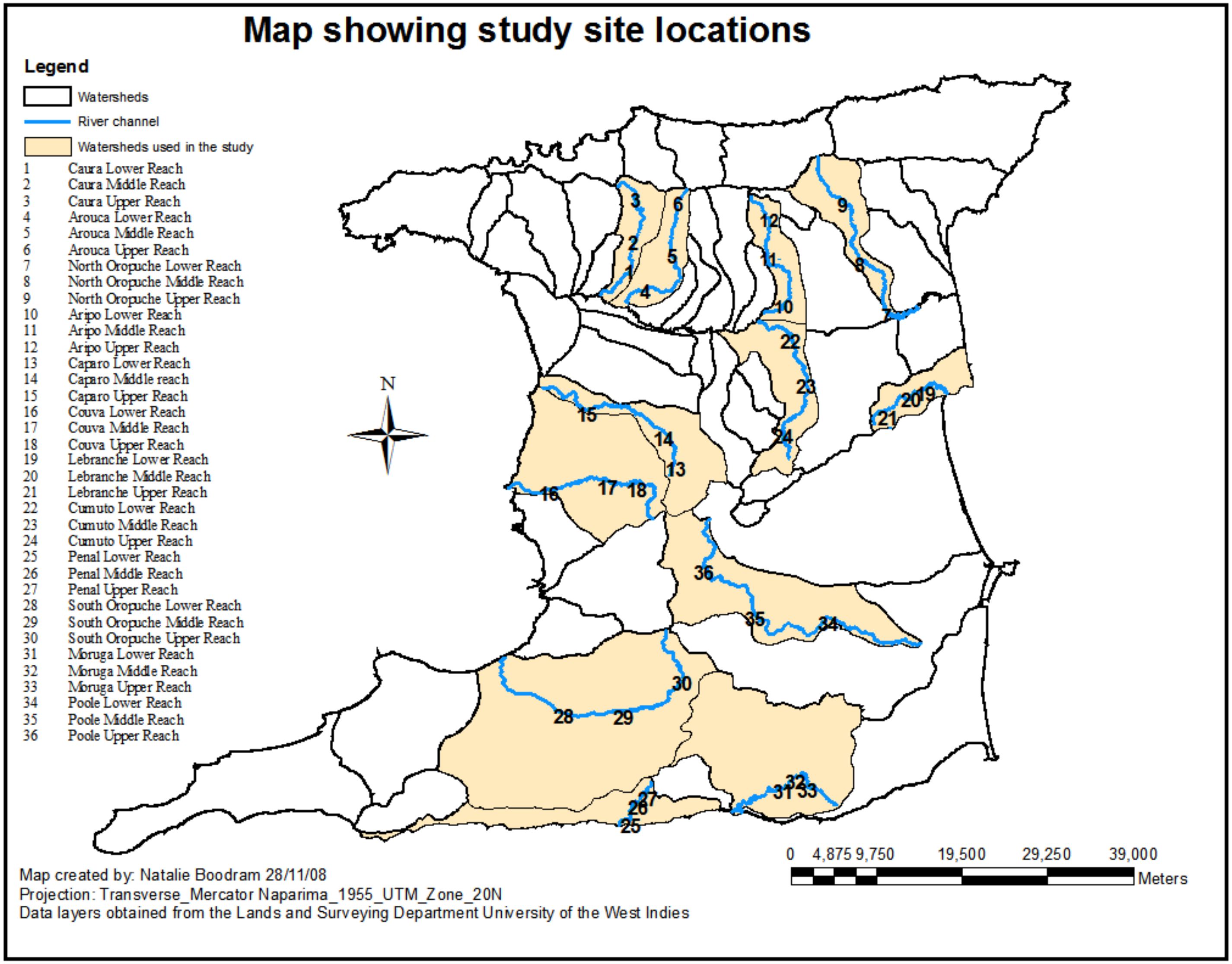

Figure 2-6. Site locations

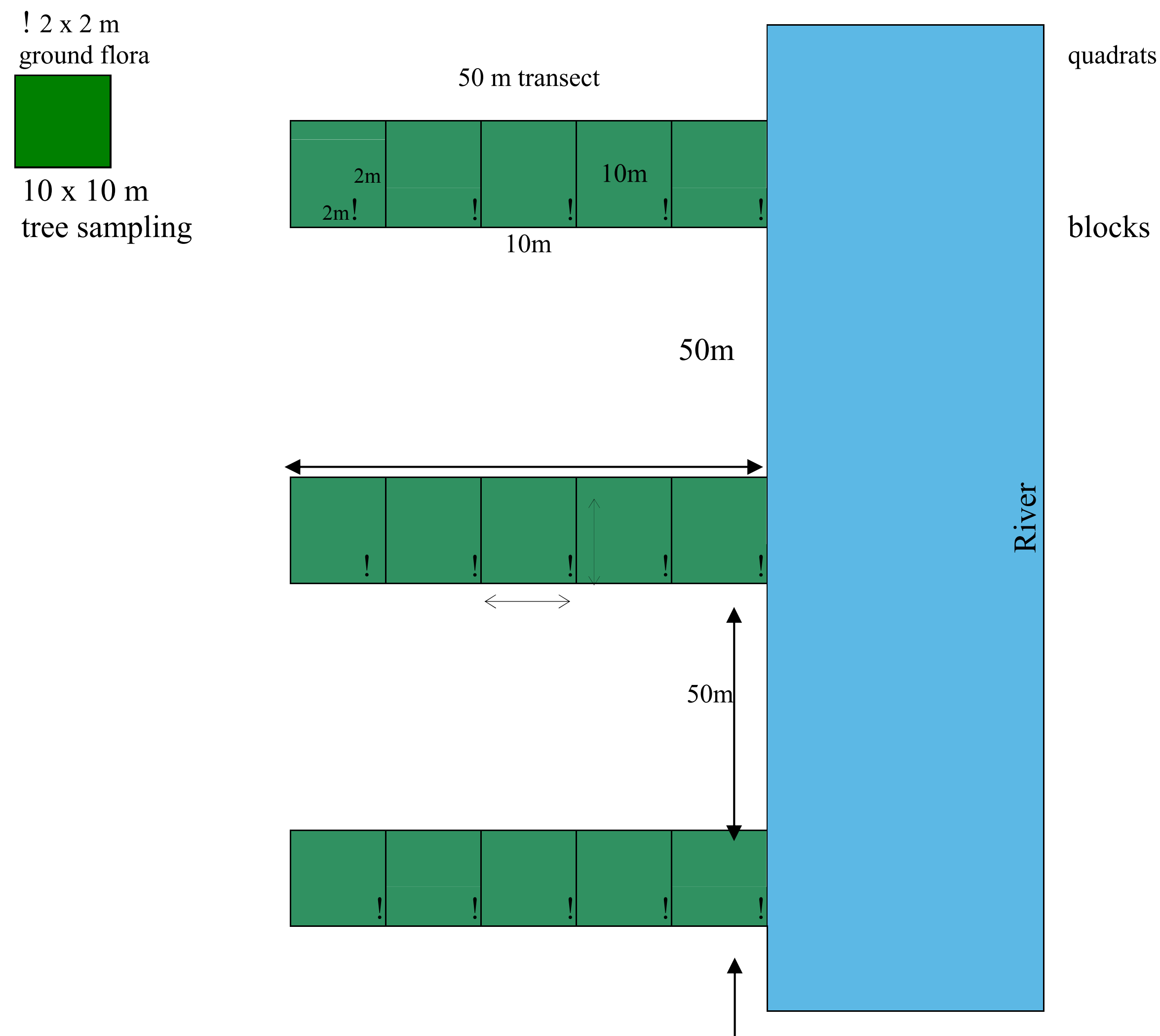

Figure 2-7. Location and dimensions of transects and quadrats at each site   (Diagram not drawn to scale)

CHAPTER 3
RIPARIAN VEGETATION GROUPS AND DETERMINANTS IN TRINIDAD

Introduction

Riparian vegetation is shaped by hydrological, terrestrial, geomorphological, biological, and anthropogenic factors. These parameters influence species composition, abundance, plant distribution, health and life history. They can also create distinct riparian groups often typified by one or more indicator species (Roberts & Ludwig 1991; Veneklaas 2005).

Hydrological factors, in particular flooding frequency, duration, timing and spatial extent are among the most important factors controlling riparian vegetation (Tabacchi et al. 1998; Bendix & Hupp 2000). Flooding regimes directly influence riparian plant germination and dispersal, but also indirectly affect plants through sediment deposition or creation of anaerobic soil conditions (Gregory et al. 1991; Petit & Froend 2001; Gergel et al. 2002). Other relevant hydrological factors include river discharge and current velocity, which can affect species richness and distribution within the riparian zone (Naiman & Decamps 1997; Baattrup-Pedersen et al. 2005).

Hydrological effects are tempered by geomorphological factors. For example, in steep valleys that typify upper watershed reaches, riparian zones are narrow and linear due to limited flooding. In middle and lower reaches, gentler topography gives rise to more flooding, wider riparian zones and a different complement of riparian plants (Tabacchi et al. 1998; Turner et al. 2004). On a fine scale, flooding effects are modified by riparian zone geomorphology like elevation, slope and distance from bank (Turner et al. 2004; Baattrup-Pedersen et al. 2005). On a coarser geomorphological scale, watershed shape, length, and area control sediment delivery and surface runoff to the riparian zone (Gregory & Walling 1973), in turn modifying riparian vegetation characteristics (Naiman et al. 2005). Watershed surface runoff and resulting sediment delivery also depend on climatic regimes. Furthermore, climate controls temperature, available soil moisture, and ultimately riparian plants (Williams & Wiser 2004; Lite et al. 2005).

Biological elements are also determinants of riparian vegetation. For example, animals affect vegetation by dispersal, herbivory and habitat modification (Tabacchi et al. 1998). Plants also influence each other through competition and disease (Dahm et al. 2002). Native riparian plants are often out-competed by exotics that are suited to high disturbance conditions in riparian areas (National Research Council 2002).

Anthropogenic factors can also have substantial effects on riparian flora. Riparian zone plants may be removed for agriculture or settlement. Land use both within and upland of the riparian zone are noted determinants of riparian vegetation (Petersen 1992; Stanley 2001; Gergel et al. 2002). Vegetation may be modified by recreational activities, pollution, fire, channelization or levee construction in the riparian zone (National Research Council 2002). Dam construction can lead to inundation of riparian zones in the immediate area, but water and sediment starvation downstream. Riparian zone activities also differ based on land ownership. Jansen & Roberston (2001) noted the prevalence of grazing on private riparian land compared to public land in Australia with subsequent impacts on vegetation.

Watershed level anthropogenic variables are also important. For example, increased urbanization on steep slopes can alter the timing and volume of surface runoff. This can lead to riparian vegetation changes as the water flows into the river (National Research Council 2002). The arrangement of land use types in the watershed is also relevant.

Urban or forest area configuration affects sediment and water delivery to the riparian zone (Burel & Baudry 2003) with subsequent changes in riparian vegetation (Allan & Johnson 1997;

Burel & Baudry 2003). On a smaller scale vegetation can differ depending on riparian vegetation patch sizes, shapes and arrangement (Freeman et al. 2003; Turner et al. 2004).

As demonstrated above, factors affecting riparian vegetation can exert their effects at different scales. Feld and Hering (2007) use the terms micro, meso, macro and mega to describe different levels of variables affecting aquatic invertebrates. These terms can also be applied to variables affecting riparian vegetation. Soil nutrients and light are micro scale variables operating within small areas of the riparian zone (Chen et al. 1999; Turner et al. 2004). Light levels, in particular, are key determinants of ground flora patterns (Naiman & Decamps 1997). River discharge, flooding regime, channel width or overall soil type can affect the entire riparian reach at the meso level (Naiman & Decamps 1997; Robertson & Augspurger 1999). Braiding, seen at the meso scale, is associated with low riparian plant diversity, while meandering is associated with high diversity (Naiman et al. 2005). Dominant land use within the watershed, watershed size or shape can be considered coarse, macro scale factors (Baker 1989). Climate and geomorphology exert their effect at the coarsest level or mega scale. Variables are often linked across scales (Baker 1989). For example, larger catchments often have rivers with greater flooding magnitudes (Naiman et al. 2005).

The study of the structure and composition, grouping and determinants of riparian vegetation allows for better understanding of riparian systems. In turn, this facilitates maximal use of riparian zone functions and properties, for example, as water quality buffers (Naiman & Decamps 1997), and wildlife corridors (Tabacchi et al. 1998). It also allows for informed manipulation of environmental and anthropogenic factors for riparian restoration if needed. Determining the scale at which influencing variables operate, suggests where, and what level of restoration is required. Pinpointing vegetation indicator species can aid in rapid identification of riparian groups and expedite designation of areas for restoration and conservation.

Baseline information on riparian systems in Trinidad was provided in Chapter 2. Riparian vegetation structure and composition were described for 12 rivers on the island along with concurrent environmental and anthropogenic characteristics. Baseline data indicated a high degree of human interference, as riparian zone modification through agriculture, urbanization, dredging, recreation and fire was evident. Of 36 sites studied across the island, 15 were located in abandoned agricultural estates, and seven sites were in active agricultural fields. It is likely that, given the level of human activity encountered, anthropogenic variables play a greater role in shaping riparian vegetation in Trinidad than hydrological, geomorphological or biological variables. This chapter analyses the baseline riparian data to identify vegetation groups across the island and determine their indicator species. It also identifies the most significant variables affecting the composition and distribution of the groups, determines the most important scale at which these variables operate and test the hypothesis that human intervention most heavily influences the composition and distribution of riparian vegetation groups in Trinidad.

Methods

Data Collection and Scaling

Data were collected on vegetation, environmental and anthropogenic variables along three, 30 m transects at 36 sites in Trinidad. Ground flora percentage cover and tree basal area were recorded within 10 m^2 blocks along each transect. Environmental and anthropogenic data were collected for 54 variables at four scales, namely the micro, meso, macro and mega scales following Feld & Hering (2007) seen in Table 3-1. Micro scale variables (the finest scale) include soil nutrients and canopy closure within each 10 m^2 vegetation-sampling block. The meso scale is the reach or site scale at which parameters such as river discharge were recorded.

Macro variables consisted of data recorded at the catchment scale such as percentage forest cover in the watershed. Mega scale variables refer to very coarse scale variables based on allocation of sample catchments into Ecoregions, geomorphological units and high human impact vs. low human impact catchments (Table 3-1). Macro and mega scale data were derived from GIS layers and pertinent literature, while micro and meso scale data were more based on field data. For more details on data collection see Chapter 2.

Statistical Analyses

Vegetation groups

Hierarchical cluster analysis was used to determine riparian vegetation groups. Analyses were carried out using 10 m^2 vegetation sample blocks, along 30 m transects at each site, amalgamated by distance from the river margin (Figure 3-1) to provide three, 30 m^2 blocks per site. Coarser scale analyses using combined vegetation data at each of the 36 sites were carried out to validate results of the block data and to examine any other possible patterns at this scale. Cluster analyses were performed on tree abundance data (basal area), ground flora abundance data (percentage cover) as well as a combined tree and ground flora presence/absence data set. Non Metric Multi-Dimensional Scaling (NMDS) was carried out to validate patterns derived from each cluster analysis. Clustering and NMDS were done using PRIMER (Plymouth Routines In Multivariate Ecological Research) Version 5.2.9.

Plant data were first reduced for both cluster analysis and NMDS by eliminating the species that occurred at only one site. Tree basal area and ground flora coverage data were 4^{th} root transformed to reduce the impact of high abundance species (Clarke & Warwick 2001). Blocks and sites with no trees and ground flora were eliminated. Clustering and ordination were performed using the Bray-Curtis Similarity Index to emphasize abundant species within a data set and to ignore joint absences among sites (Clarke & Warwick 2001; McCune et al. 2002).

Clustering utilized the group average linkage clustering method, which uses the mean distance between group pairs (Clarke & Warwick 2001). Ten iterations were used for the NMDS procedure. The significance of differences in species composition between groups was tested using the analysis of similarities (ANOSIM) routine in PRIMER. This is equivalent to a one-way ANOVA; however, the null hypothesis is that there is no significant difference in species composition among groups.

Indicator species analysis

Species that typified a particular cluster group were determined using the SIMPER routine in PRIMER. This gives species percentage contribution to group similarity. A species with a high percentage contribution to the similarity in the group and low standard deviation suggests it was abundant and consistent at sites within a group, and therefore, represents the group (Clarke & Warwick 2004). SIMPER analysis was carried out on presence/absence data, tree abundance and ground flora abundance data. Tree basal area and ground flora cover data were 4^{th} root transformed before SIMPER analysis to reduce the impact of abundant species.

Environmental and anthropogenic determinants of riparian vegetation

Data were recorded on 54 environmental and anthropogenic variables, which were potential riparian vegetation determinants (Table 3-1). Eight were categorical variables, six were ordinal and the other 40 were metric data. Rankings for ordinal variables such as recreation intensity, fire, pollution and channel modification, were based on additive effects at each site (Appendix G). For example, a site where bathing was the only recreational activity was assigned a recreation ranking of 1, while a site with three recreational activities like bathing, cooking and shelter construction was assigned a ranking of 3 to indicate more intensive use of the site. Sites were also ranked to indicate the level of edaphic modification (measure of human disturbance) of the riparian zone and the area 50-100 m upland of the riparian zone. Sites with impervious, irreversible land cover, for example, concrete buildings and paved roads were assigned the lowest ranking of 4 and sites with no modification 0. Further details of land use rankings and classifications are provided in Appendix H.

Spearman rank correlations were performed (using SPSS version 15) on the 46 metric and ordinal variables to remove redundant variables. Ten variables with correlations >0.7, $p=0.001$ (Appendix I) were removed. The remaining 36 metric and ordinal variables, along with eight categorical variables were subjected to BIOENV and BVSTEP analysis in PRIMER to assess the relationship between vegetation clusters and environmental variables. These routines superimpose an environmental similarity matrix onto the vegetation similarity matrix, providing the best combinations of explanatory variables, which produce the highest rank similarity (ρ) between plant and environmental matrices (Clarke & Warwick 2001).

BVSTEP uses a stepwise algorithm, moving forwards and backwards, adding and dropping variables to select the best matching variables to derive an optimal solution. BIOENV starts with one environmental variable moving up to a matrix of all variables. It is not recommended for analyses with more than 15 explanatory variables (Clarke & Warwick 2004); hence, BIOENV was used to find the best 1-6 variable solutions, while BVSTEP was used to assess a matrix of all 44 possible explanatory variables. Vegetation similarity matrices used in these two analyses were the identical Bray-Curtis Similarity indices used in cluster analyses.

Environmental/anthropogenic similarity matrices were derived using a Log (x+1) Normalized Euclidean similarity measure. The six BIOENV selected variables were superimposed on presence/absence NMDS maps to graphically illustrate patterns between vegetation groups and variables. Additionally, individual Spearman rank correlations were performed between BIOENV variables and group indicator species abundance. Tree basal area was log transformed before correlation analyses to reduce the effect of high basal areas species like *Bambusa vulgaris.* Transformations were not necessary for ground flora data given the relatively small percentage cover range compared to tree basal area. The significance of rank correlations between plant similarity matrices and environmental/anthropogenic data was tested using the RELATE routine in PRIMER. This is a permutation procedure (n=999 permutations) testing the null hypothesis that there is no relationship between environmental and vegetation matrices. For this test, ρ is calculated using all the environmental variables and if it is greater than the value found in 95% of the permutations, then the null hypothesis can be rejected.

BIOENV analyses were conducted using 30 m^2 combined blocks (micro scale) as the basic analytical unit for both plant and environmental data. Average values for the three blocks were used for cumulative elevation and slope. For bankslope and elevation data, constants were added to remove negative values before statistical analysis. Missing soil data were replaced using either the series means for the transect or data for the site soil type as described in Brown & Bally (1968). This was necessary for 1.95% of the soil data, which were missing due to human error in the field or laboratory.

Results

Nine major vegetation clusters were found. These were seen in the presence/absence data and were also evident in the ground flora and/or tree data. Groups were as follows: *Justicia secunda-Eschweilera subglandulosa, Mora excelsa-Bactris major, Bambusa vulgaris, Flemingia strobilifera, Saccharum officinarum, Justicia secunda, Axonopus compressus, Sorghum* sp. and *Acroceras zizanioides*. Groups were named using dominant species (highest % contribution) in each group as seen in the presence/absence data. Groups and indicator species for all three data sets are listed in Tables 3-2, 3-3 and 3-4 and demarcated on dendrograms in Figures 3-2, 3-3 and 3-4.

Only groups at the 10% similarity level from the amalgamated block data have been reported, as in all cases the coarser scale site level clusters echoed block data patterns, validating block level clusters, as was expected. ANOSIM showed that groups at the 10% similarity level were significant for all three data sets (presence/absence-global R 0.623, p=0.001; ground flora global R 0.679, p=0.001; tree data global R 0.779, p=0.001). NMDS analysis validated groups found in cluster analysis. Figure 3-5 shows the presence/absence NMDS map (stress value 0.2) and the nine major vegetation groups superimposed on the ordination map.

BVSTEP results (Table 3-5) showed a combination of six variables that best explained the presence/absence vegetation data set (ρ=0.445). Variables included canopy closure, fire, geomorphology, channel modification, upland edaphic modification and form factor. The BVSTEP best solution for the ground flora was eight variables (ρ=0.429) including all aforementioned variables except upland edaphic modification, which was replaced by riparian zone edaphic modification land ownership. The BVSTEP results for the trees showed a best combination of 14 variables listed in Table 3-5, but with a lower ρ of 0.321.

BIOENV results showed canopy closure was the most important single variable explaining vegetation community patterns in the presence/absence and ground flora data sets. However, with tree data, the strongest single explanatory variable was upland edaphic modification (Table 3-5). Best six variable BIOENV solutions are also shown in Table 3-5. Six variables was the cut off point as this was the number of variables in the BVSTEP presence/absence solution and also a manageable number of variables for comparison. The best six variable BIOENV solution for both the presence/absence and ground flora data included geomorphology, channel modification, fire, form factor and canopy closure. However, the presence/absence data also had upland edaphic modification, while in the ground flora upland edaphic modification was replaced by either riparian zone edaphic modification or land ownership. There were two alternatives for the ground flora as riparian zone edaphic modification and land ownership could be substituted for each other with the same resulting ρ value of 0.420. The best six variable solution for the tree data included distance from paved roads, form factor, pollution, upland edaphic modification, geomorphology and canopy closure. RELATE analyses indicated significant relationships ($p<0.05$) between all vegetation and environmental/anthropogenic similarity matrices.

Bubble plot graphs (Figure 3-5) and indicator species correlations (Table 3-6) showed that the *Saccharum officinarum* (Sugarcane) group was positively correlated with fire, and negatively correlated with canopy closure. This is expected as sugarcane is gown in large fields devoid of tree canopy and fire is used in the sugarcane harvesting process. The *Axonopus compressus* (Lawn grass) group was comprised of blocks either in citrus orchards or in a soccer field where grass was used as ground cover. In the tree data set, the *Axonopus compressus* group was typified by *Citrus* sp. This group was found along modified river channels on private land (Table 3-6 and Figure 3-5). Both *Saccharum officinarum* and *Axonopus compressus* groups can be regarded as agricultural groups.

The *Sorghum* sp. group was associated with modified channels, low canopy closure, high riparian zone edaphic modification and low catchment form factor (Figure 3-5 & Table 3-6). *Sorghum* sp. is a weedy grass, and the *Sorghum* sp. group as a whole had a number of weeds like *Pueraria phaseoloides* and *Euphorbia hyssopifolia* L. Another grass, *Acroceras zizanioides* typified another group. It is a native grass, found in moist and swampy areas (Adams & Baksh-Comeau Unpublished). This group also had the native grass *Paspalum fasciculatum* Willd. ex Flüggé, which has been previously found in riparian areas. This group is associated with low canopy closure (Figure 3-5).

An introduced weed, *F. strobilifera,* typified another group. This group was most strongly associated with fire (Table 3-6 & Figure 3-5). *B. vulgaris,* an introduced grass (Adams & Baksh-Comeau Unpublished), characterized the largest tree group consisting of 29 blocks across the island. This group was also evident in the presence/absence data set. *B. vulgaris* was found at sites with upland edaphic modification (Table 3-7 and Figure 3-5).

The *Mora excelsa-Bactris major* group was found in unpolluted sites with low edaphic modification, both within and upland of the riparian zone. The group was found in the South Geomorphological Unit, in short watersheds (high form factor) on public land (Tables 3-6, 3-7 and Figure 3-5). *Mora excelsa* is a forest tree species, and *Bactris major* is a palm found along rivers, in swamps and forest understories (Adams & Baksh-Comeau Unpublished).

The *Justicia secunda-Eschweilera subglandulosa* group was restricted to sample blocks at one site in the North Geomorphological Unit (Figure 3-5). This group was associated with low levels of pollution, low edaphic modification both within and upland of the riparian zone, low incidence of fire but high canopy cover. (Tables 3-6, 3-7 and Figure 3-5). *Eschweilera subglandulosa* is a common forest tree species. *Terminalia amazonia* (J.F. Gmel.) Exell was also found in this group. While the tree *E. subglandulosa* typified this group in the presence/absence data, the high basal area of *T. amazonia* resulted in the dominance of this species in the equivalent tree data group. The *Mora excelsa-Bactris major* and *Justicia secunda-Eschweilera subglandulosa* group could be regarded as representative of south and north riparian forest, respectively.

The largest vegetation group was the *Justicia secunda* group, which in the presence/absence data was comprised of 45 blocks distributed across Trinidad. *J. secunda* is a ground flora species, associated with moist, shady areas (Adams & Baksh-Comeau

Unpublished). C. *peltata* and *Spondias mombin* represented the *Justicia secunda* group in the tree data, as 17 of the 23 blocks in this tree group were also in the *Justicia secunda* group in the presence/absence data set. *C.peltata* and *S. mombin* are common disturbed/secondary vegetation species (Adams & Baksh-Comeau Unpublished). This group was associated with a low incidence of fire, low riparian zone edaphic modification but high canopy closure (Table 3-6, Figure 3-5)

Apart from these major groups, there were minor groups found in only one data set or with only one or two blocks in the group. These are described in Tables 3-2, 3-3, 3-4. They included Group 1 in the presence/absence data set, which consisted of two sites along the Poole River with *Zygia latifolia* (L.) Fawc. & Rendle. Group 9 in the presence/absence data set consisted of one 10 m combined block at the Caparo Middle Reach site (CAPM). It is the only block and site with *Crudia glaberrima* commonly called Water Locust. Group 4 of the ground flora data was typified by *Inga ingoides* common in moist, disturbed areas (Adams & Baksh-Comeau Unpublished). Group 7 of the ground flora data was typified by *Pueraria phaseoloides,* a weedy species. There were six minor groups in the tree data set including Group 1 characterized by *Musa* sp. (Banana) and Group 10 dominated by the fruit tree *Syzygium malaccense* (Pomerac). There was also a *Tectona grandis* (Teak) group consisting of all three combined blocks at the Penal Upper (PENU) site in south Trinidad, and a *Cordia collococca* dominated group also in the Southern Plain. In the Northern Range, there was a group of two blocks, at separate sites with *Ochroma pyramidale* (Cav. ex Lam.) Urb. in common. The last minor tree group was typified by *Lonchocarpus sericeus* found at sites in both the North and South Geomorphological Units.

Discussion

Vegetation Groups

Nine major vegetation groups were identified and named according to typifying species, distribution and major determinants. These are *Justicia secunda-Eschweilera subglandulosa* (North Forest), *Mora excelsa-Bactris major* (South Forest), *Saccharum officinarum* (Agricultural), *Axonopus compressus* (Agricultural), *Justicia secunda* (Secondary Vegetation), *Flemingia strobilifera* (Fire Influenced), *Sorghum sp.* (Weedy Species), *Acroceras zizanioides* (Native Grasses) and *Bambusa vulgaris* (Bamboo) groups.

The *Justicia secunda* (Secondary Vegetation) sample blocks coalesced on the basis of ground flora species such as *Justicia secunda* and trees like *Cecropia peltata* and *Spondias mombin. J. secunda* was also a typifying species of the *Justicia-Eschweilera* (North Forest) group. However, cluster analysis separated these two groups due to the presence of forest trees in the latter group, instead of agricultural species in the former. Agricultural species were in the *Justicia secunda* group, as sites in this group were located in abandoned agricultural estates. From a practical perspective, the north forest group can serve as an example of native riparian vegetation typical of Beard's (1946) Lower Montane Rain Forest, which he described for the Northern Range in Trinidad. In the NMDS maps (Figure 3-5) the Caura Middle Reach (CAUM) blocks were located in the vicinity of the north forest group indicating similar species composition. However, cluster analysis placed these blocks into the bamboo dominated vegetation group pointing to the influence of *B. vulgaris* on vegetation groupings and overall structure and composition of riparian vegetation in Trinidad. The species composition of the south forest riparian group was expected, as sample blocks fell within the geographic range of Beard's (1946) *Mora* faciation of Evergreen Seasonal forest. This, Beard (1946) noted as consisting of almost monotypic stands of *Mora excelsa*.

The weedy species group had a prevalence of exotic species including the indicator species *Sorghum* sp. Native riparian plants are often out-competed by exotics, which are suited to high disturbance conditions in riparian areas. Exotics may also be promoted by hydrological alteration (National Research Council 2002). This was seen in Trinidad where *Sorghum* sp. was positively correlated with channel modification.

Exotic species are often deliberately introduced into riparian areas, for example, for riverbank stabilization, or indirectly introduced, for example, through dispersal along roads. The exotic species *B. vulgaris* was planted along rivers in Trinidad for bank stabilization (Forestry Division pers comm.). Elsewhere in the Caribbean, O'Connor et al. (2000) linked the dominance of monotypic bamboo stands along rivers in Puerto Rico to the plant's ability to reproduce vegetatively. In particular, they highlighted the ability of broken culms to reestablish downstream after transportation along the river. It is likely that the same processes have accounted for the dominance of bamboo in riparian areas in this study.

Environmental and Anthropogenic Determinants of Riparian Vegetation

For this study, block data at each site were pooled for cluster analysis based on distance from river, i.e, 10 m blocks, 20 m blocks and 30 m blocks. As seen in Tables 3-2, 3-3 and 3-4, the amalgamated blocks tended to cluster more on the basis of sites than distance from river. Distance from river has been used as a proxy for flooding regime in riparian studies (Turner et al. 2004), and flooding is acknowledged as one of the main riparian vegetation influencing factors (Tabacchi et al. 1998; Bendix & Hupp 2000). In Trinidad; however, neither flooding nor other hydrological factors were strong predictors of riparian vegetation groups. However, distance from river was one of the variables in the eight variable BVSTEP solution for the ground flora, indicating some influence on the distribution of ground flora plants.

In Trinidad, the best predictors of riparian vegetation groups appear to be canopy closure, degree of upland and riparian zone edaphic modification, geomorphology, fire, channel modification, distance from paved roads, land ownership, pollution and form factor. Canopy closure, one of the strongest predictors in this study, is a key determinant of riparian ground flora, as it affects the amount of light available to ground flora species (Naiman & Decamps 1997).

Form factor is the ratio of catchment area to the square of catchment length. A higher form factor implies a shorter catchment. Smaller, shorter catchments tend to have more surface runoff resulting in faster sediment and nutrient delivery to the riparian zone (Gregory & Walling 1973). Thus, the positive correlation of *Mora excelsa* and *Bactris major* with form factor suggests that these indicator species and associated groups are tolerant of, or are effectively able to exploit rapid buildups of sediment and nutrients in the riparian zone. The *Mora excelsa-Bactris major* forest group was in south Trinidad and the other forest group *Justicia secunda-Eschweilera subgladulosa* in north Trinidad. Hence, the role of geomorphology as a predictor of riparian vegetation is noted. However, this may not be specific to riparian vegetation as south sample blocks fell within the geographic range of Beard's (1946) *Mora* faciation of Evergreen Seasonal forest, while *Justicia secunda-Eschweilera subglandulosa* group was in the range of Beard's (1946) Lower Montane Forest.

Edaphic modification included beds, furrows, dirt roads, soil compaction along trails, and paved areas or concrete buildings. These changes are reflective of human intervention, for example, agriculture or urbanization. Within-zone modification influenced ground flora patterns while upland modification influenced tree groups. Soil compaction or creation of impervious surfaces, whether within or upland of riparian areas, can alter surface runoff and nutrient delivery to riparian vegetation affecting growth and distribution of the plants. Researchers including Petersen (1992) have also found that land use beyond 100 m was a useful determinant of riparian vegetation patterns, particularly for small rivers. Forest groups were associated with low edaphic modification, while agricultural groups were associated with higher levels of edaphic modification as to be expected.

Other relevant anthropogenic variables included fire, which was positively associated with the *Flemingia strobilifera* and *Saccharum officinarum* groups. As mentioned before, fire is used in harvesting sugarcane. *Flemingia strobilifera* group species may be fire tolerant. Supporting evidence is seen in Ross (1961) who noted the association of *Bactris* spp. and *Spondias mombin* (*Flemingia strobilifera* group members) with burnt teak fields.

Agricultural groups were associated with channel modification in riparian areas. Although agricultural group species may be flood tolerant, it is more likely that dredging in agricultural areas reduced the likelihood of flooding, thus, allowing agricultural species to survive. Agricultural groups were more prevalent on private land, while forest groups were more likely to be found on public land. In particular the *Mora excelsa-Bactris major* groups were located in forest reserves in south Trinidad.

Of the initial 54 variables, 10 were eliminated from analyses based on significant correlations of > 0.7 (p=0.001). Eliminated variables included 60 cm soil parameters, which were correlated with their counterparts at the 30 cm soil depth. While relationships with environmental variables were significant overall, weak correlations between vegetation and environmental/anthropogenic matrices suggested that the explanatory variables did not sufficiently explain the vegetation patterns. Weak correlations were also evident between individual indicator species and environmental/anthropogenic variables. However, Naiman et al.

(2005) suggested that it is sometimes difficult to link vegetation and environmental variables in riparian zones due to “patchy abiotic conditions”.

Variable Scales

Riparian vegetation groups in Trinidad were influenced by variables at different scales. At the micro scale, canopy closure was significant, while at the meso scale, edaphic modification (riparian and upland), fire, pollution, land ownership and channel modification were important. Form factor was a significant catchment (macro) level variable, and geomorphological unit was a vegetation group determinant at the mega (island) scale. This study, therefore, supports others, for example, Baker (1989) and Turner (2004) that point to the importance of variables at different scales in explaining riparian vegetation structure and function.

Baker (1989) found that coarse scale watershed characteristics explained more variance in riparian vegetation than micro scale variables in Western Colorado, USA. Similarly, Turner (2004) found that coarse scale physiographic data were more important than fine scale soil parameters in explaining riparian vegetation patterns in Wisconsin, USA. However, Streng et al. (1989) and Robertson & Augspurger (1999) and found that fine scale variables like soil texture and light were more important explanatory variables in Louisiana, USA. It thus appears difficult to generalize about the relative importance of different scales of variables. In Trinidad, out of a 4-level hierarchy of variables, the highest number of significant variables (four out of six for the presence/absence data set) was at the meso scale. However, the strongest correlation of those six variables was canopy closure at the micro scale.

In addition to different scales of variables affecting riparian vegetation, variables are often linked (Baker 1989; Naiman et al. 2005). Moreover, patterns and processes in ecosystems are believed to operate simultaneously in a multi-scale hierarchy (Allen & Starr 1982; Turner et al. 1989). For example, larger, longer catchments often have wider channels and higher discharge

(Gregory & Walling 1973; Baker 1989). This in turn influences flooding regime and riparian vegetation. Allan et al. (1997) noted that catchment relief and geology influence sediment and nutrient delivery to rivers and riparian systems, thus linking coarse scale catchment factors to micro scale soil factors. Both scales of variables interacted and simultaneously impacted riparian vegetation. In Trinidad, while multi-scale variables impacted riparian vegetation links between the different scales of significant variables were not easy to discern. For example, even though high form factor (short watersheds) is normally associated with faster sediment and nutrient delivery to riparian zones, there was no significant correlation between this macro scale factor and micro scale factors at sites in Trinidad. With the exception of canopy closure, micro scale soil factors were overall not important determinants of riparian vegetation in Trinidad. Given the importance of anthropogenic variables like fire and channel modification in shaping riparian vegetation in Trinidad, it is likely that multi-scaled linked environmental variables were not that relevant.

Riparian Species in Trinidad

Possible riparian species from Adams & Baksh-Comeau (Unpublished) have been identified in Table 2-12 (Chapter 2). This chapter provides additional suggestions for Trinidadian riparian species using the forest vegetation group indicator species, which contributed more than 50% of the group similarity (Table 3-8). These vegetation groups represented the most natural state vegetation in the study. Some forest group species, for example, *Bactris major,* do in fact overlap with possible riparian species as listed by Adams & Baksh-Comeau (Unpublished). Indicator species for agriculture, fire tolerant and weedy species groups were not included in Table 3-8, as species were either exotics, planted for agriculture or their presence may be the result of non-riparian factors. For this reason, the exotics from Table 2-12 (Chapter 2) were also removed from Table 3-8 to provide a final list of 57 native riparian species for Trinidad.

Non agricultural, native indicator species found in secondary vegetation groups, were also included as possible riparian species in Table 3-8, as it was felt that conditions at sites with secondary vegetation approximated forested conditions. Thus, species such as *Costus scaber* and *Heliconia bihai/spatho-circinada* were included as riparian species. *E. subglandulosa* was also included in Table 3-8. While this is a species typical of the widespread Evergreen Seasonal Forest Association (Beard 1946), and therefore, not limited to riparian zones, its presence indicates tolerance of riparian conditions. The secondary vegetation generalist and pioneer species *Cecropia peltata* was also included as a riparian species for this same reason. Further research is needed to differentiate facultative and obligate riparian species, including experimental work to verify the conditions under which such species can survive.

Conclusion

Human intervention was the major influence on riparian vegetation inclusive of riparian zone and upland edaphic modification, channel modification, pollution, land ownership and fire. These variables exerted their effect at the meso or reach level. While this study showcased the high level of human interaction and subsequent degradation of riparian zones in Trinidad, it can also form the basis for riparian restoration and conservation using the information generated on riparian groups, indicator species and their determinants.

The forest groups are representative of natural state conditions. These should be conserved along with other areas in Trinidad with similar species composition. Forest groups can also be used as reference vegetation types, for choosing the best species and species combinations for restoration of disturbed riparian areas. Potential restoration plants can also be drawn from native riparian species determined in this study. Reference conditions should be specific to the geomorphological region, as differences between north and south forested riparian sites were found in this study. Given the low number of sites in the forest groups, sites with secondary vegetation may be the next best alternative for riparian conservation reference sites, especially advanced secondary growth sites with remnant or re-established riparian plants. Degraded sites can be restored by, *inter alia*, re-establishing the original hydrological regime and natural species composition of the area. Physically modified or fire prone sites may not be suitable for conservation or restoration given persistent human interaction. Sites with agricultural vegetation are a better restoration alternative if hydrology can be restored.

Table 3-1. Scales of environmental and anthropogenic variables measured in the study

Scale	Variable type	Variable
Mega	Categorical	Ecoregion: Dry vs. Wet
Mega	Categorical	Gemorophological Unit: Northern Range vs. Central Plain vs. Southern Plain.
Mega	Categorical	Level of human impact: High impact vs. low impact
Macro	Metric	Catchment area
Macro	Metric	Catchment length
Macro	Metric	Catchment relief (relief ratio)
Macro	Metric	Catchment shape (form factor)
Macro	Metric	Maximum basin relief
Macro	Metric	Percentage forest cover in watershed (1994 & 2001)
Meso	Categorical	Evidence of braiding
Meso	Categorical	Evidence of meandering
Meso	Categorical	Land ownership: private vs. public
Meso	Categorical	Presence/absence of animal activities
Meso	Categorical	Soil type
Meso	Metric	Distance from sample point to nearest paved road
Meso	Metric	Elevation above sea level
Meso	Metric	Mean bankfull depth
Meso	Metric	Mean bankfull width
Meso	Metric	Mean channel width
Meso	Metric	Mean river discharge
Meso	Metric	Mean riverbank slope
Meso	Metric	Number of land cover types per reach
Meso	Metric	Riverbank length
Meso	Ordinal	Channel modification, for example, channelization or dredging
Meso	Ordinal	Fire
Meso	Ordinal	Level of human modification of the site
Meso	Ordinal	Level of human modification 50-100 m upland of site
Meso	Ordinal	Pollution
Meso	Ordinal	Recreation intensity
Micro	Metric	Canopy closure
Micro	Metric	Distance of transect block from water's edge (length along transect)
Micro	Metric	Elevation above water margin
Micro	Metric	Slope
Micro	Metric	Soil calcium (0-30 cm & 30-60 cm)
Micro	Metric	Soil organic carbon content (0-30 cm & 30-60 cm)
Micro	Metric	Soil particle size (% sand,% silt,% gravel,% clay) 0-30 cm level only
Micro	Metric	Soil pH (0-30 cm & 30-60 cm)
Micro	Metric	Soil plant available phosphates (0-30 cm & 30-60 cm)
Micro	Metric	Soil magnesium (0-30 cm & 30-60 cm)
Micro	Metric	Soil electroconductivity (0-30 cm & 30-60 cm)
Micro	Metric	Soil potassium (0-30 cm & 30-60 cm)
Micro	Metric	Soil total nitrogen (0-30 cm & 30-60 cm)

Table 3-2. Indicator species for vegetation group clusters of presence/absence data for 108 amalgamated blocks

Group	Blocks	Group name	Indicator species contributing to >50% of cumulative similarity within group	% contribution to group similarity
1	POOL1, POOU3	*Zygia latifolia*	*Zygia latifolia* (L.) Fawc. & Rendle	50.00
2	MORL1 MORL2 MORL3 MORM2 MORM3 MORU1 MORU2 MORU3 PENL1 PENL2 PENL3 PENM1 PENM2 PENM3	*Mora excelsa* - *Bactris major*	*Mora excelsa* Benth.	17.39
			Bactris major Jacq.	17.20
			Costus scaber Ruiz & Pav.	8.00
			Swartzia pinnata (Vahl) Willd.	6.40
			Sabal mauritiiformis (H. Karst.) Griseb. & H. Wendl.	4.74
3	CAUL2 CAUM1 CAUM2 CAUM3 COUL1 COUL2 COUL3 CUMU1	*Bambusa vulgaris*	*Bambusa vulgaris* Schrad. ex J.C.	45.23
			Wendl.	17.61
			Andira inermis (W. Wright) Kunth ex DC.	
4	CAPM2 CAPM3 CAUL1 COUM1 PENU1 PENU2 PENU3	*Flemingia strobilifera*	*Flemingia strobilifera* (L.) R. Br.	28.29
			Bactris major Jacq.	17.43
			Spondias mombin L.	15.36
5	NORU1 NORU2 NORU3	*Justicia secunda*- *Eschweilera subglandulosa*	*Justicia secunda* Vahl	23.27
			Eschweilera subglandulosa	23.27
			(Steud. ex O. Berg) Miers	8.08
			Terminalia amazonia (J.F. Gmel.) Exell	

Data clustered using Bray Curtis Similarity Index with group average linkage on a reduced data set of plants found in more than one transect. Groups described at the 10% similarity level.

Table 3-2. Continued

Group	Blocks	Group name	Indicator species contributing to >50% of cumulative similarity within group	% contribution to group similarity
6	ARIM1, ARIM2 ARIM3 ARIU1 ARIU2 ARIU3 AROM1 AROM2 AROM3 AROU1 AROU2 AROU3 CAUU1 CAUU2 CAUU3 COUM2 COUM3 COUU1 COUU2 COUU3 CUML1 CUML2 CUML3 CUMU2 CUMU3 LEBL1 LEBL2 LEBL3 LEBM2 LEBM3 LEBU1 LEBU2 LEBU3 NORL1 NORL2 NORL3 NORM1 NORM2 NORM3 POOL2 POOL3 POOM2 POOM3 POOU2 POOU3	*Justicia secunda*	*Justicia secunda* Vahl *Costus scaber* Ruiz & Pav. *Bambusa vulgaris* Schrad. ex J.C. Wendl. *Heliconia bihai or spatho-circinada* *Dieffenbachia seguine* (Jacq.) Schott *Pueraria phaseoloides* (Roxb.) Benth. *Blechum pyramidatum* (Lam.) Urb.	13.47 11.23 6.96 6.47 5.91 4.80 4.65
7	CUMM1 CUMM2 CUMM3 CAUL3	*Axonopus compressus*	*Axonopus compressus* (Sw.) P. Beauv. Poaceae	31.34 26.39
8	ARIL1 ARIL2 ARIL3 AROL1 AROL2 AROL3 CAPL1 CAPL2 CAPL3 CAPU2	*Sorghum* sp.	*Sorghum* sp. *Pueraria phaseoloides* (Roxb.) Benth. Euphorbia hyssopifolia L.	28.56 12.71 11.99
9	CAPM1		Only one block in the group, with *Crudia glaberrima* (Steud.) J.F. Macbr. exclusive to this site	
10	CAPU3, SOUU3, SOUM3, SOUU2	*Saccharum officinarum*	*Saccharum officinarum* L.	100.00
11	SOUL1 SOUL2 SOUL3 SOUM1 SOUM2 SOUU1 MORM1 CAPU1 POOM1	*Acroceras zizanioides*	*Acroceras zizanioides* (Kunth) Dandy *Paspalum fasciculatum* Willd. ex Flüggé	34.66 17.96

Data clustered using Bray Curtis Similarity Index with group average linkage on a reduced data set of plants found in more than one transect. Groups described at the 10% similarity level.

Table 3-3. Indicator species for group clusters of ground flora for 108 amalgamated blocks.

Group	Blocks	Group name	Indicator species contributing to >50% of cumulative similarity within group	% contribution to group similarity
1	CAPU2 CAPU3 SOUM2 SOUM3 SOUU2 SOUU3	*Saccharum officinarum*	*Saccharum officinarum* L.	98.02
2	CAUL3 CUMM2 CUMM3	*Axonopus compressus*	*Axonopus compressus* (Sw.) P. Beauv.	73.86
3	ARIL1 AROL1 AROL2 AROL3 CAPL1 CAPL2 CAPL3 CAPU1 CUMM1	*Sorghum* sp.	*Sorghum* sp. Poaceae	47.27 17.53
4	CAUM1 CAUM2 CAUM3 CUML1 LEBM1 MORM3 MORU2 MORU3 NORL1 NORL2 NORL3 POOU1	*Inga ingoides*	*Inga ingoides* (Rich.) Willd. *Oplismenus hirtellus* (L.) P. Beauv. *Adiantum* sp.	26.14 14.73 14.23
5	MORU1		Less than two samples in the group	
6	ARIM1 ARIU1 ARIU2 ARIU3 AROU1 AROU2 AROU3 CAUU1 CAUU2 CAUU3 COUM2 COUM3 COUU1 COUU2 COUU3 CUML2 CUML3 CUMU1 CUMU2 CUMU3 LEBL2 LEBL3 LEBM2 LEBM3 LEBU2 LEBU3 NORM3 NORU1 NORU2 NORU3 POOL1 POOL2 POOL3 POOM2 POOM3 POOU2 POOU3	*Justicia secunda*	*Justicia secunda* Vahl *Costus scaber* Ruiz & Pav. *Heliconia bihai or spatho-circinada* *Coffea* sp.	30.68 9.62 9.18 9.00
7	ARIM3 AROM1 AROM2 AROM3 LEBU1 NORM1 NORM2	*Pureria phaseoloides*	*Pueraria phaseoloides* (Roxb.) Benth. *Scleria melaleuca* Rchb. ex Schltdl. & Cham. *Hippobroma longiflora* (L.) G. *Costus scaber* Ruiz & Pav. *Blechum pyramidatum* (Lam.) Urb.	18.29 12.00 10.21 8.94 7.93
8	MORL1 MORL2 MORL3 PENL1 PENL2 PENL3 PENM1 PENM2 PENM3 PENU2 PENU3	*Bactris major*	*Bactris major* Jacq.	73.03
9	ARIM2 CAPM2 CAPM3 CAUL1 COUL1 COUL2 COUL3 COUM1 PENU1	*Flemingia strobilifera*	*Flemingia strobilifera* (L.) R. Br.	59.02

Data clustered using Bray Curtis Similarity Index with group average linkage on a reduced data set of plants found in more than one transect. Ground flora percentage cover data 4th root transformed prior to analysis. Groups described at the 10% similarity level.

Table 3-4. Indicator species for group clusters of trees for 84 amalgamated blocks.

Group	Blocks	Group name	Indicator species contributing to >50% of cumulative similarity within group	% contribution to group similarity
1	CUMM1 CUMM2 CUMM3	*Citrus* sp.	*Citrus* sp.	100.00
2	CAPU1 CAUL1 CAUL2 CAUM1 CAUM2 CAUU1 CAUU2 CAUU3 COUL1 COUL2 COUL3 COUM1 COUM2 COUU1 COUU2 COUU3 CUML1 CUML2 CUMU1 CUMU3 LEBL1 LEBL2 LEBM1 LEBM3 NORL1 NORM1 NORM3 POOM1 SOUL1	*Bamboo vulgaris*	*Bambusa vulgaris* Schrad. ex J.C. Wendl.	98.99
3	PENL2 SOUM1		*Cordia collococca* L.	100.00
4	NORU1 NORU2	*Terminalia amazonia*	*Terminalia amazonia* (J.F. Gmel.) Exell *Hieronyma laxiflora* (Tul.) Müll. Arg.	41.01 31.36
5	PENM1 MORL1 MORL2 MORL3 MORM2 MORU1 MORU2 MORU3 NORU3	*Mora excelsa*	*Mora excelsa* Benth.	51.04
6	ARIM3 NORM2	*Ochroma pyramidale*	*Ochroma pyramidale* (Cav. ex Lam.) Urb.	100.00
7	POOM3 POOU2 POOU3 AROM1	*Syzgium malaccense*	*Syzygium malaccense* (L.) Merr. & L.M. Perry	64.08
8	POOL3		Only one site in group	
9	PENU1 PENU2 PENU3		*Tectona grandis* L. f.	100.00
10	COUM3 POOM2		*Musa* sp.	100.00
11	ARIU1 AROU2 POOL1 POOU1		*Lonchocarpus sericeus* (Poir.) Kunth ex DC	65.66
12	NORL3 AROM2 ARIM1 ARIM2 ARIU2 ARIU3 AROM3 AROU1 AROU3 CAPM2 CUML3 LEBL3 LEBM2 LEBU1 LEBU3 MORM3 NORL2 PENL1 PENL3 PENM2 PENM3 SOUL2 POOL2	*Cecropia peltata*	*Cecropia peltata* L. *Spondias mombin* L.	39.93 30.96

Data clustered using Bray Curtis Similarity Index with group average linkage on a reduced data set of plants found in more than one transect. Groups described at the 10% similarity level.

Table 3-5. BIOENV and BVSTEP results

Data set	Analysis	No. of variables	Variables	ρ
Presence/ absence	BIOENV	1	44	0.391
	BIOENV	6	9,31,33,35,38,44	0.445
	BVSTEP (optimal variable solution out 44 possible explanatory variables)	6	9,31,33,35,38,44	0.445
Ground flora	BIOENV	1	44	0.324
	BIOENV	6	9,31,33,34/43,38,44	0.420
	BVSTEP (optimal variable solution out of 44 possible explanatory variables)	8	4,9,31,33,34,38,43,44	0.429
Trees	BIOENV	1	35	0.267
	BIOENV	6	5,9,32,35,38,44	0.313
	BVSTEP (optimal variable solution out of 44 possible explanatory variables)	14	5,6,9,13,23,25,28,32,35, 38,39,42-44	0.321

1 clay 2 silt 3 gravel 4 distance from river (m) 5 distance from paved road (m) 6 elevation above sea level (m) 7 catchment length (km) 8 maximum basin relief 9 form factor (area/length ^{2}) 10 percentage forest cover (1994) 11 pH (30 cm) 12 N (30 cm) (g kg^{-1}) 13 P(30 cm) (mg kg^{-1}) 14 K(30 cm) (c mol kg^{-1}) 15 Ca (30 cm) (c mol kg^{-1}) 16 Mg (30 cm) (c mol kg^{-1}) 17 EC (30 cm) (mS cm^{-1}) 18 OC (30 cm) (g kg^{-1}) 19 N (60 cm) (g kg^{-1}) 20 OC (60 cm) (g kg^{-1}) 21 discharge (m^{3}) 22 channel width (m) 23 bankfull width (m) 24 bank length (m) 25 bank slope+60 26 average slope+50 27 average elevation (m) 28 number of land use types 29 maintenance activities 30 recreation intensity 31 channel modification 32 pollution 33 fire 34 edaphic modification in riparian zone 35 edaphic modification upland of riparian zone (50-100 m) 36 catchment impact level 37 Ecoregion 38 geomorphology 39 animal presence/absence 40 braiding 41 meandering 42 soil type 43 land ownership 44 average canopy closure

Table 3-6. Correlations between ground flora indicator species abundance and metric and ordinal variables from the 1-6 BIOENV variable solutions

Species	Form factor (area/length^2)	Channel modification	Fire	Riparian edaphic modification	Average canopy closure
Axonopus compressus (Sw.) P. Beauv.	-0.074	0.265(**)	-0.028	0.237(*)	-0.208(*)
Bactris major Jacq.	0.430(**)	-0.236(*)	0.153	-0.08	-0.053
Flemingia strobilifera (L.) R. Br.	0.047	-0.052	0.313(**)	0.033	0.033
Inga ingoides (Rich.) Willd.	-0.103	-0.007	-0.104	-0.072	0.255(**)
Justicia secunda Vahl	-0.105	-0.159	-0.299(**)	-0.206(*)	0.268(**)
Paspalum fasciculatum Willd. ex Flüggé	-0.001	0.157	0.269(**)	-0.007	-0.311(**)
Pueraria phaseoloides (Roxb.) Benth.	-0.159	0.07	-0.072	0.152	-0.216(*)
Saccharum officinarum L.	0.064	0.221(*)	0.379(**)	0.247(*)	-0.374(**)
Acroceras zizanioides (Kunth) Dandy	0.058	0.61	0.269 (**)	-0.054	-0.0223(*)
Sorghum sp.	-0.293(**)	0.361(**)	0.099	0.326(**)	-0.382(**)

* significant at p=0.01 ** significant at p=0.001

Table 3-7. Correlations between tree indicator species abundance and metric and ordinal variables from the 1-6 BIOENV variable solutions

Species	Distance from paved road (m)	Form factor (area/l^2)	Pollution	Upland edaphic modification	Average canopy closure
Bambusa vulgaris Schrad. ex J.C. Wendl.	-0.099	-0.079	0.236(*)	0.310(**)	0.009
Cecropia peltata L.	-0.184	-0.025	0.131	-0.076	0.139
Citrus sp.	0.121	-0.096	-0.161	0.143	-0.218(*)
Mora excelsa Benth.	0.057	0.362(**)	-0.305(**)	-0.370(**)	0.136
Terminalia amazonia (J.F. Gmel.) Exell	-0.177	-0.036	-0.093	-0.233(*)	0.138
Eschweilera subglandulosa (Steud. ex O. Berg) Miers	-0.013	0.071	-0.227(*)	0.350(**)	0.123

* significant at p=0.01 ** significant at p=0.001

Table 3-8. List of Riparian species for Trinidad.

Scientific name	Common Name in Trinidad
Acroceras zizanioides (Kunth) Dandy	
Adiantum sp.	
Andira inermis (W. Wright) Kunth ex DC.	
Bactris major Jacq.	Gru-Gru
Calathea lutea Schult.	Sohari Leaf
Carapa guianensis Aubl.	Crappo
Casearia sylvestris Sw.	
Cecropia peltata L.	
Cnemidaria ?spectabilis	Tree fern
Combretum fruticosum (Loefl.) Stuntz	
Cordia collococca L.	
Costus scaber Ruiz & Pav.	
Crudia glaberrima (Steud.) J.F. Macbr	Water Locust
Cyclanthus bipartitus Poit	
Cyperus luzulae (L.) Rottb. ex Retz.	
Cyperus surinamensis Rottb.	
Eschweilera subglandulosa (Steud. ex O. Berg) Miers	
Faramea occidentalis (L.) A. Rich	
Ficus yaponensis Desv	
Gynerium sagittatum (Aubl.) P. Beauv.	
Heliconia bihai (L.) L.	Baliser
Heliconia bihai or spatho-circinada	
Heliconia hirsuta L. f.	
Hieronyma laxiflora (Tul.) Müll. Arg.	
Hymenachne amplexicaulis (Rudge) Nees	
Hypoderris brownii J.Sm.	
Isertia parviflora Vahl	
Justicia comata (L.) Lam.	
Lasiacis ligulata Hitchc. & Chase	

Table 3-8. Continued.

Scientific name	Common Name in Trinidad
Leptochloa ?longa	
Lomariopsis japurensis (Mart.) J.Sm.	
Lonchocarpus heptaphyllus (Poir.) DC.	
Lonchocarpus sericeus (Poir.) Kunth ex DC.	
Manilkara bidentata (A. DC.) A. Chev.	Balata
Mimosa pigra L.	
Mouriri rhizophorifolia (DC.) Triana	Monkey bone
Pachystachys coccinea (Aubl.) Nees	Black stick
Palicourea crocea (Sw.) Roem. & Schult.	
Panicum ?frondescens	
Paspalum fasciculatum Willd. ex Flüggé	Bull grass
Pharus latifolius L.	
Phenax sonneratii (Poir.) Wedd.	
Piper ?aequale	
Piper ?hispidum	
Piresia sympodica (Döll) Swallen	
Psychotria capitata Ruiz & Pav.	
Pterocarpus officinalis Jacq.	Bloodwood
Pterolepis glomerata (Rottb.) Miq.	
Quiina cruegeriana Griseb.	
Renealmia alpinia (Rottb.) Maas	
Sapindus saponaria L.	Soapseed
Spathiphyllum cannifolium Schott.	Maraval lilly
Thelypteris serrata (Cav.) Alston	
Tripogandra serrulata (Vahl) Handlos	
Virola surinamensis (Rol. ex Rottb.) Warb.	
Vismia cayennensis (Jacq.) Pers.	

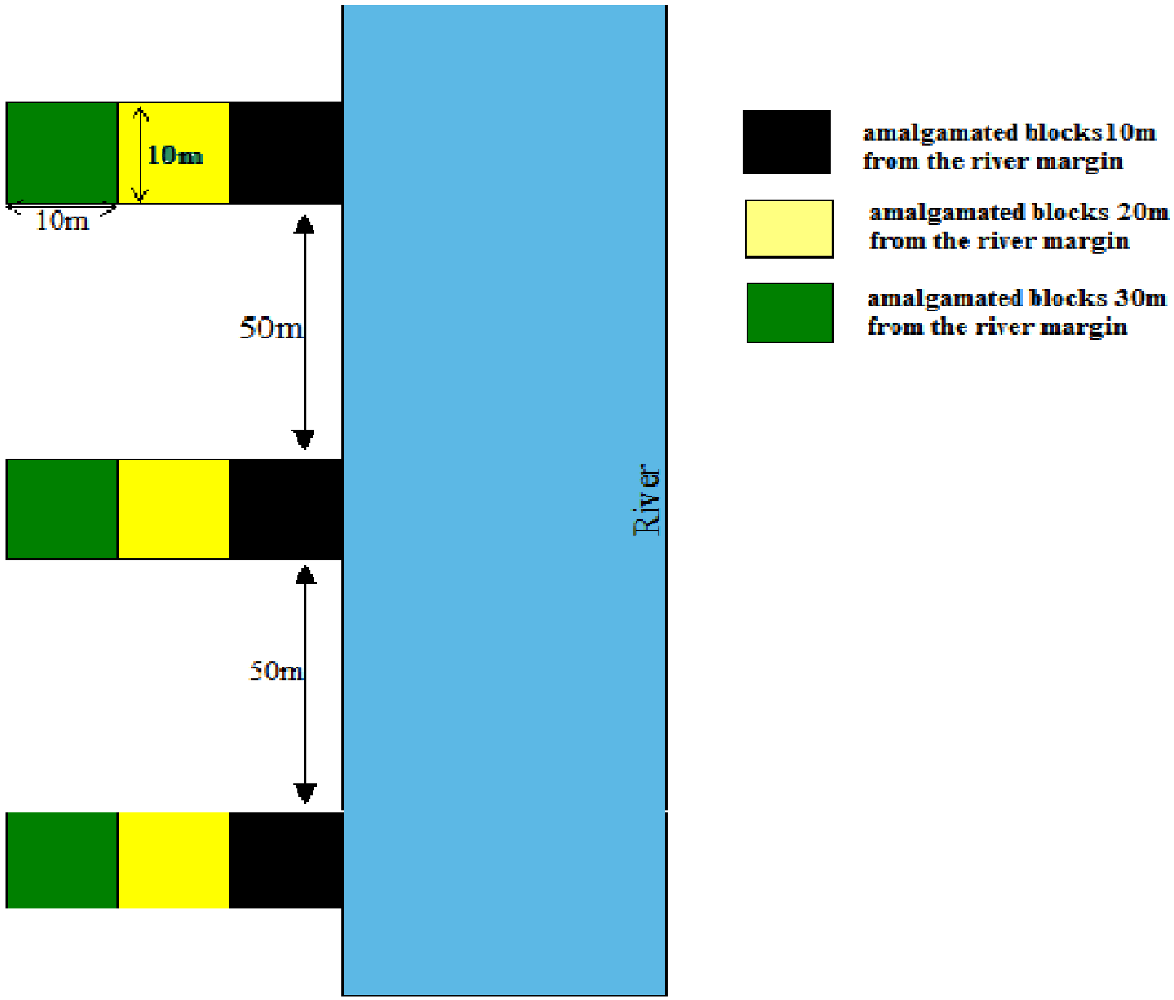

Figure 3-1. Combined vegetation sample blocks, used in hierarchical cluster analysis grouped according to distance from river

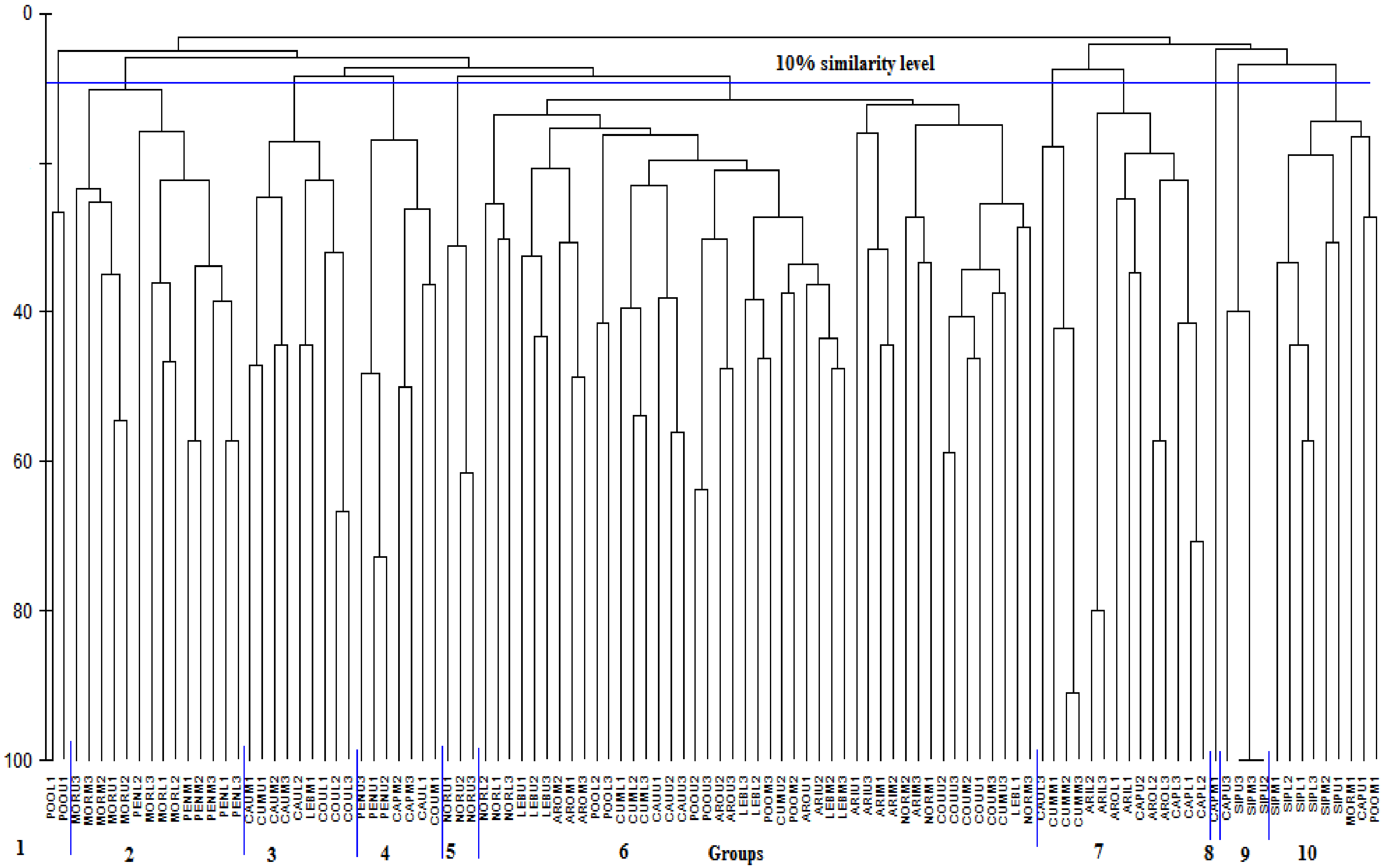

Figure 3-2. Dendrogram of hierarchical cluster analysis of presence/absence data for 108 amalgamated blocks. Data clustered using Bray Curtis Similarity Index with group average linkage on a reduced data set of plants found in more than one transect. Groups described at the 10% similarity level.

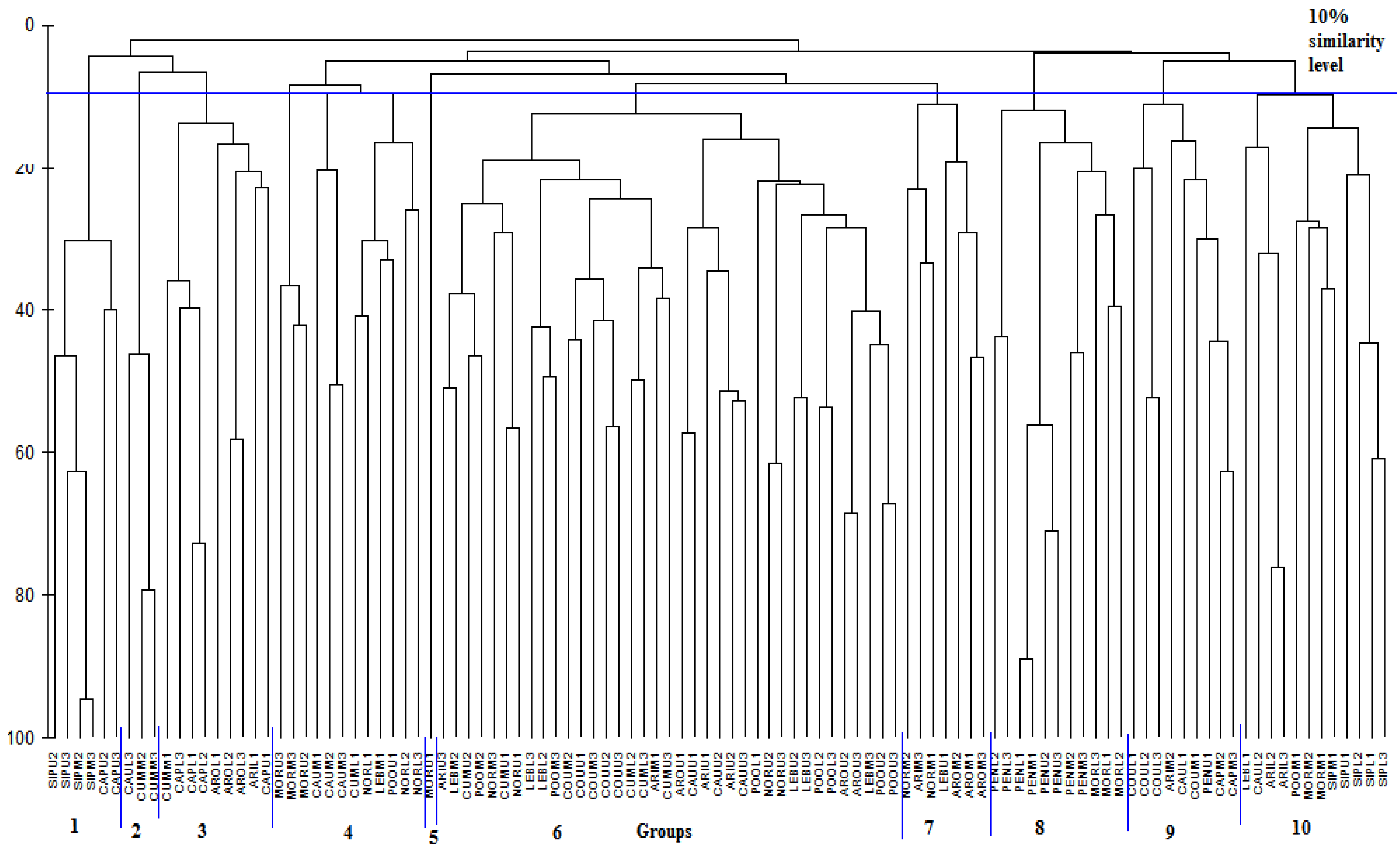

Figure 3-3. Dendrogram of hierarchical cluster analysis of ground flora data for 108 amalgamated blocks. Data clustered using Bray Curtis Similarity Index with group average linkage on a reduced data set of plants found in more than one transect. Ground flora percentage cover data 4th root transformed prior to cluster analysis. Groups described at the 10% similarity level.

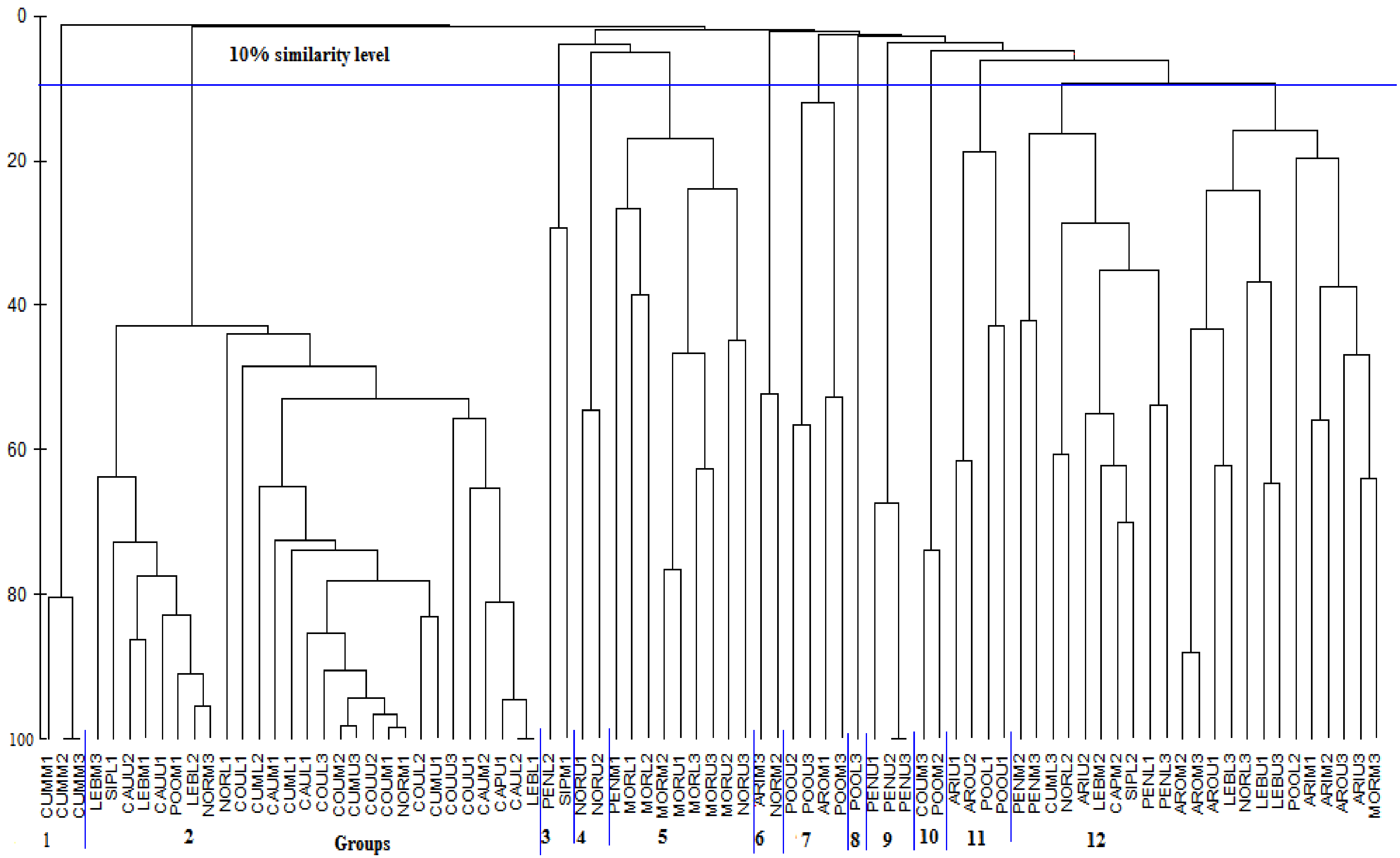

Figure 3-4. Dendrogram of hierarchical cluster analysis of tree data for 84 amalgamated blocks Data clustered using Bray Curtis Similarity Index with group average linkage on a reduced data set of plants found in more than one transect. Tree data 4th root transformed. Groups described at the 10% similarity level

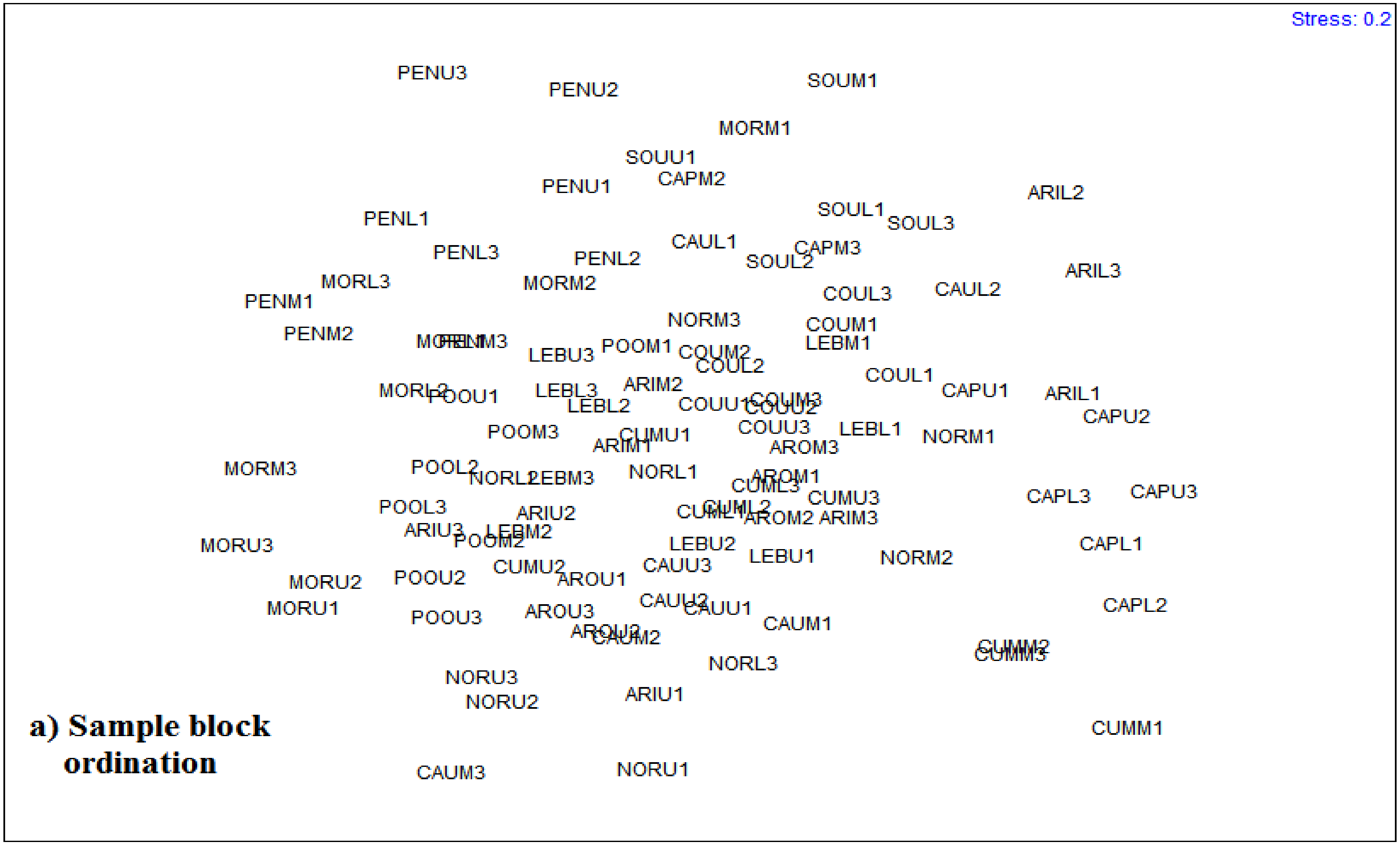

Figure 3-5. NMDS ordination map of presence/absence block plant data. Outliers CAUL3 AROL1 AROL2, SOUU2, SOUM3, SOUM2, SOUU2, CAPM1 removed. a) Original block ordination, b-l) categorical and ordinal data superimposed on ordination maps, b) vegetation groups from cluster, c) geomorphological units, d) land ownership, e) riparian zone edaphic modification, f) upland edaphic modification g) channel modification h) form factor, i) fire, j) pollution, k)canopy closure, l) distance from paved roads

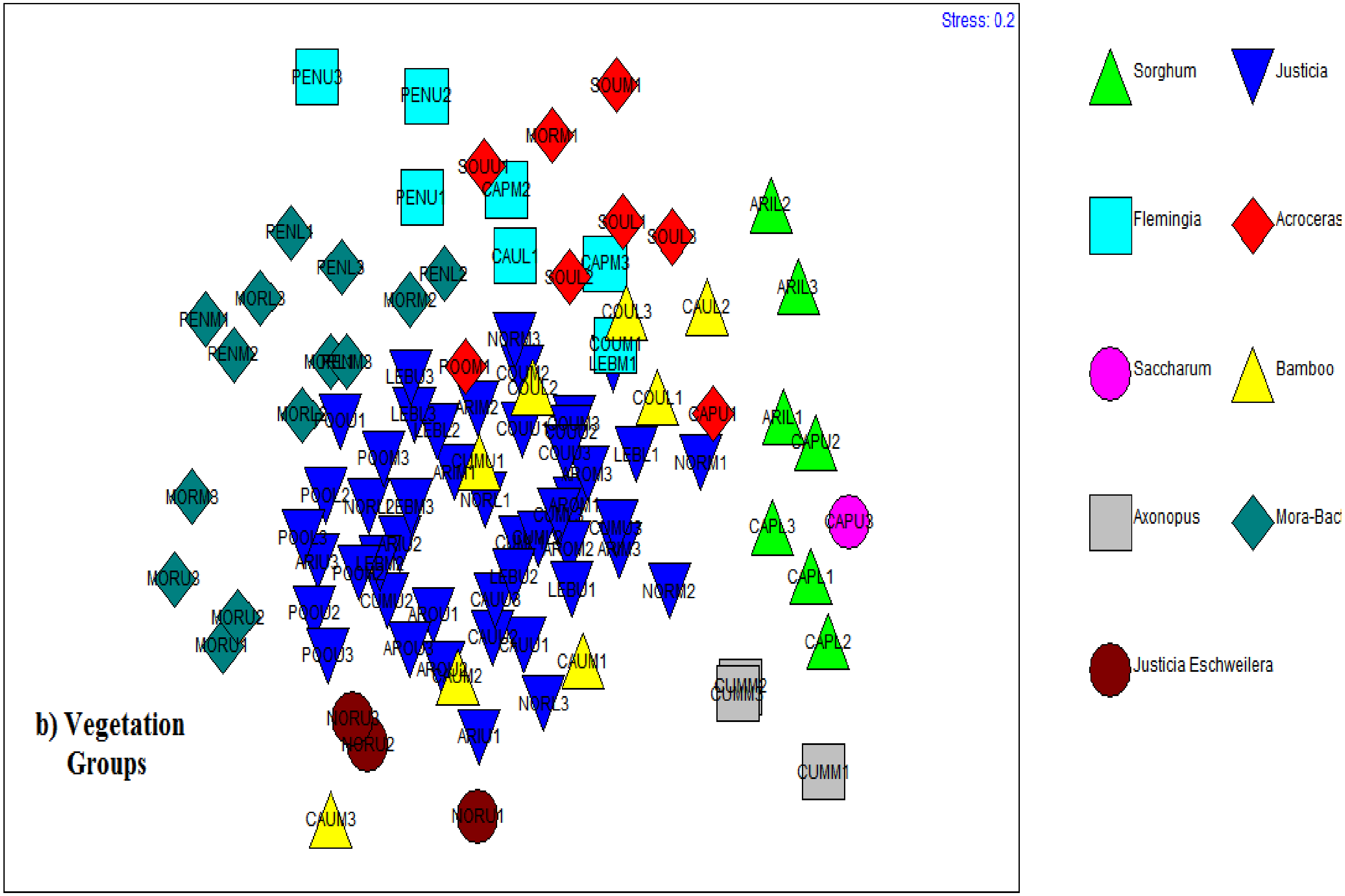

Figure 3-5. Continued

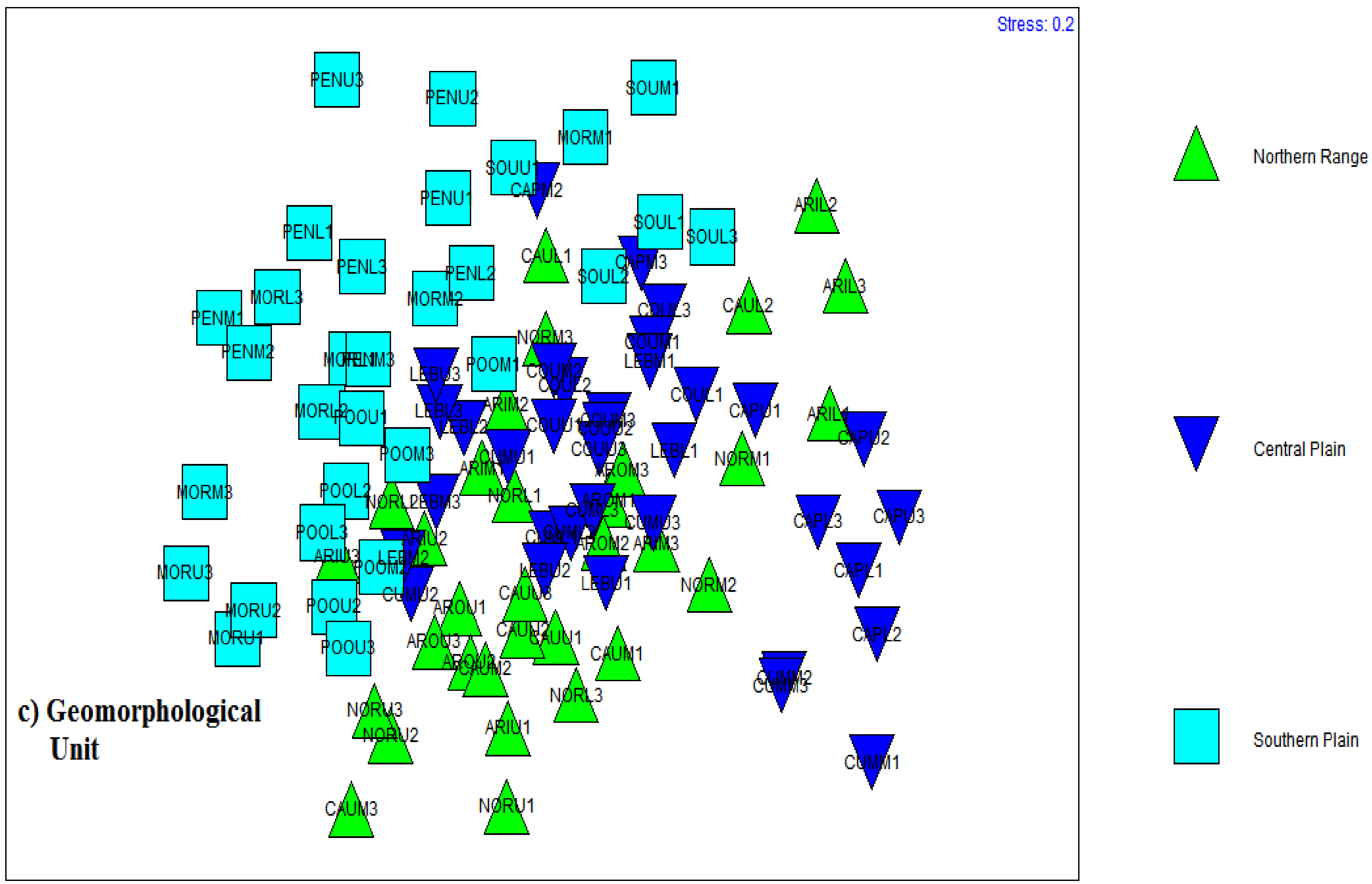

Figure 3-5. Continued

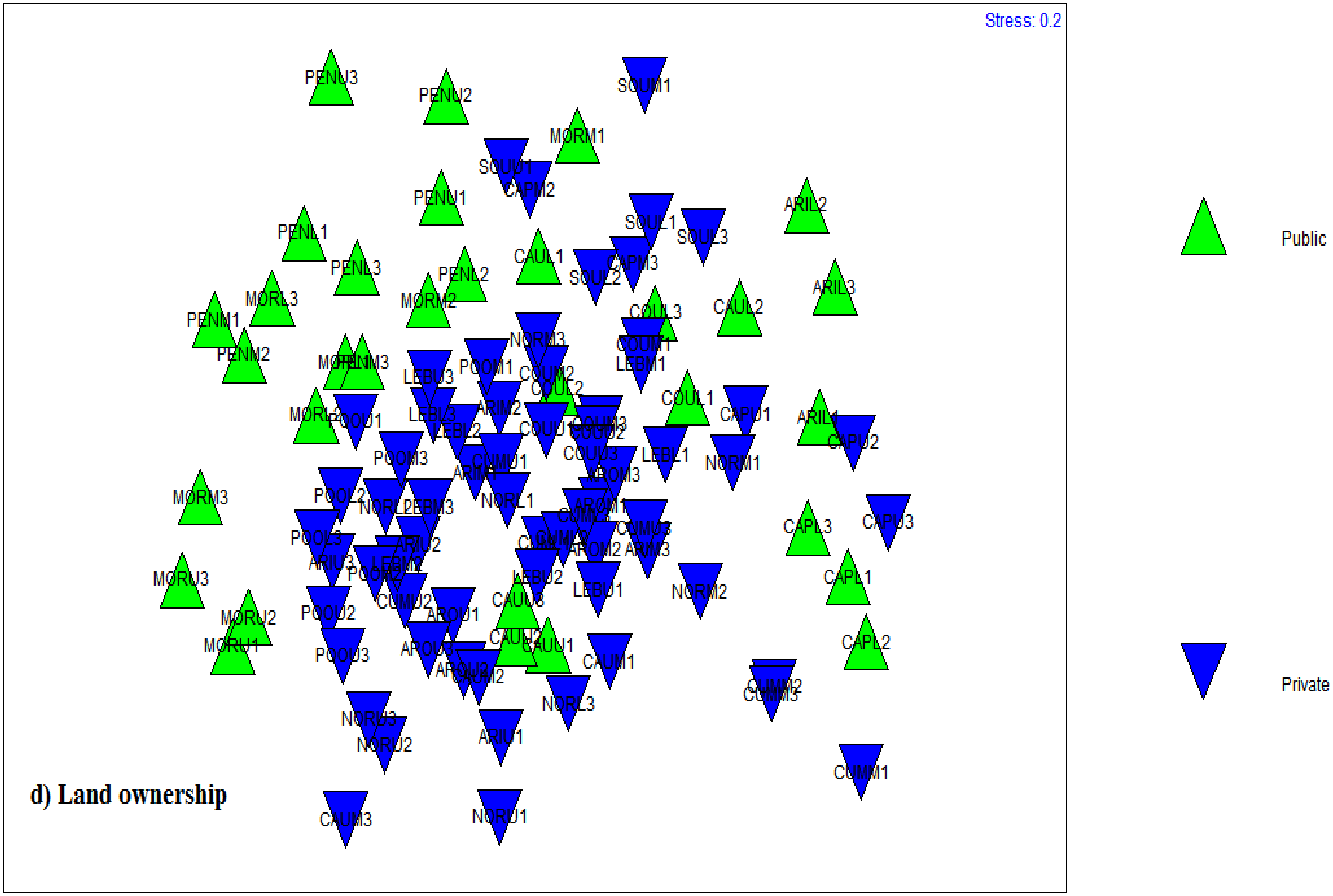

Figure 3-5 Continued

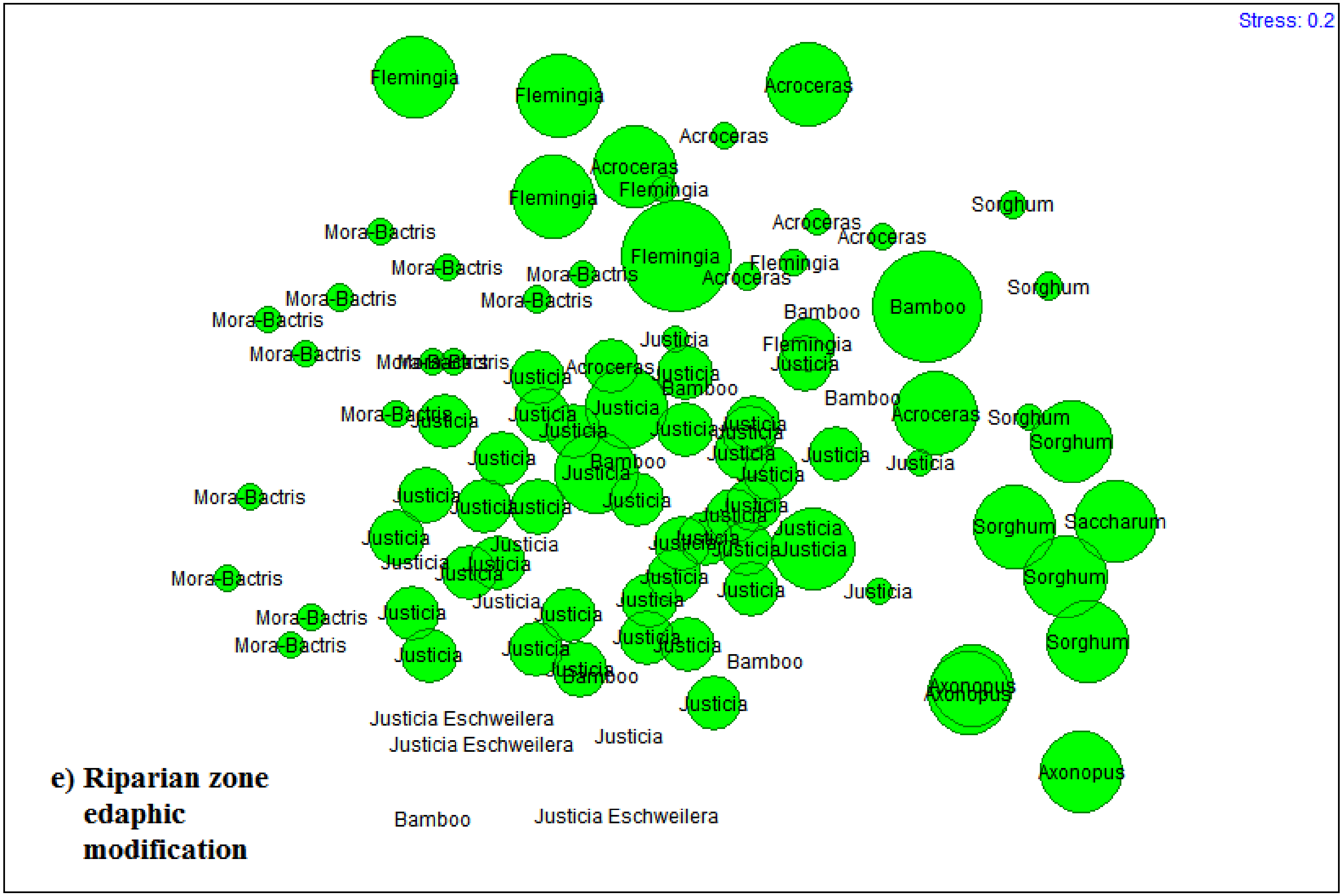

Figure 3-5. Continued

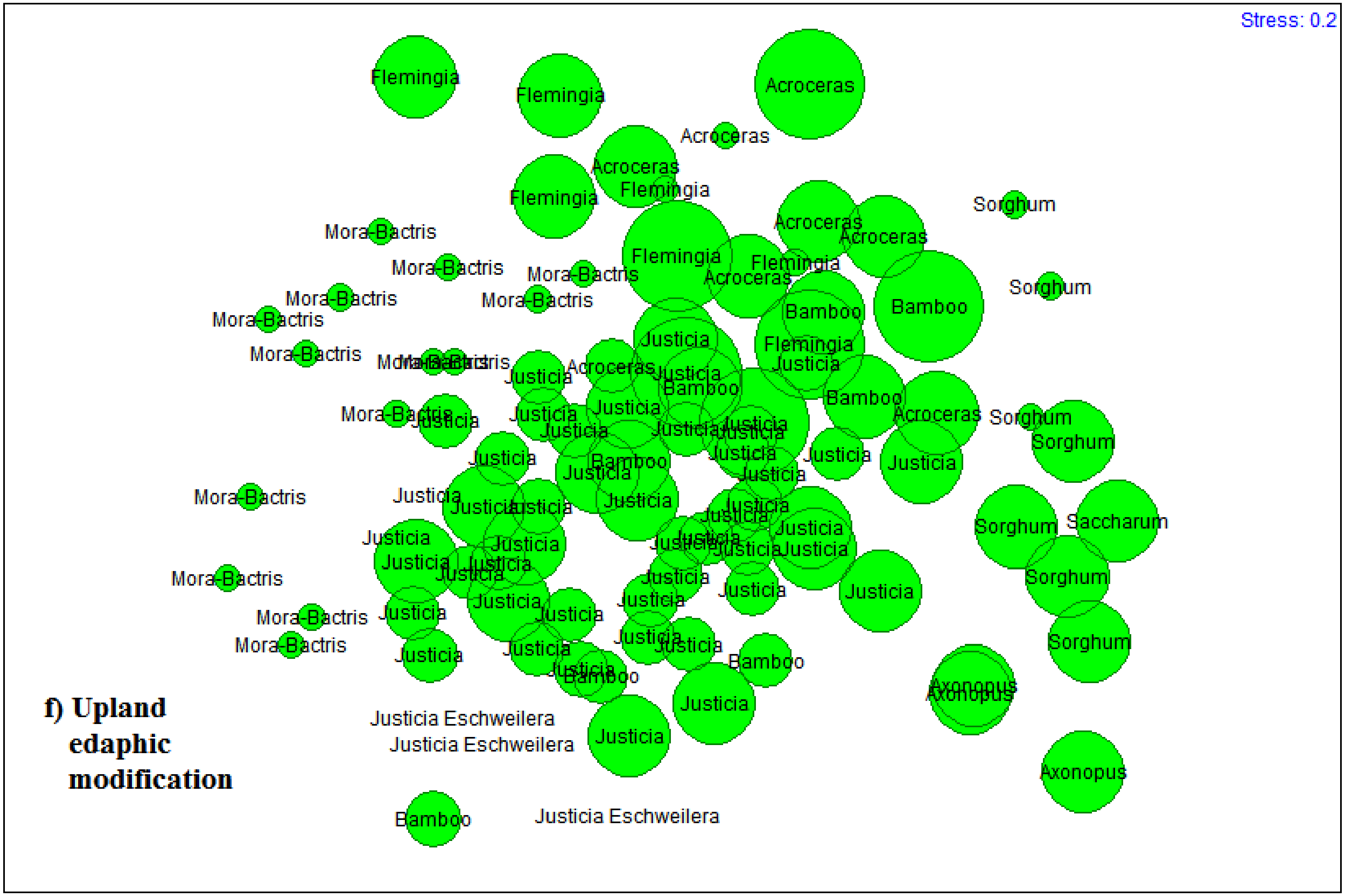

Figure 3-5. Continued

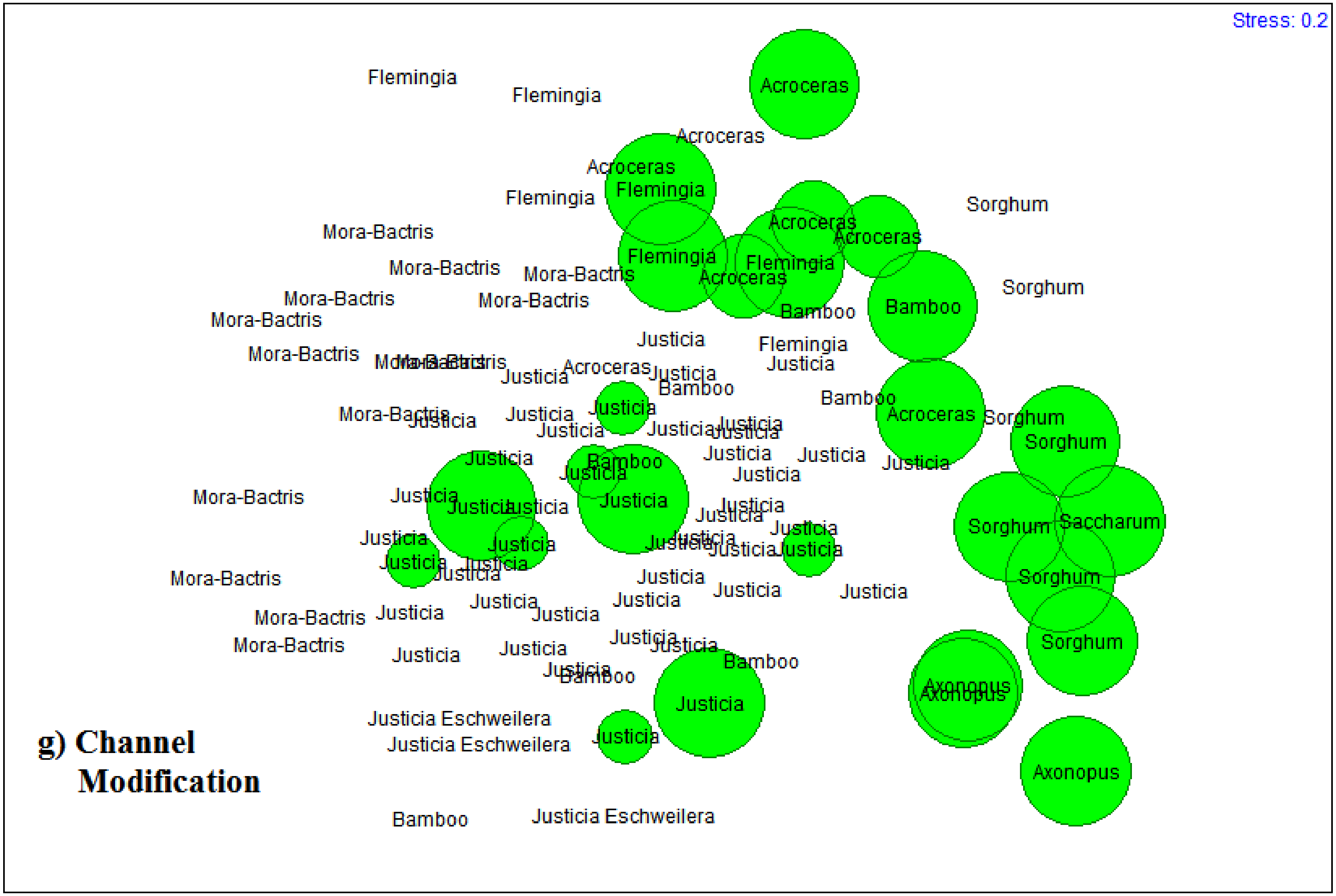

Figure 3-5. Continued

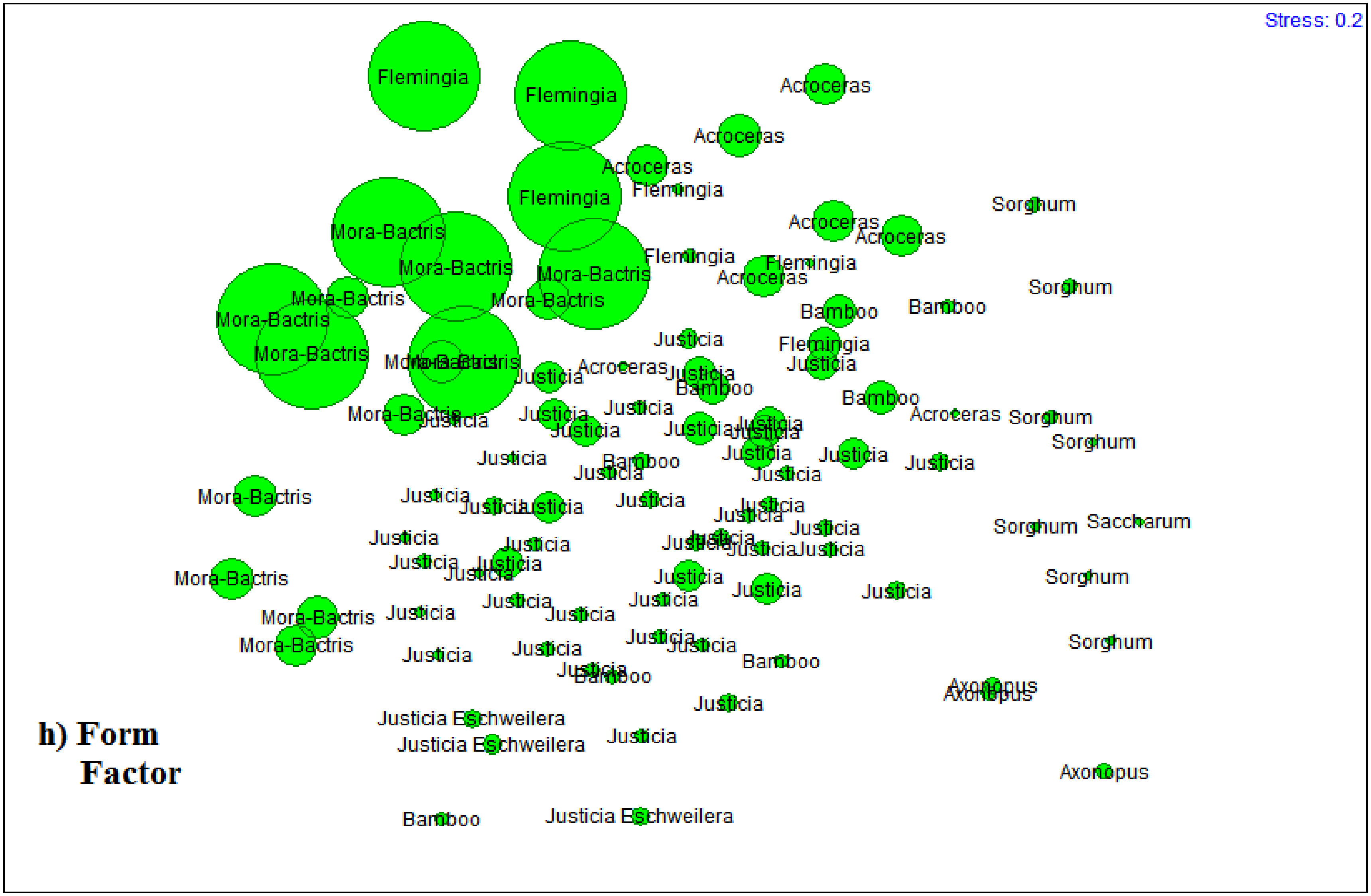

Figure 3-5. Continued

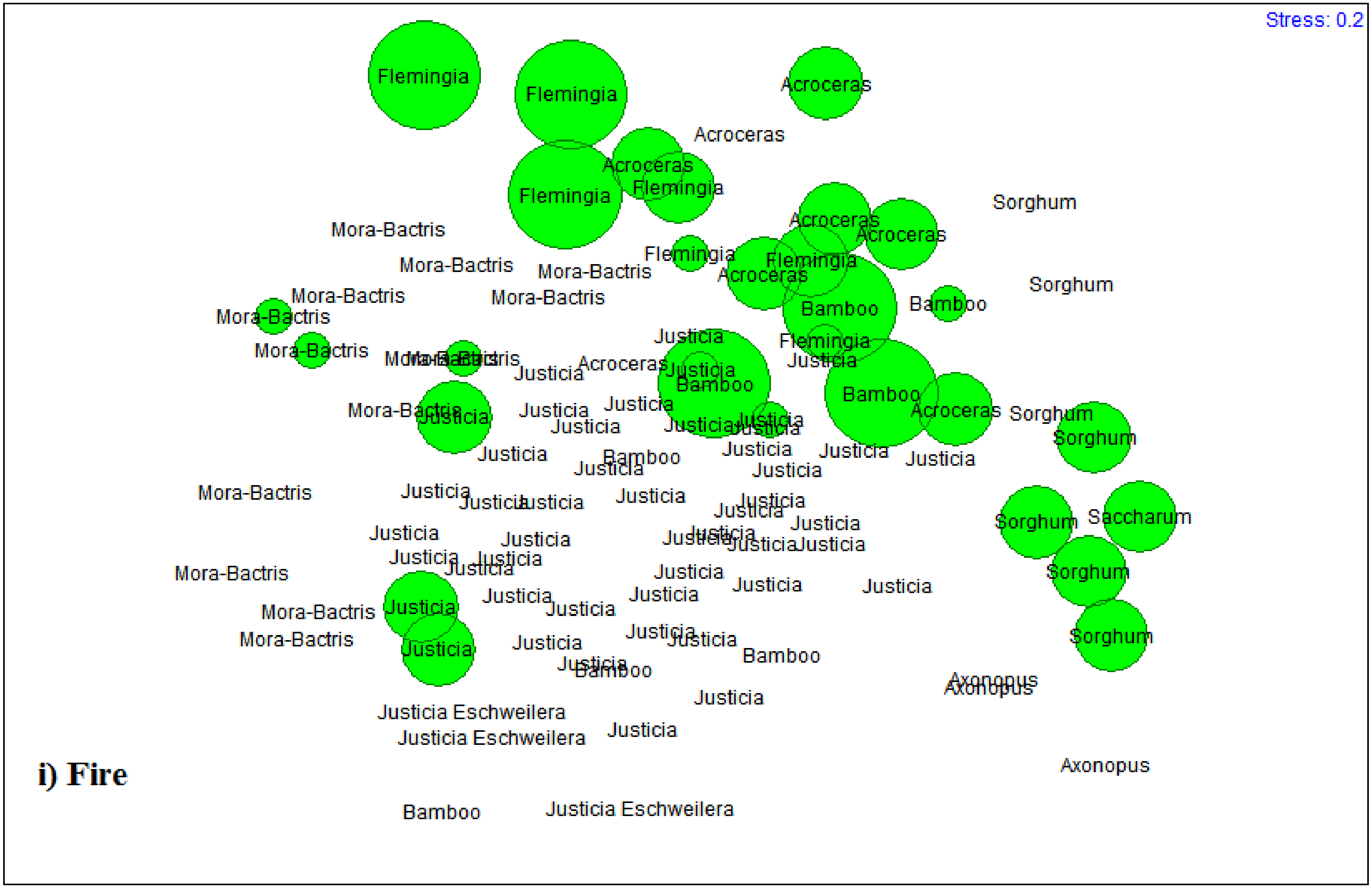

Figure 3-5. Continued

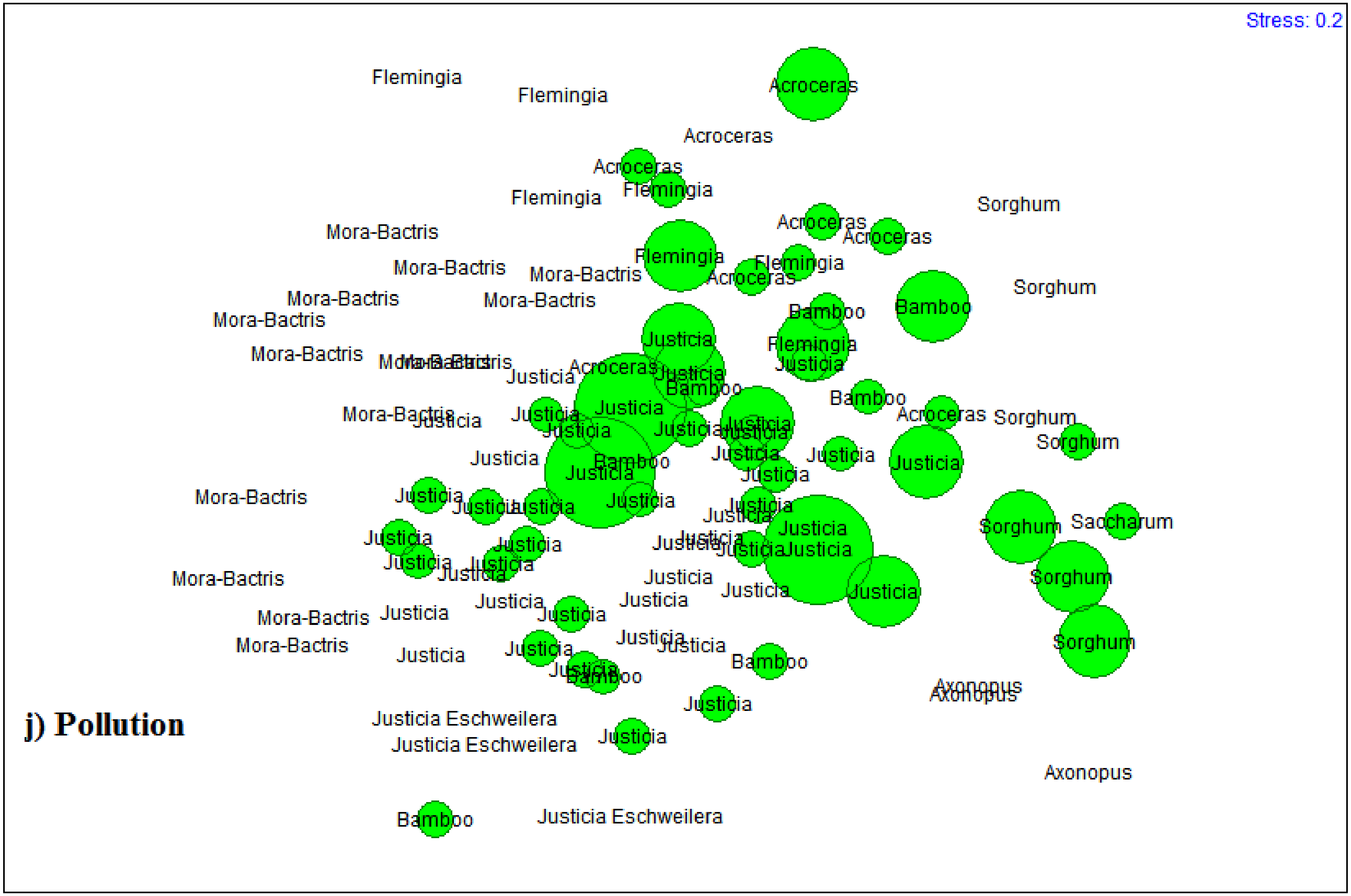

Figure 3-5. Continued

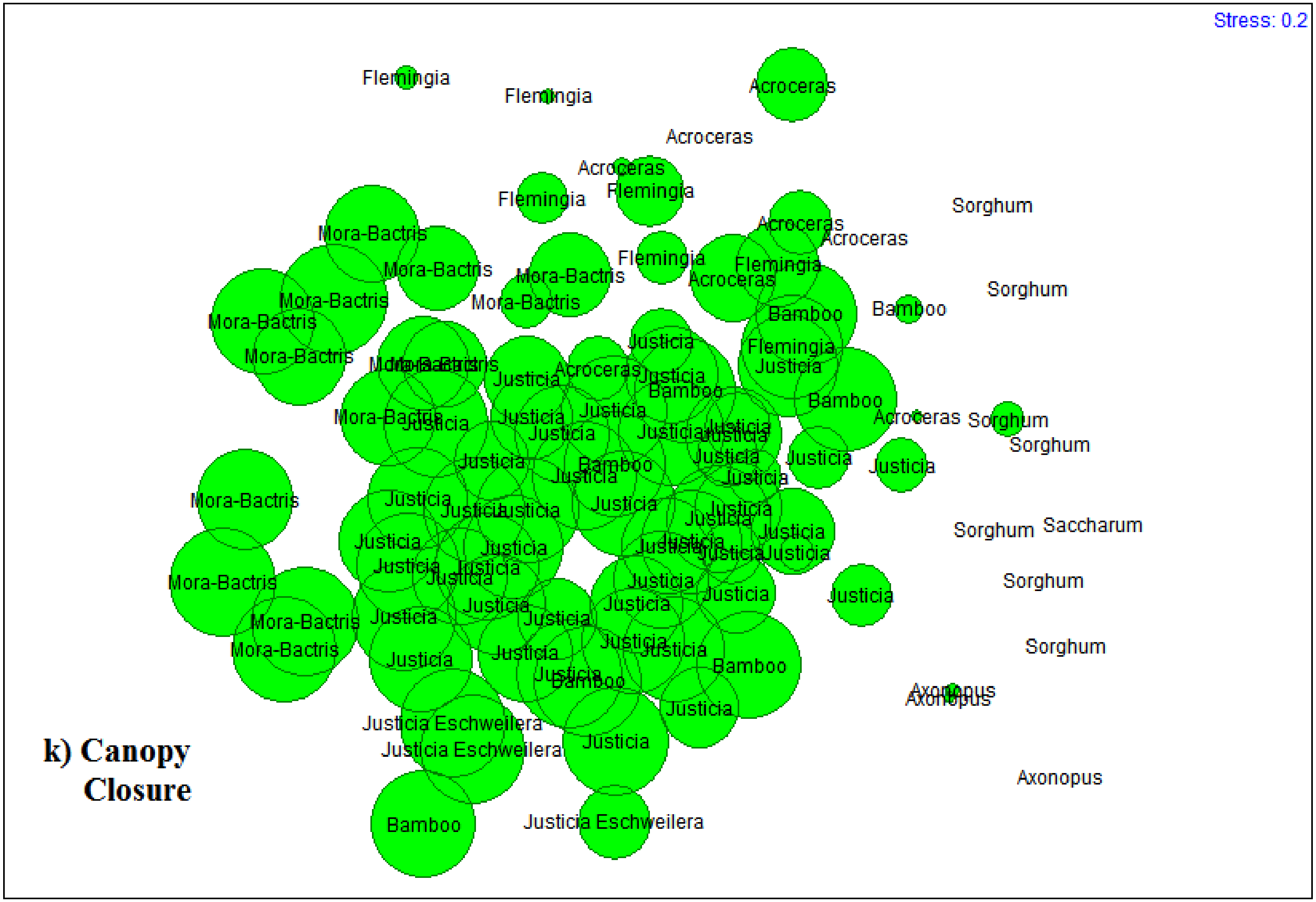

Figure 3-5. Continued

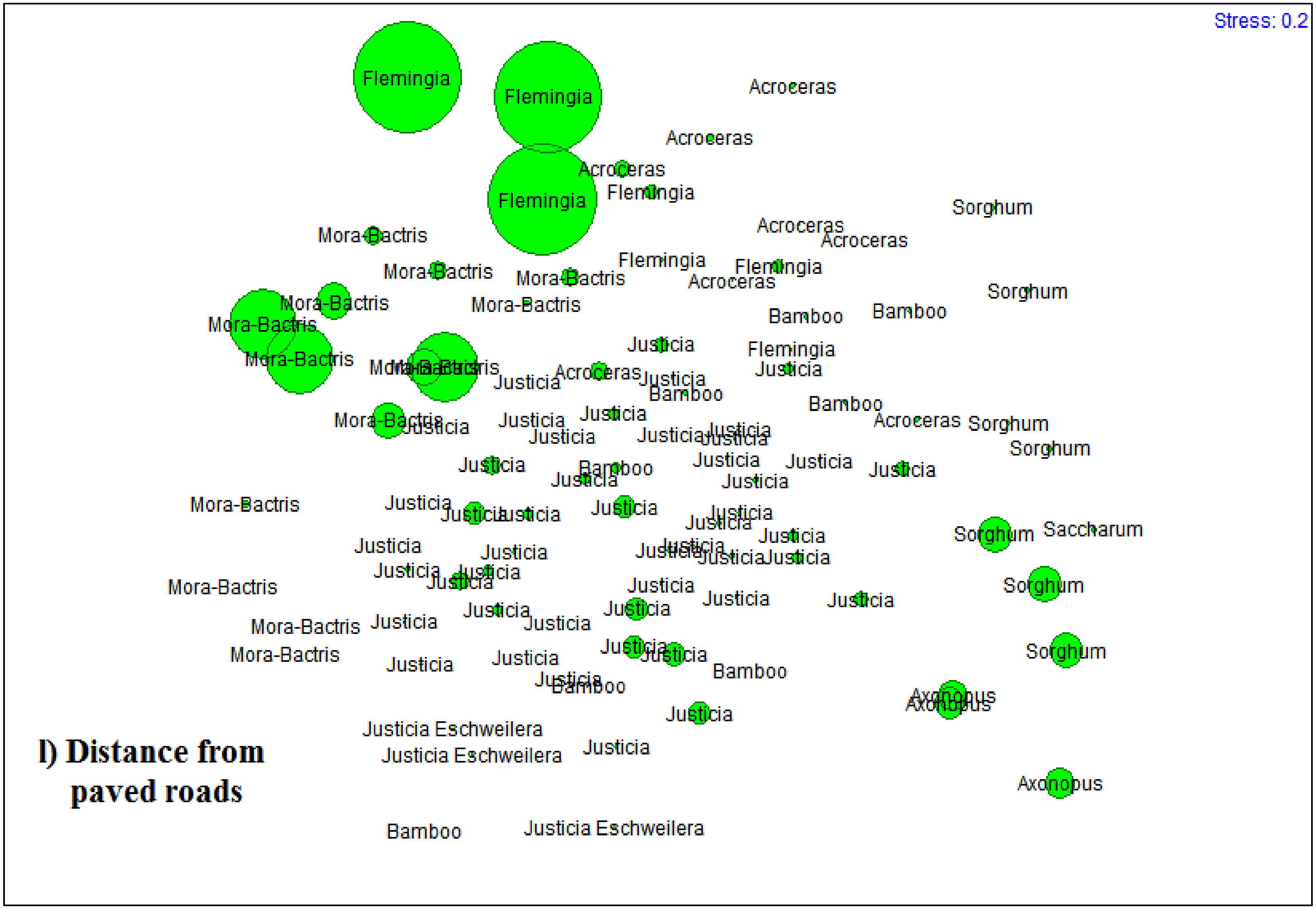

Figure 3-5. Continued

CHAPTER 4

A RIPARIAN CONSERVATION AND RESTORATION INDEX FOR TRINIDAD

Introduction

Human Impacts on Riparian Zones

Riparian ecosystems are subject to extensive disturbance as people have traditionally settled along rivers for transport and trade (Goodwin et al.1997; Freeman et al. 2003). In the United States, for example, Kentula (1997b) noted that approximately 90% of riparian corridors have been degraded. Disturbance may be due to direct or indirect influences.

Direct effects include the clearing and replacement of riparian forest by agriculture, roads, buildings or levees. Recreational activities can result in vegetation trampling, removal of woody riparian plants for firewood, and construction of shelters, boat landings or trails. Remaining riparian vegetation may be grazed, trampled by livestock, or contaminated by agricultural or industrial chemicals (National Research Council 2002). Indirect impacts on riparian zones include alterations in hydrology, and geomorphology of the riparian zone and associated watershed (Williams & Wiser 2004). These alterations can modify flood regimes and sediment delivery (Miller et al. 1995), reducing spatial connectivity and altering the structure, composition and health of riparian vegetation (Karr 1981). Reduction in spatial connectivity of riparian vegetation can impede plant dispersal and movement of animals along the riparian corridor (Naiman et al. 2005). Altered vegetation can also lead to impairment of riparian zone ecological functions such as nutrient cycling (Tabacchi et al. 1998). Human activities in the riparian zone also encourage the spread of exotic species at the expense of native species. A homogenous riparian flora dominated by exotic species may not be able to support diverse or abundant wildlife (National Research Council 2002).

Riparian Restoration

The negative consequences of riparian degradation have spurred substantial interest in riparian restoration. Restoration can be defined as "reestablishing the structure and function of a system to return the habitat to a close approximation of their conditions prior to human disturbance" (Williams et al. 1997). System restoration involves replacing missing structural components such as native plant species and attempting to facilitate natural processes such as succession and nutrient cycling. Several authors have emphasized that biological integrity should be a critical component and goal of restoration (Angermeier 1997; Williams et al. 1997). Biological integrity refers to the "capability of supporting and maintaining a balanced integrated adaptive community of organisms, having a species composition, diversity and functional organization comparable to that of a natural habitat of the region" (Karr & Dudley 1981). Williams et al. (1997) have; however, suggested that given the extent of anthropogenic modification of ecological systems, restoration to pre-disturbance levels is impractical. For instance, it may not be feasible to remove toxic sediments, or biologically impossible to replace extirpated species (Goodwin et al. 1997).

Given the difficulty in establishing pre-disturbance conditions, restoration attempts are often focused on replacing some specific ecological function of most benefit to humans. For example, Hyatt et al. (2004) described riparian restoration attempts in the Pacific Northwest, USA, where restoration procedures were specifically geared towards increasing salmon populations in rivers. Salmon are partial to shady pools, thus riparian restoration was focused on maintaining large riparian trees that shade the river and contribute large woody debris, which in turn creates pools. In restoration attempts such as these, it is hoped that by re-creating the original structure, some aspects of the function of the ecosystem may be restored (Goodwin et al. 1997).

Effective restoration projects also require clear, functional, physical and ecological objectives, and an effective monitoring program to compare restoration outputs against appropriate reference systems (National Research Council 2002). One can try to remove some of the stressors, for example, livestock grazing on agricultural riparian land (Goodwin et al. 1997). There may be the need to eradicate exotics and replant native species. Other common practices in riparian restoration include reestablishing fluvial landforms such as meanders and hydrological variables such as flooding regime (Bunn et al. 1998). However, in urbanized areas, reestablishing flooding regimes would not be possible, and removal of the stressor, i.e., human habitation is not usually an option. In these cases, restoration should be concentrated elsewhere, or there could be some mitigation attempts in the urbanized setting (Goodwin et al. 1997).

Riparian restoration is difficult given the dynamic, complex nature of the riparian zone, the simultaneous impact of riverine and terrestrial influences, and the multitude of processes operating within the riparian zone. As a result, there is no one prescription for riparian restoration, and each site has to be assessed individually (Goodwin et al. 1997). For restoration to be successful, the site must be physically able to support riparian vegetation or else has to be manipulated to create suitable abiotic conditions. In addition, riparian restoration has to take into account the larger spatial context, such as watershed influences on the riparian zone (Kentula 1997b). To increase the likelihood of a successful riparian restoration, it is sensible to identify the most suitable sites *a priori*. Given possible financial and human resource constraints, a means of prioritizing these sites would also be beneficial.

Riparian Indices

Restoration sites can be designated using a suitably designed index as a decision making tool. Restoration indices are generally combined with conservation indices to identify sites that should be conserved, those that can be restored, and those that are so degraded that restoration may not be worthwhile (Harris & Olson 1997; Russell et al. 1997). O'Neill et al. (1997) emphasized the need for these types of indices, suggesting that for too long, riparian zone management has been taking place without this important evaluation.

Index design varies depending on specific conservation and restoration goals. Goals may range from improving water quality by riparian sediment retention, to improving riverine fish stocks, to providing wildlife corridors for large mammals. A riparian area, restored for sediment retention, may be of a different width or species composition to an area restored for wildlife habitat (Hawes & Smith 2005). Consequently, a conservation or restoration index should have different variables and cutoff points, depending on conservation and restoration goals. Index design may also differ depending on available resources, for example, funding and labor. However, indices should be "simple, expedient, flexible and have general applicability" to allow modification to suit local conditions (O'Neill et al. 1997). Innis et al. (2000) also advocate "common sense" and the need to avoid complex "unrealistic" methods.

Riparian indices generally assess site biological integrity, physical characteristics and levels of anthropogenic disturbance. Biological or ecological integrity indicators can include wildlife parameters such as butterfly presence/absence (Nelson & Andersen 1994); however, riparian vegetation characteristics are more commonly used (Landers 1997). Anthropogenic indicators suggest the potential success of conservation and restoration depending on how "defensible" a site may be against current and future human intervention. Thus, Kittel et al. (1999) included indicators such as fire and land use history in their assessment of riparian vegetation in Colorado. Similarly, Salinas et al. (2000) measured the types and intensity of human impacts for each site they assessed. Physical variables include flooding regime and soil wetness. For example, Russell et al. (1997) devised a composite riparian index based on soil moisture, land cover and position in the watershed. While riparian reach characteristics appear to be most often used in riparian integrity indices, there is also recognition of the utility of catchment scale measures as indicators of riparian integrity (Kentula 1997b; Landers 1997). Overall, it appears that indices rely on a wide range of measures to provide a holistic picture of a site's conservation and restoration potential. Examples of riparian indices are provided in Table 4-1 including general methodologies, scoring systems and validation techniques. Table 4-2 lists and categorizes the indicators used in the riparian index literature in Table 4-1.

As studies on tropical island riparian zones are lacking, so too are means of assessing the biological integrity of riparian sites and their suitability for restoration and conservation. From a theoretical perspective, it would be useful to assess common riparian indicators for applicability in tropical island riparian zones. From a practical perspective, given the level of degradation along rivers in Trinidad as outlined in Chapters 2 & 3, a suitable index could jumpstart riparian restoration and conservation efforts on the island.

Objectives

The goal of this Chapter is to develop and test an index to determine and prioritize riparian sites for conservation and restoration in Trinidad. Indices vary depending on available resources and specific restoration objectives. Thus, for this study, the following goals and boundaries will be followed: The index will be designed to assess sites for conservation or restoration for improving river water quality via riparian nutrient absorption and sediment retention. It will assume a 30 m buffer width, which was determined as the active riparian zone width for Trinidad, and is the width recommended for sediment retention by others, for example, Wenger (1999). The index will assume that the more similar a site is to reference riparian conditions, the better able it is to maintain ecological functions such as sediment retention, nutrient absorption and provision of wildlife habitat. The index will also assume that people carrying out the assessment may not have strong plant taxonomic skills, but can be trained to recognize key indicator plants. In addition, the index will be a rapid assessment technique utilizing a minimum number of pertinent, easily measurable variables.

Index limits outlined above are based on what might be practical and feasible in Trinidad. There are currently no riparian buffer strips designated under Trinidadian law; however, there is some interest by the Water Resources Agency to establish them (Water Resources Agency pers comm.). The absence of national riparian buffer regulations is one constraint to consider in the design and implementation of riparian restoration schemes in Trinidad. In the absence of pertinent regulations, narrow buffers may be more feasible. If riparian buffers were legislated, a narrower buffer would be easier to enforce. A narrow 30 m buffer can serve its sediment retention function, but at the same time, confer some protection to terrestrial and aquatic wildlife. The other constraint in designating and choosing areas to restore or conserve is the length of the buffer along a stream. Generally, it is recommended that buffers be continuous to avoid channelized runoff into rivers through riparian vegetation gaps (Hawes & Smith 2005). It may not be possible to have continuous buffers over long distances along rivers, but perhaps it may be feasible in certain key areas.

Methods

Literature Review

Riparian literature was reviewed and assessed for general trends regarding riparian indices, format, design and suitable rapid assessment techniques. One hundred and six papers were examined. Riparian index review papers, for example, Kentula (1997a) & Innis et al. (2000) were especially useful in this study. Vegetation based index papers were emphasized as plant indicators are more frequently used than wildlife indicators (Landers 1997). Wetland index papers were excluded following Innis et al. (2000), who suggested that wetland and riparian ecosystems should be treated separately. Papers where riparian assessments were part of a larger riverine assessment were also excluded; focusing instead on papers where riparian health assessment was the end point.

General Methodology

The index was based on vegetation and abiotic parameters using methods and indicators derived from the literature and data gathered from a study of riparian vegetation and its determinants in Trinidad. Results from the Trinidad study are presented in Chapters 2 & 3, and summaries of index methods and indicators from the literature are provided in Tables 4-1 and 4-2.

The formulation of the index drew heavily from Innis et al. (2000), who outlined a hierarchy of steps for conducting riparian ecological assessments. These authors recommended an initial ecological inventory, followed by classification of the data collected, then identification of indicators and finally, ecological assessment (Figure 4-1). An inventory provides detailed information on the biological, physical and anthropogenic characteristics of a site. Classification groups sites on the basis of common features. Indicators are selected to capture and represent a wide range of site information. Assessments compare indicator values amongst sites or against some predefined reference condition. In the papers described in Table 4-1, reference conditions were assigned on the basis of specific vegetation types, minimal or no anthropogenic disturbance, or the authors' professional judgment. Index variables outlined in Table 4-2 were delineated using information from detailed inventories, indicators from other assessments or literature on plant characteristics.

These general trends were retained for the Trinidadian riparian index. To make the index more robust; however, the following modifications were incorporated: 1) The index used three types of indicators: biological, physical and anthropogenic variables merged into one comprehensive index to provide the best possible assessment of the site. 2) Information from riparian site inventories and the classification exercise for Trinidad were used to establish reference conditions, and also to make management decisions as to which of the sites should be conserved, restored or left as is. 3) Abiotic and anthropogenic variables identified in the literature for potential use in the index, also had to be statistically significant determinants of riparian vegetation groups in Trinidad.

Inventory, Classification and Establishment of Reference Conditions

Thirty-six sites were inventoried with regard to their biological (vegetative), anthropogenic and environmental characteristics. These data were recorded along 3, 30 m transects at each site, as described in Chapter 3. At each site, plant species composition, tree species importance value and ground flora percentage cover were noted. Records from the National Herbarium of Trinidad and Tobago (TRIN), described in Adams & Baksh-Comeau (Unpublished) were used to determine species habitat preferences and traits. It was noted whether plants were previously recorded along rivers, in wetlands or in moist areas, or if they were commonly found in forested areas. It was also noted if they were natives or exotics. Site anthropogenic characteristics like evidence of recreation, edaphic modification, fire and distance from roads were recorded, as well as environmental variables like river discharge. These site details have been provided in Chapters 2 & 3. Vegetation classes were delineated using cluster analysis of 108 sample blocks at the 36 sites sampled. Riparian group composition was compared to historical data (Beard 1946) to assess similarity to natural state vegetation for specific geographic locales. Sites with natural state vegetation were designated as reference sites and also potential conservation sites, especially if there was little anthropogenic disturbance. Sites with weedy, agricultural or disturbed vegetation groups, for example, fire impacted vegetation were not recommended for restoration or conservation. A decision tree for determining management strategies based on inventory and classification data is provided in Figure 4-2.

Indicators

The most common biological variables (Table 4-2) were used for the Trinidad index, provided they were easy to measure and calculate (Figure 4-3). Frequently used defensibility and physical integrity indicators were also used, provided they were statistically significant determinants of riparian vegetation groups in Trinidad. Statistical significance was determined by a rank correlation method where 43 environmental and anthropogenic variables were subjected to BVSTEP and BIOENV analyses in the software program PRIMER to assess the relationships between vegetation clusters and potential explanatory variables. PRIMER routines superimposed an environmental similarity matrix onto a vegetation similarity matrix, providing the best combinations of explanatory variables, which produced the highest rank similarity (ρ) between the plant and environmental matrices (Clarke &Warwick 2001). Details are provided in Chapter 3.

Figure 4-4 outlines the overall decision-making process for selecting index parameters. Variables were repeatedly added and discarded until the smallest number of easily measured, effective discriminating variables was achieved.

Index Design and Validation

The index was designed and tested so that when it was utilized in the field, the indicators would provide the same management suggestions as the detailed inventory and classification process, but with substantially less work. Three possible management options were designated for both the index and detailed analyses, namely, conserve, restore or no action. Sites recommended for conservation were also potential riparian reference sites and warranted some level of protection even in the absence of legislated riparian buffers. Conservation sites were characterized in the inventory and classification stage by natural state vegetation type and minimal anthropogenic activity. In the index, rapidly assessed indicators were used instead to represent the high biological integrity of natural state vegetation sites and low biological integrity of degraded sites. It was assumed that if biological integrity was high, the hydrological regime and physical integrity were intact. The most defensible conservation sites were assigned a higher priority for conservation. Sites which had high biological integrity but were threatened by current or potential future human activity (less defensible) had a lower conservation priority.

In the inventory and classification phase, "no action" sites were either those with agricultural or fire influenced vegetation types or sites in developed areas. These were also physically unsuitable for restoration, for example, impaired flooding regime through channel modification. Restoration sites required removal of threats, for example, grazing or exotic species or replanting of natives. Restoration was considered worthwhile if there was a high number of native species. In the index, "no action sites" had low biological integrity and low defensibility. The more defensible the site, the higher the restoration priority. In the index, restoration sites fell between the "no action" and conservation sites in terms of biological integrity and defensibility.

Priority was assigned by highest scores in biological integrity, physical integrity and defensibility categories. Scoring followed schemes from the literature focusing on simple additive methods without the need for complex and time consuming observations and calculations. For validation, the index was designed using the 12 sites from the North Geomorphological Unit and tested using the 12 sites from the South Geomorphological Unit. This followed the general approach in the literature, where indices were validated using different geographic locales (Table 4-1).

Results

Literature Review

Riparian assessments and associated indicators have been highlighted in Tables 4-1 and 4-2. The 35 indicators in Table 4-2 were categorized into five defensibility, 22 biological, six physical and two biogeochemical indicators. Biogeochemical integrity indicators assessed riparian zone functioning. The most frequently used indicator was a defensibility parameter, namely land use/disturbance followed by channel morphology, a physical integrity parameter. The most frequently used vegetation indicator was "structure", for example, number of vegetation layers.

The scoring techniques highlighted in Table 4-1 were both qualitative and quantitative. Where quantitative systems were used, they were generally simple and additive. Jansen & Roberston (2001) & Petersen (1992) weighted variables differently depending on what they considered to be most important indicators.

Inventory, Classification and Vegetation Determinants

The following vegetation groups were delineated from cluster and correlation analyses: *Eschweilera subglandulosa-Justicia secunda* (North Forest), *Mora excelsa-Bactris major* (South Forest), *Saccharum officinarum* (Agriculture), *Axonopus compressus* (Agriculture), *Bambusa vulgaris*, *Flemingia strobilifera* (Fire Influenced), *Sorghum* sp. (Weedy Species), *Justicia secunda* (Secondary Vegetation) and *Acroceras zizanioides* (Native Grasses). The best predictors of riparian vegetation groups were canopy closure, degree of upland and riparian zone edaphic modification, geomorphology, fire, channel modification, distance from paved roads, land ownership, pollution and form factor. See Tables 3-2 to 3-7 in Chapter 3 for details on these groups and their significant predictors. The *Eschweilera subglandulosa-Justicia secunda* and the *Mora excelsa-Bactris major* groups had few exotic species and were associated with unmodified river channels, low levels of edaphic modification, high canopy closure and an absence of fire. They were also located far away from paved roads. Given the similarity of their vegetation composition to Beard's (1946) description of natural state vegetation and the absence of fire and channel modification, sites with these vegetation types were recommended for both conservation and as reference sites (Table 4-3 and Figure 4-2).

The *Axonopus compressus* and *Saccharum officinarum* agricultural groups were associated with channel modification. The *S. officinarum* and *F. strobilifera* groups were associated with fire. Sites with these vegetation types were recommended for "no action". The *Sorghum* sp. group consisted of weedy species. It was recommended for "no action" if it was found in areas with fire, concrete structures or paved areas (Table 4-3 and Figure 4-2).

Sites in the *Justicia secunda* (Secondary Vegetation) group were found mostly in abandoned agricultural estates and allocated as potential conservation areas, especially if they were in an advanced state of regeneration and had riparian or wetland species as described in Adams & Baksh-Comeau (Unpublished). The *Acroceras zizanioides* group was dominated by native grass species. It was recommended for conservation provided human interference, for example, fire and edaphic modification was minimal. The *Bambusa vulgaris g*roup, while characterized by an exotic grass, was recommended for conservation if there were native plant species, no evidence of fire and limited edaphic modification (Table 4-3 and Figure 4-2). Overall out of 24 sites assessed, 11 were recommended for conservation, seven for no action, and six for restoration.

Indicators

The biological integrity variables used were the number of trees and the presence/absence of the following species: *Bambusa vulgaris*, *Sorghum* sp., *Pureria phaseoloides*, *Cecropia peltata*, *Ochroma pyramidale*, *Heliconia bihai/spathocircinada*, *Spondias mombin* and *Hura* *crepitans* (Appendix J). Fire was used as an anthropogenic/site defensibility variable. It was weighted negatively, as fire can modify or completely destroy riparian vegetation. Also recurring fires can hamper restoration attempts. Disturbance was the other anthropogenic/site defensibility variable. This variable was a combination of vegetation group, level of edaphic modification and canopy closure. It was further divided into upland and riparian zone disturbance. Index variables are highlighted in Appendix J, which also provides the format and instructions for using the index in the field.

Index results for North Unit sites are shown in Table 4-4. The index recommendations for these sites match those of the detailed inventory and classification results (Tables 4-3, 4-4). The results of the validation exercise using South Geomorphological Unit sites also match the recommendations from the detailed analyses (Tables 4-3 and 4-5). It thus appears that the index is suitable for use throughout Trinidad. Overall, four sites in the Northern Range were demarcated for conservation, six for restoration, while no action was recommended for two sites. Index validation using the Southern Geomorphological Unit resulted in six sites recommended for conservation, one for restoration and five for "no action".

Discussion

Suitablility of Metrics

Of 35 potential indicator variables identified (Table 4-2), only eight variables were utilized in the index as these were adequate to discriminate between sites, as well as being quick and easy to measure. Additionally, they were significant determinants of riparian vegetation in Trinidad. No more variables were necessary, and this index follows other compact indices, for example, Part et al. (2003) who utilized four variables in their index.

The first biological integrity variable chosen was tree species richness. Site diversity was also tested, but richness adequately segregated the sites without additional data collection and calculations needed for diversity measurements. Diversity and species richness are common riparian indicators (Table 4-2). Trees were used instead of ground flora, given an overall low number of trees at the sites studied, which meant that less time was needed to count the number of tree morphotypes. Tree species richness was a good discriminant for all vegetation groups, as sites with agricultural and secondary vegetation had either monocultures or a few agricultural species resulting in a lower biological integrity compared to forest sites.

Percentage exotic species was another commonly used index variable but was not used for this index because it would be time consuming to identify and count the large number of riparian exotic species found in Trinidad (49 species as noted in Chapter 2). Instead, easily recognizable exotic species such as *B. vulgaris*, *Sorghum* sp. and *P. phaseoloides* were singled out as poor biological integrity indicators. Other easily identifiable species were also used in the index including the secondary vegetation species *C. peltata* and *O. pyramidale*. An abandoned agricultural estate with a high abundance of these species suggests a long period of agricultural abandonment regression towards historical riparian conditions. Abandoned agricultural estates with a high abundance of secondary indicator species were, therefore, considered potential conservation sites in this study.

Forest group species were not utilized in this index, as they are difficult to identify. Also, with the exception of the Mora forests in south Trinidad, forest species consisted of few individuals distributed across a large number of species. In addition, it appeared that riparian plants could include generalist forest species as described in Chapter 3. Thus, trying to pinpoint riparian forest species would not be practical. Furthermore, there were differences in forest species amongst geomorphological units in Trinidad. For example, south forest species included *Mora excelsa*, which was not encountered in the North or Central Geomorphological Units. On the other hand *B. vulgaris* was found across all geomorphological units. The most frequently used biological integrity indicator in Table 4-2, vegetation structure, was represented in this index by tree species richness. Fragmentation indicators, although commonly used (Table 4-2), were not utilized in this study due to unavailability of reliable spatial data.

The site defensibility indicators used were fire and disturbance. Fire can destroy riparian vegetation or riparian species can be replaced by more fire tolerant species (Bendix 1994; Naiman et al. 2005). It is difficult to defend against and was heavily negatively weighted. Attempting restoration and conservation in fire prone sites is not worthwhile unless biological integrity is extremely high. The disturbance variable (the most commonly used variable in Table 4-2) attempted to quantify human interference at riparian sites (exclusive of fire). It was based in part on edaphic modification, which was a significant determinant of riparian vegetation in Chapter 3 and included aspects like soil compaction, the presence of beds and furrows, and the presence of paved or concrete areas. Disturbance also included vegetation type and canopy closure components. Sites with agricultural groups or low canopy closure were representative of more human interference and degraded condtions (Appendix J).

The only physical integrity indicator used was channel modification. Other potential physical variables like soil parameters were not utilized as they were not significant determinants of riparian vegetation (Chapter 3). Modified channels (resulting mostly from dredging in Trinidad) reduces flooding in riparian areas (Wissmar & Beschta 1998; National Research Council 2002). Although beneficial for settlement and agriculture, reduced flooding is deleterious to riparian vegetation growth. At agricultural sites, it may be possible to restore hydrology by bank modification, but this may not be justifiable in terms of the time and labour needed and perhaps restoration should be concentrated in areas with intact channel morphology and hydrology. Sites in agricultural areas, which were dredged long ago and are unlikely to be dredged in the future, could be considered restoration sites. This is because, over the years channels may have filled in, and deposition may have reduced bank gradients, increasing the likelihood of a natural flooding regime. As a result, sites with dredging had a low restoration priority.

Kentula (1997b) pointed out the utility of multi scale variables including watershed level variables in riparian integrity indices. Watershed landscape metrics (percentage catchment forest cover) was not a good predictors of riparian vegetation groups in Trinidad (See Chapter 3) because of much stronger relationships with reach level factors like fire and channel modification. Hence, watershed variables were not utilized in the index.

Index Design, Validation and Constraints

Variables utilized in the index were rapid visual assessments such as presence/absence of certain species or evidence of specific human activities. Variables requiring observer estimations were not used to reduce assessor variability in carrying out the assessment. Vegetation and environmental data were derived from 30 m^2 sample blocks. This area can be retained for the index, given that variables used needed only rapid visual evaluations. The scoring scheme was a simple additive method; no lengthy calculations were needed. Priority for restoration and conservation was assigned based on higher scores in each category (O'Neill et al. 1997).

The index is flexible, allowing for the addition of other criteria as circumstances necessitate (Oetter et al. 2004). The validation exercise using sites in the South Geomorphological Unit showed that it was possible to differentiate among south sites using metrics derived from the north sites. For example, the index suggested that the Moruga River sites were high priority conservation sites, as did the more detailed classification inventory exercises (Table 4-3).

This study focused on identifying appropriate variables and a rating scheme for use in a rapid riparian conservation and restoration assessment. The next step should be testing the suggested protocol (Appendix J) to assess the time needed to carry out the assessment and determine how user-friendly it is. Field-testing would also identify modifications to reduce inter-person variability in data collection Prat (2003). The index can serve as a baseline and more elaborate work including taxonomic analyses can solve any site specific dilemmas (Ward et al. 2003). The index was designed for Trinidad but can be modified and applied to other Caribbean islands depending on their riparian species composition and determinants. Additionally, the index can be used to monitor effects of restoration and conservation measures (Dixon et al. 2005).

Tropical Island Context

There is limited literature on island riparian vegetation, and by extension, limited examples of island riparian indices. General metrics suggested by the literature appear relevant to small islands as well, as demonstrated by this study. Given the small size of rivers in Trinidad (Chapter 2), variables applicable to small streams in temperate areas were relevant. For example, one variable used in the index was disturbance beyond the riparian zone. Peterson (1992) used upland land use as a variable in the Riparian Channel and Environmental Inventory (RCE) index (Table 4-1) as it was a determinant of riparian vegetation along small streams. Land use beyond the riparian zone also indicates connectivity to natural ecosystems (Petersen 1992; Kittel et al. 1999). Overall, it appears that parameters and methodologies used in riparian indices worldwide are also applicabile to tropical islands.

Restoration Techniques

This study does not provide a blueprint for riparian restoration in Trinidad. The index just seeks to identify places that should be conserved and places where restoration is likely to be successful. However, riparian vegetation characteristics and determinants suggest some factors, which should be considered in any restoration attempt in Trinidad. This index was designed to aid in riparian management decisions for improved river water quality and to a lesser extent wildlife and biodiversity protection. Thus, suggestions for restoration are geared towards these goals as well.

High biological integrity sites are more capable of supporting ecosystem functions (Karr & Dudley 1981). In the case of riparian zones, this can include nutrient absorption and sediment retention, which are important aspects for river water quality (Peterjohn & Correll 1984; Anbumozhi et al. 2005). Proposed conservation areas could be left as is for biodiversity purposes, assuming the functions of sediment and nutrient retention are adequately maintained under natural vegetative conditions. However, in agricultural areas marked for restoration, it may be more practical to focus on replanting select species, which through further experimental work may be identified as fast growing or useful for nutrient and sediment retention. This type of restoration may be particularly useful at sites close to water extraction points. Restoration geared towards biological integrity could be relegated to areas where water quality is not as critical or where there may be a greater need to protect the site for riparian wildlife or plant biodiversity.

For restoration, there may be the need to eradicate exotics and replant native species especially if biological integrity is a primary goal. The prevalence of exotic bamboo along rivers in Trinidad would then warrant special attention. It is fast growing, aggressive and difficult to eradicate (McClure 1993). It may be that given feasibility, time or financial constraints, bamboo could be left in place at low priority, less defensible restoration sites. Additionally, given the plant's dense matted root network, leaving bamboo along rivers can be justified for sediment retention and bank stabilization. Bamboo has in fact been planted along rivers in Trinidad for bank stabilization purposes (Forestry Division pers comm.). A higher priority for bamboo removal may be in upper river reaches, as the plant can reestablish itself from broken culms transported downstream (O'Connor et al. 2000).

Common practices in riparian restoration include reestablishing fluvial landforms such as meanders and hydrological variables such as flooding regime. Accumulated sediment may have to be removed (Bunn et al. 1998). In the Trinidad context, this may not be practical as the areas where hydrology and geomorphology have been altered are close to human habitation or agricultural areas. However, hydrology and geomorphology can perhaps be restored in abandoned agricultural areas.

River Management

The index designed in this study is specific to riparian zones. However, riparian restoration and management are often tightly linked to river restoration (Petersen 1992; Goodwin et al. 1997). This index can be utilized as a component of a river management index, which may also incorporate water quality and aquatic fauna indicator species. Aquatic variables may also identify areas where riparian restoration is urgently needed. Some riparian restoration decisions become more complicated within the larger context of river restoration. For example, the plants used in riparian restoration would have to be considered in terms of their impact on aquatic wildlife, for example, if they would be a good food source for riverine species. Both riparian and river management should also be considered in terms of overall watershed management. Kentula (1997b) & Landers (1997) advocate a watershed approach to riparian restoration recognizing the control that watershed processes and spatial characteristics have on riparian ecosystems (Allan et al. 1997).

Table 4.1. Examples of riparian assessment methodologies, applications, scoring and validation methods

Index summary	Scoring and validation methods
Innis et al. (2000) reviewed riparian index papers and suggested their own indicators of ecological integrity. Their positive indicators were: increasing levels of canopy development, biodiversity, microclimate, river seston and patch heterogeneity. Increasing terrestrialization was seen as a negative indicator. They also outlined a hierarchy of information for conducting ecological assessments moving from detailed inventories, to classification, to the derivation of indicators and finally the highest level ecological assessment.	Only outlined their suggested variables, no mention of validation or scoring.
Kittel et al. (1999) ranked sites using indicators of 1. Quality: vegetation patch sizes, connectedness to natural ecosystems, degree of stream flow alteration. 2. Condition: number of exotic species, soil compaction levels, livestock grazing, amount of human disturbance, stand age, species composition and water quality. 3. Viability: hydrological regime integrity and current site management. 4. Defensibility: site threats, factors affecting the site survival. Subsequent revision of the index after two years extended the parameters to include: 5. Landscape context: adjacent land use, habitat fragmentation, watershed hydrology changes, activities immediately outside the riparian zone. 6. Overall size of vegetation patch, and size relative to pre-settlement conditions. Sites were compared to reference conditions, which the authors based on professional judgment.	Riparian health was calculated as the average of quality, condition, viability and defensibility, landscape context and patch size indicators, and then ranked from the highest A to the poorest D. An A ranked site possessed characteristics like: few exotics, limited soil compaction, riparian vegetation connected to surrounding vegetation and limited human activity in the watershed. "A" ranked sites were recommended for protection.

Table 4.1 Continued

Index summary	Scoring and validation methods
Dixon et al. (2005) developed the Tropical Rapid Assessment of Riparian Conditions (TRARC) for tropical savannah areas in Australia. The TRARC used 21 riparian zone function indicators (Naiman & Decamps 1997) to delineate sites for conservation and restoration and to judge the success of these types of activities. Indicators were divided into five categories, i.e. cover, debris, natives, regeneration and disturbance. Johansen et al. (2007) compared the TRARC field based approach to a remote sensing approach (Quickbird imagery). The two approaches were found to be complementary. Remote sensing methods were recommended for coarser scale analysis fine tuned by the TRARC field methods.	Each of the 21 indicators were given a score from 0-4. For example for ground cover: no ground cover=0, 1-30% ground cover=1, 30-60% ground cover=2, 60-85% ground cover=3 and 85-100% ground cover=4. Indicators such as number of juveniles in the understory scored double highlighting the importance ascribed by the authors to regeneration as a biological integrity indicator. Final score was calculated as the sum of all indicators out of a maximum of 100.
Jansen & Roberston (2001) described a rapid appraisal method focusing on the effect of grazing on the riparian zone. Physical, biological and landscape indicators were used, grouped within six general categories i.e. cover, bank characteristics, natives, debris, habitat and species characteristics.	Used reference sites in relatively pristine sites. Scores ranged from 0-50. Variables were weighted, for example, the woody debris category could capture a maximum of 10/50 points while natives only 5/50.
Salinas et al. (2000) evaluated the degradation state of riparian vegetation in south-east Spain. Positive indicators included evidence of regeneration, plant percentage cover and species richness. The number of exotic species was used as a negative indicator. Human impact intensity was also noted. The index was designed to show the most degraded sites and those needing restoration.	No validation method presented. Degradation level based on sum of the values assigned to each indicator.
Prat (2003) outlined the Qualitat del Bosc de Ribera (QBR) index to measure riparian ecological integrity. Partly based on Petersen (1992), variables included total vegetation cover, vegetation quality, vegetation structure and channel modification. High scoring sites had complex vegetation structures, high species richness and little or no channel modification. The index was found to be applicable to different regions in Spain.	The index was developed in Catalonia, Spain, tested using 72 sampling sites and validated at sites along the Mediterranean Spanish coast. Each variable was worth a maximum of 25 points and the total possible score was 100.

Table .4-1. Continued

Index summary	Scoring and validation methods
Simon (2001) developed a rapid multi-metric biotic integrity assessment for riverine wetlands following Karr (1981), using plant variable substitutes for Karr's fish indicators. Variables included number of individuals of indicator plant species, for example, *Carex* and *Potamogeton*, number of emergent species, number of perennial species and number of sensitive plant species. The higher the score for these variables the greater the biological integrity and closer to reference conditions. The higher the number of exotic species, and the greater the number of plant abnormalities, for example, rust and lesions, the lower the biological integrity.	No validation only initial set of variables presented for further testing. Metrics were used to produce an overall score between 1-5 with 5 being the best site score.
Fry et al. (1994) outlined the Riparian Evaluation and Site Assessment (RESA), which ranked sites according to functions and benefits. This was a rapid assessment based on the US Soil Conservation Service Land Evaluation and Site Assessment (LESA). Biological, physical and anthropogenic parameters were used.	No validation method stated. Scored using a simple additive method.
Oetter et al. (2004) used a GIS approach to prioritize restoration sites based on land cover, channel modification and floodplain vegetation. Sites with lower levels of development and relatively complex channel and vegetation structures were recommended for restoration.	No scoring provided just developed relevant GIS layers.
O'Neill et al. (1997) used GIS to characterize geomorphology, hydrology, relative soil moisture, disturbance (stream energy), land use and vegetation to determine site restoration potential.	Parameters scored from -2 to +6. Highest scoring sites were assigned as priority restoration areas. The method was tested using two field sites.
Russell et al. (1997) used a GIS approach to identify potential restoration sites using wetness and land use classes. Wetness was determined from Digital Elevation Models. Areas with high/medium wetness and natural vegetation were allocated for preservation. Agricultural and barren sites with medium wetness were designated for restoration. Restoration priority was based on proximity to existing riparian vegetation areas and size of the existing patch.	No scoring or validation, just developed GIS layers.

Table 4.1. Continued

Index summary	Scoring and validation methods
Petersen (1992) developed Riparian Channel and Environmental Inventory (RCE) for small streams. This was a rapid semi-quantitative method with weighted metrics. Variables included land use, vegetation characteristics and channel morphology. The total score (maximum of 360) was used to assign status and prescribe management actions. For example a site scoring between 293-360 was considered in excellent condition and recommended for protection. A score of 86-153 was deemed a site in fair condition with major alterations needed.	The index was designed for agricultural settings and tested under alternative land use categories. The authors allotted higher weights (maximum of 30) to variables like riparian zone completeness as opposed to riparian zone plant density (maximum of 25 points).
Ward et al. (2003) described a simple visual riparian health assessment method. Variables included flooding regime and bank stability. This technique deviated a bit from other methods as it included stream integrity characteristics, for example, fish and macro-invertebrate habitat to assess riparian health.	Score was the sum of either 12 or 6 points per variable. Bank stability, for example, was weighted lower (maximum of 6 points) than flooding regime (maximum of 12 points).
Coles-Ritchie et al. (2007) assessed ecological integrity using average weighted scores based on community classes following Winward's (2000) vegetation classification. Sites with hydric vegetation classes scored higher.	Calculated a site wetland index based on community type. For example, a plant community with only obligate wetland species scored 100 and a community type with only upland species scored 0. The site wetland index was calculated based on the percentage of each community type at each site.
Hauer & Smith (1998) and the more detailed Hauer et al. (2002) assessed sites using indicators of riparian zone function, compared to reference conditions. Functions were divided into hydrological, biogeochemical, vegetation and faunal maintenance categories. The index was used to assess sites before and after impacts, in restoration planning and to monitor restoration efforts.	Scoring was based relative to reference systems. Numerous calculations were required for this functional index.

Table 4.1 Continued

Index summary	Scoring and validation methods
Harris & Olson (1997) prioritized riparian areas for protection and restoration by combining coarse scale remote sensing techniques with fine scale field methods. In the first stage aerial photos and maps were used to rank sites on the basis of land use. Sites with > 30% urban or agricultural land cover were eliminated as potential restoration or protection sites. Possible restoration sites were identified on the basis of 60-90% riparian cover, low fragmentation and <10% agriculture or urban land use. Potential restoration sites were visited in the field and assessed in terms of geomorphology and their associated vegetation communities, then compared to reference conditions. Reference conditions were selected based on the authors' professional judgment and indicators selected which characterized the reference conditions and by extension distinguished between the high integrity reference conditions and other sites.	Validation via application to riparian areas in southern California as described in Olson & Harris (1997). A specific scoring system was not provided.

Table 4-2. Most commonly used field indicator variables from Table 4-1

Variable type	Variable	No. of times used
Biogeochemical	Water quality	2
Biogeochemical	Nutrient cycling/nutrient export/organic matter export/organic matter decomposition/particulate retention	1
Biological integrity	% bare ground	1
Biological integrity	% canopy juveniles in the understory	1
Biological integrity	% grass cover	1
Biological integrity	% ground cover	2
Biological integrity	Abundance of a specific indicator species or vegetation community type/species composition	5
Biological integrity	Biodiversity/species richness	4
Biological integrity	Canopy coverage/% shading/overstory cover/canopy continuity	3
Biological integrity	Evidence of plant regeneration/% canopy juveniles in the ground flora	3
Biological integrity	No./% of exotic species	5
Biological integrity	No. of native species/native plant coverage	3
Biological integrity	Patch connectivity/floodplain habitat connectivity/fragmentation/completeness of riparian zone	7
Biological integrity	Plant % coverage/total vegetation coverage	4
Biological integrity	River seston	1
Biological integrity	Soil organic material/thickness of each horizon layer/soil structure	2
Biological integrity	Vegetation patch heterogeneity	1
Biological integrity	Vegetation patch size/riparian zone width	3
Biological integrity	Vegetation quality, for example, rust and lesions	1
Biological integrity	Vegetation stand age	1

Table 4-2. Continued

Variable type	Variable	No. of times used
Biological integrity	Vegetation structure, for example, presence or absence of trees/variation in structure/density/ability to maintain characteristic plant community structure/tree density/shrub coverage/herb coverage/no of vegetation layers	7
Biological integrity	Wildlife/riparian zone wildlife habitat/in stream aquatic habitat	3
Biological integrity	Woody debris including: fine woody, coarse woody and standing dead/detrital biomass/large woody debris/aquatic woody debris.	3
Defensibility	Adjacent land use/upland land use	3
Defensibility	Amount of human disturbance/long-term site viability/site management practices/intensity of human impacts/recreational use/riparian zone land use/degree of development/land cover type	11
Defensibility	Animal impact	1
Defensibility	Fire impact	2
Defensibility	Watershed integrity including:% natural forest/% agriculture/proportionality of landscape features	3
Physical integrity	Channel morphology/channel structure/evidence of slumping/gully erosion/bank stability	9
Physical integrity	Degree of soil compaction	1
Physical integrity	Degree of stream flow alteration/channel modification/geomorphic modification	4
Physical integrity	Degree of terrestrialization	1
Physical integrity	Intactness of hydrological regime/surface and subsurface flooding/surface and subsurface water storage (groundwater)	4
Physical integrity	Soil moisture level	1

Table 4-3. Recommended site management strategies based on detailed taxonomic and classification analyses

Geomorphological Unit	Site	Site Acronym	Management Strategy
North	Aripo Lower Reach	ARIL	Restore
North	Aripo Middle Reach	ARIM	Restore
North	Aripo Upper Reach	ARIU	Conserve
North	Arouca Lower Reach	AROL	Restore
North	Arouca Middle Reach	AROM	Restore
North	Arouca Upper Reach	AROU	Conserve
North	Caura Lower Reach	CAUL	No action
North	Caura Middle Reach	CAUM	Conserve
North	Caura Upper Reach	CAUU	Restore
North	North Oropouche Lower Reach	NORL	Conserve
North	North Oropouche Middle Reach	NORM	No action
North	North Oropouche Upper Reach	NORU	Conserve
South	Moruga Lower Reach	MORL	Conserve
South	Moruga Middle Reach	MORM	Conserve
South	Moruga Upper Reach	MORU	Conserve
South	Penal Lower Reach	PENL	Conserve
South	Penal Middle Reach	PENM	Conserve
South	Penal Upper Reach	PENU	No action
South	Poole Lower Reach	POOL	Conserve
South	Poole Middle Reach	POOM	Restore
South	Poole Upper Reach	POOU	No action
South	South Oropouche Lower Reach	SOUL	No action
South	South Oropouche Middle Reach	SOUM	No action
South	South Oropouche Upper Reach	SOUU	No action

Table 4-4. Index results for sites in the North Geomorphological Unit

Site	Rating according to no. of trees	*Bambusa* presence/ absence	*Sorghum*/ *Puereria* presence/ absence	Secondary species presence/ absence	Disturb- ance	Disturbance 50-100 m from the river channel	Evidence of fire	Biological integrity subtotal	Site defensibilit y subtotal	Total	Management recommendatio n
ARIL	2	10	0	0	3	10	50	12	63	75	Restore
ARIM	4	10	0	5	2	2	50	19	54	73	Restore
ARIU	6	10	5	5	10	2	50	26	62	88	Conserve
AROL	0	10	0	0	3	0	50	10	53	63	Restore
AROM	4	0	2	0	6	6	50	6	62	68	Restore
AROU	6	10	2	5	6	6	50	23	62	85	Conserve
CAUL	2	0	5	0	0	0	0	7	0	7	No action
CAUM	6	0	5	0	10	10	50	11	70	81	Conserve
CAUU	4	0	2	0	6	6	50	6	62	68	Restore
NORL	6	0	2	5	6	2	50	13	58	71	Restore
NORM	2	0	2	0	3	3	0	4	6	10	No action
NORU	10	10	5	0	10	10	50	25	70	95	Conserve

Key >80 Conserve, 50-80 Restore, <50 No action

Table 4-5. Index results for sites in the South Geomorphological Unit

Site	Rating according to no. of trees	*Bambusa* presence/ absence	*Sorghum*/ *Pureria* presence absence	Secondary vegetation species/absence	Disturb-ance	Disturbance 50-100 m from the river channel	Evidence of fire	Biological integrity subtotal	Site defen-sibility subtotal	Total	Management recommendation
MORL	6	10	5	0	10	10	50	21	70	91	Conserve
MORM	4	10	5	5	10	10	50	24	70	94	Conserve
MORU	4	10	5	0	10	10	50	19	70	89	Conserve
PENL	6	10	5	5	10	10	50	26	70	96	Conserve
PENM	6	10	5	5	10	10	50	26	70	96	Conserve
PENU	2	10	5	0	2	2	0	17	4	21	No action
POOL	10	10	5	5	6	10	50	30	66	96	Conserve
POOM	2	0	2	0	6	6	50	4	62	66	Restore
POOU	10	10	5	5	6	6	0	30	12	42	No action
SOUL	2	0	2	5	6	0	0	9	6	15	No action
SOUM	2	10	5	0	2	0	0	17	2	19	No action
SOUU	2	10	5	0	2	2	0	17	4	21	No action

Key >80 Conserve, 50-80 Restore, <50 No action

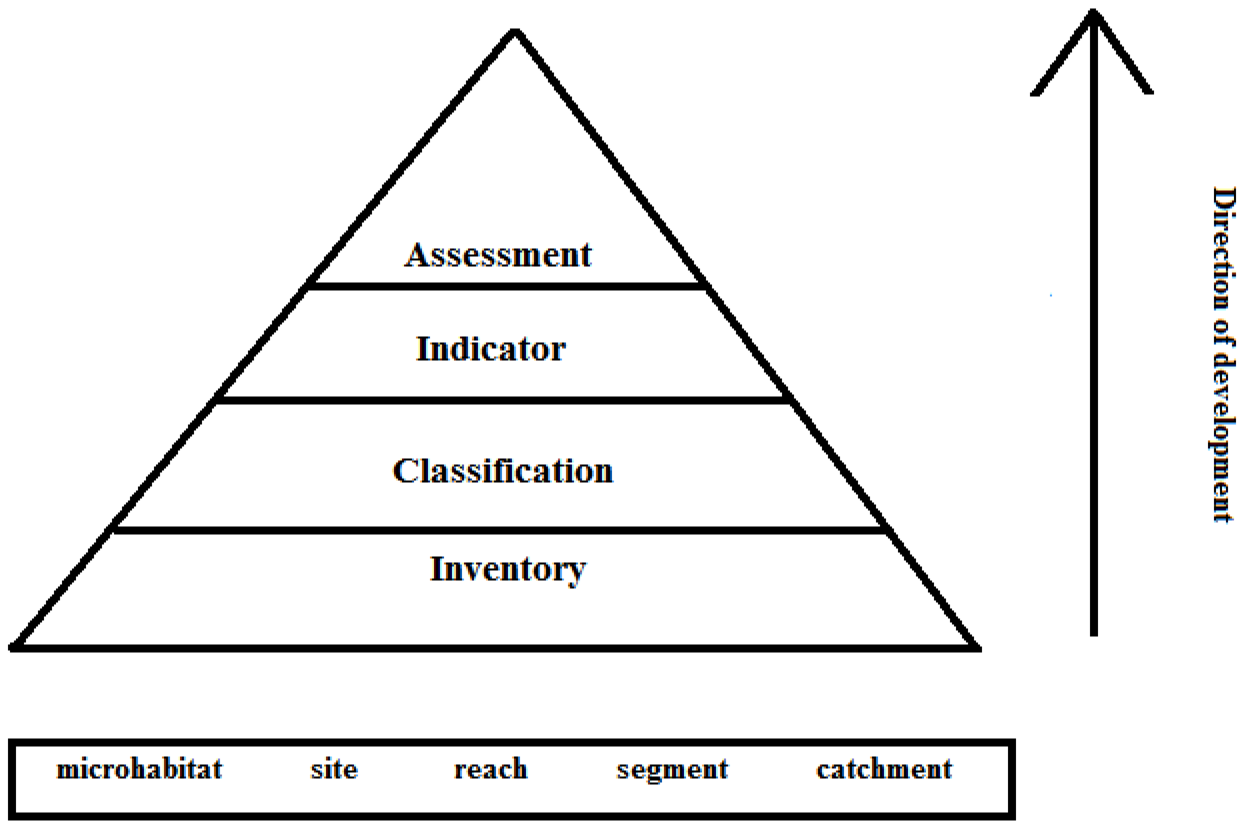

Figure 4-1. Hierarchy of information of ecological information (Modified by permission from Innis, S. A., Naiman, R. J. & Elliott, S. R. 2000. Indicators and assessment methods for measuring the ecological integrity of semi-aquatic terrestrial environments. Figure 1 pg 116. *Hydrobiologia* 422/423

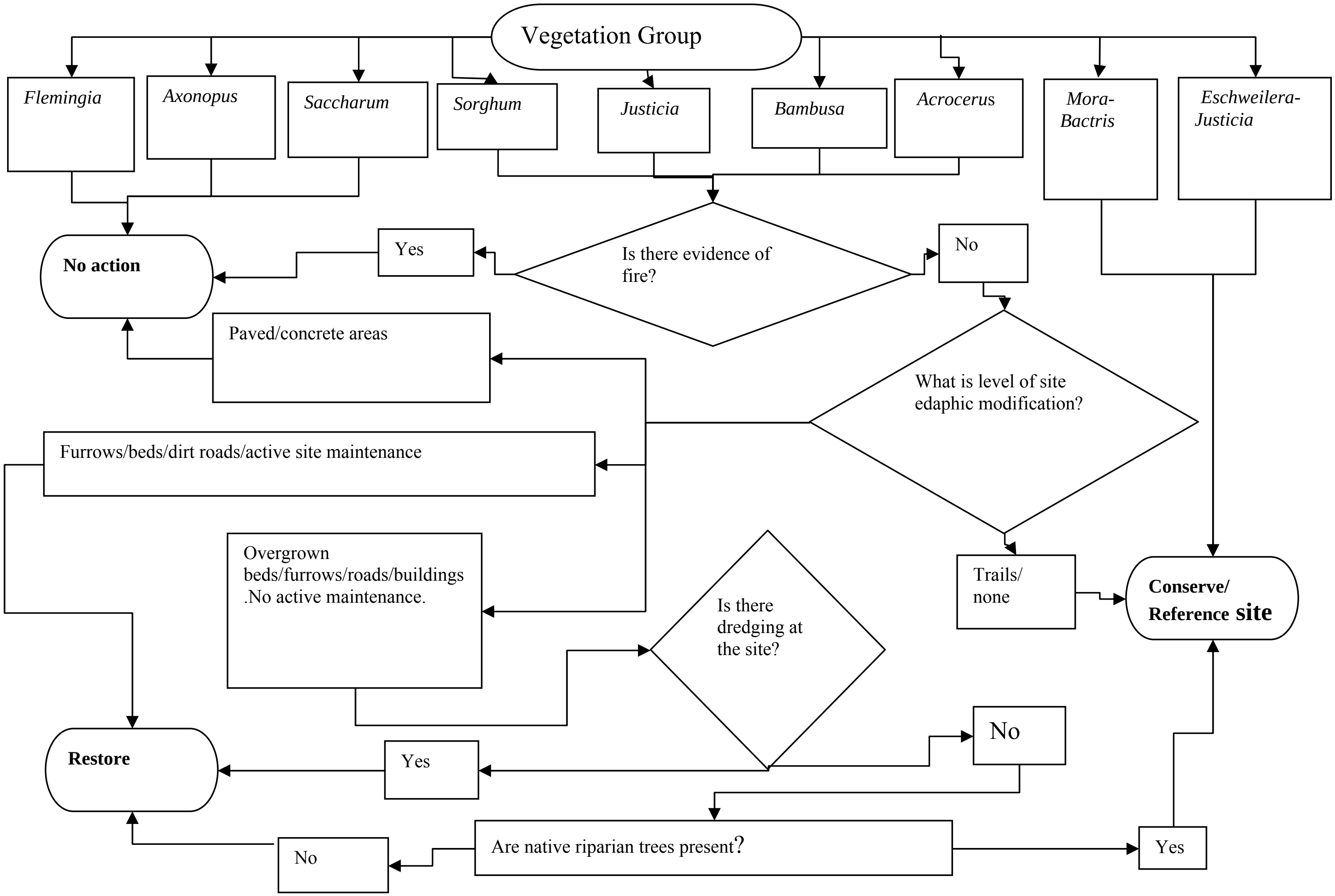

Figure 4-2. Site management strategies based on taxonomic and classification data

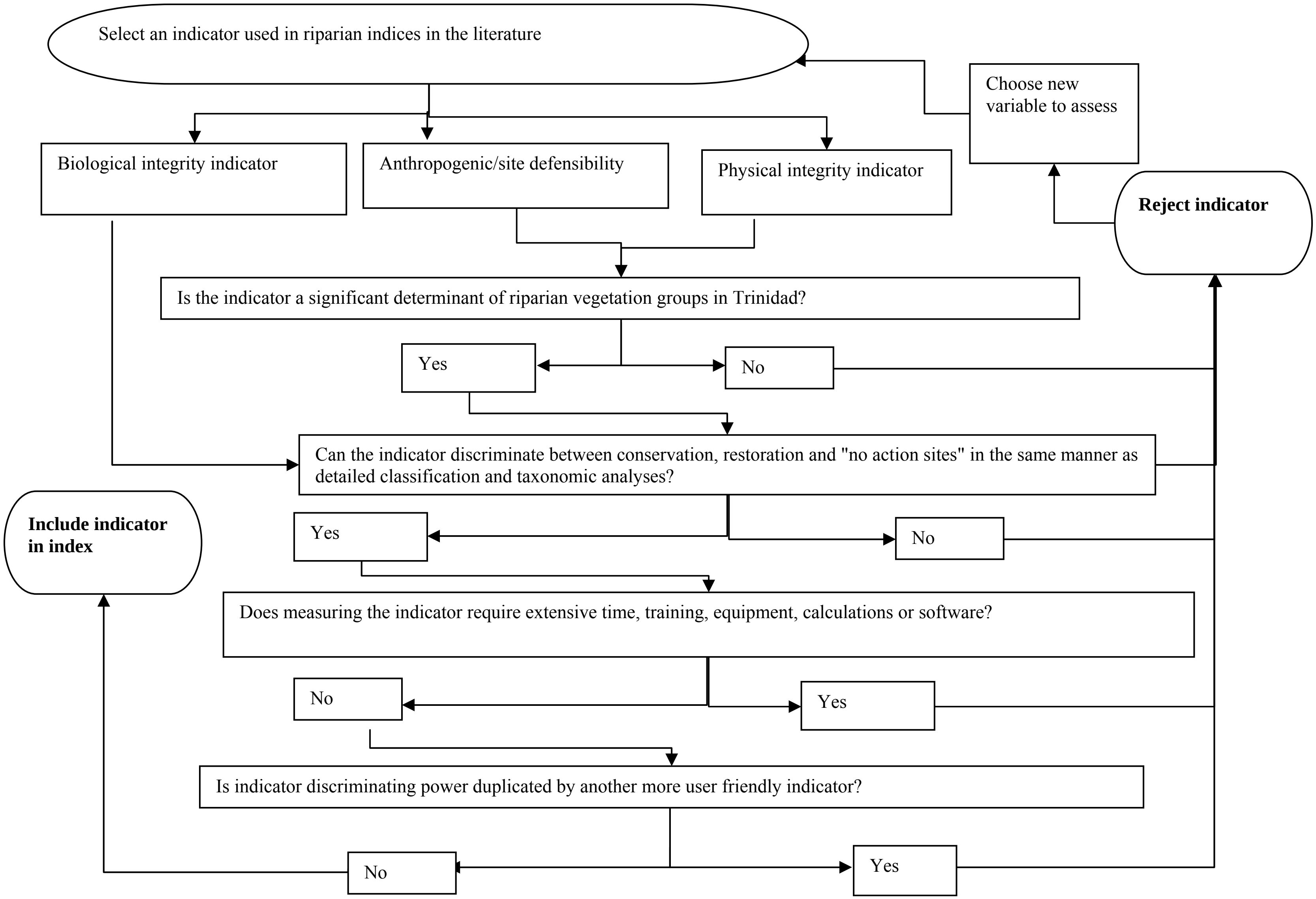

Figure 4-3- Indicator selection process

CHAPTER 5
CONCLUSIONS

Research Synthesis

This study examined the structure, composition and determinants of riparian vegetation in Trinidad to provide a baseline for conservation and restoration of the island's riparian ecosystems. A list of 57 native riparian species was identified out of 426 morphoptyes collected. Only 57 plants were classified as riparian, as the other plants were indicative of agriculture and development, rather than riparian conditions. Weeds and exotic species were excluded from the list, although the exotic species *Bambusa vulgaris* (Bamboo) had the highest importance value of all the tree species collected and *Coffea* sp. (Coffee), another exotic had the highest percentage coverage in the ground flora. Overall, 49 exotic species were identified. The list of riparian plants included common forest trees like *Carapa guianensis*, which appear to be facultative species, tolerant of riparian zone conditions.

The study showcased a high level of human-induced modification of riparian zones and riparian vegetation. Out of 36 sites studied, only nine were classified as forest (FO). Fifteen sites were characterized as secondary vegetation (SV), four as grassland (GR), seven as agriculture (AG) and one as developed (DE). SV sites consisted largely of abandoned agricultural estates. Apart from land use, riparian zone modification also occurred through channel dredging and fires. The influence of land use and exotics was evident in the vegetation groups found, in which sites clustered into distinct FO, AG and SV groups. There were also a weedy species group, a grass dominated group and one group dominated by Bamboo. Geomorphology separated the FO group into Northern Range and Southern Plain riparian forest. A final, fire influenced group was also found. Significant determinants of the riparian groups delineated included canopy closure, degree of upland and riparian zone edaphic modification, geomorphology, fire, channel modification, distance from paved roads, land ownership, pollution and form factor.

While highlighting the modification and degradation of riparian zones in Trinidad, this study can also be used as a conservation and restoration guide. The FO sites in this study are representative of natural riparian conditions and can be used as reference and conservation sites, as can the SV sites, especially those in advanced stages of forest regeneration. AG and GR sites were identified as potential restoration sites, once the natural hydrological regime was intact. Developed sites and fire prone areas were not recommended for conservation or restoration owing to persistent human activity.

The above management recommendations were based on the detailed, taxonomic and environmental analyses carried out in this study. This study also developed a rapid assessment index, to quickly delineate site management strategies. Indicators included disturbance, fire and the presence/absence of specific exotics like *B. vulgaris* and *Sorghum* sp. An FO site with no exotics and no weeds received a higher index score than a DE site with exotics. High scoring sites were recommended for conservation. Overall, an active riparian width of 30 m was identified. It is recommended that where possible, this should be the minimum riparian buffer width for Trinidad.

Riparian Research Needs

This study provided baseline data on riparian plants in Trinidad. Tobago was not surveyed due to time and budget constraints, but this research gap needs to be filled to improve the knowledge base for riparian management of the entire country. Also, while Trinidad is a continental island with two large flat plains, Tobago is a steep, volcanic island (Water Resources Agency 2001) and a better riparian model for other Caribbean islands.

The reference sites identified in this study can provide the species template for ecological integrity restoration. However, if the restoration focus is water quality, the emphasis may be on plants, which provide effective sediment retention and nutrient absorption. This in turn would require experimental work to identify specific plants for use. There is already some anecdotal information available to build on. For example, Quesnel & Farrell (2000) suggest that *Senna* sp. may be good nutrient absorbers. In the interest of ecological integrity, experimental work may also be needed to ensure that the plants selected for nutrient and pollutant absorption, are still capable of providing an adequate food source for terrestrial and aquatic wildlife.

Riparian Management in Trinidad

Riparian management options in Trinidad include conservation, restoration of sites or else no action because of irreversible land modification or persistent human activity. Sites identified for conservation are high ecological integrity sites, which are generally capable of supporting ecosystem functions (Karr & Dudley 1981).

Low integrity sites can be restored especially if the hydrological regime is intact or if the land use is agriculture and grassland instead of more permanent development. The current paradigm for restoration is holistic ecosystem restoration. This entails an emphasis on species diversity and heterogeneity in an attempt to ensure ecological resilience (Stanford et al. 1996). Although this is desirable, in Trinidad it may be necessary to focus on specific needs like water quality protection and emphasize plants that effectively uptake nutrients and pollutants. However, ecological integrity should not be overlooked and one possibility is restoration for water quality in heavily polluted areas and restoration for ecological integrity elsewhere.

Given the prevalence of exotics in riparian areas, their eradication has to be factored into any restoration scheme in Trinidad. This may not be an easy process as exotics like Bamboo are aggressive colonizers (McClure 1993) and also serve specific purposes, for example, riverbank stabilization (Forestry Division pers comm.). Bamboo removal could be carried out in high priority restoration areas where riverbank stabilization is not as great a priority.

Riparian restoration often requires reestablishing flooding regimes (Bunn et al. 1998). This may not be possible in Trinidad due to development close to riverbanks and also because of the overwhelming negative public perception of flooding. Public awareness programs may help in this regard, but it may be more practical to emphasize conservation in remote areas with intact flooding regimes or restoration in remote abandoned agricultural areas. Acceptance and support of restoration schemes may be enhanced if historical or cultural links to the rivers are emphasized (Higgs 2005). In Trinidad, for example, restoration practitioners could enlist the support of Hindus and Spiritual Baptists who use riparian areas for religious ceremonies. Ameliorative activities in developed areas could include establishing set back levees, which may allow some flooding but protect houses and flood intolerant agriculture beyond the levees.

River Management in Trinidad

Riparian zone and river management is an important issue in Trinidad, given that 77% of the island's water supply comes from surface water sources and also because of the poor quality and quantity of water from these sources (Water Resources Agency 2001). Pollutants like solid waste, sediments, industrial discharges, heavy metals and agricultural chemicals are found in Trinidad's rivers. Water shortages occur due to seasonality, exacerbated by unaccounted for water losses in the distribution system (Water Resources Agency 2001). River management is also important as Trinidad's aquatic biodiversity has been identified as a priority for conservation at the regional scale (Olson et al. 1998).

This project complements the riverine research program of the Department of Life Sciences, University of the West Indies (UWI), Trinidad. The department has generated faunal and environmental data for rivers in Trinidad. These data in have been used to design a protocol to monitor anthropogenic impacts on the island's rivers for the Environmental Management Authority (Maharaj & Alkins-Koo 2007). The protocol scores sites based on macroinvertebrate taxa supported by physico-chemical data from each site. Land use data are also included in the protocol as are riparian metrics such as percentage vegetation cover in the riparian zone and vegetation type whether trees, Bamboo, shrubs and grasses (Maharaj & Alkins-Koo 2007). Future revisions of the protocol can perhaps include metrics from the riparian index from this study, for example, presence/absence of exotics like *Sorghum* sp. as negative indicators of riverine health.

APPENDIX A
LIST OF SPECIES FOUND IN RIPARIAN ZONES IN TRINIDAD

Family	Revised name	Plant Identification	Common name in Trinidad
Acanthaceae		Acanthaceae	
Acanthaceae		*Blechum pyramidatum* (Lam.) Urb.	
Acanthaceae		*Bravaisia integerrima* (Spreng.) Standl.	Jiggerwood/White Mangue
Acanthaceae		*Justicia comata* (L.) Lam.	
Acanthaceae		*Justicia pectoralis* Jacq.	
Acanthaceae		*Justicia secunda* Vahl	
Acanthaceae	*Pachystachys spicata* (Ruiz & Pav.) Wassh.	*Pachystachys coccinea* (Aubl.) Nees	Black stick
Acanthaceae		*Ruellia tuberosa* L.	Minnie Root
Acanthaceae	*Lepidagathis alopecuroidea* (Vhal) R. Br.ex Griseb.	*Teliostachya alopecuroidea* (Vahl) Nees	
Amaranthaceae		*Alternanthera tenella* Colla	
Amaranthaceae		*Amaranthus dubius* Mart. ex Thell.	
Amaryllidaceae		*Hymenocallis tubiflora* Salisb.	Onion lilly
Anacardiaceae		*Anacardium occidentale* L.	Cashew
Anacardiaceae		*Mangifera indica* L.	Mango
Anacardiaceae		*Spondias mombin* L.	Hogplum
Annonaceae		*Annona muricata* L.	Soursop
Annonaceae		*Annona squamosa* L.	Sugar apple
Annonaceae		*Rollinia exsucca* (DC. ex Dunal) A. DC.	
Apiaceae		*Eryngium foetidum* L.	Shadowbenny
Apocynaceae		*Marsdenia macrophylla* (Humb. & Bonpl. ex Schult.) E. Fourn.	
Apocynaceae		*Prestonia quinquangularis* (Jacq.) Spreng	.
Apocynaceae		*Tabernaemontana undulata* Vahl	
Araceae		*Dieffenbachia seguine* (Jacq.) Schott	Dumb cane
Araceae		*Monstera obliqua* Miq.	
Araceae		Monstera sp.	
Araceae		*Philodendron acutatum* Schott	
Araceae		*Philodendron krugii* Engl.	

Family	Revised name	Plant Identification	Common name in Trinidad
Araceae		*Philodendron lingulatum* (L.) K. Koch	
Araceae		*Philodendron* sp.	
Araceae		*Spathiphyllum cannifolium* Schott.	Maraval lilly
Araceae		*Xanthosoma ?undipes*	
Araceae		*Colocasia esculenta (L.) Schott*	Dasheen
Araliaceae			Dendropanax arboreus (L.) Decne. & Planch.
Araliaceae		*Schefflera morototoni* (Aubl.) Maguire, Steyerm. & Frodin	Jereton
Arecaceae		*Attalea maripa* (Aubl.) Mart.	Cocorite
Arecaceae		*Bactris major* Jacq.	Gru-Gru
Arecaceae		*Cocos nucifera* L.	Coconut
Arecaceae		*Desmoncus orthacanthos* Mart	Wait a while
Arecaceae		*Desmoncus polyacanthos* Mart.	Wait a while
Arecaceae		*Desmoncus* sp.	
Arecaceae		*Euterpe oleracea* Mart.	
Arecaceae		*Euterpe precatoria* Mart.	
Arecaceae		*Manicaria saccifera* Gaertn.	
Arecaceae		*Roystonea oleracea* (Jacq.) O.F. Cook	Royal palm
Arecaceae		*Sabal mauritiiformis* (H. Karst.) Griseb. & H. Wendl.	Carat palm
Asteraceae		*Ageratum conyzoides* L.	
Asteraceae		*Bidens alba* (L.) DC.	Railway daisy
Asteraceae	*Eupatorium iresinoides* Kunth	*Condylidium iresinoides* (Kunth) R.M.King & H.Rob	
Asteraceae	*Conyza apurensis* Kunth	*Conyza laevigata* (Rich.) Pruski	
Asteraceae	*Eclipta alba* (L.) Hassk.	*Eclipta prostrata* (L.) L.	
Asteraceae	*Chromolaena odorata* (L.) R.M.King & H.Rob	*Eupatorium odoratum* L.	Christmas bush
Asteraceae		*Mikania ?scabra*	

Family	Revised name	Plant Identification	Common name in Trinidad
Asteraceae			*Mikania hookeriana var. platyphylla* (DC.) B.L. Rob.
Asteraceae		*Mikania micrantha* Kunth	
Asteraceae		*Mikania* sp.1	
Asteraceae		*Mikania vitifolia* DC.	
Asteraceae		*Neurolaena lobata* (L.) Cass.	
Asteraceae		*Parthenium hysterophorus* L.	Whitehead
Asteraceae		*Rolandra fruticosa* (L.) Kuntze	
Asteraceae		*Struchium sparganophorum* (L.) Kuntze	
Asteraceae		*Tridax procumbens* L.	
Asteraceae	*Cyanthillium cinereum* (L.) H.Rob.	*Vernonia cinerea* (L.) Less.	
Asteraceae	*Sphagneticola trilobata* (L.) Pruski	*Wedelia trilobata* (L.) Hitchc.	
Asteraceae	*Tilesia baccata* (L.) Pruski	*Wulffia baccata* (L.) Kuntze	
Bignoniaceae		Bignoniaceae	
Bignoniaceae		Bignoniaceae 1	
Bignoniaceae		Bignoniaceae 2	
Bignoniaceae		Bignoniaceae 3	
Bignoniaceae		Bignoniaceae 4	
Bignoniaceae		*Crescentia cujete* L.	Calabash
Bignoniaceae		*Macfadyena unguis-cati* (L.) A.H. Gentry	Cats claw
Bignoniaceae		*Phryganocydia corymbosa* (Vent.) Bureau ex K. Schum.	
Bignoniaceae	*Pithecoctenium crucigerum* (L.) A.H. Gentry	*Pithecoctenium echinatum* (Jacq.) Baill.	Monkey hair brush
Blechnaceae		*Blechnum occidentale* L.	
Bombaceae		*Ceiba pentandra* (L.) Gaertn.	Silk Cotton, Kapok
Bombaceae		*Ochroma pyramidale* (Cav. ex Lam.) Urb.	Balsa, Bois Flot
Bombaceae		*Pachira insignis* (Sw.) Sw. ex Savigny	Wild chataigne
Boraginaceae		*Cordia alliodora* (Ruiz & Pav.) Oken	Cypre
Boraginaceae		*Cordia bicolor* A. DC.	
Boraginaceae		*Cordia collococca* L.	Manjack.
Boraginaceae		*Cordia curassavica* (Jacq.) Roem. & Schult.	Black sage

Family	Revised name	Plant Identification	Common name in Trinidad
Boraginaceae		*Heliotropium angiospermum* Murray	Eyebright/Eyewash
Boraginaceae		*Heliotropium indicum* L.	
Boraginaceae		*Heliotropium procumbens* Mill	
Brassicaceae (Cruciferae)	*Rorippa officinale* R.Br.	Watercress	
Brassicaceae (Cruciferae)	*Rorippa indica* (L.) Hiern	*Rorippa sinapis* (Burm. f.) Ohwi & H. Hara	
Burseraceae		*Bursera simaruba* (L.) Sarg.	Naked Indian
Burseraceae		*Protium guianense* (Aubl.) Marchand	Incense
Campanulaceae		*Centropogon cornutus* (L.) Druce	Deermeat
Campanulaceae		*Hippobroma longiflora* (L.) G. Don	Star of Bethlehem
Campanulaceae		*Sphenoclea zeylanica* Gaertn	
Capparaceae	*Capparis frondosa* Jacq.	*Capparis baducca* L.	
Capparaceae		*Cleome gynandra* L.	
Capparaceae		*Cleome rutidosperma* DC.	
Capparaceae		*Cleome spinosa* Jacq.	
Capparaceae		*Crateva tapia* L.	Toke
Capparaceae		*Morisonia americana* L.	
Caricaceae		*Carica papaya* L.	Paw-paw
Cecropiaceae		*Cecropia peltata* L.	Bois canot
Celestraceae		Celestraceae 1	
Celestraceae		Celestraceae 2	
Chrysobalanaceae		*Hirtella racemosa* Lam.	
Chrysobalanaceae		*Hirtella triandra* Sw.	
Clusiaceae		*Calophyllum lucidum* Benth.	Galba
Clusiaceae		*Mammea americana* L.	Mamme sepo
Clusiaceae	*Garcinia madruno* (Kunth) Hammel	*Rheedia acuminata* (Ruiz & Pav.) Planch. & Triana	Wild primose
Clusiaceae		*Vismia cayennensis* (Jacq.) Pers.	
Clusiaceae		*Vismia laxiflora* Reichardt	
Combretaceae		*Buchenavia tetraphylla* (Aubl.) R.A. Howard	Yellow Olivier
Combretaceae		*Combretum fruticosum (Loefl.) Stuntz*	
Combretaceae		*Terminalia amazonia* (J.F. Gmel.) Exell	Olivier
Combretaceae		*Terminalia catappa* L.	Indian Almond

Family	Revised name	Plant Identification	Common name in Trinidad
Combretaceae		*Terminalia dichotoma* G. Mey.	Water Olivier
Commelinaceae		*Commelina diffusa* Burm. f.	
Commelinaceae		*Commelina erecta* L.	
Commelinaceae		*Commelina* sp.	
Commelinaceae		*Gibasis geniculata* (Jacq.) Rohweder	
Commelinaceae		*Tripogandra serrulata* (Vahl)	Handlos
Connaraceae		*Rourea surinamensis* Miq.	
Convolvulaceae		Convolvulaceae	
Convolvulaceae		Convolvulaceae?	
Convolvulaceae		*Ipomea* sp.	
Convolvulaceae		*Iseia luxurians* (Moric.) O'Donell	
Convolvulaceae		*Merremia umbellata* (L.) Hallier f.	
Costaceae		*Costus ?scaber*	
Costaceae		*Costus scaber* Ruiz & Pav.	
Costaceae		*Costus* sp.	
Cucurbitaceae		Cucurbitaceae	
Cyatheaceae		*Cnemidaria ?spectabilis*	Tree fern
Cyatheaceae		*Cyathea* sp.[1]	
Cyclanthaceae		*Asplundia rigida* (Aubl.) Harling	
Cyclanthaceae		*Cyclanthus bipartitus* Poit	
Cyperaceae		*Abildgaardia ovata*?	
Cyperaceae		Cyperaceae	
Cyperaceae		*Cyperus luzulae* (L.) Rottb. ex Retz.	
Cyperaceae		*Cyperus* sp.	
Cyperaceae		*Cyperus surinamensis* Rottb.	
Cyperaceae		*Hypolytrum longifolium* (Rich.) Nees	
Cyperaceae			Scleria melaleuca Rchb. ex Schltdl. & Cham.
Cyperaceae		*Scleria* sp.	
Cyperaceae		*Torulinum odoratum* (L.)	
Dilleniaceae	Pinzona coriacaea Mart.& Zucc.	*Pinzona calineoides* Eichler	Watervine
Dracaenaceae		*Sansevieria hyacinthoides* (L.)	Mother in Laws tongue

Family	Revised name	Plant Identification	Common name in Trinidad
Dryopteridaceae		*Cyclopeltis semicordata* (SW.) J.Sm.	
Dryopteridaceae		*Diplazium grandifolium* (Sw.) Sw.	
Dryopteridaceae		*Polybotrya caudata* Kunze	
Dryopteridaceae		*Tectaria* sp.[2]	
Ebenaceae		*Diospyros inconstans* Jacq.	
Elaeocarpaceae		*Muntingia calabura* L.	
Euphorbiaceae		*Acalypha arvensis* Poepp. & Endl.	
Euphorbiaceae		*Croton gossypiifolius* Vahl	Bloodwood
Euphorbiaceae		*Croton lobatus* L.	
Euphorbiaceae	*Chamaesyce hirta* (L.) Millsp	*Euphorbia hirta* L.	
Euphorbiaceae	*Chamaesyce hyssopifolia* (L.) Smnall	*Euphorbia hyssopifolia* L.	
Euphorbiaceae	*Hieronyma alchorneoides* Allemao	*Hieronyma laxiflora* (Tul.) Müll. Arg.	Tapana
Euphorbiaceae		*Hura crepitans* L.	Sandbox
Euphorbiaceae		*Sapium glandulosum* (L.) Morong	Milkwood
Gentiaceae		Enicostema verticillatum (L.) Engl. ex Gilg	
Gesneriaceae		*Chrysothemis pulchella* (Donn) Decne.	Cocoa Flower
Gesneriaceae		*Drymonia serrulata* (Jacq.) Mart.	
Heliconiaceae		*Heliconia bihai* (L.) L.	Baliser
Heliconiaceae		*Heliconia bihai/spatho-circinada*	
Heliconiaceae		*Heliconia hirsuta* L. f.	
Heliconiaceae		*Heliconia spatho-circinada* Aristeg.	
Hernandiaceae		*Hernandia sonora* L.	Toporite
Hymenophyllaceae		*Trichomanes pinnatum* Hedw.	
Lacistemataceae		*Lacistema aggregatum* (P.J. Bergius) Rusby	
Lamiaceae (Labiatae)		*Hyptis atrorubens* Poit.	
Lauraceae		Lauraceae 1	
Lauraceae		Lauraceae 2	
Lauraceae		Lauraceae 3	
Lauraceae		Lauraceae 4	

Family	Revised name	Plant Identification	Common name in Trinidad
Lauraceae	*Nectandra tubacensis* (Kunth) Nees	*Nectandra rectinervia* Meisn.	
Lauraceae		*Ocotea eggersiana* Mez	
Lauraceae		*Persea americana* Mill.	Avocado
Lecythidaceae		*Eschweilera subglandulosa* (Steud. ex O. Berg) Miers	
Leguminosae (Fabaceae)	Leguminosae		
Leguminosae (Fabaceae) Subfamily Caesalpinioideae	*Brownea coccinea* Jacq. subsp. capitella (Jacq.) D.Velasquez & Agostini	*Brownea latifolia* Jacq.	Mountain Rose
Leguminosae (Fabaceae) Subfamily Caesalpinioideae		*Cassia reticulata* Willd.	Senna
Leguminosae (Fabaceae) Subfamily Caesalpinioideae		*Crudia glaberrima* (Steud.) J.F. Macbr.	
Leguminosae (Fabaceae) Subfamily Caesalpinioideae		*Mora excelsa* Benth.	
Leguminosae (Fabaceae) Subfamily Caesalpinioideae		*Senna bacillaris* (L. f.) H.S. Irwin & Barneby	Senna
Leguminosae (Fabaceae) Subfamily Caesalpinioideae		*Senna* sp.	
Leguminosae (Fabaceae) Subfamily Caesalpinioideae		*Swartzia pinnata* (Vahl) Willd.	
Leguminosae (Fabaceae) Subfamily Caesalpinioideae		*Swartzia simplex* (Sw.) Spreng.	
Leguminosae (Fabaceae) Subfamily Mimosoideae		*Abarema jupunba* (Willd.) Britton & Killip	Puni

Family	Revised name	Plant Identification	Common name inTrinidad
Leguminosae (Fabaceae) Subfamily Mimosoideae	*Albizia niopoides* (Spruce ex. Benth.) Burkart	*Albizia caribaea* (Urb.) Britton & Rose Tantakayo	
Leguminosae (Fabaceae) Subfamily Mimosoideae	*Inga ingoides* (Rich.) Willd.	Padoux	
Leguminosae (Fabaceae) Subfamily Mimosoideae	*Inga laurina* (Sw.) Willd.		
Leguminosae (Fabaceae) Subfamily Mimosoideae	*Inga* sp.		
Leguminosae (Fabaceae) Subfamily Mimosoideae	*Inga thibaudiana* DC.		
Leguminosae (Fabaceae) Subfamily Mimosoideae		*Machaerium robiniifolium* (DC.) Vogel	
Leguminosae (Fabaceae) Subfamily Mimosoideae	*Machaerium isadelpheum* (E.Mey.) Amshoff	*Machaerium tobagense* Urb.	
Leguminosae (Fabaceae) Subfamily Mimosoideae		*Mimosa casta* L.	
Leguminosae (Fabaceae) Subfamily Mimosoideae		*Mimosa pigra* L.	
Leguminosae (Fabaceae) Subfamily Mimosoideae	.	*Mimosa pudica* L	Tee marie
Leguminosae (Fabaceae) Subfamily Mimosoideae		*Pentaclethra macroloba* (Willd.) Kuntze	Fine leaf

Family	Revised name	Plant Identification	Common name in Trinidad
Leguminosae (Fabaceae) Subfamily Mimosoideae		*Zygia latifolia* (L.) Fawc. & Rendle	
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Alysicarpus vaginalis* (L.) DC.	
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Andira inermis* (W. Wright) Kunth ex DC.	Angelin
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Centrosema pubescens* Benth.	
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Clathrotropis brachypetala* (Tul.) Kleinhoonte	Mayaro Poui
Leguminosae (Fabaceae) Subfamily Papilionoideae	*Coursetia ferruginea* (Kunth) Lavin	*Coursetia ?arborea*	
Leguminosae (Fabaceae) Subfamily Papilionoideae	*Desmodium adscendens* (Sw.) DC.		
Leguminosae (Fabaceae) Subfamily Papilionoideae	*Dioclea hexandra* (Roxb.) Mabb.	*Dioclea reflexa* Hook. f.	Donkey Eye
Leguminosae (Fabaceae) Subfamily Papilionoideae	*Dipteryx odorata* (Aubl.) Willd.		Tonka Bean
Leguminosae (Fabaceae) Subfamily Papilionoideae	*Erythrina fusca* Lour.	*Erythrina glauca* Willd.	Water Immortelle
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Erythrina pallida* Britton	Immortelle
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Erythrina poeppigiana* (Walp.) O.F. Cook	Immortelle Immortelle

Family	Revised name	Plant Identification	Common name in Trinidad
Leguminosae (Fabaceae) Subfamily Papilionoideae	.	Erythrina variegata L	
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Flemingia strobilifera* (L.) R. Br.	Wild Hops
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Lonchocarpus heptaphyllus* (Poir.) DC.	
Leguminosae (Fabaceae) Subfamily Papilionoideae	.	*Lonchocarpus sericeus* (Poir.) Kunth ex DC	
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Platymiscium trinitatis* Benth. Roble	
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Pterocarpus officinalis* Jacq.	Bloodwood
Leguminosae (Fabaceae) Subfamily Papilionoideae		*Pueraria phaseoloides* (Roxb.) Benth.	Kudzoe
Lomariospidaceae		*Lomariopsis japurensis* (Mart.) J.Sm.	
Malpighiaceae		*Stigmaphyllon* sp.	
Malvaceae		*Malachra fasciata* Jacq.	
Malvaceae		*Pavonia castaneifolia* A. St.-Hil. & Naudin	
Malvaceae		*Sida acuta Burm*. f.	
Malvaceae		*Sida rhombifolia* L.	
Malvaceae		*Sida* sp.	
Malvaceae		*Triumfetta ?althaeoides*	
Malvaceae (Sterculiaceae)		*Guazuma ulmifolia* Lam.	Bois L'holme
Malvaceae (Sterculiaceae)		*Sterculia pruriens* (Aubl.) K. Schum.	Mahoe
Malvaceae (Sterculiaceae)		*Theobroma cacao* L.	Cocoa
Maranthaceae		*Calathea lutea* Schult.	
Maranthaceae		*Ischnosiphon arouma* (Aubl.) Körn.	Tirite

Family	Revised name	Plant Identification	Common name in Trinidad
Maranthaceae		*Maranta gibba* Sm.	
Melastomataceae		*Clidemia ?hirta*	
Melastomataceae		*Clidemia hirta* (L.) D. Don	
Melastomataceae		*Clidemia sp*. 1	
Melastomataceae		*Clidemia* sp. 2	
Melastomataceae		*Miconia acinodendron* (L.) Sweet	
Melastomataceae		*Miconia nervosa* (Sm.) Triana	
Melastomataceae		*Miconia punctata* (Desr.) D. Don ex DC.	
Melastomataceae		*Miconia* sp.	
Melastomataceae		*Miconia* sp. 1	
Melastomataceae		*Miconia* sp. 2	
Melastomataceae		*Miconia* sp. 3	
Melastomataceae		*Mouriri rhizophorifolia* (DC.) Triana	Monkey bone
Melastomataceae		Pterolepis glomerata (Rottb.) Miq.	
Meliaceae		*Carapa guianensis* Aubl.	Crappo
Meliaceae		*Cedrela odorata* L.	Cedar
Meliaceae		*Guarea glabra* Vahl	
Meliaceae		*Guarea guidonia* (L.) Sleumer	
Meliaceae		*Swietenia macrophylla* King	
Meliaceae		*Trichilia pallida* Sw.	
Meliaceae		*Trichilia pleeana* (A. Juss.) C. DC.	
Moraceae		*Artocarpus altilis* (Parkinson) Fosberg	Breadfruit/chataigne
Moraceae		*Artocarpus lakoocha* Wall. ex Roxb.	Barahar
Moraceae		*Brosimum alicastrum* SW.	Moussara
Moraceae		*Castilla elastica* Sessé ex Cerv.	Rubber
Moraceae		*Ficus amazonica* (Miq.) Miq.	
Moraceae		*Ficus broadwayi* Urb.	
Moraceae		*Ficus maxima* Mill.	
Moraceae		*Ficus numphaeifolia* L.	
Moraceae		*Ficus trigonata* L.	
Moraceae		*Ficus yaponensis* Desv	
Mrytaceae		*Myrcia splendens* (Sw.) DC.	
Musaceae		*Musa* sp.	Banana
Myristaceae		*Virola surinamensis* (Rol. ex Rottb.) Warb.	
Myrsinaceae		*Stylogyne lateriflora* (Sw.) Mez	
Myrtaceae		*Eugenia baileyi* Britton	
Myrtaceae		*Eugenia monticola* (Sw.) DC	
Myrtaceae		*Eugenia procera* (Sw.) Poir.	

Family	Revised name	Plant Identification	Common name in Trinidad
Myrtaceae		*Eugenia* sp. 1	
Myrtaceae		Myrtaceae	
Myrtaceae		Myrtaceae?	
Myrtaceae		*Psidium guajava* L.	Guava
Myrtaceae		*Syzygium cumini* (L.) Skeels	Gulub Jamoon
Myrtaceae		*Syzygium malaccense* (L.) Merr. & L.M. Perry	Pomerac
Nyctaginaceae		*Pisonia cuspidata* Heimerl	
Nyctaginaceae		*Pisonia eggersiana* Heimerl	
Nyctaginaceae		*Pisonia salicifolia* Heimerl	
Oleaceae		*Chionanthus compactus* Sw.	
Onagraceae		*Ludwigia ?decurrens*	
Onagraceae		*Ludwigia erecta* (L.) H. Hara	
Onagraceae		*Ludwigia peruviana* (L.) H. Hara	
Onagraceae		*Ludwigia* sp.	
Onagraceae		*Ludwigia* sp. 1	
Onagraceae		*Ludwigia* sp. 2	
Oxalidaceae		*Oxalis frutescens* L.	
Passifloraceae		*Passiflora serratodigitata* L.	
Phyllanthaceae		*Phyllanthus urinaria* L.	
Piperaceae		*Peperomia pellucida* (L.) Kunth	
Piperaceae		*Piper ?aequale*	
Piperaceae		*Piper ?hispidum*	
Piperaceae		*Piper aduncum* L.	
Piperaceae		*Piper hispidum* Sw.	
Piperaceae		*Piper marginatum* Jacq.	
Piperaceae		*Piper* sp.	
Piperaceae		*Piper sp*. 1	
Piperaceae		*Piper* sp. 2	
Piperaceae		*Piper* sp. 3	
Piperaceae		*Piper tuberculatum* Jacq.	
Piperaceae	*Lepianthes peltata* in synonymy	*Pothomorphe peltata* (L.) Miq.	

Family	Revised name	Plant Identification	Common name in Trinidad
Poaceae		*Acroceras zizanioides* (Kunth) Dandy	
Poaceae		*Axonopus compressus* (Sw.) P. Beauv.	
Poaceae		*Bambusa vulgaris* Schrad. ex J.C. Wendl.	
Poaceae		*Chrysopogon zizanioides*?	
Poaceae		*Cynodon dactylon* (L.) Pers.	
Poaceae		*Dichanthium caricosum* (L.) A. Camus	
Poaceae		*Digitaria ?ciliaris*	
Poaceae		*Echinochloa colonum* (L.) Link	
Poaceae		*Eleusine indica* (L.) Gaertn.	
Poaceae		*Eriochloa punctata* (L.) Desv. ex Ham.	
Poaceae		*Gynerium sagittatum* (Aubl.) P. Beauv.	
Poaceae		*Hymenachne amplexicaulis* (Rudge) Nees	
Poaceae		*Hymenachne* sp.	
Poaceae		*Imperata brasiliensis* Trin.	
Poaceae		*Ischaemum timorense* Kunth	
Poaceae		*Lasiacis ligulata* Hitchc. & Chase	
Poaceae		*Lasiacis* sp.	
Poaceae		*Leptochloa ?longa*	
Poaceae		*Leptochloa* sp.	
Poaceae		*Leptochloa virgata* (L.) P. Beauv.	
Poaceae		*Olyra latifolia* L.	
Poaceae		*Oplismenus hirtellus* (L.) P. Beauv.	
Poaceae	*Panicum stoloniferum* Poir.	*Panicum ?frondescens*	
Poaceae		*Panicum maximum* Jacq.	Guinea grass or bull grass
Poaceae		*Panicum* sp.	
Poaceae		*Panicum* sp.?	
Poaceae		*Paspalum fasciculatum* Willd. ex Flüggé	Bull grass
Poaceae		*Paspalum* sp.	
Poaceae		*Pennisetum ?purpureum*	
Poaceae		*Pennisetum purpureum* Schumach.	Elephant grass
Poaceae		*Pennisetum* sp.	
Poaceae		*Pennisetum* sp.?	
Poaceae		*Pharus latifolius* L.	

Family	Revised name	Plant Identification	Common name in Trinidad
Poaceae		Piresia sympodica (Döll) Swallen	
Poaceae		Poaceae	
Poaceae		Poaceae 1	
Poaceae		Poaceae 2	
Poaceae		Poaceae 3	
Poaceae		Poaceae 4	
Poaceae		Poaceae 5	
Poaceae		Poaceae 6	
Poaceae		Saccharum officinarum L.	Sugarcane
Poaceae		Setaria ?barbata	
Poaceae		Setaria sp.	
Poaceae		Sorghum arundinacium/halepense	
Poaceae		Urochloa mutica (Forssk.) T.Q. Nguyen	Para grass
Polygalaceae		Securidaca diversifolia (L.) S.F. Blake	
Polygonaceae		Coccoloba fallax Lindau	
Polygonaceae		Coccoloba sp.1	
Polygonaceae		Coccoloba venosa L.	
Portulaceace		Portulaca quadrifida L.	
Pteridaceae		Adiantum obliquum Willd.	
Pteridaceae		Adiantum pulverulentum L.	
Pteridaceae		Adiantum sp.[3]	
Pteridaceae		Adiantum tetraphyllum Hook.	
Pteridaceae		Pityrogramma calomelanos (L.) Link	
Quiinaceae		Quiina cruegeriana Griseb.	
Rubiaceae		Amaioua corymbosa?	
Rubiaceae		Chimarrhis cymosa Jacq.	Bois Riviere
Rubiaceae		Coffea sp.	Coffee
Rubiaceae		Coussarea paniculata (Vahl) Standl.	
Rubiaceae		Diodea ?ocymifolia	
Rubiaceae		Faramea occidentalis (L.) A. Rich	
Rubiaceae		Genipa americana L	
Rubiaceae		Gonzalagunia hirsuta (Jacq.) Schumann	
Rubiaceae		Gonzalagunia spicata (Lam.) M. Gómez	
Rubiaceae		Isertia parviflora Vahl	
Rubiaceae		Palicourea crocea (Sw.) Roem. & Schult.	

Family	Revised name	Plant Identification	Common name in Trinidad
Rubiaceae		Psychotria capitata Ruiz & Pav.	
Rubiaceae	Pschotria bahiensis /cuspidata	Psychotria cuspidata Bredem. ex Roem. & Schult.	
Rubiaceae	Psychotria deflexa /patens	Psychotria patens Sw.	
Rubiaceae		Psychotria poeppigiana Müll. Arg.	
Rubiaceae		Psychotria sp.	
Rubiaceae		Rudgea hostmanniana Benth.	Bois tatoo
Rubiaceae		Spermacoce latifolia Aubl.	
Rubiaceae		Spermacoce sp.	
Rutaceae		Citrus sp.	Citrus
Rutaceae		Zanthoxylum martinicense (Lam.) DC.	
Rutaceae	Zanhoxylum rhoifolium Lam.	Zanthoxylum microcarpum Griseb.	
Rutaceae		Zanthoxylum sp.	
Salicaceae		Casearia ?guianensis	
Salicaceae		Casearia guianensis (Aubl.) Urb.	
Salicaceae		Casearia sylvestris Sw.	
Salicaceae		Ryania speciosa Vahl	
Salicaceae		Xylosoma seemannii?	
Sapindaceae		Cardiospermum microcarpum Kunth	
Sapindaceae		Cupania americana L.	
Sapindaceae		Paullinia cururu L	
Sapindaceae		Paullinia fuscescens Kunth	
Sapindaceae		Paullinia leiocarpa Griseb.	
Sapindaceae		Paullinia pinnata L	
Sapindaceae		Sapindus saponaria L.	Soapseed
Sapindaceae		Serjania paucidentata DC	
Sapotaceae		Chrysophyllum argenteum Jacq.	
Sapotaceae		Chrysophyllum cainito L.	Caimate
Sapotaceae		Manilkara bidentata (A. DC.) A. Chev.	Balata
Sapotaceae		Manilkara zapota (L.) P. Royen	Sapodilla

Family	Revised name	Plant Identification	Common name in Trinidad
Sapotaceae	*Pouteria coriacea* (Pierre) Pierre	*Pouteria minutiflora* (Britton) Sandwith	Monkey balata
Sapotaceae		*Pouteria multiflora* (A. DC.) Eyma	
Schizaeaceae		*Lygodium venustum* Sw.	
Schizaeaceae		*Lygodium volubile* Sw.	
Schizaeaceae		*Schizaea elegans* (Vahl) Sw.	
Scrophulariaceae		*Lindernia crustacea* (L.) F. Muell.	
Selaginellaceae		*Selaginella hartii* Hieron	
Selaginellaceae		*Selaginella plana* (Desv. ex Poir.) Hieron.	
Simaroubaceae		*Simarouba amara* Aubl.	
Smilacaceae		*Smilax cumanensis* Humb. & Bonpl. ex Willd.	
Solanaceae		*Acnistus arborescens* (L.) Schltdl.	
Solanaceae		Solanaceae	
Solanaceae		Solanum jamaicense Mill.	
Solanaceae		Solanum sp.	
Tectariaceae		*Hypoderris brownii* J.Sm.	
Tectariaceae		*Lastreopsis effusa* (Sw.) Tindale var divergens (Willd. Ex Schkuhr)	
Thelypteridaceae		*Thelypteris serrata* (Cav.) Alston	
Thelypteridaceae		*Thelypteris* sp. [4]	
Ulmaceae		*Trema micranthum* (L.) Blume	
Urticaceae		*Boehmeria ramiflora* Jacq.	
Urticaceae		*Phenax sonneratii* (Poir.) Wedd.	
Urticaceae		*Pilea microphylla* (L.) Liebm.	
Urticaceae		*Urera baccifera* (L.) Gaudich. ex Wedd.	
Verbenaceae		*Lantana trifolia* L.	
Verbenaceae		*Priva lappulacea* (L.) Pers.	
Verbenaceae		*Stachytarpheta jamaicensis* (L.) Vahl	Vervine
Verbenaceae		*Tectona grandis* L. f.	Teak
Vitaceae		*Cissus* sp.	
Vitaceae		*Cissus verticillata* (L.) Nicolson & C.E. Jarvis	Snake vine
Zingiberaceae		*Renealmia alpinia* (Rottb.) Maas	
Zingiberaceae		*Zingiber officinale* Roscoe	Ginger

Nomeclature follows (Adams & Baksh-Comeau Unpublished)

APPENDIX B
PHOTOGRAPHS OF THE LOWER MIDDLE AND UPPER REACHES OF EACH RIVER STUDIED


B-1 Caura Lower


B-2 Caura Lower


B-3 Caura Middle


B-4 Caura Middle


B-5 Caura Upper


B-6 Caura Upper

B-7 Arouca Lower

B-8 Arouca Lower

B-9 Arouca Middle

B-10 Arouca Middle

B-11 Arouca Upper

B-12 Arouca Upper


B-13 North Oropuche Lower


B-14 North Oropuche Lower


B-15 North Oropuche Middle


B-16 North Oropuche Middle


B-17 North Oropuche Upper


B-18 North Oropuche Upper


B-19 Aripo Lower

B-20 Aripo Lower


B-21 Aripo Middle

B-22 Aripo Middle


B-23 Aripo Upper

B-24 Aripo Upper


B-25 Caparo Lower


B-26 Caparo Lower


B-27 Caparo Middle


B-28 Caparo Middle


B-29 Caparo Upper


B-30 Caparo Upper


B-31 Couva Lower


B-32 Couva Lower


B-33 Couva Middle


B-34 Couva Middle


B-35 Couva Upper


B-36 Couva Upper


B-37 L’ebranche Lower


B-38 L’ebranche Lower


B-39 L’ebranche Middle


B-40 L’ebranche Middle


B-41 L’ebranche Upper


B-42 L’ebranche Upper

B-43 Cumuto Lower

B-44 Cumuto Lower

B-45 Cumuto Middle

B-46 Cumuto Middle

B-47 Cumuto Upper

B-48 Cumuto Upper


B-49 Penal Lower


B-50 Penal Lower


B-51 Penal Middle


B-52 Penal Middle


B-53 Penal Upper


B-54 Penal Upper

B-67 South Oropuche Lower

B-68 South Oropuche Lower

B-69 South Oropuche Middle

B-70 South Oropuche Middle

B-71 South Oropuche Upper

B-72 South Oropuche Upper


B-55 Moruga Lower


B-56 Moruga Lower


B-57 Moruga Middle


B-58 Moruga Middle


B-59 Moruga Upper


B-60 Moruga Upper


B-61 Poole Lower


B-62 Poole Lower


B-63 Poole Middle


B-64 Poole Middle


B-65 Poole Upper


B-66 Poole Upper

APPENDIX C
SITE LEVEL ENVIRONMENTAL AND LAND USE DATA

Site	Brai-ding	Meand-ering	Elevation above sea level (m)	Discharge ($m^3 s^{-1}$)	Bank-slope	Channel width (m)	Bankfull width (m)	Bankfull length (m)	Bankfull depth (m)
ARIL	Y	N	30.48	0.86	-28.67	9.82	12.61	148.33	1.38
ARIM	Y	N	76.20	0.17	-30.33	6.37	9.98	690.00	3.24
ARIU	N	N	228.60	0.02	-14.00	5.66	12.13	270.00	0.90
AROL	N	N	15.24	0.64	-21.00	5.27	27.56	2535.33	9.53
AROM	N	N	91.44	0.56	-18.00	14.09	20.23	258.67	0.98
AROU	N	N	228.60	0.17	-31.67	2.79	11.52	675.00	6.10
CAPL	N	Y	6.10	0.06	-20.67	3.00	31.67	1232.67	4.86
CAPM	N	Y	12.19	0.03	-37.00	2.05	9.36	393.67	2.78
CAPU	N	N	12.19	0.04	-32.67	2.85	11.39	573.00	3.50
CAUL	N	N	30.48	0.79	-36.67	10.41	21.45	1116.67	2.62
CAUM	N	N	91.44	2.17	-18.00	11.63	20.03	719.00	2.63
CAUU	N	N	152.40	0.39	-24.33	5.78	10.19	536.00	7.09
COUL	N	Y	6.10	0.14	-28.67	5.22	18.63	703.00	3.83
COUM	N	Y	12.19	0.03	-23.67	2.83	14.24	674.00	3.49
COUU	N	Y	21.34	0.03	-40.33	2.58	11.76	404.00	3.12
CUML	N	Y	30.48	0.09	-28.33	2.83	17.53	740.67	3.99
CUMM	N	N	12.19	0.05	-27.00	4.07	23.46	1052.67	4.98
CUMU	N	Y	21.34	0.00	-33.00	3.98	8.37	433.33	2.43
LEBL	N	N	3.05	0.07	-35.67	5.05	16.23	678.00	4.16
LEBM	N	Y	3.05	0.04	-40.33	4.87	13.29	973.33	7.06
LEBU	N	N	12.19	0.00	-36.67	4.30	5.20	143.33	0.86
MORL	N	Y	2.30	0.00	-25.33	2.88	15.63	1241.67	5.72
MORM	N	N	2.30	0.03	-30.00	2.47	8.66	316.67	1.91
MORU	N	N	21.33	0.00	-25.33	1.91	10.51	609.00	2.78
NORL	Y	N	7.62	6.42	-35.00	12.72	18.61	743.33	5.17
NORM	Y	N	45.72	0.21	-20.00	10.58	12.53	375.00	1.80
NORU	N	N	152.40	3.23	-50.67	24.36	30.47	1256.67	11.29
PENL	N	Y	16.40	0.00	-30.00	7.53	10.31	936.00	4.90
PENM	N	Y	49.21	0.00	-34.33	4.53	13.17	556.67	3.21
PENU	N	N	67.26	0.00	-21.33	4.57	7.83	293.33	0.84
POOL	N	Y	32.81	0.01	-34.67	4.01	21.64	748.00	4.73
POOM	N	Y	49.21	0.00	-18.33	3.68	28.89	1584.67	5.45
POOU	N	Y	65.62	0.00	-33.00	1.79	9.67	462.00	3.03
SOUL	N	N	8.20	0.68	-25.33	12.94	21.41	491.00	3.83
SOUM	N	N	16.40	0.12	-33.00	4.03	21.68	603.33	3.95
SOUU	N	N	32.81	0.07	-15.67	2.03	17.00	1140.00	2.76

Y= Yes, N= No, L= Lower Reach, M= Middle Reach, U=Upper Reach, ARI=Aripo, ARO=Arouca, CAP=Caparo, CAU=Caura, CUM=Cumuto, COU=Couva, LEB=L'ebranche, MOR=Moruga, NOR=North Oropouche, PEN=Penal, POO=Poole, SOU=South Oropouche, L= Lower Reach, M= Middle Reach, U= Upper Reach. De= Developed, W=Water, SV=Secondary Vegetation, FO=Forest, Ag=Agriculture, GR= Grassland

APPENDIX D

LAND USE, CANOPY CLOSURE, SLOPE AND CUMULATIVE ELEVATION FOR EACH 10 X 10 M BLOCK

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Aripo	L	0 m	4.00	GR	0.16	-1.74	0.00
Aripo	L	0 m	1.00	GR	0.16	-0.52	3.00
Aripo	L	0 m	2.00	GR	0.16	-1.05	3.00
Aripo	L	0 m	3.00	GR	0.16	-1.74	4.00
Aripo	L	0 m	5.00	GR	0.16	-2.79	6.00
Aripo	L	100 m	1.00	GR	96.36	2.59	-15.00
Aripo	L	100 m	2.00	GR	0.16	3.98	-8.00
Aripo	L	100 m	4.00	GR	0.16	3.98	-5.00
Aripo	L	100 m	5.00	GR	16.02	3.81	1.00
Aripo	L	100 m	3.00	GR	0.16	3.11	5.00
Aripo	L	50 m	1.00	GR	0.16	1.91	-11.00
Aripo	L	50 m	4.00	GR	0.16	1.56	-3.00
Aripo	L	50 m	2.00	GR	0.16	1.56	2.00
Aripo	L	50 m	5.00	GR	92.72	1.04	3.00
Aripo	L	50 m	3.00	GR	0.16	1.04	3.00
Aripo	M	0 m	1.00	FO	98.44	4.07	-24.00
Aripo	M	0 m	2.00	SV	98.70	4.42	-2.00
Aripo	M	0 m	4.00	SV	15.76	4.59	-1.00
Aripo	M	0 m	5.00	SV	0.16	4.59	0.00
Aripo	M	0 m	3.00	SV	98.70	4.42	0.00
Aripo	M	100 m	1.00	FO	97.66	2.59	-15.00
Aripo	M	100 m	4.00	AG	0.16	2.59	-2.00
Aripo	M	100 m	5.00	AG	0.16	2.76	-1.00
Aripo	M	100 m	2.00	AG	99.74	2.76	-1.00
Aripo	M	100 m	3.00	AG	0.16	2.24	3.00
Aripo	M	50 m	1.00	FO	93.50	2.42	-14.00
Aripo	M	50 m	2.00	FO	95.58	3.46	-6.00
Aripo	M	50 m	3.00	AG	0.16	3.81	-2.00
Aripo	M	50 m	4.00	AG	0.16	3.81	0.00
Aripo	M	50 m	5.00	AG	0.16	3.81	0.00
Aripo	U	0 m	4.00	SV	80.24	6.58	-14.00
Aripo	U	0 m	2.00	FO	94.80	2.42	-13.00
Aripo	U	0 m	5.00	AG	0.16	8.66	-12.00
Aripo	U	0 m	3.00	FO	87.52	4.16	-10.00
Aripo	U	0 m	1.00	FO	99.74	0.17	-1.00
Aripo	U	100 m	3.00	FO	96.62	11.23	-24.00
Aripo	U	100 m	2.00	FO	89.08	7.16	-23.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Aripo	U	100 m	1.00	FO	97.92	3.26	-19.00
Aripo	U	100 m	5.00	SV	98.70	12.80	-6.00
Aripo	U	100 m	4.00	SV	96.36	11.75	-3.00
Aripo	U	50 m	5.00	SV	29.54	11.58	-15.00
Aripo	U	50 m	1.00	FO	93.50	2.59	-15.00
Aripo	U	50 m	4.00	SV	82.58	8.99	-14.00
Aripo	U	50 m	3.00	FO	99.22	6.57	-13.00
Aripo	U	50 m	2.00	FO	92.98	4.32	-10.00
Arouca	L	0 m	1.00	GR	0.16	3.58	-21.00
Arouca	L	0 m	2.00	GR	0.16	5.83	-13.00
Arouca	L	0 m	5.00	DE	0.16	3.21	-3.67
Arouca	L	0 m	4.00	DE	0.16	2.57	-3.67
Arouca	L	0 m	3.00	GR	0.16	1.93	23.00
Arouca	L	100 m	1.00	GR	0.16	3.09	-18.00
Arouca	L	100 m	2.00	GR	0.16	5.68	-15.00
Arouca	L	100 m	5.00	W	0.16	4.46	1.00
Arouca	L	100 m	3.00	GR	0.16	5.16	3.00
Arouca	L	100 m	4.00	DE	0.16	4.63	3.00
Arouca	L	50 m	1.00	GR	0.16	4.23	-25.00
Arouca	L	50 m	2.00	GR	0.16	6.81	-15.00
Arouca	L	50 m	3.00	GR	0.16	7.86	-6.00
Arouca	L	50 m	4.00	DE	0.16	4.44	20.00
Arouca	L	50 m	5.00	DE	0.16	5.55	*
Arouca	M	0 m	2.00	SV	77.90	10.60	-32.00
Arouca	M	0 m	1.00	SV	80.24	5.30	-32.00
Arouca	M	0 m	5.00	SV	93.24	24.98	-30.00
Arouca	M	0 m	3.00	SV	70.62	15.60	-30.00
Arouca	M	0 m	4.00	SV	68.02	19.98	-26.00
Arouca	M	100 m	5.00	SV	8.48	17.87	-26.00
Arouca	M	100 m	4.00	SV	45.92	13.48	-24.00
Arouca	M	100 m	3.00	SV	0.16	9.42	-23.00
Arouca	M	100 m	1.00	SV	64.12	3.09	-18.00
Arouca	M	100 m	2.00	SV	28.76	5.51	-14.00
Arouca	M	50 m	2.00	SV	61.00	6.97	-26.00
Arouca	M	50 m	5.00	SV	93.24	19.49	-25.00
Arouca	M	50 m	3.00	SV	77.90	11.20	-25.00
Arouca	M	50 m	4.00	SV	74.26	15.27	-24.00
Arouca	M	50 m	1.00	SV	98.44	2.59	-15.00
Arouca	U	0 m	1.00	SV	82.06	1.91	-11.00
Arouca	U	0 m	2.00	SV	98.70	3.64	-10.00
Arouca	U	0 m	4.00	SV	94.54	4.34	-5.00
Arouca	U	0 m	3.00	SV	92.46	3.47	1.00
Arouca	U	0 m	5.00	SV	99.22	3.99	2.00
Arouca	U	100 m	1.00	SV	50.08	8.39	-57.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Arouca	U	100 m	2.00	SV	96.88	12.29	-23.00
Arouca	U	100 m	5.00	SV	98.70	16.80	-13.00
Arouca	U	100 m	3.00	SV	96.10	14.03	-10.00
Arouca	U	100 m	4.00	SV	95.32	14.55	-3.00
Arouca	U	50 m	1.00	SV	84.40	5.45	-33.00
Arouca	U	50 m	2.00	SV	97.92	7.01	-9.00
Arouca	U	50 m	5.00	SV	76.86	7.01	0.00
Arouca	U	50 m	3.00	SV	71.92	7.01	0.00
Arouca	U	50 m	4.00	SV	31.88	7.01	0.00
Caparo	L	0 m	1.00	GR	0.16	3.91	-23.00
Caparo	L	0 m	3.00	DE	0.16	3.91	-1.00
Caparo	L	0 m	2.00	GR	0.16	3.73	1.00
Caparo	L	0 m	4.00	GR	0.16	3.73	1.00
Caparo	L	0 m	5.00	GR	0.16	3.38	2.00
Caparo	L	100 m	1.00	GR	0.16	3.42	-20.00
Caparo	L	100 m	5.00	GR	0.16	0.31	-1.00
Caparo	L	100 m	4.00	GR	0.16	0.13	-1.00
Caparo	L	100 m	3.00	GR	0.16	-0.04	5.00
Caparo	L	100 m	2.00	GR	0.16	0.83	15.00
Caparo	L	50 m	1.00	GR	0.16	3.91	-23.00
Caparo	L	50 m	3.00	DE	0.16	1.83	-1.00
Caparo	L	50 m	5.00	AG	0.16	1.66	0.00
Caparo	L	50 m	4.00	AG	0.16	1.66	1.00
Caparo	L	50 m	2.00	GR	0.16	1.66	13.00
Caparo	M	0 m	1.00	FO	98.18	0.35	-2.00
Caparo	M	0 m	2.00	SV	23.04	0.35	0.00
Caparo	M	0 m	5.00	GR	0.16	-0.87	0.00
Caparo	M	0 m	3.00	SV	84.40	0.00	2.00
Caparo	M	0 m	4.00	SV	77.38	-0.87	5.00
Caparo	M	100 m	1.00	FO	91.68	1.05	-6.00
Caparo	M	100 m	3.00	SV	85.70	0.52	0.00
Caparo	M	100 m	4.00	GR	93.50	0.17	2.00
Caparo	M	100 m	2.00	SV	85.18	0.52	3.00
Caparo	M	100 m	5.00	GR	67.76	-0.35	3.00
Caparo	M	50 m	1.00	FO	93.76	1.05	-6.00
Caparo	M	50 m	3.00	SV	59.44	1.74	-3.00
Caparo	M	50 m	4.00	SV	94.28	1.92	-1.00
Caparo	M	50 m	2.00	SV	83.10	1.22	-1.00
Caparo	M	50 m	5.00	SV	95.84	1.92	0.00
Caparo	U	0 m	1.00	GR	0.16	0.52	-3.00
Caparo	U	0 m	5.00	AG	0.16	0.17	-1.00
Caparo	U	0 m	3.00	AG	0.16	0.17	0.00
Caparo	U	0 m	4.00	AG	0.16	0.00	1.00
Caparo	U	0 m	2.00	AG	0.16	0.17	2.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Caparo	U	100 m	1.00	GR	37.08	0.87	-5.00
Caparo	U	100 m	2.00	AG	0.16	1.05	-1.00
Caparo	U	100 m	4.00	AG	0.16	0.87	-1.00
Caparo	U	100 m	3.00	AG	0.16	0.70	2.00
Caparo	U	100 m	5.00	AG	0.16	0.35	3.00
Caparo	U	50 m	1.00	GR	0.16	0.87	-5.00
Caparo	U	50 m	2.00	AG	0.16	0.87	0.00
Caparo	U	50 m	3.00	AG	0.16	0.87	0.00
Caparo	U	50 m	4.00	AG	0.16	0.87	0.00
Caparo	U	50 m	5.00	AG	0.16	0.87	0.00
Caura	L	0 m	1.00	FO	47.22	7.66	-50.00
Caura	L	0 m	2.00	DE	70.88	8.36	-4.00
Caura	L	0 m	3.00	DE	0.16	8.36	0.00
Caura	L	0 m	4.00	DE	0.16	8.36	0.00
Caura	L	0 m	5.00	DE	0.16	8.36	0.00
Caura	L	100 m	1.00	FO	0.16	1.74	-10.00
Caura	L	100 m	2.00	DE	0.16	1.74	0.00
Caura	L	100 m	3.00	DE	0.16	1.74	0.00
Caura	L	100 m	4.00	DE	0.16	1.74	0.00
Caura	L	100 m	5.00	DE	0.16	1.74	0.00
Caura	L	50 m	1.00	FO	98.18	5.88	-36.00
Caura	L	50 m	2.00	DE	8.22	5.88	0.00
Caura	L	50 m	3.00	DE	0.16	5.88	0.00
Caura	L	50 m	4.00	DE	0.16	5.88	0.00
Caura	L	50 m	5.00	DE	0.16	5.88	0.00
Caura	M	0 m	5.00	FO	98.96	12.40	-29.00
Caura	M	0 m	4.00	FO	94.54	7.55	-21.00
Caura	M	0 m	1.00	FO	87.26	2.59	-15.00
Caura	M	0 m	2.00	FO	98.44	4.67	-12.00
Caura	M	0 m	3.00	FO	97.66	3.97	4.00
Caura	M	100 m	4.00	FO	98.96	23.51	-40.00
Caura	M	100 m	3.00	FO	91.68	17.08	-40.00
Caura	M	100 m	2.00	FO	96.62	10.65	-40.00
Caura	M	100 m	1.00	FO	98.96	4.23	-25.00
Caura	M	100 m	5.00	FO	98.44	26.10	-15.00
Caura	M	50 m	4.00	FO	77.90	14.82	-30.00
Caura	M	50 m	3.00	FO	97.66	9.82	-30.00
Caura	M	50 m	5.00	FO	96.10	18.24	-20.00
Caura	M	50 m	1.00	FO	99.74	3.26	-19.00
Caura	M	50 m	2.00	FO	98.44	4.82	-9.00
Caura	U	0 m	1.00	SV	96.88	1.39	-8.00
Caura	U	0 m	4.00	SV	91.68	1.57	-1.00
Caura	U	0 m	5.00	SV	82.84	1.57	0.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Caura	U	0 m	2.00	SV	95.84	1.39	0.00
Caura	U	0 m	3.00	SV	95.58	1.39	0.00
Caura	U	100 m	5.00	SV	97.66	18.01	-36.00
Caura	U	100 m	4.00	SV	81.54	12.14	-23.00
Caura	U	100 m	1.00	SV	95.58	3.75	-22.00
Caura	U	100 m	2.00	SV	90.38	6.84	-18.00
Caura	U	100 m	3.00	SV	66.20	8.23	-8.00
Caura	U	50 m	1.00	GR	89.08	2.08	-12.00
Caura	U	50 m	5.00	SV	92.46	4.52	-5.00
Caura	U	50 m	3.00	SV	96.88	3.65	-5.00
Caura	U	50 m	2.00	SV	98.18	2.78	-4.00
Caura	U	50 m	4.00	SV	93.24	3.65	0.00
Couva	L	0 m	3.00	GR	87.52	9.53	-24.00
Couva	L	0 m	1.00	FO	91.16	4.07	-24.00
Couva	L	0 m	2.00	FO	94.54	5.46	-8.00
Couva	L	0 m	4.00	GR	92.98	10.40	-5.00
Couva	L	0 m	5.00	GR	0.16	10.40	0.00
Couva	L	100 m	1.00	FO	96.36	4.23	-25.00
Couva	L	100 m	3.00	FO	94.28	6.65	-13.00
Couva	L	100 m	5.00	FO	94.02	7.70	-5.00
Couva	L	100 m	4.00	FO	94.80	6.82	-1.00
Couva	L	100 m	2.00	FO	91.42	4.40	-1.00
Couva	L	50 m	1.00	FO	93.50	5.30	-32.00
Couva	L	50 m	2.00	GR	95.06	10.45	-31.00
Couva	L	50 m	3.00	FO	95.58	13.04	-15.00
Couva	L	50 m	4.00	FO	66.46	13.56	-3.00
Couva	L	50 m	5.00	GR	0.16	13.56	0.00
Couva	M	0 m	4.00	GR	19.92	7.45	-15.00
Couva	M	0 m	1.00	SV	94.80	1.74	-10.00
Couva	M	0 m	3.00	GR	14.46	4.86	-10.00
Couva	M	0 m	2.00	GR	95.32	3.13	-8.00
Couva	M	0 m	5.00	DE	0.16	7.45	0.00
Couva	M	100 m	5.00	DE	0.16	5.60	-26.00
Couva	M	100 m	4.00	SV	96.62	1.22	-5.00
Couva	M	100 m	2.00	SV	74.00	0.52	-5.00
Couva	M	100 m	3.00	SV	83.36	0.35	1.00
Couva	M	100 m	1.00	SV	89.60	-0.35	2.00
Couva	M	50 m	3.00	SV	86.74	5.49	-22.00
Couva	M	50 m	2.00	SV	90.12	1.74	-8.00
Couva	M	50 m	1.00	SV	95.58	0.35	-2.00
Couva	M	50 m	4.00	GR	61.52	5.84	-2.00
Couva	M	50 m	5.00	DE	0.16	5.84	0.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Couva	U	0 m	2.00	SV	90.12	3.96	-18.00
Couva	U	0 m	3.00	SV	51.90	4.83	-5.00
Couva	U	0 m	1.00	SV	96.36	0.87	-5.00
Couva	U	0 m	5.00	SV	96.62	5.01	-1.00
Couva	U	0 m	4.00	SV	84.40	4.83	0.00
Couva	U	100 m	3.00	SV	22.26	5.44	-25.00
Couva	U	100 m	5.00	SV	51.12	9.43	-14.00
Couva	U	100 m	4.00	SV	94.02	7.01	-9.00
Couva	U	100 m	1.00	SV	97.14	1.22	-7.00
Couva	U	100 m	2.00	SV	80.76	1.22	0.00
Couva	U	50 m	2.00	SV	92.46	4.60	-23.00
Couva	U	50 m	5.00	SV	91.42	7.56	-10.00
Couva	U	50 m	3.00	SV	97.14	5.48	-5.00
Couva	U	50 m	1.00	SV	96.36	0.70	-4.00
Couva	U	50 m	4.00	SV	88.04	5.83	-2.00
Cumuto	L	0 m	1.00	SV	95.06	2.25	-13.00
Cumuto	L	0 m	4.00	SV	88.04	3.82	-3.00
Cumuto	L	0 m	3.00	SV	93.24	3.30	-3.00
Cumuto	L	0 m	2.00	SV	85.44	2.77	-3.00
Cumuto	L	0 m	5.00	SV	47.48	3.47	2.00
Cumuto	L	100 m	1.00	SV	65.68	3.75	-22.00
Cumuto	L	100 m	2.00	SV	97.92	4.62	-5.00
Cumuto	L	100 m	5.00	SV	40.72	5.32	-4.00
Cumuto	L	100 m	3.00	SV	96.62	4.62	0.00
Cumuto	L	100 m	4.00	SV	61.00	4.62	0.00
Cumuto	L	50 m	4.00	SV	93.24	1.05	-3.00
Cumuto	L	50 m	3.00	SV	97.40	0.52	-3.00
Cumuto	L	50 m	5.00	SV	95.84	1.05	0.00
Cumuto	L	50 m	1.00	SV	97.66	0.00	0.00
Cumuto	L	50 m	2.00	SV	97.14	0.00	0.00
Cumuto	M	0 m	1.00	GR	0.16	3.26	-19.00
Cumuto	M	0 m	4.00	AG	0.16	1.51	2.00
Cumuto	M	0 m	2.00	AG	0.16	2.73	3.00
Cumuto	M	0 m	5.00	AG	0.16	0.99	3.00
Cumuto	M	0 m	3.00	AG	0.16	1.86	5.00
Cumuto	M	100 m	1.00	GR	0.16	3.91	-23.00
Cumuto	M	100 m	2.00	GR	0.16	4.60	-4.00
Cumuto	M	100 m	5.00	AG	0.16	4.43	-1.00
Cumuto	M	100 m	3.00	AG	0.16	4.43	1.00
Cumuto	M	100 m	4.00	AG	0.16	4.26	1.00
Cumuto	M	50 m	1.00	GR	0.16	6.69	-42.00
Cumuto	M	50 m	2.00	AG	38.38	6.52	1.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Cumuto	M	50 m	3.00	AG	30.58	6.17	2.00
Cumuto	M	50 m	4.00	AG	0.16	5.82	2.00
Cumuto	M	50 m	5.00	AG	0.16	5.30	3.00
Cumuto	U	0 m	1.00	FO	87.52	4.07	-24.00
Cumuto	U	0 m	2.00	AG	88.04	6.32	-13.00
Cumuto	U	0 m	4.00	AG	0.16	8.06	-5.00
Cumuto	U	0 m	3.00	AG	90.64	7.19	-5.00
Cumuto	U	0 m	5.00	AG	0.16	8.58	-3.00
Cumuto	U	100 m	1.00	FO	92.72	4.23	-25.00
Cumuto	U	100 m	2.00	FO	85.18	5.10	-5.00
Cumuto	U	100 m	3.00	AG	45.92	5.62	-3.00
Cumuto	U	100 m	4.00	AG	1.46	5.62	0.00
Cumuto	U	100 m	5.00	AG	0.16	5.10	3.00
Cumuto	U	50 m	1.00	FO	98.96	5.00	-30.00
Cumuto	U	50 m	3.00	FO	95.58	6.40	-4.00
Cumuto	U	50 m	2.00	FO	98.96	5.70	-4.00
Cumuto	U	50 m	4.00	AG	88.82	6.92	-3.00
Cumuto	U	50 m	5.00	FO	78.42	7.09	-1.00
L’ebranche	L	0 m	3.00	SV	53.20	6.88	-18.00
L’ebranche	L	0 m	1.00	GR	34.22	3.09	-18.00
L’ebranche	L	0 m	5.00	DE	0.16	8.62	-5.00
L’ebranche	L	0 m	4.00	DE	14.20	7.75	-5.00
L’ebranche	L	0 m	2.00	SV	69.84	3.79	-4.00
L’ebranche	L	100 m	1.00	SV	45.66	6.56	-41.00
L’ebranche	L	100 m	4.00	SV	92.98	8.82	-8.00
L’ebranche	L	100 m	2.00	SV	91.42	7.95	-8.00
L’ebranche	L	100 m	5.00	SV	31.10	8.47	2.00
L’ebranche	L	100 m	3.00	SV	79.20	7.43	3.00
L’ebranche	L	50 m	1.00	GR	89.60	4.85	-29.00
L’ebranche	L	50 m	4.00	SV	17.84	8.98	-18.00
L’ebranche	L	50 m	2.00	SV	98.70	6.41	-9.00
L’ebranche	L	50 m	5.00	DE	0.16	10.02	-6.00
L’ebranche	L	50 m	3.00	SV	97.40	5.89	3.00
L’ebranche	M	0 m	1.00	SV	88.82	3.91	-23.00
L’ebranche	M	0 m	2.00	GR	93.76	5.30	-8.00
L’ebranche	M	0 m	3.00	SV	99.22	6.00	-4.00
L’ebranche	M	0 m	5.00	SV	96.62	5.65	0.00
L’ebranche	M	0 m	4.00	SV	91.94	5.65	2.00
L’ebranche	M	100 m	1.00	SV	84.92	5.30	-32.00
L’ebranche	M	100 m	2.00	SV	96.10	6.69	-8.00
L’ebranche	M	100 m	5.00	SV	96.62	5.47	0.00
L’ebranche	M	100 m	3.00	SV	97.14	6.52	1.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
L'ebranche	M	100 m	4.00	SV	98.18	5.47	6.00
L'ebranche	M	50 m	1.00	SV	97.40	4.23	-25.00
L'ebranche	M	50 m	4.00	SV	97.14	4.57	-5.00
L'ebranche	M	50 m	2.00	SV	97.14	4.40	-1.00
L'ebranche	M	50 m	5.00	SV	93.76	4.40	1.00
L'ebranche	M	50 m	3.00	SV	84.40	3.70	4.00
L'ebranche	U	0 m	1.00	SV	96.10	1.91	-11.00
L'ebranche	U	0 m	5.00	GR	79.46	2.26	-5.00
L'ebranche	U	0 m	4.00	SV	84.14	1.38	-3.00
L'ebranche	U	0 m	2.00	SV	95.06	1.56	2.00
L'ebranche	U	0 m	3.00	SV	90.90	0.86	4.00
L'ebranche	U	100 m	1.00	SV	97.66	2.59	-15.00
L'ebranche	U	100 m	3.00	SV	91.42	2.76	-3.00
L'ebranche	U	100 m	4.00	SV	92.72	2.76	0.00
L'ebranche	U	100 m	2.00	GR	96.88	2.24	2.00
L'ebranche	U	100 m	5.00	GR	91.42	2.06	4.00
L'ebranche	U	50 m	2.00	SV	70.36	0.70	-4.00
L'ebranche	U	50 m	4.00	SV	4.32	1.22	-3.00
L'ebranche	U	50 m	5.00	SV	56.84	1.22	0.00
L'ebranche	U	50 m	3.00	SV	51.90	0.70	0.00
L'ebranche	U	50 m	1.00	GR	23.04	0.00	0.00
Moruga	L	0 m	1.00	FO	71.92	3.91	-23.00
Moruga	L	0 m	5.00	FO	98.44	6.52	-10.00
Moruga	L	0 m	2.00	FO	78.16	4.78	-5.00
Moruga	L	0 m	3.00	FO	99.22	4.95	-1.00
Moruga	L	0 m	4.00	FO	97.92	4.78	1.00
Moruga	L	100 m	1.00	FO	90.64	5.59	-34.00
Moruga	L	100 m	3.00	FO	99.48	14.04	-25.00
Moruga	L	100 m	2.00	FO	94.54	9.82	-25.00
Moruga	L	100 m	4.00	FO	97.92	16.63	-15.00
Moruga	L	100 m	5.00	FO	97.14	11.78	29.00
Moruga	L	50 m	1.00	FO	88.82	4.07	-24.00
Moruga	L	50 m	2.00	FO	88.56	7.49	-20.00
Moruga	L	50 m	4.00	FO	98.18	13.67	-18.00
Moruga	L	50 m	3.00	FO	98.96	10.58	-18.00
Moruga	L	50 m	5.00	FO	99.48	16.42	-16.00
Moruga	M	0 m	1.00	GR	0.16	3.09	-18.00
Moruga	M	0 m	2.00	GR	0.16	4.83	-10.00
Moruga	M	0 m	3.00	GR	71.40	6.22	-8.00
Moruga	M	0 m	4.00	FO	96.88	7.09	-5.00
Moruga	M	0 m	5.00	FO	96.62	8.86	*
Moruga	M	100 m	1.00	GR	0.16	3.91	-23.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Moruga	M	100 m	5.00	FO	98.44	7.06	-10.25
Moruga	M	100 m	2.00	FO	60.48	4.78	-5.00
Moruga	M	100 m	3.00	FO	97.66	5.30	-3.00
Moruga	M	100 m	4.00	FO	99.22	5.65	-2.00
Moruga	M	50 m	1.00	GR	0.16	4.85	-29.00
Moruga	M	50 m	2.00	FO	84.66	6.07	-7.00
Moruga	M	50 m	3.00	FO	100.00	6.94	-5.00
Moruga	M	50 m	4.00	FO	100.00	6.76	1.00
Moruga	M	50 m	5.00	FO	100.00	8.45	*
Moruga	U	0 m	3.00	FO	98.18	8.57	-24.00
Moruga	U	0 m	2.00	FO	99.22	4.50	-13.00
Moruga	U	0 m	1.00	FO	99.22	2.25	-13.00
Moruga	U	0 m	4.00	FO	96.62	10.30	-10.00
Moruga	U	0 m	5.00	FO	98.18	6.24	24.00
Moruga	U	100 m	1.00	GR	87.00	3.91	-23.00
Moruga	U	100 m	3.00	FO	98.70	5.47	-7.00
Moruga	U	100 m	4.00	FO	98.96	6.52	-6.00
Moruga	U	100 m	2.00	FO	99.22	4.26	-2.00
Moruga	U	100 m	5.00	FO	99.74	5.65	5.00
Moruga	U	50 m	3.00	FO	93.76	7.31	-24.00
Moruga	U	50 m	1.00	FO	98.96	3.42	-20.00
Moruga	U	50 m	2.00	FO	95.06	3.25	1.00
Moruga	U	50 m	4.00	FO	98.70	6.96	2.00
Moruga	U	50 m	5.00	FO	91.68	3.06	23.00
North Oropuche	L	0 m	1.00	FO	97.14	2.59	-15.00
North Oropuche	L	0 m	3.00	FO	97.66	5.20	-10.00
North Oropuche	L	0 m	2.00	FO	98.44	3.46	-5.00
North Oropuche	L	0 m	4.00	SV	92.72	5.02	1.00
North Oropuche	L	0 m	5.00	SV	0.16	4.85	1.00
North Oropuche	L	100 m	1.00	SV	98.44	2.08	-12.00
North Oropuche	L	100 m	2.00	SV	91.16	3.82	-10.00
North Oropuche	L	100 m	5.00	AG	0.16	5.03	-7.00
North Oropuche	L	100 m	3.00	SV	33.96	3.82	0.00
North Oropuche	L	100 m	4.00	AG	50.08	3.82	0.00
North Oropuche	L	50 m	1.00	SV	87.78	3.58	-21.00
North Oropuche	L	50 m	3.00	SV	85.70	7.05	-14.00
North Oropuche	L	50 m	2.00	SV	90.90	4.63	-6.00
North Oropuche	L	50 m	4.00	SV	98.18	7.22	-1.00
North Oropuche	L	50 m	5.00	SV	91.16	7.05	1.00
North Oropuche	M	0 m	1.00	SV	93.50	3.91	-23.00
North Oropuche	M	0 m	5.00	SV	43.84	10.12	-16.00
North Oropuche	M	0 m	2.00	GR	78.94	6.50	-15.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
North Oropuche	M	0 m	4.00	GR	18.88	7.37	-6.00
North Oropuche	M	0 m	3.00	SV	84.40	6.32	1.00
North Oropuche	M	100 m	2.00	SV	61.00	3.28	-16.00
North Oropuche	M	100 m	5.00	GR	0.16	6.06	-11.00
North Oropuche	M	100 m	4.00	GR	89.34	4.15	-7.00
North Oropuche	M	100 m	1.00	GR	8.74	0.52	-3.00
North Oropuche	M	100 m	3.00	GR	90.90	2.93	2.00
North Oropuche	M	50 m	5.00	GR	88.30	6.56	-30.00
North Oropuche	M	50 m	1.00	GR	43.58	1.91	-11.00
North Oropuche	M	50 m	4.00	GR	33.44	1.56	-5.00
North Oropuche	M	50 m	2.00	GR	28.24	1.56	2.00
North Oropuche	M	50 m	3.00	GR	0.16	0.69	5.00
North Oropuche	U	0 m	1.00	FO	78.94	7.07	-45.00
North Oropuche	U	0 m	5.00	FO	98.96	7.76	-10.00
North Oropuche	U	0 m	4.00	FO	97.66	6.03	-3.00
North Oropuche	U	0 m	3.00	FO	97.14	5.50	4.00
North Oropuche	U	0 m	2.00	FO	92.46	6.20	5.00
North Oropuche	U	100 m	1.00	FO	66.72	6.43	-40.00
North Oropuche	U	100 m	4.00	FO	96.10	11.40	-20.00
North Oropuche	U	100 m	3.00	FO	97.92	7.98	-14.00
North Oropuche	U	100 m	5.00	FO	100.00	13.65	-13.00
North Oropuche	U	100 m	2.00	FO	98.96	5.56	5.00
North Oropuche	U	50 m	1.00	FO	53.98	7.66	-50.00
North Oropuche	U	50 m	5.00	SV	98.96	9.52	-19.00
North Oropuche	U	50 m	3.00	FO	95.84	7.14	-5.00
North Oropuche	U	50 m	4.00	FO	95.58	6.27	5.00
North Oropuche	U	50 m	2.00	FO	98.96	6.27	8.00
Penal	L	0 m	1.00	FO	85.44	5.74	-35.00
Penal	L	0 m	2.00	FO	69.06	9.80	-24.00
Penal	L	0 m	3.00	FO	86.48	13.71	-23.00
Penal	L	0 m	4.00	FO	88.04	15.45	-10.00
Penal	L	0 m	5.00	FO	83.62	16.67	-7.00
Penal	L	100 m	1.00	FO	85.70	5.30	-32.00
Penal	L	100 m	2.00	FO	87.78	7.89	-15.00
Penal	L	100 m	4.00	FO	89.08	11.36	-12.00
Penal	L	100 m	5.00	FO	37.34	12.92	-9.00
Penal	L	100 m	3.00	FO	62.30	9.28	-8.00
Penal	L	50 m	4.00	FO	84.66	14.79	-35.00
Penal	L	50 m	1.00	FO	89.34	5.00	-30.00
Penal	L	50 m	5.00	FO	89.08	19.64	-29.00
Penal	L	50 m	3.00	FO	78.68	9.05	-25.00
Penal	L	50 m	2.00	FO	69.32	4.83	1.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Penal	M	0 m	1.00	FO	95.58	4.69	-28.00
Penal	M	0 m	2.00	FO	64.12	7.11	-14.00
Penal	M	0 m	5.00	FO	97.14	9.72	-10.00
Penal	M	0 m	3.00	FO	59.44	7.99	-5.00
Penal	M	0 m	4.00	FO	90.64	7.99	0.00
Penal	M	100 m	1.00	FO	96.62	3.91	-23.00
Penal	M	100 m	4.00	FO	91.94	4.95	-4.00
Penal	M	100 m	3.00	FO	93.76	4.26	-1.00
Penal	M	100 m	2.00	FO	97.40	4.08	-1.00
Penal	M	100 m	5.00	FO	86.22	4.26	4.00
Penal	M	50 m	1.00	FO	90.64	4.23	-25.00
Penal	M	50 m	5.00	FO	78.16	8.01	-18.00
Penal	M	50 m	4.00	FO	14.72	4.92	-5.00
Penal	M	50 m	2.00	FO	97.92	4.23	0.00
Penal	M	50 m	3.00	FO	75.56	4.05	1.00
Penal	U	0 m	2.00	AG	12.90	5.84	-19.00
Penal	U	0 m	1.00	AG	69.32	2.59	-15.00
Penal	U	0 m	5.00	AG	4.84	9.50	-8.00
Penal	U	0 m	3.00	AG	39.16	7.24	-8.00
Penal	U	0 m	4.00	AG	5.10	8.11	-5.00
Penal	U	100 m	1.00	AG	8.22	3.91	-23.00
Penal	U	100 m	4.00	AG	20.96	10.12	-19.00
Penal	U	100 m	5.00	AG	4.06	12.87	-16.00
Penal	U	100 m	3.00	AG	19.14	6.86	-10.00
Penal	U	100 m	2.00	AG	18.88	5.13	-7.00
Penal	U	50 m	3.00	AG	6.66	6.05	-15.00
Penal	U	50 m	1.00	AG	64.90	2.59	-15.00
Penal	U	50 m	4.00	AG	5.10	8.30	-13.00
Penal	U	50 m	5.00	AG	5.10	9.86	-9.00
Penal	U	50 m	2.00	AG	14.98	3.46	-5.00
Poole	L	0 m	1.00	SV	91.42	3.75	-22.00
Poole	L	0 m	5.00	SV	96.62	8.60	-10.00
Poole	L	0 m	2.00	SV	95.84	5.31	-9.00
Poole	L	0 m	4.00	SV	78.94	6.88	-8.00
Poole	L	0 m	3.00	SV	75.56	5.48	-1.00
Poole	L	100 m	2.00	FO	94.80	5.80	-33.00
Poole	L	100 m	4.00	FO	92.20	13.93	-25.00
Poole	L	100 m	3.00	FO	97.40	9.70	-23.00
Poole	L	100 m	5.00	FO	95.06	15.85	-20.50
Poole	L	100 m	1.00	FO	92.72	0.35	-2.00
Poole	L	50 m	3.00	SV	97.66	11.72	-36.00
Poole	L	50 m	4.00	SV	90.64	16.57	-29.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
Poole	L	50 m	5.00	SV	96.62	18.64	-21.88
Poole	L	50 m	2.00	SV	87.00	5.84	-19.00
Poole	L	50 m	1.00	SV	93.50	2.59	-15.00
Poole	M	0 m	1.00	SV	0.16	3.09	-18.00
Poole	M	0 m	2.00	SV	83.10	5.85	-16.00
Poole	M	0 m	4.00	SV	96.88	5.15	1.00
Poole	M	0 m	5.00	SV	72.70	4.80	2.00
Poole	M	0 m	3.00	SV	95.84	5.32	3.00
Poole	M	100 m	1.00	SV	78.94	4.69	-28.00
Poole	M	100 m	2.00	SV	83.62	7.11	-14.00
Poole	M	100 m	5.00	SV	93.50	6.94	0.00
Poole	M	100 m	4.00	SV	90.12	6.94	0.00
Poole	M	100 m	3.00	SV	93.76	6.94	1.00
Poole	M	50 m	1.00	AG	91.94	3.26	-19.00
Poole	M	50 m	2.00	SV	96.10	5.33	-12.00
Poole	M	50 m	3.00	SV	22.00	5.86	-3.00
Poole	M	50 m	4.00	SV	97.66	5.68	1.00
Poole	M	50 m	5.00	SV	100.00	5.51	1.00
Poole	U	0 m	1.00	SV	98.44	1.39	-8.00
Poole	U	0 m	2.00	SV	97.66	1.92	-3.00
Poole	U	0 m	3.00	SV	95.32	2.09	-1.00
Poole	U	0 m	5.00	SV	96.62	1.57	0.00
Poole	U	0 m	4.00	SV	95.84	1.57	3.00
Poole	U	100 m	1.00	SV	96.88	1.56	-9.00
Poole	U	100 m	5.00	SV	94.80	1.39	-3.00
Poole	U	100 m	3.00	SV	97.66	1.39	0.00
Poole	U	100 m	2.00	SV	97.66	1.39	1.00
Poole	U	100 m	4.00	SV	93.24	0.87	3.00
Poole	U	50 m	4.00	SV	94.28	4.69	-11.00
Poole	U	50 m	2.00	SV	93.50	2.78	-8.00
Poole	U	50 m	1.00	SV	94.28	1.39	-8.00
Poole	U	50 m	5.00	SV	91.42	5.21	-3.00
Poole	U	50 m	3.00	SV	90.12	2.78	0.00
South Oropouche	L	0 m	1.00	SV	94.28	0.87	-5.00
South Oropouche	L	0 m	2.00	SV	71.66	1.39	-3.00
South Oropouche	L	0 m	3.00	AG	0.16	1.92	-3.00
South Oropouche	L	0 m	5.00	SV	0.16	1.57	1.00
South Oropouche	L	0 m	4.00	AG	0.16	1.74	1.00
South Oropouche	L	100 m	1.00	SV	79.20	3.91	-23.00
South Oropouche	L	100 m	3.00	SV	0.16	4.26	-2.00
South Oropouche	L	100 m	4.00	AG	0.16	4.43	-1.00
South Oropouche	L	100 m	2.00	SV	66.98	3.91	0.00

River	Reach	Transect	Block	Land use	Canopy closure (%)	Cumulative elevation (m)	Slope
South Oropouche	L	100 m	5.00	AG	0.16	3.91	3.00
South Oropouche	L	50 m	1.00	SV	0.16	2.76	-16.00
South Oropouche	L	50 m	2.00	SV	94.80	4.49	-10.00
South Oropouche	L	50 m	3.00	SV	0.16	4.49	0.00
South Oropouche	L	50 m	4.00	AG	0.16	4.49	0.00
South Oropouche	L	50 m	5.00	AG	0.16	4.32	1.00
South Oropouche	M	0 m	1.00	FO	97.92	3.91	-23.00
South Oropouche	M	0 m	3.00	AG	0.16	4.95	-3.00
South Oropouche	M	0 m	2.00	AG	0.16	4.43	-3.00
South Oropouche	M	0 m	5.00	AG	0.16	5.13	-1.00
South Oropouche	M	0 m	4.00	AG	0.16	4.95	0.00
South Oropouche	M	100 m	1.00	GR	51.64	3.91	-23.00
South Oropouche	M	100 m	2.00	AG	0.16	4.08	-1.00
South Oropouche	M	100 m	3.00	AG	0.16	4.08	0.00
South Oropouche	M	100 m	4.00	AG	0.16	3.56	3.00
South Oropouche	M	100 m	5.00	AG	0.16	3.04	3.00
South Oropouche	M	50 m	1.00	GR	49.04	3.91	-23.00
South Oropouche	M	50 m	3.00	AG	0.16	4.78	-4.00
South Oropouche	M	50 m	5.00	AG	0.16	5.13	-1.00
South Oropouche	M	50 m	4.00	AG	0.16	4.95	-1.00
South Oropouche	M	50 m	2.00	AG	0.16	4.08	-1.00
South Oropouche	U	0 m	3.00	AG	0.16	2.79	-9.00
South Oropouche	U	0 m	2.00	AG	0.16	1.22	-4.00
South Oropouche	U	0 m	1.00	GR	30.06	0.52	-3.00
South Oropouche	U	0 m	4.00	AG	0.16	3.31	-3.00
South Oropouche	U	0 m	5.00	AG	0.16	2.44	5.00
South Oropouche	U	100 m	1.00	GR	24.86	1.91	-11.00
South Oropouche	U	100 m	2.00	AG	23.56	2.43	-3.00
South Oropouche	U	100 m	4.00	AG	0.16	2.43	-1.00
South Oropouche	U	100 m	5.00	AG	0.16	2.43	0.00
South Oropouche	U	100 m	3.00	AG	0.16	2.26	1.00
South Oropouche	U	50 m	1.00	GR	0.16	3.91	-23.00
South Oropouche	U	50 m	2.00	AG	0.16	7.00	-18.00
South Oropouche	U	50 m	5.00	AG	0.16	9.09	-6.00
South Oropouche	U	50 m	4.00	AG	0.16	8.04	-3.00
South Oropouche	U	50 m	3.00	AG	0.16	7.52	-3.00

De= Developed, W=Water, SV=Secondary Vegetation, FO=Forest, Ag=Agriculture, GR= Grassland. L= Lower Reach, M=Middle Reach, U=Upper Reach

APPENDIX E
PHYSICAL AND CHEMICAL SOIL PARAMETERS FOR EACH 10 X 10 M BLOCK

River	Reach	Block	pH (30 cm)	N (30 cm) (g kg-1)	P(30 cm) (mg kg-1)	K(30 cm) (c mol kg-1)	Ca(30 cm) (c mol kg-1)	Mg(30 cm) (c mol kg-1)	EC (30 cm) (mS cm-1)	OC (30 cm) (g kg-1)	pH (60 cm)	N (60 cm) (g kg-1)	P(60 cm)(mg kg-1)	K(60 cm) (c mol kg-1)	Ca(60 cm) (c mol kg-1)	Mg(60 cm) (c mol kg-1)	EC (60 cm) (mS	OC (60 cm) (g kg-1)	% clay	% sand	% silt	% gravel
Aripo	L	1	6.37	0.90	16.00	0.01	2.53	0.23	0.20	5.00	6.15	1.20	15.00	0.01	2.260	0.17	0.13	5.00	4.00	78.59	17.41	0.00
Aripo	L	2	6.01	1.00	14.00	0.01	2.11	0.24	0.46	7.00	5.22	0.60	10.00	0.01	1.190	0.21	0.18	2.00	8.98	61.55	29.47	0.00
Aripo	L	3	6.55	8.00	13.00	0.01	3.17	0.28	0.21	8.00	6.35	10.00	18.00	0.01	3.370	0.22	0.14	10.00	7.56	66.64	25.80	0.00
Aripo	L	4	7.10	19.00	31.00	0.02	6.52	0.45	0.51	19.00	6.49	12.00	15.00	0.01	2.710	0.19	0.21	12.00	11.59	37.65	50.76	0.00
Aripo	L	5	6.77	1.40	17.00	0.01	5.83	0.28	0.28	16.00	5.77	1.40	11.00	0.01	3.415	0.27	0.20	17.00	12.90	3 6	49.94	0.00
Aripo	M	1	8.14	2.00	4.00	0.01	14.11	0.04	0.16	0.70	8.01	1.00	3.00	0.01	12.670	0.06	0.12	0.00	1.62	50.03	0.90	47.45
Aripo	M	2	7.20	9.00	10.00	0.01	7.54	0.24	0.22	12.00	7.00	2.00	8.00	0.01	6.800	0.11	0.28	13.00	4.11	75.09	13.17	7.62
Aripo	M	3	5.78	1.70	24.00	0.01	4.34	0.32	0.13	20.00	5.77	1.70	6.00	0.01	1.135	0.04	0.09	14.00	5.89	49.77	44.34	0.00
Aripo	M	4	5.26	1.40	57.00	0.04	4.13	0.30	0.20	19.00	5.22	2.10	10.00	0.02	4.280	0.22	0.07	7.00	5.89	62.00	32.11	0.00
Aripo	M	5	5.55	1.80	92.00	0.03	5.70	0.21	0.18	20.00	5.32	1.80	78.00	0.02	4.335	0.19	0.17	16.00	14.19	63.24	22.57	0.00
Aripo	U	1	7.90	2.20	2.00	0.02	23.28	1.03	0.69	42.00	7.86	1.60	2.00	0.01	25.975	0.97	0.31	26.00	2.29	45.44	11.14	41.13
Aripo	U	2	7.85	2.80	3.00	0.02	26.01	1.33	0.79	48.00	7.93	2.50	2.00	0.02	26.505	1.24	0.66	42.00	10.69	60.34	28.98	0.00
Aripo	U	3	7.90	2.70	15.00	0.01	25.97	1.13	0.63	53.00	7.88	2.80	3.00	0.01	26.580	0.93	0.69	48.00	3.53	69.04	27.43	0.00
Aripo	U	4	7.74	3.90	5.00	0.02	25.58	1.34	1.07	89.00	7.97	2.10	3.00	0.02	26.685	0.85	0.66	40.00	4.40	75.25	20.35	0.00
Aripo	U	5	7.91	2.30	1.00	0.01	25.80	0.83	0.62	30.00	5.65	0.50	2.00	0.01	25.335	0.79	0.43	20.00	4.82	24.59	12.22	58.37
Arouca	L	1	7.27	0.80	13.00	0.01	6.31	0.37	0.19	9.00	7.49	1.00	20.00	0.01	4.060	0.38	0.20	7.00	6.41	74.69	18.90	0.00
Arouca	L	2	7.55	1.00	17.00	0.01	5.57	0.43	0.22	6.00	7.46	1.00	13.00	0.01	5.390	0.30	0.25	8.00	4.40	77.32	18.28	0.00
Arouca	L	3	6.81	1.40	24.00	0.02	7.16	0.88	0.27	15.00	7.25	1.80	13.00	0.02	5.655	0.83	0.25	19.00	16.08	34.79	49.14	0.00
Arouca	L	4	6.91	2.60	26.00	0.12	10.26	1.37	0.70	25.00	6.94	2.20	26.00	0.13	9.370	1.05	0.72	27.00	13.51	36.93	49.57	0.00
Arouca	L	5	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	10.10	55.93	33.97	0.00
Arouca	M	1	7.39	0.30	5.00	0.01	2.09	0.33	0.11	4.00	7.37	1.70	4.00	0.01	3.580	0.53	0.08	10.00	2.35	58.99	3.92	34.74
Arouca	M	2	5.66	0.80	2.00	0.02	4.44	1.55	0.14	31.00	5.70	1.30	2.00	0.01	3.845	0.45	0.08	16.00	2.96	36.16	7.73	53.16
Arouca	M	3	5.41	n	2.00	0.02	5.14	0.53	0.11	26.00	5.57	2.60	3.00	0.01	2.910	0.21	0.05	10.00	10.77	56.07	33.16	0.00
Arouca	M	4	5.42	1.80	3.00	0.05	6.03	1.15	0.16	38.00	5.75	2.10	2.00	0.03	4.340	0.68	0.11	19.00	16.86	43.86	39.28	0.00
Arouca	M	5	5.80	1.50	1.00	0.02	6.27	1.16	0.16	40.00	5.76	n	2.00	0.02	5.635	0.51	0.15	30.00	12.80	48.00	39.20	0.00
Arouca	U	1	5.14	2.60	5.00	0.05	1.66	1.23	0.22	18.00	4.75	1.40	5.00	0.05	0.880	1.12	0.14	12.00	5.89	59.96	34.15	0.00
Arouca	U	2	4.76	1.80	6.00	0.04	0.48	1.78	0.21	40.00	4.58	1.30	7.00	0.02	0.305	1.15	0.11	12.00	14.32	43.65	42.03	0.00
Arouca	U	3	4.26	2.30	13.00	0.02	0.88	1.13	0.06	40.00	4.29	0.90	5.00	0.02	0.220	0.51	0.06	13.00	20.11	28.05	51.84	0.00

River	Reach	Block	pH (30 cm)	N (30 cm) (g kg-1)	P(30 cm) (mg kg-1)	K(30 cm) (c mol kg-1)	Ca(30 cm) (c mol kg-1)	Mg(30 cm) (c mol kg-1)	EC (30 cm) (mS cm-1)	OC (30 cm) (g kg-1)	pH (60 cm)	N (60 cm) (g kg-1)	P(60 cm)(mg kg-1)	K(60 cm) (c mol kg-1)	Ca(60 cm) (c mol kg-1)	Mg(60 cm) (c mol kg-1)	EC (60 cm) (mS	OC (60 cm) (g kg-1)	% clay	% sand	% silt	% gravel
Arouca	U	4	4.52	1.90	3.00	0.02	1.43	1.38	0.16	29.00	4.41	1.30	2.00	0.02	0.140	0.76	0.08	8.00	16.75	31.90	51.35	0.00
Arouca	U	5	4.15	0.90	5.00	0.04	0.32	0.91	0.18	26.00	4.22	0.80	2.00	0.01	0.040	0.24	0.06	14.00	19.48	25.85	54.67	0.00
Caparo	M	1	5.39	15.10	20.00	0.04	11.40	3.35	1.09	43.00	4.27	17.30	12.00	0.04	7.905	2.33	0.54	41.00	33.68	12.95	53.37	0.00
Caparo	M	2	5.98	n	27.00	0.05	16.32	4.68	0.38	44.00	5.87	15.70	24.00	0.03	11.545	3.76	0.15	22.00	21.27	39.32	39.42	0.00
Caparo	M	3	5.20	23.80	17.00	0.03	12.92	4.13	0.31	39.00	5.59	20.40	20.00	0.03	10.740	3.49	0.17	20.00	18.70	49.81	31.49	0.00
Caparo	M	4	5.39	12.30	17.00	0.03	13.43	3.76	0.19	39.00	5.62	13.70	17.00	0.02	10.885	3.23	0.10	22.00	43.72	10.07	46.21	0.00
Caparo	M	5	5.77	9.10	19.00	0.02	13.74	4.31	0.21	35.00	5.36	18.90	17.00	0.02	5.335	4.76	0.14	17.00	48.23	5.55	46.22	0.00
Caparo	U	1	6.96	16.20	27.00	0.02	16.73	2.85	0.23	6.00	6.94	5.70	28.00	0.01	15.400	2.76	0.16	8.00	23.53	33.97	42.51	0.00
Caparo	U	2	6.98	15.60	35.00	0.03	23.11	4.74	0.32	21.00	6.42	19.20	29.00	0.03	21.955	3.50	0.24	27.00	23.71	18.28	58.01	0.00
Caparo	U	3	6.35	15.40	27.00	0.03	19.20	3.82	0.17	25.00	6.43	15.60	19.00	0.03	11.760	2.35	0.12	14.00	32.59	16.23	51.18	0.00
Caparo	U	4	5.88	18.00	21.00	0.03	13.04	3.02	0.17	31.00	6.07	13.90	17.00	0.03	10.810	2.74	0.12	15.00	30.48	16.56	52.96	0.00
Caparo	U	5	6.04	15.90	15.00	0.05	11.25	2.04	0.20	36.00	xx	xx	xx	xx	xx	xx	xx	xx	28.37	19.67	51.96	0.00
Caparo	L	1	7.83	1.70	17.00	0.01	6.77	7.79	0.71	3.00	8.10	1.40	16.00	0.02	6.760	8.34	0.78	4.00	29.61	19.93	50.47	0.00
Caparo	L	2	5.40	0.70	15.00	0.07	7.83	5.08	0.42	19.00	5.95	0.70	7.00	0.05	6.275	5.72	0.39	12.00	40.03	3.10	56.87	0.00
Caparo	L	3	7.07	1.90	19.00	0.05	7.22	4.66	2.02	17.00	6.21	1.80	18.00	0.03	4.930	2.96	1.13	3.00	26.85	11.42	61.73	0.00
Caparo	L	4	4.72	2.00	10.00	0.09	6.86	5.65	0.27	17.00	4.83	1.90	11.00	0.05	6.010	5.13	0.16	16.00	30.32	11.42	58.27	0.00
Caparo	L	5	4.86	1.00	6.00	0.06	6.62	5.11	0.13	16.00	4.93	1.60	6.00	0.04	5.795	5.39	0.15	15.00	27.88	15.31	56.81	0.00
Caura	L	1	6.69	1.70	11.00	0.01	13.02	1.11	0.26	24.00	7.94	1.60	8.00	0.01	5.610	1.09	0.53	18.00	5.74	28.81	24.94	40.51
Caura	L	2	6.53	0.50	10.00	0.01	4.65	0.47	0.09	13.00	6.44	1.80	7.00	0.01	5.950	0.81	0.12	18.00	8.77	48.43	42.80	0.00
Caura	L	3	6.97	0.50	9.00	0.02	2.14	0.37	0.18	9.00	6.30	0.70	5.00	0.01	2.820	0.25	0.07	5.00	5.54	70.86	23.60	0.00
Caura	L	4	7.14	0.20	68.00	0.03	9.31	1.38	0.20	31.00	7.28	1.30	70.00	0.02	14.840	0.85	0.22	27.00	6.12	68.75	25.13	0.00
Caura	L	5	6.89	2.30	73.00	0.12	17.50	3.65	0.45	43.00	7.20	1.30	77.00	0.05	13.520	2.58	0.27	26.00	9.36	49.15	41.49	0.00
Caura	M	1	6.96	1.20	7.00	0.01	5.70	0.80	0.19	11.00	6.96	0.70	8.00	0.01	1.535	0.43	0.18	8.00	2.91	69.86	8.07	19.16
Caura	M	2	4.76	2.10	3.00	0.03	1.53	0.65	0.11	51.00	4.60	2.40	2.00	0.02	1.095	0.56	0.08	34.00	3.68	69.04	27.27	0.00
Caura	M	3	6.92	1.50	3.00	0.02	0.45	0.56	0.09	29.00	4.51	0.70	2.00	0.01	0.050	0.32	0.04	11.00	5.31	61.58	33.11	0.00
Caura	M	4	4.79	2.10	7.00	0.02	1.82	0.77	0.19	45.00	4.68	1.90	4.00	0.02	1.480	0.58	0.11	32.00	6.12	54.94	38.94	0.00
Caura	M	5	4.65	6.40	8.00	0.03	2.24	0.91	0.17	47.00	4.63	2.10	3.00	0.02	1.815	0.73	0.14	24.00	7.74	60.27	31.99	0.00
Caura	U	1	5.72	0.90	9.00	0.01	1.44	1.32	0.17	12.00	5.72	1.40	11.00	0.01	0.810	1.30	0.10	5.00	1.30	30.38	4.34	63.98
Caura	U	2	5.70	1.30	10.00	0.01	4.14	1.70	0.30	32.00	5.61	2.70	8.00	0.01	3.360	1.55	0.33	26.00	3.68	83.12	13.20	0.00
Caura	U	3	5.37	0.90	10.00	0.01	2.60	1.38	0.22	27.00	5.60	1.60	8.00	0.01	2.810	1.26	0.14	20.00	9.57	62.21	28.22	0.00
Caura	U	4	4.85	1.20	5.00	0.02	1.72	1.46	0.31	28.00	4.72	1.60	2.00	0.01	0.530	1.00	0.11	14.00	4.25	47.57	48.18	0.00
Caura	U	5	4.60	1.50	4.00	0.02	1.18	1.38	0.26	24.00	4.33	1.40	4.00	0.02	0.795	1.01	0.19	16.00	7.56	41.40	51.04	0.00
Couva	L	1	7.18	18.00	25.00	0.03	17.67	5.22	0.61	18.00	8.11	7.00	38.00	0.02	20.890	4.78	0.36	7.00	23.69	41.19	35.12	0.00
Couva	L	2	7.62	1.80	58.00	0.03	22.63	4.48	0.74	30.00	7.70	2.40	72.00	0.03	22.610	3.95	0.46	28.00	18.76	58.19	23.05	0.00

River	Reach	Block	pH (30 cm)	N (30 cm) (g kg-1)	P(30 cm) (mg kg-1)	K(30 cm) (c mol kg-1)	Ca(30 cm) (c mol kg-1)	Mg(30 cm) (c mol kg-1)	EC (30 cm) (mS cm-1)	OC (30 cm) (g kg-1)	pH (60 cm)	N (60 cm) (g kg-1)	P(60 cm)(mg kg-1)	K(60 cm) (c mol kg-1)	Ca(60 cm) (c mol kg-1)	Mg(60 cm) (c mol kg-1)	EC (60 cm) (mS	OC (60 cm) (g kg-1)	% clay	% sand	% silt	% gravel
Couva	L	3	5.68	36.00	7.00	0.05	9.62	5.23	0.31	36.00	5.76	23.00	6.00	0.03	7.565	4.73	0.17	23.00	17.49	34.17	48.34	0.00
Couva	L	4	5.70	36.00	3.00	0.05	8.14	4.10	0.16	36.00	5.62	19.00	3.00	0.02	4.930	3.57	0.08	19.00	20.95	24.84	54.21	0.00
Couva	L	5	5.11	22.00	3.00	0.04	7.16	3.58	0.10	22.00	5.39	14.00	3.00	0.03	5.895	3.92	0.08	14.00	30.31	21.54	48.15	0.00
Couva	M	1	7.76	1.40	43.00	0.03	19.12	4.17	0.93	13.00	7.99	1.80	40.00	0.02	18.300	4.38	0.81	15.00	21.91	35.22	42.88	0.00
Couva	M	2	6.39	2.20	20.00	0.05	10.34	3.91	0.27	12.00	5.77	2.90	17.00	0.03	9.335	4.85	0.18	27.00	17.49	42.67	39.84	0.00
Couva	M	3	7.11	2.20	151.00	0.04	10.81	3.95	0.15	23.00	5.77	1.30	20.00	0.02	9.545	4.05	0.17	12.00	10.36	48.70	40.94	0.00
Couva	M	4	5.82	3.60	12.00	0.08	8.43	2.65	0.31	42.00	5.46	2.10	8.00	0.05	6.945	2.48	0.31	22.00	18.89	31.57	49.54	0.00
Couva	M	5	5.12	2.30	12.00	0.07	10.49	3.12	0.47	48.00	4.84	0.70	7.00	0.04	4.455	2.46	0.19	23.00	20.76	34.40	44.84	0.00
Couva	U	1	6.78	1.60	5.00	0.01	5.13	0.75	0.20	18.00	7.27	1.60	6.00	0.01	5.775	0.76	0.27	19.00	10.77	63.03	26.21	0.00
Couva	U	2	6.33	1.60	6.00	0.01	4.67	0.82	0.17	20.00	6.47	1.60	6.00	0.01	4.965	0.77	0.14	19.00	8.19	49.71	23.40	18.70
Couva	U	3	6.21	1.60	20.00	0.01	4.84	0.85	0.23	25.00	6.17	1.60	5.00	0.01	3.800	0.86	0.22	15.00	2.06	40.59	26.10	31.25
Couva	U	4	6.23	1.60	6.00	0.01	4.35	0.84	0.33	24.00	6.43	1.60	5.00	0.01	4.695	0.83	0.22	18.00	8.14	69.33	22.53	0.00
Couva	U	5	6.63	1.60	6.00	0.01	5.38	1.07	0.20	23.00	6.55	1.60	3.00	0.01	4.310	1.04	0.18	16.00	9.52	59.09	31.39	0.00
Cumuto	L	1	4.84	8.40	10.00	0.02	4.55	0.94	0.11	9.00	4.35	5.80	7.00	0.02	3.050	0.56	0.11	10.00	18.85	54.22	26.94	0.00
Cumuto	L	2	4.59	11.50	5.00	0.02	2.64	0.51	0.16	21.00	4.77	8.60	4.00	0.02	2.160	0.42	0.05	6.00	15.35	43.75	40.90	0.00
Cumuto	L	3	4.27	8.10	9.00	0.02	2.28	0.54	0.11	15.00	4.40	3.40	5.00	0.01	2.505	0.43	0.05	2.00	17.64	36.19	46.17	0.00
Cumuto	L	4	5.59	10.10	7.00	0.02	2.83	0.50	0.15	16.00	5.58	7.20	5.00	0.02	2.610	0.41	0.10	5.00	18.93	29.91	51.16	0.00
Cumuto	L	5	5.58	8.40	5.00	0.02	4.27	0.65	0.13	14.00	5.58	1.60	4.00	0.02	0.515	0.24	0.08	5.00	18.35	27.12	54.53	0.00
Cumuto	M	1	4.56	9.00	8.00	0.01	0.37	1.67	0.08	0.60	4.25	1.10	5.00	0.01	0.435	1.18	0.06	0.70	18.26	62.83	18.91	0.00
Cumuto	M	2	5.65	2.30	7.00	0.04	8.11	2.33	0.25	32.00	5.67	1.90	7.00	0.02	7.200	2.23	0.15	29.00	9.76	47.28	42.95	0.00
Cumuto	M	3	5.44	1.60	8.00	0.07	7.86	2.58	0.25	37.00	4.90	1.80	5.00	0.04	6.185	2.48	0.16	23.00	15.67	28.79	55.54	0.00
Cumuto	M	4	5.35	2.30	4.00	0.06	5.84	5.51	0.23	36.00	5.05	1.60	4.00	0.03	4.150	5.02	0.06	13.00	29.62	19.84	50.54	0.00
Cumuto	M	5	5.82	1.50	4.00	0.04	5.37	3.85	0.09	22.00	5.45	1.70	3.00	0.02	4.845	3.76	0.08	14.00	16.46	41.62	41.92	0.00
Cumuto	U	1	7.87	2.30	8.00	0.02	6.45	2.09	0.28	16.00	5.29	1.10	5.00	0.01	5.730	1.31	0.15	5.00	22.96	28.78	48.26	0.00
Cumuto	U	2	6.85	3.40	16.00	0.02	14.75	2.16	0.45	46.00	6.69	2.20	9.00	0.02	11.635	2.05	0.21	23.00	26.63	40.32	33.05	0.00
Cumuto	U	3	5.97	xx	7.00	0.02	10.51	2.53	0.28	41.00	6.49	xx	11.00	0.01	9.965	2.01	0.30	16.00	11.16	30.33	58.51	0.00
Cumuto	U	4	5.68	xx	6.00	0.02	8.37	2.73	0.28	42.00	5.69	xx	4.00	0.02	7.190	2.43	0.13	23.00	13.00	27.61	59.39	0.00
Cumuto	U	5	5.67	xx	6.00	0.02	8.15	2.61	0.29	36.00	5.55	xx	6.00	0.02	8.135	0.43	0.10	12.00	18.71	29.07	52.21	0.00
L’ebranche	L	1	5.94	3.10	5.00	0.02	5.47	0.70	0.78	15.00	6.38	1.50	4.00	0.01	4.360	0.61	0.62	0.00	18.67	60.78	20.56	0.00
L’ebranche	L	2	5.84	1.80	5.00	0.02	4.63	0.70	0.33	17.00	5.74	0.90	3.00	0.01	3.675	0.62	0.14	1.00	20.64	50.90	28.47	0.00
L’ebranche	L	3	5.62	3.10	4.00	0.04	8.44	0.98	0.27	31.00	5.63	2.20	3.00	0.03	8.555	0.90	0.14	26.00	22.39	36.80	40.81	0.00
L’ebranche	L	4	5.61	2.70	5.00	0.03	8.01	0.88	0.23	31.00	5.61	2.50	4.00	0.02	7.910	0.83	0.13	13.00	25.76	19.51	54.72	0.00
L’ebranche	L	5	7.97	2.00	5.00	0.10	25.41	0.44	0.31	35.00	7.88	2.90	5.00	0.11	25.320	0.44	0.35	25.00	15.83	55.48	28.69	0.00
L’ebranche	M	1	5.24	1.80	1.00	0.03	3.66	0.79	0.12	23.00	5.04	1.40	1.00	0.02	3.020	0.79	0.07	12.00	24.31	42.03	33.66	0.00

River	Reach	Block	pH (30 cm)	N (30 cm) (g kg-1)	P(30 cm) (mg kg-1)	K(30 cm) (c mol kg-1)	Ca(30 cm) (c mol kg-1)	Mg(30 cm) (c mol kg-1)	EC (30 cm) (mS cm-1)	OC (30 cm) (g kg-1)	pH (60 cm)	N (60 cm) (g kg-1)	P(60 cm)(mg kg-1)	K(60 cm) (c mol kg-1)	Ca(60 cm) (c mol kg-1)	Mg(60 cm) (c mol kg-1)	EC (60 cm) (mS	OC (60 cm) (g kg-1)	% clay	% sand	% silt	% gravel
L'ebranche	M	2	6.17	1.90	2.00	0.03	10.46	2.01	0.24	39.00	6.60	1.70	2.00	0.02	6.480	1.62	0.12	17.00	17.08	40.18	42.74	0.00
L'ebranche	M	3	5.47	2.40	2.00	0.03	8.30	2.80	0.26	35.00	5.12	1.30	1.00	0.02	5.190	1.99	0.13	24.00	25.69	23.20	51.11	0.00
L'ebranche	M	4	4.88	1.80	2.00	0.02	5.63	1.71	0.12	20.00	4.93	1.40	1.00	0.02	5.440	1.23	0.09	20.00	30.19	15.51	54.31	0.00
L'ebranche	M	5	4.96	2.30	1.00	0.02	5.08	1.96	0.14	26.00	5.03	1.60	1.00	0.02	4.520	1.69	0.08	15.00	29.48	17.87	52.65	0.00
L'ebranche	U	1	4.70	2.60	5.00	0.05	2.96	1.43	0.33	22.00	4.72	2.10	3.00	0.05	2.510	1.18	0.34	26.00	35.25	23.41	41.35	0.00
L'ebranche	U	2	4.54	5.10	3.00	0.03	1.43	1.31	0.11	20.00	4.60	2.40	2.00	0.03	1.200	1.31	0.11	18.00	38.22	15.82	45.96	0.00
L'ebranche	U	3	5.13	5.10	4.00	0.04	4.69	2.28	0.21	35.00	4.93	2.40	3.00	0.03	2.890	1.28	0.23	28.00	29.75	22.79	47.46	0.00
L'ebranche	U	4	5.86	4.50	6.00	0.09	12.26	3.43	0.55	72.00	5.55	3.10	5.00	0.07	5.890	2.53	0.30	40.00	29.75	30.57	39.68	0.00
L'ebranche	U	5	4.76	4.90	7.00	0.12	5.13	3.64	0.27	55.00	4.63	2.80	3.00	0.14	4.235	3.80	0.27	35.00	38.43	25.25	36.33	0.00
Moruga	L	1	6.70	1.20	13.00	0.03	4.34	1.23	0.45	15.00	6.55	1.00	10.00	0.03	3.610	0.98	0.38	13.00	24.18	31.36	44.46	0.00
Moruga	L	2	5.36	1.20	10.00	0.03	4.21	0.83	0.24	25.00	5.55	1.60	9.00	0.03	3.090	1.04	0.19	17.00	11.59	57.68	30.73	0.00
Moruga	L	3	4.80	2.10	4.00	0.05	3.07	0.88	0.22	31.00	4.67	1.90	2.00	0.04	2.425	1.05	0.18	24.00	18.12	35.36	46.51	0.00
Moruga	L	4	4.90	1.70	1.00	0.08	3.70	1.33	0.28	26.00	4.29	1.30	3.00	0.05	1.470	0.97	0.12	16.00	27.90	21.09	51.01	0.00
Moruga	L	5	4.87	1.10	2.00	0.05	3.86	1.40	0.11	15.00	4.34	0.90	1.00	0.04	0.715	0.97	0.10	10.00	28.38	32.65	38.97	0.00
Moruga	M	1	5.36	1.10	8.00	0.04	7.36	3.52	0.38	29.00	5.30	1.20	6.00	0.02	6.655	3.30	0.29	29.00	19.00	39.68	41.32	0.00
Moruga	M	2	5.28	2.60	10.00	0.07	8.24	0.41	0.23	17.00	5.13	1.40	8.00	0.02	4.165	0.17	0.16	18.00	16.68	40.86	42.46	0.00
Moruga	M	3	5.41	1.10	5.00	0.05	5.04	0.08	0.20	27.00	5.33	0.10	4.00	0.01	2.875	0.03	0.08	9.00	21.56	30.71	47.73	0.00
Moruga	M	4	4.67	2.00	3.00	0.14	5.00	0.13	0.11	11.00	4.68	1.40	3.00	0.05	2.330	0.13	0.06	7.00	16.89	35.30	34.76	13.05
Moruga	M	5	5.20	0.80	4.00	0.21	4.28	0.10	0.11	17.00	5.01	2.20	4.00	0.02	2.195	0.10	0.08	10.00	16.77	45.94	31.17	6.11
Moruga	U	1	5.16	1.80	18.00	0.06	5.88	4.03	0.67	31.00	4.55	1.60	18.00	0.05	4.720	3.52	0.79	23.00	13.81	48.00	38.19	0.00
Moruga	U	2	5.36	2.00	20.00	0.04	6.97	5.42	0.38	36.00	5.49	1.40	15.00	0.03	5.695	4.84	0.23	27.00	21.77	24.05	54.18	0.00
Moruga	U	3	5.37	2.60	11.00	0.04	6.83	5.99	0.36	41.00	5.22	2.20	6.00	0.03	5.765	5.27	0.25	32.00	24.99	26.07	48.94	0.00
Moruga	U	4	4.66	1.70	4.00	0.03	1.65	2.57	0.24	26.00	4.90	1.40	4.00	0.02	0.795	2.26	0.14	17.00	5.88	49.51	18.50	26.10
Moruga	U	5	7.69	2.20	4.00	0.04	3.11	2.44	0.65	43.00	5.12	2.70	2.00	0.02	2.415	1.94	0.15	28.00	5.17	59.23	23.37	12.23
North Oropouche	L	1	4.09	xx	6.00	0.01	1.72	0.25	0.10	xx	4.12	xx	5.00	0.01	0.515	0.06	0.11	xx	6.58	83.97	9.46	0.00
North Oropouche	L	2	4.97	xx	2.00	0.01	1.10	0.34	0.06	xx	5.06	xx	3.00	0.01	0.525	0.20	0.05	xx	10.59	71.28	18.13	0.00
North Oropouche	L	3	4.32	xx	3.00	0.01	0.87	0.26	0.08	xx	4.24	xx	2.00	0.01	0.690	0.18	0.04	xx	16.61	27.82	55.57	0.00
North Oropouche	L	4	3.94	xx	3.00	0.01	0.78	0.22	0.10	xx	3.94	xx	4.00	0.01	0.530	0.23	0.07	xx	20.30	12.54	67.16	0.00
North Oropouche	L	5	3.81	xx	4.00	0.01	3.07	0.59	0.10	xx	3.96	xx	8.00	0.01	0.595	0.23	0.07	xx	18.28	10.99	70.72	0.00
North Oropouche	M	1	8.19	2.00	5.00	0.02	7.99	0.35	0.27	39.00	7.23	1.00	6.00	0.01	6.265	0.26	0.36	0.00	2.22	49.28	1.83	46.66

River	Reach	Block	pH (30 cm)	N (30 cm) (g kg-1)	P(30 cm) (mg kg-1)	K(30 cm) (c mol kg-1)	Ca(30 cm) (c mol kg-1)	Mg(30 cm) (c mol kg-1)	EC (30 cm) (mS cm-1)	OC (30 cm) (g kg-1)	pH (60 cm)	N (60 cm) (g kg-1)	P(60 cm)(mg kg-1)	K(60 cm) (c mol kg-1)	Ca(60 cm) (c mol kg-1)	Mg(60 cm) (c mol kg-1)	EC (60 cm) (mS	OC (60 cm) (g kg-1)	% clay	% sand	% silt	% gravel
North Oropouche	M	2	8.09	1.70	12.00	0.01	11.01	0.33	0.19	0.00	8.09	0.50	5.00	0.01	10.035	0.36	0.22	1.00	1.53	50.28	1.45	46.74
North Oropouche	M	3	7.73	1.70	10.00	0.01	23.46	0.48	0.45	40.00	7.82	1.60	9.00	0.02	21.400	0.42	0.39	24.00	3.08	71.24	25.68	0.00
North Oropouche	M	4	6.55	1.30	8.00	0.01	7.29	0.28	0.29	31.00	6.51	1.40	9.00	0.01	5.100	0.24	0.35	26.00	3.70	66.73	29.58	0.00
North Oropouche	M	5	6.81	2.30	20.00	0.03	17.24	3.35	0.46	47.00	7.50	0.40	7.00	0.01	11.685	1.60	0.38	27.00	6.98	59.71	33.31	0.00
North Oropouche	U	1	7.31	1.20	55.00	0.02	15.22	1.03	0.80	22.00	7.78	0.80	19.00	0.02	10.915	0.69	0.63	4.00	5.89	51.20	42.91	0.00
North Oropouche	U	2	4.84	1.30	8.00	0.02	2.73	0.40	0.48	27.00	4.26	2.20	3.00	0.01	0.695	0.25	0.24	18.00	9.80	60.34	29.86	0.00
North Oropouche	U	3	4.09	0.80	6.00	0.03	1.67	0.52	0.45	41.00	4.12	2.50	3.00	0.01	1.130	0.58	0.17	22.00	20.76	49.77	29.47	0.00
North Oropouche	U	4	4.25	1.30	3.00	0.02	1.18	0.30	0.13	34.00	4.22	1.40	2.00	0.01	0.680	0.46	0.01	26.00	17.81	53.03	29.16	0.00
North Oropouche	U	5	4.23	1.60	3.00	0.01	2.34	0.46	0.25	27.00	4.08	n	3.00	0.01	1.180	0.40	0.13	32.00	35.77	35.48	28.75	0.00
Penal	L	1	6.00	2.30	15.00	0.06	11.21	2.40	1.11	43.00	4.89	2.00	15.00	0.06	10.155	2.45	0.73	30.00	47.08	13.23	39.69	0.00
Penal	L	2	5.96	2.40	4.00	0.04	8.55	2.08	0.17	25.00	5.71	1.20	2.00	0.04	6.100	2.41	0.09	12.00	24.84	37.78	37.38	0.00
Penal	L	3	6.09	2.80	8.00	0.05	8.72	1.63	0.28	45.00	6.08	2.20	5.00	0.04	7.150	1.92	0.18	28.00	21.89	30.08	48.03	0.00
Penal	L	4	6.98	2.50	3.00	0.07	13.12	1.61	0.40	39.00	7.70	3.00	5.00	0.05	13.385	1.95	0.55	46.00	38.04	21.10	40.86	0.00
Penal	L	5	5.92	2.80	6.00	0.06	8.72	3.07	0.29	41.00	5.71	2.00	4.00	0.05	6.415	3.04	0.20	23.00	21.57	38.45	39.98	0.00
Penal	M	1	7.87	1.80	22.00	0.03	24.99	2.99	0.81	18.00	7.32	2.00	13.00	0.05	14.210	1.68	0.70	13.00	45.07	25.63	29.30	0.00
Penal	M	2	5.60	2.70	6.00	0.08	7.25	2.26	0.26	29.00	4.99	2.30	3.00	0.06	5.680	2.26	0.16	23.00	20.69	39.70	39.61	0.00
Penal	M	3	6.41	2.90	7.00	0.08	11.12	1.84	0.31	40.00	6.30	2.90	6.00	0.07	10.330	2.29	0.29	38.00	16.48	46.82	36.69	0.00
Penal	M	4	5.46	3.10	5.00	0.05	7.92	2.65	0.21	35.00	5.46	2.70	4.00	0.05	7.830	2.67	0.23	33.00	23.29	35.35	41.36	0.00
Penal	M	5	5.99	2.30	4.00	0.08	8.92	3.64	0.34	33.00	5.91	2.30	4.00	0.08	8.330	4.13	0.32	20.00	27.74	36.75	35.51	0.00
Penal	U	1	6.05	1.50	2.00	0.05	10.94	3.00	0.56	14.00	6.02	1.20	2.00	0.04	10.730	3.61	0.36	16.00	54.66	13.52	31.82	0.00
Penal	U	2	6.48	2.30	2.00	0.08	9.42	0.97	0.34	48.00	5.80	1.90	2.00	0.06	7.770	1.05	0.26	27.00	29.06	44.87	26.06	0.00
Penal	U	3	4.82	2.30	2.00	0.09	2.97	1.32	0.27	18.00	4.55	2.30	3.00	0.08	2.925	1.58	0.21	16.00	53.40	23.60	23.00	0.00
Penal	U	4	4.95	2.80	4.00	0.11	4.79	1.75	0.24	34.00	4.80	2.00	3.00	0.10	3.540	1.78	0.18	14.00	51.76	21.15	27.09	0.00
Penal	U	5	5.10	2.90	4.00	0.11	3.71	1.40	0.41	42.00	4.52	1.80	3.00	0.09	3.100	1.67	0.19	17.00	41.11	37.20	21.69	0.00
Poole	L	1	4.80	11.40	8.00	0.03	5.07	2.55	0.17	12.00	4.80	8.50	6.00	0.03	4.780	2.50	0.18	15.00	33.86	15.43	50.71	0.00
Poole	L	2	4.52	14.00	5.00	0.02	3.18	1.26	0.12	13.00	4.58	7.90	5.00	0.02	1.170	0.92	0.09	8.00	15.62	51.50	32.88	0.00
Poole	L	3	4.35	10.20	5.00	0.02	2.33	2.02	0.14	19.00	4.45	8.40	5.00	0.02	1.410	1.03	0.09	8.00	16.24	49.91	33.85	0.00

River	Reach	Block	pH (30 cm)	N (30 cm) (g kg-1)	P(30 cm) (mg kg-1)	K(30 cm) (c mol kg-1)	Ca(30 cm) (c mol kg-1)	Mg(30 cm) (c mol kg-1)	EC (30 cm) (mS cm-1)	OC (30 cm) (g kg-1)	pH (60 cm)	N (60 cm) (g kg-1)	P(60 cm)(mg kg-1)	K(60 cm) (c mol kg-1)	Ca(60 cm) (c mol kg-1)	Mg(60 cm) (c mol kg-1)	EC (60 cm) (mS	OC (60 cm) (g kg-1)	% clay	% sand	% silt	% gravel
Poole	L	4	4.46	5.40	4.00	0.02	0.71	1.23	0.08	15.00	4.76	2.90	5.00	0.01	0.355	1.23	0.06	9.00	20.34	50.59	29.06	0.00
Poole	L	5	4.35	8.60	5.00	0.04	1.32	1.91	0.20	39.00	4.39	5.60	5.00	0.02	0.445	1.59	0.09	11.00	16.86	43.86	39.28	0.00
Poole	M	1	5.88	11.70	10.00	0.05	8.64	4.99	0.17	6.00	5.17	3.60	8.00	0.04	8.145	5.13	0.13	10.00	27.03	35.77	37.20	0.00
Poole	M	2	5.88	11.90	17.00	0.02	11.64	3.00	0.11	20.00	5.88	12.10	14.00	0.02	7.025	1.88	0.10	16.00	21.67	39.06	39.27	0.00
Poole	M	3	4.75	16.90	11.00	0.03	8.74	3.16	0.10	20.00	4.68	1.60	9.00	0.03	7.260	2.94	0.06	12.00	21.52	21.10	57.37	0.00
Poole	M	4	6.88	25.80	11.00	0.04	21.95	2.02	0.54	36.00	6.21	6.30	11.00	0.03	16.300	1.54	0.20	17.00	15.14	39.94	44.92	0.00
Poole	M	5	4.88	14.80	11.00	0.03	6.65	2.54	0.12	19.00	4.78	12.70	10.00	0.03	5.635	2.63	0.12	16.00	21.62	18.28	60.10	0.00
Poole	U	1	5.08	2.30	7.00	0.02	5.63	3.49	0.36	18.00	5.69	1.30	4.00	0.02	4.765	2.79	0.36	9.00	23.12	39.30	37.58	0.00
Poole	U	2	4.39	2.00	7.00	0.02	1.84	1.18	0.14	20.00	4.73	2.20	7.00	0.02	1.345	0.69	0.08	8.00	35.14	12.95	51.91	0.00
Poole	U	3	4.56	1.50	9.00	0.02	4.25	2.15	0.12	23.00	4.56	0.60	8.00	0.02	3.165	2.12	0.09	12.00	27.89	15.31	56.80	0.00
Poole	U	4	4.67	1.60	5.00	0.02	6.04	3.36	0.10	16.00	4.65	1.70	4.00	0.02	3.335	3.37	0.06	3.00	27.54	13.52	58.94	0.00
Poole	U	5	4.74	2.00	7.00	0.03	6.47	3.63	0.11	8.00	4.73	2.10	6.00	0.03	5.425	3.84	0.13	5.00	21.31	17.74	60.96	0.00
South Oropouche	L	1	5.96	12.00	11.00	0.13	8.93	5.83	9.60	39.00	5.92	4.90	11.00	0.15	7.300	5.64	7.85	24.00	43.05	25.54	31.41	0.00
South Oropouche	L	2	6.02	5.70	21.00	0.10	8.77	5.12	0.36	20.00	5.82	4.10	18.00	0.10	8.455	4.88	0.36	21.00	31.74	20.22	48.03	0.00
South Oropouche	L	3	4.92	11.90	7.00	0.08	10.41	5.37	0.41	21.00	4.91	10.90	7.00	0.07	8.725	5.79	0.22	15.00	57.18	15.00	27.82	0.00
South Oropouche	L	4	4.97	12.40	2.00	0.07	7.93	4.33	0.15	15.00	4.69	9.60	2.00	0.07	9.545	5.05	0.13	7.00	65.05	19.40	15.55	0.00
South Oropouche	L	5	4.89	13.20	6.00	0.08	8.55	4.79	0.29	20.00	4.66	11.10	3.00	0.07	9.785	4.97	0.16	8.00	66.68	20.40	12.92	0.00
South Oropouche	M	1	5.49	1.30	14.00	0.04	6.00	3.58	0.22	28.00	5.75	1.20	13.00	0.03	6.600	3.87	0.28	29.00	27.56	41.61	30.84	0.00
South Oropouche	M	2	5.63	1.80	12.00	0.03	5.76	4.58	0.16	12.00	4.73	1.80	9.00	0.03	4.940	3.98	0.13	14.00	34.54	35.15	30.31	0.00
South Oropouche	M	3	5.23	1.30	5.00	0.05	6.93	4.60	0.15	14.00	4.67	1.30	5.00	0.05	5.725	3.99	0.10	15.00	42.12	15.63	42.25	0.00
South Oropouche	M	4	5.17	1.30	4.00	0.05	4.58	3.38	0.11	15.00	5.05	1.80	5.00	0.04	4.755	3.61	0.08	7.00	17.49	34.66	47.85	0.00
South Oropouche	M	5	5.13	1.70	10.00	0.05	5.82	4.49	0.36	20.00	5.14	0.90	7.00	0.05	5.620	4.37	0.10	5.00	45.16	14.18	40.66	0.00
South Oropouche	U	1	6.15	1.10	9.00	0.05	7.58	3.68	0.13	24.00	5.83	0.90	7.00	0.04	6.310	3.59	0.16	17.00	46.80	22.49	30.71	0.00
South Oropouche	U	2	5.11	2.00	4.00	0.05	7.28	4.33	0.15	40.00	5.24	1.90	3.00	0.04	6.965	4.22	0.20	23.00	49.37	14.18	36.45	0.00
South Oropouche	U	3	4.67	0.90	2.00	0.05	2.95	2.96	0.06	28.00	4.78	1.40	3.00	0.05	1.930	2.53	0.06	3.00	50.51	26.48	23.01	0.00

River	Reach	Block	pH (30 cm)	N (30 cm) (g kg-1)	P(30 cm) (mg kg-1)	K(30 cm) (c mol kg-1)	Ca(30 cm) (c mol kg-1)	Mg(30 cm) (c mol kg-1)	EC (30 cm) (mS cm-1)	OC (30 cm) (g kg-1)	pH (60 cm)	N (60 cm) (g kg-1)	P(60 cm)(mg kg-1)	K(60 cm) (c mol kg-1)	Ca(60 cm) (c mol kg-1)	Mg(60 cm) (c mol kg-1)	EC (60 cm) (mS	OC (60 cm) (g kg-1)	% clay	% sand	% silt	% gravel
South Oropouche	U	4	4.76	1.90	2.00	0.04	3.20	3.06	0.09	15.00	4.86	0.50	3.00	0.04	2.575	3.09	0.07	7.00	45.14	24.43	30.43	0.00
South Oropouche	U	5	4.36	2.50	7.00	0.03	0.82	1.60	0.08	8.00	4.71	1.60	4.00	0.05	1.145	2.23	0.07	7.00	42.19	24.86	32.95	0.00

xx= missing data; n=negligible values. L=lower reach, M= Middle Reach, U= Upper Reach

APPENDIX F
SPECIES FOUND AT ONLY ONE SITE

River	Upper Reach	Middle Reach	Lower Reach
Aripo	Chrysothemis pulchella (Donn) Decne.	Carica papaya L.	Cassia reticulata Willd
	Hypoderris brownii J.Sm.	Digitaria ciliaris (Retz.) Koeler	Hymenachne sp.
	Poaceae 4	Cleome rutidosperma DC.	Ludwigia peruviana (L.) H. Hara
	Rorippa nasturtium-aquaticum (L.) Hayek	Ischaemum timorense Kunth	Mimosa casta L.
	UT14	Peperomia pellucida (L.) Kunth	UG19
	Boehmeria ramiflora Jacq.	Pilea microphylla (L.) Liebm.	UG20
	Ficus yaponensis Desv	Rorippa sinapis (Burm. f.) Ohwi & H. Hara	Setaria barbata (Lam.) Kunth
		Eleusine indica (L.) Gaertn.	Commelina erecta L.
		Lauraceae 1	
		Ludwigia sp. 1	
		Portulaca quadrifida L.	
		UG21	
Arouca	Annona squamosa L.	Blechnum occidentale L.	Conyza apurensis Kunth
	Ceiba pentandra (L.) Gaertn.	Chrysopogon zizanioides (L.) Roberty	Cyperus surinamensis Rottb.
	Lauraceae 2	Clidemia sp. 1	Eclipta prostrata (L.) L.
	Manilkara bidentata (A. DC.) A. Chev.	Combretum fruticosum (Loefl.) Stuntz	Heliotropium indicum L.
	Vismia cayennensis (Jacq.) Pers.	Enicostema verticillatum (L.) Engl. ex Gilg	Muntingia calabura L.
	Zingiber officinale Roscoe	Miconia sp.	Pennisetum sp.
		Neurolaena lobata (L.) Cass.	UG23
		Persea americana Mill.	Ludwigia erecta (L.) H. Hara
		UG14	Alysicarpus vaginalis (L.) DC.
		UG22	
		Gonzalagunia hirsuta (Jacq.) Schumann	
		Pouteria multiflora (A. DC.) Eyma	
		Psidium guajava L.	
		Cocos nucifera L.	
		Coursetia arborea Griseb	
		Mammea americana L.	

River	Upper Reach	Middle Reach	Lower Reach
Caparo	Echinochloa colona (L.) Link	Lantana trifolia L.	Condylidium iresinoides (Kunth) R.M.King & H.Rob
	Leptochloa virgata (L.) P. Beauv.	UG13	Dichanthium caricosum (L.) A. Camus
	Oxalis frutescens L.	UG16	Malachra fasciata Jacq.
	Piper sp.2	UG17	UG8
	Triumfetta althaeoides Lam.	Setaria sp.	Mimosa pigra L.
	UG24	Crudia glaberrima (Steud.) J.F. Macbr	
Caura	Annona muricata L.	Abildgaardia ovata (Burm. f.) Kral	
	Cordia alliodora (Ruiz & Pav.) Oken	Coccoloba sp.1	
	Cordia bicolor A. DC.	Hirtella racemosa Lam.	
	Erythrina variegata L.	Hirtella triandra Sw.	
	Mikania hookeriana var. platyphylla (DC.) B.L. Rob.	Philodendron acutatum Schott	
	UG11	Pouteria minutiflora (Britton) Sandwith	
	Manilkara zapota (L.) P. Royen	Psychotria patens Sw.	
	UT16	Swartzia simplex (Sw.) Spreng.	
	Cedrela odorata L.	Tabernaemontana undulata Vahl	
		Teliostachya alopecuroidea (Vahl) Nees	
		Trichomanes pinnatum Hedw.	
		UG2	
		UG25	
		UG26	
		UT1	
		UT36	
		Ageratum conyzoides L.	
		Isertia parviflora Vahl	
		Lacistema aggregatum (P.J. Bergius) Rusby	
		Lygodium volubile Sw.	
		Schizaea elegans (Vahl) Sw.	
		UT15	
		Abarema jupunba (Willd.) Britton & Killip	
		Psychotria poeppigiana Müll. Arg.	
		Miconia punctata (Desr.) D. Don ex DC.	

River	Upper Reach	Middle Reach	Lower Reach
Couva	Gibasis geniculata (Jacq.) Rohweder	Anacardium occidentale L.	Poaceae 1
	Ludwigia decurrens Walter	Poaceae 6	UG31
	Priva lappulacea (L.) Pers.	Securidaca diversifolia (L.) S.F. Blake	Machaerium tobagense Urb.
		UG27	
		UT8	
		Justicia pectoralis Jacq.	
Cumuto	Mikania sp.1	UG33	Euterpe oleracea Mart.
	Pterolepis glomerata (Rottb.) Miq.	UG34	Hyptis atrorubens Poit.
	Urera baccifera (L.) Gaudich. ex Wedd.	UG36	Monstera sp.
	Commelina diffusa Burm. f.	UG35	Simarouba amara Aubl.
	Zanthoxylum martinicense (Lam.) DC.	Cyperus sp.	UG32
	Leptochloa longa Griseb.	Ludwigia sp.	Swietenia macrophylla King
L’ebranche	Bignoniaceae 4	UG38	Cissus sp.
	Dioclea reflexa Hook. f.	UG39	Clidemia sp. 2
	Drymonia serrulata (Jacq.) Mart.	Costus sp.	Marsdenia macrophylla (Humb. & Bonpl. ex Schult.) E. Fourn.
	Lasiacis ligulata Hitchc. & Chase		UG37
	Mikania scabra DC.		
	Palicourea crocea (Sw.) Roem. & Schult.		
	Passiflora serratodigitata L.		
	Pterocarpus officinalis Jacq.		
	Reach		
River	Upper	Middle	Lower
Moruga	Crateva tapia L.	Cleome spinosa Jacq.	Celestraceae 2
	Cyclopeltis semicordata (SW.) J.Sm.	Wedelia trilobata (L.) Hitchc.	Cleome gynandra L.
	Lomariopsis japurensis (Mart.) J.Sm.	Terminalia dichotoma G. Mey.	Croton lobatus L.
	Pavonia castaneifolia A. St.-Hil. & Naudin	Piper hispidum Sw.	Guarea glabra Vahl
	Trema micrantha (L.) Blume		Heliotropium angiospermum Murray
	UT18		Lastreopsis effusa (Sw.) Tindale var divergens (Willd. Ex Schkuhr)
	UT19		Senna sp. Mill.
	Pharus latifolius L.		UG40
	UG12		UG9
	Piresia sympodica (Döll) Swallen		UT11
	Heliconia spatho-circinada Aristeg.		UT17

River	Upper Reach	Middle Reach	Lower Reach
			Mouriri rhizophorifolia (DC.) Triana
			Adiantum pulverulentum L.
			Leptochloa sp.
North Oropouche	Asplundia rigida (Aubl.) Harling	Acanthaceae	Eugenia monticola (Sw.) DC
	Dendropanax arboreus (L.) Decne. & Planch		UG46
		Piper hispidum	
	Diplazium grandifolium (Sw.) Sw.	Pothomorphe peltata (L.) Miq.	UT20
	Ficus amazonica (Miq.) Miq.	UG6	UT21
	Miconia nervosa (Sm.) Triana	Panicum maximum Jacq.	UT22
	Ocotea eggersiana Mez		
	Quiina cruegeriana Griseb.		
	Ryania speciosa Vahl		
	Thelypteris serrata (Cav.) Alston		
	UT2		
	UT23		
	UT24		
	UT3		
	UT4		
	UT5		
	UT9		
	Xanthosoma undipes (K. Koch & C.D. Bouché) K. Koch		
	Calophyllum lucidum Benth.		
	Chimarrhis cymosa Jacq.		
	Psychotria capitata Ruiz & Pav.		
	Cyathea sp.		
	Hernandia sonora L.		
	Hieronyma laxiflora (Tul.) Müll. Arg.		
	Manicaria saccifera Gaertn.		
	Cnemidaria spectabilis (Kunze) R.M. Tryon		
	Reach		

River	Upper Reach	Middle Reach	Lower Reach
Penal	Diospyros inconstans Jacq.	Capparis baducca L.	Bursera simaruba (L.) Sarg.
	Machaerium robiniifolium (DC.) Vogel	Eugenia baileyi Britton	Chionanthus compactus Sw.
	Tectona grandis L. f.	Morisonia americana L.	Crescentia cujete L.
		UG42	Eugenia sp.1
		UG47	Leguminosae
		UT27	Phryganocydia corymbosa (Vent.) Bureau ex K. Schum.
		Lauraceae 4	Sansevieria hyacinthoides (L.)
		Zanthoxylum microcarpum Griseb.	UG18
		UT26	UG3
			UG41
			UT25
			Desmoncus orthacanthos Mart
			Nectandra rectinervia Meisn.
			Paullinia leiocarpa Griseb.
Poole	Paullinia pinnata L	UG45	Lauraceae 3
	Solanaceae	UG48	Myrcia splendens (Sw.) DC.
	UT7	UG1	UG10
		UG7	UT28
		UT32	UT30
		UT33	UT31
			UT29
			Buchenavia tetraphylla (Aubl.) R.A. Howard
South Oropouche	Paullinia pinnata L	Eriochloa punctata (L.) Desv. ex Ham.	Bignoniaceae 2
	Solanaceae	Heliotropium procumbens Mill	Hymenachne amplexicaulis (Rudge) Nees
	UT7	Merremia umbellata (L.) Hallier f.	Imperata brasiliensis Trin.
			UG28
			UG5
			Urochloa mutica (Forssk.) T.Q. Nguyen
			Terminalia catappa L.

APPENDIX G
ORDINAL VARIABLE RANKINGS AND JUSTIFICATIONS

Reach	Level of recreation	Recreation rank justification	Level of channel modification	Channel modification rank justification	Level of pollution	Pollution rank justification	Level of fire	Fire rank Justification
ARIL	1	Trails	0		0		0	
ARIM	3	sheds, cooking, bathing	2	large number of pools created by placing concrete columns in the river	3	algae, fertilizers, solid waste	0	
ARIU	1	bathing	2	tributaries were dammed for water cress production	1	solid waste	0	
AROL	0		4	dredging resulting in vegetation removal and changes to slope and channel morphology	2	solid waste and stench	0	
AROM	1	bathing	0		1	solid waste	0	
AROU	1	bathing	0		1	solid waste	0	
CAPL	0		4	dredging resulting in vegetation removal and changes to slope and channel morphology	2	solid waste and stench	2	repeated burnings for agriculture

Reach	Level of recreation	Recreation rank justification	Level of channel modification	Channel modification rank justification	Level of pollution	Pollution rank justification	Level of fire	Fire rank Justification
CAPM	1	trails	4	dredging resulting in vegetation removal and changes to slope and channel morphology	1	solid waste	2	repeated burnings for agriculture
CAPU	0		4	dredging resulting in vegetation removal and changes to slope and channel morphology	1	solid waste	2	repeated burnings for agriculture
CAUL	2	playground, wading	4	dredging resulting in vegetation removal and changes to slope and channel morphology	2	solid waste, stench	1	isolated burnt patch
CAUM	3	bathing, cooking, firewood	0		1	solid waste	0	
CAUU	1	bathing	0		0		0	

Reach	Level of recreation	Recreation rank justification	Level of channel modification	Channel modification rank justification	Level of pollution	Pollution rank justification	Level of fire	Fire rank Justification
COUL	0		0		1	solid waste	3	repeated burnings for agriculture, also proximity near road and evidence of none non agric related fires
COUM	0		0		2	solid waste, sespit	1	isolated patch
COUU	1	cooking	0		1	solid waste	0	
CUML	0		0		0		0	
CUMM	0		4	dredging resulting in vegetation removal and changes to slope and channel morphology	0		0	
CUMU	0		0		0		0	
LEBL	0		0		1	solid waste	0	
LEBM	0		0		1	solid waste	0	
LEBU	0		0		0		0	
MORL	1	hunting	0		0		0	
MORM	1	hunting	0		0		0	
MORU	1	hunting	0		0		0	

Reach	Level of recreation	Recreation rank justification	Level of channel modification	Channel modification rank justification	Level of pollution	Pollution rank justification	Level of fire	Fire rank Justification
NORL	2	recreational drug use, trails	4	dredging resulting in change in slope, morphology and also vegetation removal	1	solid waste	0	
NORM	0		0		2	solid waste, stench	0	
NORU	1	bathing	0		0		0	
PENL	1	hunting	0		0		0	
PENM	1	hunting	0		0		1	isolated patch
PENU	1	hunting	0		0		3	fires repeated burnings
POOL	1	trails	0		1	solid waste	0	
POOM	1	hunting	0		0		0	
POOU	0		0		0		2	close to road and evidence of more than one burning
SOUL	2	trails, fishing	3	dredging resulting in change in slope, morphology and also vegetation removal. Dredging was not recent unlike the other sites.	1	solid waste	2	repeated burnings for agriculture
SOUM	0		4		2	solid waste and stench	2	repeated burnings for agriculture
SOUU	0		0		1	solid waste	2	repeated burnings

APPENDIX H
CRITERIA FOR RANKING RIPARIAN ZONE AND UPLAND EDAPHIC MODIFICATION

Rank	Criteria
0	No trails, skidder trails, buildings, drains, furrows, beds, wooden buildings, dirt, gravel, or paved roads, concrete drains or concrete buildings.
1	Trails and skidder trails present. No buildings, drains, furrows, beds, wooden buildings, dirt, gravel, or paved roads, concrete drains or concrete buildings.
2	Evidence of past modification, for example, overgrown trails, skidder trails, buildings, drains, furrows, beds. No signs of active maintenance or modification. No permanent structures, for example, concrete buildings.
3	Evidence of recent or current site modification, for example, bare earth, bulldozing, furrows, beds, non-concrete buildings and dirt roads. Signs of active maintenance of the aforementioned.
4	Permanent site modification, for example, impervious land cover , paved roads, gravel roads, concrete drains, metal pipes, concrete buildings..

APPENDIX I
SIGNIFICANT CORRELATIONS AMONG ENVIRONMENTAL AND ANTHROPOGENIC VARIABLES USED IN BIOENV ANALYSES

	Clay	catchment length(km)	Maximum basin relief	K(30 cm) (cmol kg-1)	Ca(30 cm) (cmol kg-1)	Mg(30 cm) (cmol kg-1)	EC (30 cm) (mS cm-1)	ph (60 cm)	P (60 cm) (mg kg-1)
Sand	-0.781(**)	-0.264(**)	0.474(**)	-0.580(**)	-0.209(*)	-0.610(**)	-0.138	0.200(*)	-0.076
relief ratio H/L	-0.518(**)	-0.692(**)	0.880(**)	-0.300(**)	-0.208(*)	-0.593(**)	-0.017	0.167	-0.285(**)
area km^2	0.368(**)	0.790(**)	-0.205(*)	0.336(**)	0.17	0.449(**)	0.061	-0.123	0.336(**)
form factor (area/l2)	0.281(**)	-0.259(**)	0.074	0.462(**)	0.087	0.091	0.204(*)	-0.068	-0.199(*)
% forest cover 1994	-0.215(*)	-0.378(**)	0.315(**)	-0.088	-0.183	-0.415(**)	0.071	-0.15	-0.295(**)
ph (30 cm)	-0.322(**)	-0.208(*)	0.278(**)	-0.270(**)	0.598(**)	-0.037	0.395(**)	0.889(**)	0.321(**)
P(30 cm) (mg kg-1)	0.045	0.321(**)	-0.02	-0.026	0.386(**)	0.328(**)	0.342(**)	0.338(**)	0.882(**)
K(60 cm) (c mol kg-1)	0.703(**)	0.093	-0.390(**)	0.901(**)	0.303(**)	0.679(**)	0.274(**)	-0.233(*)	0.081
Ca (60 cm) (c mol kg-1)	0.188	0.116	-0.152	0.228(*)	0.955(**)	0.485(**)	0.539(**)	0.628(**)	0.374(**)
Mg(60 cm) (c mol kg-1)	0.630(**)	0.339(**)	-0.501(**)	0.630(**)	0.469(**)	0.969(**)	0.375(**)	0.023	0.350(**)
EC (60 cm) (mS cm-1)	0.153	-0.005	0.041	0.190(*)	0.568(**)	0.345(**)	0.862(**)	0.495(**)	0.384(**)

Variables highlighted with correlations >0.7 at $p<.001$ were eliminated.

* significant at $p<0.01$, ** significant at $p<0.001$

APPENDIX J
RAPID RIPARIAN ZONE ASSESSMENT PROTOCOL FOR TRINIDAD

Instructions

1. Measure a sample block 30 m long x 30 m wide on one side of the river channel starting at the water's edge. Each side of the river should be done separately.

2. Take photos of river channel and the vegetation from the riverbank to end of the transect.

3. Record the data in Section B below and sum the results provide determine the site management strategy.

4. Determine priority levels for restoration sites using Section C.

5. Use Section D for any additional notes.

Section A: General site data

Date:

GPS UTM coordinates:

Person recording data:

Section B: Site integrity and defensibility

Section	Variable category	Variable rating	Score
1. Biological integrity	Exotic tree species	a) No *Bambusa vulgaris*, (10) b) *Bambusa vulgaris* present (0)	
	Exotic and weedy ground flora species	a) No Sorghum sp. or *Pureria phaseoloides* (5) b) Either *Sorgum* sp. or *Pureria phaseoloides* present (2) c) Both Sorghum and *Pureria* present (0)	
	Secondary vegetation indicator species	a) One or more of the following species present (5) *Cecropia peltata* *Ochroma pyramidale* *Spondias mombin* *Hura crepitans* b) None of the above species present (0)	
	No. of tree species	a) > 20 (10) b) 11-20 (6) c) 6-10 (4) d) 1-5 (2) e) 0 (0)	
Biological Integrity Subtotal			
2. Site defensibility			
	Disturbance	a) Forest-No buildings, drains, furrows, beds, wooden buildings, dirt, gravel, or paved roads, concrete drains or concrete buildings. No agricultural species. Trees are irregularly spaced, i.e. not in rows which are indicative of abandoned agricultural estates Site has canopy cover (10) b) Secondary Vegetation-Site has canopy cover. Agricultural species may be present, planted in rows with heavy unmaintained undergrowth. Evidence of past modification may be present, for example, overgrown trails, buildings, drains, furrows and agricultural beds (6) c) Grassland-No canopy cover. No active weeding or site maintenance. No buildings, drains, furrows, beds. No dirt, gravel, or paved roads (3) d) Agiculture-Cultivated species present. Evidence of site maintenance, for example, weeding or little undergrowth under crop species. Site may gave bare earth, beds, non-concrete buildings and dirt roads. e) Developed-Evidence of permanent site modification, for example, impervious land cover like paved roads, gravel roads, concrete drains, metal pipes, concrete building. Grass or ornamental plants may be present but must show signs of maintenance, for example, mowing. (0)	

	Upland Disturbance 50-100 m from river channel edge	f) Forest-No buildings, drains, furrows, beds, wooden buildings, dirt, gravel, or paved roads, concrete drains or concrete buildings. No agricultural species. Trees are irregularly spaced, i.e. not in rows which are indicative of abandoned agricultural estates Site has canopy cover (10) g) Secondary Vegetation-Site has canopy cover. Agricultural species may be present, planted in rows with heavy unmaintained undergrowth. Evidence of past modification may be present, for example, overgrown trails, buildings, drains, furrows and agricultural beds (6) h) Grassland-No canopy cover. No active weeding or site maintenance. No buildings, drains, furrows, beds. No dirt, gravel, or paved roads (3) i) Agiculture-Cultivated species present. Evidence of site maintenance, for example, weeding or little undergrowth under crop species. Site may gave bare earth, beds, non-concrete buildings and dirt roads. j) Developed-Evidence of permanent site modification, for example, impervious land cover like paved roads, gravel roads, concrete drains, metal pipes, concrete building. Grass or ornamental plants may be present but must show signs of maintenance, for example, mowing. (0)	
	Evidence of fire	Presence (0) Absence (50)	
Site defensibility Subtotal			
4. Total integrity and defensibility score			

Total integrity and defensibility score	**Management strategy recommended**
>80 **(Conserve)** 50-79 **(Possible restoration site)** <50**(Leave as is)**	

Section C: Site restoration priority levels

		Restoration Priority **(High, Medium, Low)**
Channel modification	a) Evidence of dredging or channelization at the site or dams upstream **(Low priority)** b) Other forms of channel modification which would still allow flooding, for example, pool c reation **(Medium priority)** c) No evidence of channel modification **(High priority)**	

Section D Additional notes

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BIOGRAPHICAL SKETCH

Natalie Boodram is a citizen of Trinidad and Tobago. She has a first degree in Botany and a M.Phil. in plant science both obtained from the University of the West Indies in Trinidad and Tobago. Prior to her Ph. D. program, she worked at the Caribbean Environmental Health Institute (CEHI), an inter-governmental agency, based in St. Lucia, which carries out environmental work in 16 Caribbean countries. She has served as an ecologist for a number of environmental impact assessment (EIA) companies in the Caribbean, and worked as an Environmental Education Officer at the Pointe-a-Pierre Wild Fowl Trust in Trinidad and Tobago. She has also worked at the Center for Gender and Development Studies in Trinidad where she carried out research on Gender and the Environment issues. After her Ph.D., she will continue her work in environmental management in the Caribbean.