CENTRAL AMERICAN ECOSYSTEMS MAP

Belize

Volume I

J. C. Meerman & W. Sabido

2001

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List Of Acronyms

BEnCo = Belize Environmental Consulting Ltd.
CCAD = Comisión Centroamericana de Ambiente y Desarrollo
GEF = Global Environmental Fund
GIS = Geographic Information System
GPS = Global Positioning System
ODA = Overseas Development Administration
TM = Thematic Mapper
TFAP = Tropical Forestry Action Plan
UNDP = United Nations Development Project
UNESCO = United Nations Educational, Scientific, and Cultural Organization
WICE = World Institute for Conservation and Environment

Section I: Technical Report

1. EXECUTIVE SUMMARY

The "Central America Ecosystems Mapping Project." is part of a larger project commissioned by The World Bank and the Government of the Netherlands to undertake a series of regional activities throughout Central America. For its execution the World Bank has sought the integration of the funding into its portfolio with the CCAD. As a result, the current project has become a joint venture between the CCAD, the World Bank and the Dutch Government. Furthermore, it has obtained co-financing from the Regional UNDP/GEF project

The primary objective of the "Central American Ecosystems Map" was to create a ecosystems map on the scale of 1:250,000 for the region using a uniform methodology and nomenclature. The objective of the Belizean section of the project was to update and correct where necessary the vegetation map produced by Iremonger and Brokaw (1995), and to adapt the classification nomenclature conform the UNESCO classification. Specifically, the nomenclature was to follow guidelines set aside by The Central American Ecosystems Mapping project manager in order to make comparison possible with the similar efforts in the other Central American countries.

The current product differs from these earlier classification in that the broader divisions in the hierarchy are based first on vegetation structure (forest, scrub, herbaceous), followed by seasonality, altitudinal aspects, vegetation type (broadleaf, needle-leaf, palm), ground-water regime and ultimately underlying geology and soil.

A total of 85 terrestrial ecosystems were identified for Belize. In addition, two marine ecosystems (sea grass beds and coral reefs) were identified and mapped. Agriculture was identified as a land use and subdivided in 7 different subclasses including aquaculture and forest plantations. An attempt was made to distinguish between mechanized agriculture and subsistence/shifting cultivation types of agriculture but this could not be carried out to the full extend due to difficulties in the interpretation of the available satellite imagery. Areas of secondary growth with short rotation shifting cultivation were indiscriminately mapped as either "agriculture" or "shifting cultivation".

The identified ecosystems all find their roots in the 1995 classification by Iremonger and Brokaw. Principally, the classification used in this report was adapted to the UNESCO classification adopted by the current project. Also an altitudinal component was introduced, distinguishing between lowland vegetation types (< 500 m), submontane (500 – 1000 m) and montane (> 1000 m) vegetation types.

2. ACKNOWLEDGEMENTS

The Belize project was carried out with the institutional support of Programme for Belize. Nick Brokaw, Susan Iremonger, Betsy Malory, Alain Meyrat and Daan Vreugdenhil provided valuable comments to draft versions of the ecosystems map and the vegetation classification.

3. INTRODUCTION AND OBJECTIVES

The “Central America Ecosystems Mapping Project.” is part of a larger project commissioned by The World Bank and the Government of the Netherlands to undertake a series of regional activities throughout Central America. For its execution the World Bank has sought the integration of the funding into its portfolio with the CCAD. As a result, the current project has become a joint venture between the CCAD, the World Bank and the Dutch Government. Furthermore, it has sought and obtained co-financing from the Regional UNDP/GEF project

The primary objective of the “Central American Ecosystems Map” was to create a ecosystems map on the scale of 1:250,000 for the region using a uniform methodology and nomenclature. This overall objective includes a variety of specific objectives such as providing an information source for:

- Identification of the biological hot spots of the Mesoamerican Biological Corridor;
- Prioritization of its protected areas and assess their state of conservation;
- Performance of Gap analyses;
- Development of National Conservation Strategies;
- Exchangeable monitoring data collection;
- Environmental impact assessments;
- Enhancement of a better scientific understanding of the ecology of the region among national and international scientists;
- Creation of a baseline for further ecological studies and biodiversity monitoring.

An ecosystem is the complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space. Since vegetation patterns are at the base of the biological environment. Vegetation patterns have been chosen as “proxy” for ecosystems (Vreugdenhill et all. In Press)

4. PROJECT EXECUTION AND INSTITUTIONAL PARTICIPATION

As a first step, the CCAD/World Bank selected a team of specialists, consisting of an international coordinator and experienced international scientists with a long history of vegetation mapping and Geographic information systems application in the region. In each country, the responsible authorities for biodiversity conservation and/or mapping were contacted. In the case of Belize the responsible authority was the Land Information Center (LIC).

Production options were discussed with the national authorities, and in each country collaborating scientists from national universities or other institutions were contacted. National production teams were established, each consisting of national scientists supported by a small team of international scientists. As lead institution for Belize, the NGO Programme for Belize came forward.

5. STATE OF BELIZE'S BIOLOGICAL DATA COLLECTING AND ECOSYSTEM MAPPING TO DATE

The history of collecting in Belize is being described in detail by both Balick et al. (2001) and Brokaw (in press). As described by these two authors, plant collecting in Belize for scientific purposes took a slow start in the nineteenth century. In the years 1905-1907 Morton Peck collected for Harvard University. His grass collections indicated the West Indian affinities of Belize's flora (Bartlett 1932). The next serious collectors included Samuel Record in 1926, Cyrus Lundell in 1928-1929, and J. S. Karling in 1928. William A. Schipp was an especially important early collector. He collected in Belize from 1929 to 1937 and sent most of his specimens to Paul Standley, at the Field Museum of Natural History, Chicago. Percy Gentle, a Belizean, collected from 1931 to 1958, amassing nearly 10,000 specimens, the largest number from different individual plants of any botanist in Belize. Many other botanists have collected in Belize (Spellman et al. 1975), but especially important were collectors from the Missouri Botanical Garden, St. Louis, where the best collection of Belize plants is housed. In-country collections include the Herbarium of the Forest Department, Ministry of Natural Resources, Belmopan and the Herbarium of the Belize Collage of Agriculture in Central Farm.

The first formal flora was Standley and Record's *The Forests and Flora of British Honduras* (1936). Beginning in 1946, volumes of the *Flora of Guatemala* began appearing and were intended to include all species known in Belize. From these and other sources, Spellman et al. (1975) listed the dicotylodons, Dwyer and Spellman (1981) the monocotylodons, and Hartshorn et al. (1984) the trees of Belize. Currently, the massive, gradually issued, *Flora Mesoamerica* will include Belize species, while the most recent compilation is that of Balick et al. (2001): *Checklist of the Vascular Plants of Belize.*

Numerous authors have presented species lists for local areas or study plots in Belize. Some of these areas include the Vaca Plateau and Mountain Pine Ridge (Lundell 1940), Lamanai Archaeological Reserve (Lambert and Arnason 1978), Raspaculo (Brokaw 1991), Caracol (Brokaw 1992), Rio Bravo Conservation and Management Area (Brokaw and Mallory 1992), Shipstern Nature Reserve (Meerman 1993, Bijleveld 1998), Columbia River Forest Reserve (Holst 1993a, 1993b, in press, Smith 1995), Bladen Nature Reserve (Iremonger & Sayre 1994, Iremonger et al. 1995, Brokaw et al. 1997), Monkey River Special Development Area (Meerman, 1995a) and the area near Belize's highest elevation, informally known as Doyle's Delight (Allen, 1995).

The first description of vegetation types in Belize is by Morris (1883). In his book, *The Colony of British Honduras,* he described three forest types: "pine ridge", characterized by *Pinus caribaea;* "broken ridge", a broadleaf forest of particularly uneven canopy; and "cohune ridge", a broadleaf forest with many tall *Attalea cohune* palms. The term "ridge" means forest in Belize and implies nothing topographical. Hummel (1925) and Burdon (1932) also described Belize's forest vegetation. In 1928, Stevenson, divided Belize's vegetation into five main classes (with subclasses): 1) mangroves, 2) savannas (wet and dry), 3) pine forests, 4) primary rain forests (swamp, intermediate, advanced, mountain), and 5) secondary rain forests. This work was the base for the vegetation map published by the Surveyor

General's Department, British Honduras (1933). The scale was very fine in some places. This map appears to have been re-published at least three times, each time altered according to the author' s interpretations and intentions rather than on the basis of substantial new information.

Standley and Record (1936) provided fuller descriptions of Stevenson's five classes. These efforts, however, certainly did not do justice to the variety of vegetation types in Belize. Lundell (1934) was the first to classify regional vegetation. He reviewed the whole of the Yucatan Peninsula (south to Sibun River). Using physiographic and climatic variables he divided the vegetation of the Yucatan Peninsula into five regions. The monumental The *Vegetation of Peten* (Lundell 1937), concerning the department of Guatemala that borders Belize, is not about Belize, but its detailed qualitative descriptions of different vegetation types, including physiognomy, species, successional processes, and topography-soil-vegetation relationships, are useful for Belize. Lundell adopted the locally used system in which a vegetation type was named by adding "al" to the name of a dominant species, for example, *Tacistal* where the Taciste or Palmetto palm (*Acoelorraphe wrightii)* was common.

Stevenson (1938) recognized the strong links among soils, moisture, and vegetation, and his work contains geology, topography, rainfall, and simple vegetation maps of Belize. Building upon Stevenson’s work, Charles Wright, D. H. Romley, R. H. Arbuckle, and V. E. Vial published their great landmark of Belizean plant ecology: *Land in British Honduras* (1959). Its goal was to describe the agricultural potential of Belize. This volume contains an amazing amount of information, maps and diagrams, all based on intimate acquaintance with Belize. Following earlier workers, Wright et al. (1959) emphasized the importance of soil-moisture-plant relationships, and they thoroughly discussed and illustrated the geology, soils, and climate of the country. They contributed so much to plant ecology because they used natural vegetation to indicate agricultural potential, and thus took great pains to describe, classify, interpret, and map Belize's vegetation types. To get a systematic view of the distribution and relationships among topography, soil, and vegetation, Wright and his colleagues made cross-country traverses on foot, and they analyzed aerial photographs. Wright et al. (1959) divided the vegetation of Belize in 18 main classes, which, with sub-classes, amounted to a total of 77 varieties. Each of these 77 types was described in terms of characteristic height, dominant species and plant growth form, and soil type and moisture. The accompanying map, based on ground traverses and aerial photographs, was finely detailed. Since the goal was to illustrate potential natural vegetation as an indicator of agricultural potential, cultivated areas were not shown.

King et al. (1986, 1989, 1992) described and mapped the landsystems of Belize. Although not specifically a vegetation map, the descriptions provided vegetation characteristics for each landsystem.

The following vegetation classification scheme and map was devised by Iremonger and Brokaw (1995). The purpose of this new vegetation classification was mainly to determine which vegetation types were under- or poorly-represented in Belize's system of protected areas. They used contemporary terminology and took concepts from the classification system adopted by UNESCO (Mueller-Dombois & Ellenberg 1974), while relying heavily on Wright et al. (1959). The result was 51 vegetation types. Each was described in terms of height and dominant plant life form and species, with soil descriptions from Wright et al. (1959). The map was based on the 1959 map plus satellite imagery and detailed information for some local areas. Developed for use in conservation planning, it showed actual, not potential, vegetation, as well as cultivated and urban areas. The boundaries of protected areas were overlaid on this map, enabling the planners to calculate with GIS the amount of each vegetation type that was protected.

6. THE BELIZE ECOSYSTEMS MAPPING PROJECT

a) Team

The project was executed by Programme for Belize which assigned the following team:

Jan C. Meerman: Consultant with BEnCo, Wice, Belize. Who as lead consultant, developed the new vegetation classification transformed the Iremonger and Brokaw (1995) nomenclature to the UNESCO nomenclature as had been adapted for the Central American Ecosystems Mapping Project. The lead consultant also developed country specific descriptions for each ecosystem, again based on the Iremonger and Brokaw (1995) descriptions but expanded with information from other literature sources and own observations.

Wilber Sabido: Programme for Belize representative. GIS manipulation and digitizing. Implemented adaptations and corrections to the ecosystems map using an ArcView 3.1. platform.

Marydelene Vasquez: Independent consultant. Landsat TM image manipulation.

Roger Wilson: Independent consultant. General resource assistance.

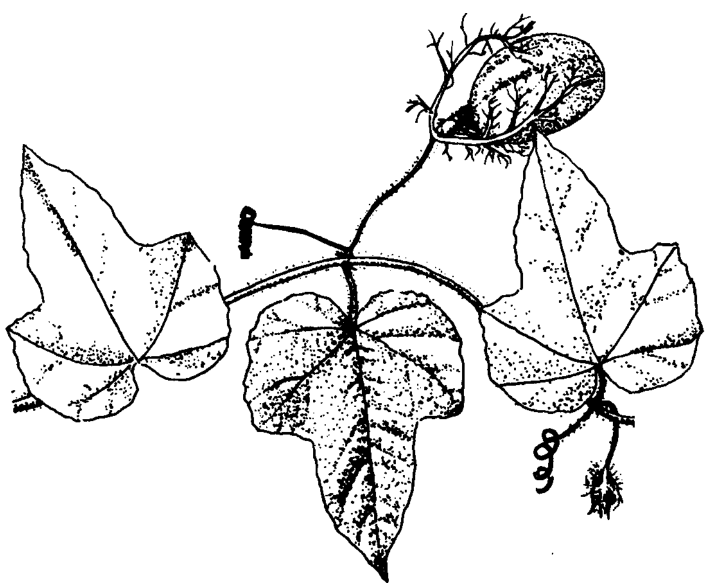
b) Objectives

The objective of the Belizean section of the CCAD/World Bank Central American Ecosystems Mapping Project was to update and correct where necessary the vegetation map produced by Iremonger and Brokaw (1995), and to adapt the classification nomenclature conform the UNESCO classification. Specifically, the nomenclature was to follow guidelines set aside by The Central American Ecosystems Mapping project manager in order to make comparison possible with similar effort in the other Central American countries.

As a consequence of the decision to update and review rather than create a new product from scratch, both the Iremonger and Brokaw map and classification system became the basis for the current project. In addition, the older vegetation map and classification system by Wright et al. (1959) was used as cross-reference. The current product differs from these earlier classification in that the broader divisions in the hierarchy are based first on vegetation structure (forest, scrub, herbaceous communities), followed by seasonality, altitudinal aspects, vegetation type (broadleaf, needle-leaf, palm), ground-water regime and ultimately underlying geology and soil.

A great number of publications and reports, many of which considered "gray literature" were used to verify, correct and describe the vegetation types recognized. All these references are listed in the literature section of the current report.

In the descriptions for the individual vegetation types, an attempt was made to list plant species frequently found in these vegetation types. This does not necessarily imply that these species are indicative for these vegetation types. The differences between vegetation types is certainly mainly in the structure of the vegetation and in relative abundance of the species constituting the community, rather than in outright presence or absence of particular species. The Cohune Palm *Attalea cohune*, for example, appears more dependent on well-drained soils, regardless of whether they are neutral or acid, while the Trumpet Tree *Cecropia peltata* depends upon light gaps and soil disturbance. Black Poisonwood *Metopium brownei* is very abundant on karst limestone hills but can also be abundant on acidic savannahs, while in the north of Belize it is abundant in flat lowlands over limestone. Santa Maria *Calophyllum brasiliense* is present in most forest habitats although it reaches highest density on acidic soils. The Mahogany *Swietenia macrophylla* is noticeably most abundant on limestone soils but is not strictly dependent on these and its abundance tends to reflect past disturbance history.



7. METHODOLOGY

a) The UNESCO classification system

The methodology adopted by UNESCO (Mueller-Dombois & Ellenberg, 1974, hereafter referred to as "UNESCO", ANNEX A), has been extensively used on all continents and by many different scientists in the world. It is a physiognomic vegetation classification system that categorizes vegetation structures as observed in the field. This system has the advantage of being relatively intuitive, globally applicable and its hierarchical structure.

Physiognomic classes or formations describe the dominant above the ground (or above the water bottom) woody and herbaceous plants in combination with a variety of biological criteria, such as leaf form, and seasonal characteristics. The system allows for specifying ecological details, such as climate, geological formations, elevation, soils, moisture. This system is species independent but in this project we have added biogeographic distribution, as well as associating or characterizing species, where this seemed appropriate.

Over the past decades, The UNESCO classification system for the identification and description of vegetation classes has proved to be easily applicable in the field. The system can be readily learned even by relatively inexperienced biologists. It has been proven suitable for the interpretation of aerial photographs, and more recently, it turned out to be a workable system in combination with GIS applications and satellite images. When analyzing the system, it had all signs that it was technically an appropriate classification system for mapping vegetation formations in the tropics of Central America. The question remained if it would be suitable to geographically differentiate sets of species in such a way that a representation/gap analysis could be realized that would capture the vast majority of species for each participating countries.

Although considered by many to be merely a vegetation classification system, Mueller-Dombois & Ellenberg (1974) considered the UNESCO system to be further reaching than that, and called it: "*Tentative Physiognomic-Ecological Classification of Plant Formations of the Earth"* (see annex A). The system includes both purely physiognomic characteristics of the vegetation, as well as typical ecological parameters such as climate, drainage, swamp/wetland, salinity and geomorphological conditions. For bare soils without any vegetation at all, the authors suggest to use a classification according to geo-morphological criteria, but they do not elaborate it. For open water systems the system offers no classification solution. Direct faunistic information is not taken into account. The system's main parameters are briefly reviewed in the following paragraphs:

The first level in the hierarchy is listed with a roman number; it classifies the main vegetation cover – ecosystem classes:

I. CLOSED FORESTS, formed by trees at least 5 m tall with their crowns interlocking, covering 65% of the sky or more

II. **WOODLANDS. (Open** stands of trees). Formed by trees at least 5 m tall, with most of their crowns not touching each other, but covering at least 30% of the sky; (In the Central American Ecosystem Mapping Project it was decided not to use this formation).

III. **SHRUBLANDS**, Mainly composed of woody phanerophytes (bushes or small trees) 0,5—5 m tall. Crowns may be touching, but covering at least 30% of the sky;

IV. **DWARF-SCRUB AND RELATED COMMUNITIES,** rarely exceeding 50 cm in height (sometimes called heaths or heath-like formations.);

V. **TERRESTRIAL HERBACEOUS COMMUNITIES.** Grasses, graminoid and other herbaceous plants are predominant in the cover, but woody plants (trees or shrubs) may be present, but not covering more than 30%. (Within this category, savannas, steppes or prairies are described. It is important to note that those classes do not refer to geomorphological conditions. Savannas or prairies may be flat, hilly or steep terrains with a predominantly herbaceous community);

VI. **DESERTS AND OTHER SCARCELY VEGETATED AREAS.** Bare mineral soil or rocks determine the aspect more or less constantly. Plants are scattered or may be absent (Sub-deserts are included in the formation classes III to V);

VII. **AQUATIC PLANT FORMATIONS**, (except marine formations), composed of rooted and (or) floating plants that endure or need water covering the soil constantly or at most times of the year.

For the ecosystems not covered under the above classes we constructed the Class "**S**" with:

SA for **AQUATIC ECOSYSTEMS** (for those ecosystems not directly covered under class VII).

SP for **PRODUCTIVE SYSTEMS** (Agriculture)

U for **URBAN** areas

The level of detail chosen for the mapping project was to coincide with the topographic maps of the respective countries, in the case of Belize 1:250,000. The authors of the UNESCO system state that it was designed for a level of detail 1:1,000,000. This statement appears to be on the very modest side, given that it lists formations that usually are of a size that can only be mapped at scales finer than 1:50,000, such as "flushes", various "forb" communities, screes and rooted floating leaves communities. The system provides ample detail for the scale chosen in this study. Nevertheless, it should be borne in mind that **the current map was designed for a scale no finer than 1:250,000 !**

b) Workshops

Ecosystems mapping is a science of biologists. It involves vegetation science, vegetation ecology, integral ecology, biogeography, aquatic ecology, etc. It requires such information and tools as:

- remotely sensed images and/or aerial photographs
- ancillary information, such as topographic and thematic maps and published information
- drawing and writing materials such as pens, paper, word processors and GIS
- analytical software, such as GIS and databases.

Table 1: **Preparatory workshops**

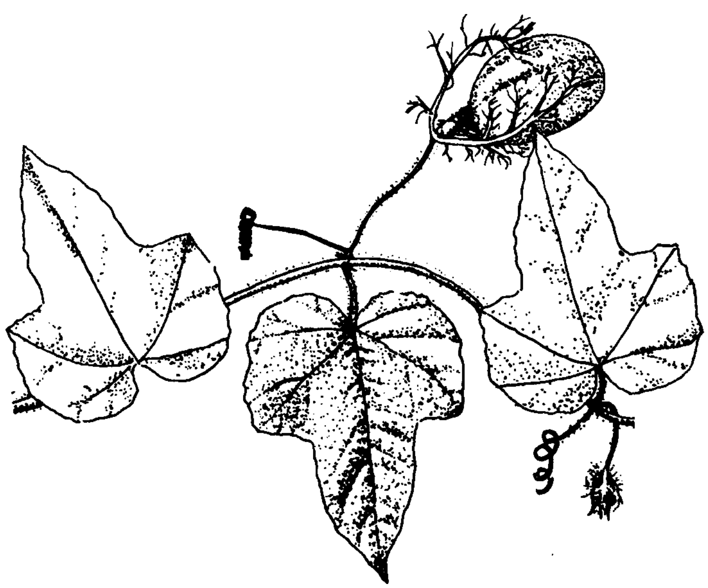
Dates	Place	Topics	Results
26 – 28 April, 1999	La Selva, Costa Rica Attended by Wilber Sabido and Jan Meerman	Selection of methodology with the lead members of the country teams and the representatives of governmental institutions for biodiversity conservation	Specialists agreement on application of the UNESCO classification method.
25 May – 2 June, 1999	Las Cruces, Costa Rica Attended by Wilber Sabido and Jan Meerman	Training course for lead specialists of country teams.	UNESCO vegetation classification methodology, Satellite image interpretation, basics of GIS, vegetation plot analysis, database management
28 September, 1999	Guatemala City, Guatemala Attended by Wilber Sabido	SICA-CCAD / World Bank meeting entitled "International Workshop on the Central America Ecosystems Map"	Official approval on methodology.
29 November – 1 December, 2000	Managua, Nicaragua Attended by Wilber Sabido and Jan Meerman	Final revision of integrated map and final document	Corrections applied to the draft maps

The selection of the sciences and production materials used depends on the purpose of the map. Nowadays, equipment for mapmaking has become very complex because of computers and their software applications. Often, scientists need support of highly specialized computer administrators and software managers (GIS, databases). However, no scientific study can be performed unless the very scientist that specializes in the field of the study to be performed, leads the process from the beginning until the end.

To be able to do so, all the scientists - and along with them the application related government officials - needed to be trained in the use of the new tools, such as remotely sensed images and the basics of GIS applications. The scientists also needed to agree on a joint methodology and exchange experiences in the field. To achieve all this, the Central American Ecosystem Mapping project organized a series of workshops, as well as on the job training and guidance throughout the project. The preparation of the map involved a total of 4 principal workshops held during the course of the mapping process. The dates and topics are listed in Table 1.

c) ancillary data

By design, the project intended to review the Iremonger and Brokaw (1995) vegetation map and classification system. Consequently, both these products were the basis for the current project. In addition, the older vegetation map and classification system by Wright et al. (1959) was used as cross-reference. A great number of publications and reports, many of which considered "gray literature" were used to verify, correct and describe the vegetation types recognized. All these references are listed in the literature section of the current report.



d) Imagery Used In The Project

A number of Landsat TM images was provided by the project:

Landsat TM Path 19 Row 47 4-XII-1998 in Erdas v7.4 format (Bands 374)
Landsat TM Path 19 Row 48 15-IX-1998 in Erdas v7.4 format (Bands 374)
Landsat TM Path 19 Row 49 12-XII-1998 in Erdas v7.4 format (Bands 374)
Landsat TM Path 19 Row 49 19-II-1999 in Erdas v7.4 format (Bands 453)
Landsat TM Path 19 Row 49 17-V-1996 in Erdas v7.4 format Bands 453)
Landsat TM Path 19 Row 48 15-IX-1998 in Erdas v7.4 format (Bands 453)

Figure 1. Satellite coverage

The first four images could not be geo-referenced and were of general low quality. Mainly as a result of heavy cloud cover. As a result, only for the North-Western and Southern most sections of Belize were adequate images available (fig 1). For the remainder - and majority - of the country only a 1993 hardcopy Landsat TM composite at a scale of 1:250.000 was available. This copy was prepared by DHV consultants BV, Holland and composed of spectral bands 4,5 and 3. For the marine environment, the same composite was used but now composed of spectral bands 3,2 and 1.

e) Methods Used For Image Interpretation

For those areas for which digital Landsat TM imagery was available, the Iremonger and Brokaw (1995) polygons were verified and where needed re-digitized directly on the computer screen using ArcView 3.1. This method proved most satisfactory. The original 1995 mapping was very coarse and reviewed areas can often be identified by their greater level of detail.

As a result of the limited availability of original, digitized Landsat TM data, the main method used to verify polygon size, shape and attributes was visual, either directly from hardcopy or from scanned hardcopy on screen, using CorelDraw 8 software. The polygons thus created were later translated into ArcView 3.1. format.

The minimal practical polygon size was found to be approximately 10 ha and only very few even smaller polygons were created.

f) Field Methodology

For the specific purpose of the current project, 38 field visits were conducted. The main aim of these fieldvisits was to bring more clarity in the complexity of the Belizean lowland savannas. At each site data were collected in 25 m radius plots conform the field form provided by the Central America Ecosystems Monitoring Database version 2.3. GPS data were collected using a Garmin GPS 12., Map datum NAD 27 Central. Reading latitude and longitude in 1000s of minutes. Digital images of the sites were procured with an Olympus D-340L digital camera. No other special equipment was used. Identification of species occurred in the field. Only positively identified species were recorded. Only in cases where dominant species could not be identified, specimens were collected for later identification in the laboratory. Literature used to identify plant specimens was primarily the Flora of Guatemala by Standley et al. (1946-1978). Nomenclature was adapted to a 1999 draft version of Balick et al. (2001) whenever possible.

No aerial surveys were conducted specifically for the project. But the project could fall back on information gained during various overflights conducted for other projects by the principal consultant.

g) Post-Fieldwork Exercises

All field data were entered in the Central America Ecosystems Monitoring Database version 2.3. using a Microsoft Access platform. In addition to the 38 sites visited, an additional 14 sites was added from the database from sites of which similar and reliable data existed. This brings the total to 52 sites entered in the database.

The fact that the Landsat TM satellite imagery provided by the project could not be geo-referenced complicated the positioning of the field sites on these images. Since the sites visited were mostly micro-habitats within the savanna ecosystem, most of these sites were too small to be mapped and were merged with the “short-grass savanna” ecosystem. In general, the fieldsites visited served to provide an accurate description of the micro-habitats within this “short-grass savanna” ecosystem.

8. RESULTS AND DISCUSSION

a) UNESCO Classes Identified

A total of 85 terrestrial ecosystems were identified of which 78 were mapped. In addition, two marine ecosystems (sea grass beds and coral reefs) were identified and mapped. Agriculture was identified as a land use and subdivided in 7 different subclasses (6 mapped) including aquaculture and forest plantations. An attempt was made to distinguish between mechanized agriculture and subsistence/shifting cultivation types of agriculture but this could not be carried out to the full extend due to difficulties in the interpretation of the available satellite imagery. Areas of secondary growth with short rotation shifting cultivation were indiscriminately mapped as either “agriculture” or “shifting cultivation”.

Based on the data obtained (1996 & 1998 satellite imagery), it was calculated that approximately 15,867 km² or 69.1% of Belize was under some form of forest (including shrublands) cover. 804 km² of this figure was Pine forest (5% of total forest cover).

More specifically:

Table 2. Broad Ecosystem Classes by Cover

Cover	% ±	km² ±
Lowland broadleaf forest and shrubland	51.4%	11,803
Agriculture, all subclasses	16.7%	3,835
Submontane and montane broadleaf forest	10.0%	2,296
Lowland savanna including pine savanna	8.8%	2,021
Mangrove and Littoral Forest	4.2%	964
Submontane pine forest (dense)	2.1%	482
Water	2.1%	482
Wetland (reed – herbaceous – *Eleocharis* swamps)	1.9%	436
Lowland pine forest (dense)	1.4%	321
Coastal Savanna (marine salt marsh)	1.1%	253
Urban	0.5%	115

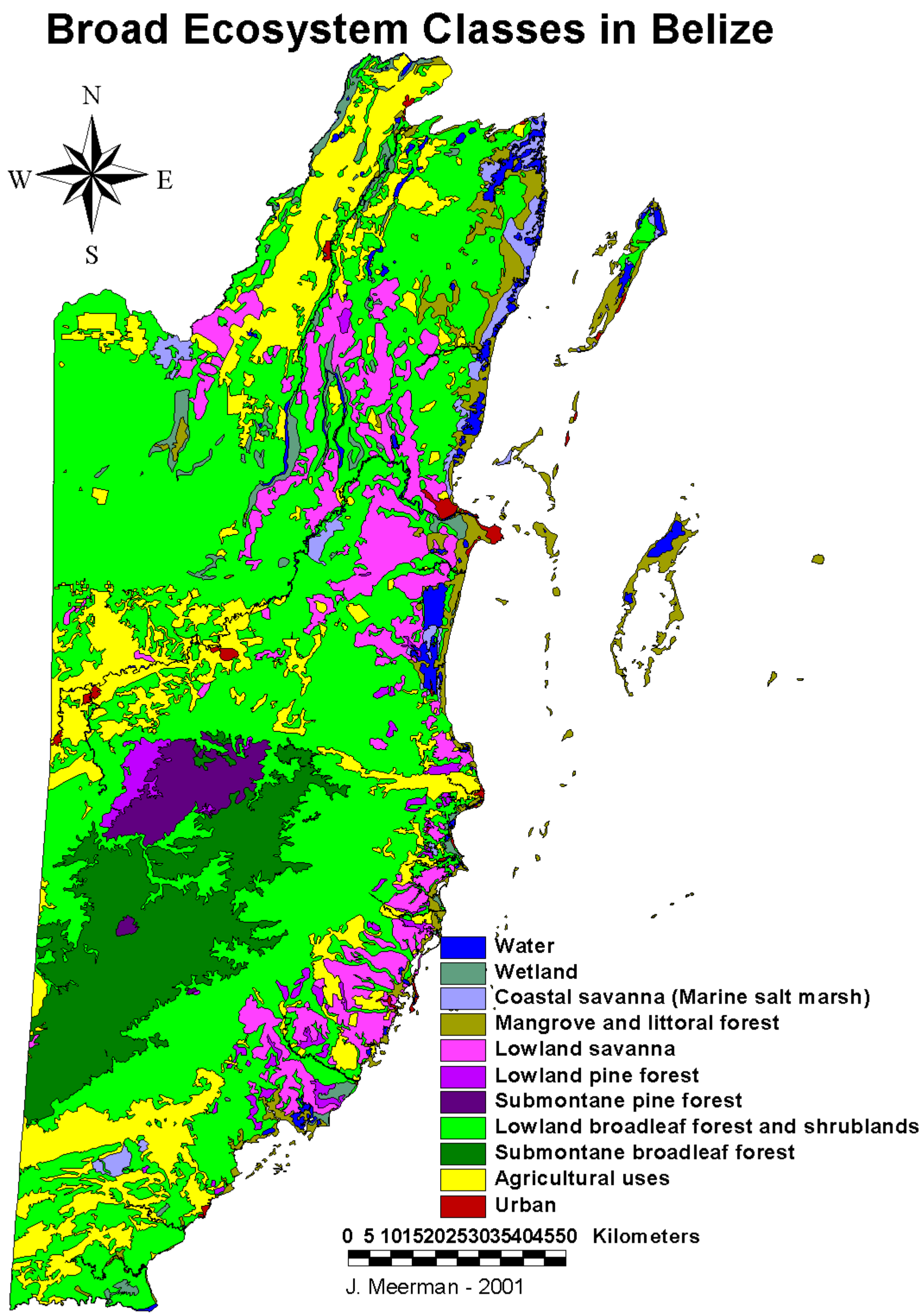
The results of table 2 are visualized in figure 2 (following page).

The identified ecosystems all find their roots in the 1995 classification by Iremonger and Brokaw. Principally, the classification used in this report was adapted to the UNESCO classification adopted by the current project. Also an altitudinal component was introduced, distinguishing between lowland vegetation types (< 500 m), submontane (500 – 1000 m) and montane (> 1000 m) vegetation types.

The descriptions of the ecosystems were augment with information from various literature sources (listed with each vegetation type) and/or personal observations.

The resulting classification was commented upon by Nick Brokaw, Susan Iremonger, Betsy Malory, Alain Meyrat, Daan Vreugdenhil and Roger Wilson. Suggested changes were implemented accordingly.

Figure 2


Broad Ecosystem Classes in Belize
N
W
E
S
Water
Wetland
Coastal savanna (Marine salt marsh)
Mangrove and littoral forest
Lowland savanna
Lowland pine forest
Submontane pine forest
Lowland broadleaf forest and shrublands
Submontane broadleaf forest
Agricultural uses
Urban
0 5 101520253035404550 Kilometers
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9. CONCLUSIONS AND RECOMMENDATIONS

The current project tried to identify ecosystems on a macro-scale. For many purposes, such as protected areas management plans, a more detailed approach will be required. But the current effort can easily serve as a base for any of such effort. Certain ecosystems proved to be too complex to map satisfactory. The most important of these are the two short-grass savanna classes and their relationship with needle-leaf dense forests. As a result, the mapping of these classes leaves much to be desired.

The hill forest types over non-calcareous rocks which are now split into the variants: "Simarouba–Terminalia", "Virola–Terminalia", "Vochysia–Terminalia" and "Calophyllum" were distinguished by Iremonger and Brokaw (1995) and are ultimately a legacy of the mapping effort by Wright et al. 1959. These forest types are clearly related but it is unclear whether these types can actually be distinguished from each other. However, with the current lack of data, it was decided to retain these variants until more detailed research results are available.

The impact of wildfires on the vegetation has received little attention (See separate article in section II) and should be further investigated.

a) Availability of the Data

The data produced in the context of this study have been produced with public funds with the objective to promote responsible biodiversity conservation in the broadest sense of the word. Any organization, whether private or public and any individual should have access to all the information produced. The World Bank considers all data and information produced in the context of this project to be public domain and it can be used by anybody without the request of permission (but with full source reference). The World Bank shall make a special effort to make all data publicly available. Digital information of limited size can be downloaded from the World Bank website http://worldbank.org/ca-env

b) Follow Up

The original data of this Belize Ecosystems Map and Classification project are lodged with both the Land Information Center (LIC) lincenbze@btl.net and Programme for Belize pfb@btl.net

The Belize Ecosystems Map and Classification should be regarded as a work in progress. Errors are inevitable and the authors apologize for these. We welcome corrections and suggestions. It is also the principal consultants intention to keep updating the map and ecosystem descriptions. Please contact meerman@btl.net or j_meerman@hotmail.com in these matters.

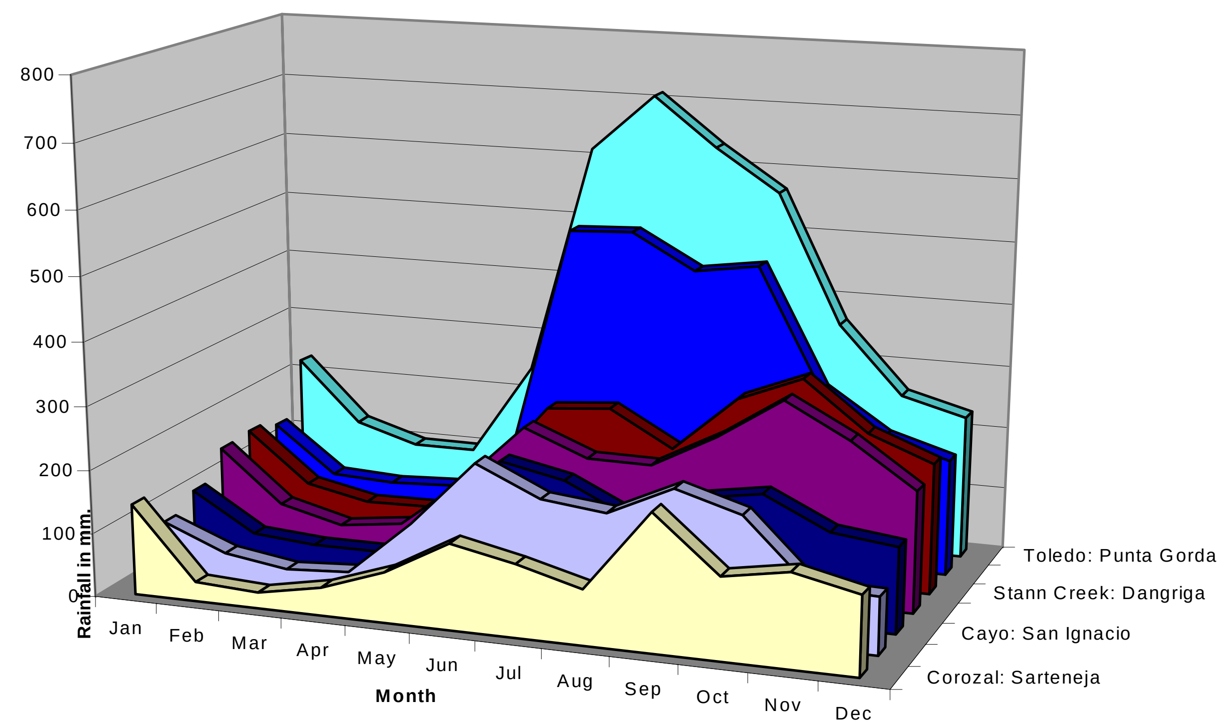
Section II: BELIZE ECOSYSTEMS MAP

10. BELIZE - INTRODUCTION

The Central American Country of Belize, formerly known as British Honduras has a population of approximately 280,000 people. It lies roughly between 15º 52' and 18º 30' North Latitude and 87º 28' and 89º 13' West Longitude and is bordered by Mexico in the North, Guatemala in the west and the Caribbean Sea in the east. It covers 22,963 km^2 (8,866 sq ml) of land area (including the approximately 1,000 cays). Belize harbors the largest unbroken Barrier Reef in the Western Hemisphere.

Belize has a subtropical to tropical environment with mean monthly minima ranging from 16º C in winter to 24º C in summer. Mean monthly maxima range from 28º C in winter to 33º C in summer. Rainfall varies from 1,200 mm (48") in the north to 4,000 mm (160") per year in the south (see figure 3). Hurricanes periodically strike the country and are an important element in the development of the forests.

Figure 3. Average monthly rainfall from North to South Belize



The northern part of Belize is mostly low-lying, gradually raised from the ocean during the Pliocene (2-13 million year BC) and now supporting a mosaic of limestone and sandy soils. The south of the country also has low-lying areas but is dominated by the Mountain Pine Ridge and the Maya Mountains, rising to 1124 m (3709')(Figure 4).

These mountains consist of quartzites, shales, and slates, with granitic intrusions, dating from the Carboniferous and Permian (250-300 million year BC). Limestone Karst foothills surround the southern mountains. These gradients in rainfall, topography, and soil support a variety of vegetation types.

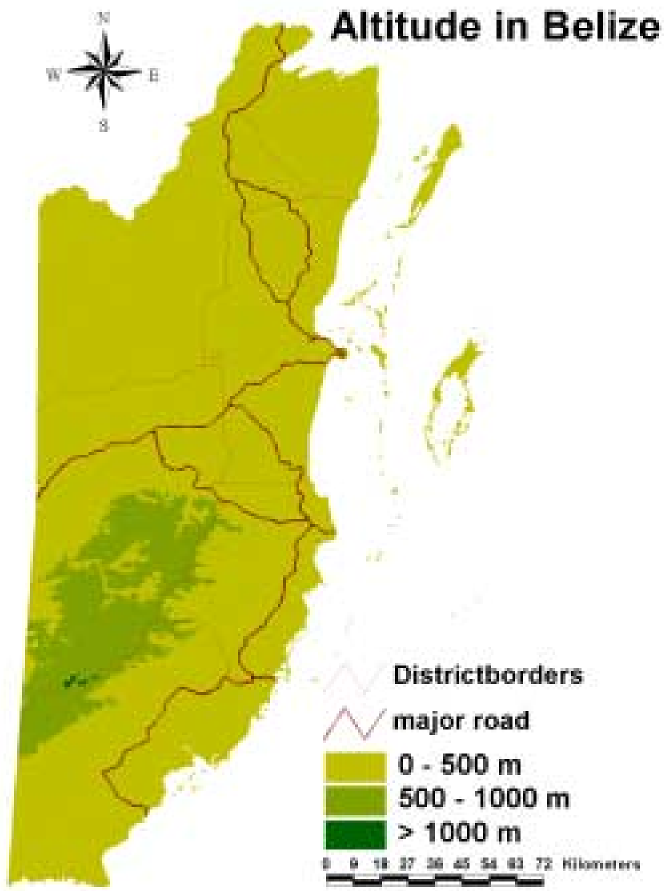


Figure 4. Altitude in Belize

An important factor in the natural history of Belize is it's past land use. For at least 2000 years the Maya Civilization was thriving in the Belizean lowlands. The complexity of the society and high population figures led to massive forest clearing for agriculture. Only after the collapse of the Maya Civilization around 900 AD, the forests were able to recover their lost territory. To what extend the returning forest resembles the "original" forest will probably remain unknown.

Stevenson (1928) considered much of the forest in Belize to be secondary, having grown up following ancient Maya agriculture. The abundance of certain tree species in the vicinity of Maya ruins has been attributed to ancient cultivation or protection of these species (Lundell 1934, Bartlett 1935). Indeed, there are many plant species characteristic of Maya ruin areas, as demonstrated quantitatively in transect studies over various substrates at Lamanai (Lambert & Arnason 1978). However, these same species also grow abundantly on natural substrates similar to those provided by Maya ruins, and the presence of such species on ruins is simply an ecological response, and there is no need to invoke human purpose to explain their abundance there (Lambert & Arnason 1982).

a) Forest fires in Belize

Fire as a threat to biodiversity and the status of the vegetation, is not well understood. The frequency, magnitude and effects that wildfires have had on biodiversity in Belize have not been documented. However, the dimensions of areas destroyed during these fires strongly imply major destruction of flora and fauna" (Rosado *in:* Jacobs & Castaneda, 1998). The ecological consequences of fire in natural ecosystems are many and have been listed by Wade et al (1980).

Fires in broadleaf forests are often ignored and bear no resemblance to the massive blazes that can be seen in burning needle-leaf forests. The fire is usually low, and slowly creeping through the leaf litter. Often it is possible to walk close up to it and even through it without too much danger. There is usually little "media value" in such fires. Only in areas with Cohune (*Attalea cohune*), the effects can be more dramatic. The abundant leaf litter under these palms explodes into flames, often igniting the crown and spraying sparks over great distances. But even in the case of these slow, low fires, the damage can be profound. Trees, especially young trees may appear unharmed but still die over time. The mortality either being the result of direct damage or indirect damage such as increased pathogen access through the fire damaged bark. Tree mortality as the result of such slow fires may continue for several years after the actual fire (pers. obs.). Each fire, which leaves more dead or dying trees behind makes the forest even more prone to fire damage.

Figure 5. Fire in Tropical evergreen seasonal broadleaf hill forest over calcareous soils in the Cayo district. May 2000. Picture: J. C. Meerman

Fire in broad-leaved forest is a relatively rare phenomenon. It is argued that in Central America most species of trees have evolved in the absence of fire and thus developed little tolerance for it (Budowski, 1966, Hopkins, 1983). Actual documentation of lowland broadleaf forest fires started by lightning is rare (Middleton et al., 1997). Consequently, fire in tropical lowland forests has traditionally been considered as human induced (Janzen, 1986; Koonce & Gonzalez-Caban, 1990). This view was also taken by the TFAP team when considering the causes for fire in the Southern Coastal Plains (ODA, 1989). This is also the reason why fires are treated here as part of the human impact factor. On the higher peaks of the Maya Mountains, however, lightning strikes appear to be the major cause of forest fires. Nearly 2/3 of the fires recorded in the Mountain Pine Ridge Forest Reserve are reportedly caused by lightning strikes (ODA, 1989).

Wolffsohn (1967) suggested that about once in every five or ten year the dry season in Belize is intense enough to create hazardous conditions. The vegetation is generally too damp to burn easily. This is especially the case in "real" rainforest but evidence of rainforest fires (dating many thousands of years back) has been collected throughout the tropics (Bassini & Becker, 1990; Horn & Sanford, 1992). Many of these large fires show a relation to human presence and it is often assumed that early man was directly or indirectly responsible for these fires (Horn & Sanford, 1992).

It is generally accepted that once every one or two centuries a series of abnormally dry years without rainy seasons dramatically increase the fire hazard on otherwise fireproof tropical rainforests (Jacobs, 1988). There are indications that the incidence of rainforest fire is on the increase worldwide. In 1982, 1983, 1992, 1993, 1997, 1998 and 2000, large surfaces of rain forest burned throughout the tropics. This increase is most likely caused by increased human encroachment on the forest and by the phenomenon of global warming (which is expected to lead to more erratic weather patterns including more frequent droughts). This is especially worrisome since these wildfires are gaining importance to the volatilization of gasses such as N_2, N_20, CH_4, CO_2 and other greenhouse gasses, i.e. those that contribute to global warming (Lugo, 1995).

Fires are most devastating on hills where an upward draft creates extremely hot fires towards the top of the hill. Fire affected hills; therefore, show the greatest damage towards the summit. Repeated hill fires result in “bald” hills with no woody vegetation but a cover of grasses or “Tigerbush” (the ferns *Dicranopteris* and *Pteridium caudatum*). The influence of fire is clearly greatest where there is drought stress and highly inflammable vegetation is present.

Fire induced vegetation in hilly areas are especially at risk since the fire resistant vegetation has a lesser capacity of retaining the soil and increased erosion is the result (Jacobs, 1989).

In the early days of the Forest Department it was noted that fire kept broad-leaved forest species from invading and replacing pine on soils which otherwise might have carried high forest. Nevertheless, pines are liable to be killed by fire when they are less than 3 m tall and are liable to damage at any age and size. The old-growth pines on the Southern Coastal Plain are frequently fire-scarred, internally and externally. The damage allows the ingress of wood-rotting fungi and termites and materially reduces the net yield (ODA, 1989).

Figure 6. Pine forest in the Mountain Pine Ridge after fire in May 2000. J.C.Meerman

Data from the Forest Department over the period 1963–1970 for the hills of the Mountain Pine Ridge Forest Reserve (Cayo district) indicate that out of 46 recorded fires during that period, 29 (63%) were reported to have been caused by lightning. The remaining 17 fires (37%) were caused by human agency. In the northern

Coastal Plain of Belize, the great majority of the lowland fires are caused by arson, by hunters after game (ODA, 1989, pers. obs.). In contrast, in the pine barrens of Florida, lightning strike is a frequent cause of fire (Lugo, 1995).

The combination of infrequent lightning strikes and a degree of fire adaptation in the savannah and needle-leaf community indicates that fire is a natural part of the Belizean savannah ecosystem, probably helped by the droughtiness of the vegetation and naturally occurring more frequently than in broadleaf forest. That said, the natural savannahs would be much smaller in extent and not burnt so often as is presently the case.

The Belizean Forest Department has had little success in fire control, even in the pine plantations. The staffing and equipment of the Forest Department have been so reduced that the fire protection scheme (Johnson, 1974) has never been implemented successfully. The priority areas for fire control outlined in the fire protection scheme have been so affected by wildfire that the stocking of healthy live trees appears to have been reduced below any level that would justify the expense (ODA, 1989).

Belize has experienced massive fires in broad-leaved forest after hurricanes, which cause large amounts of debris. Initially, these fires are usually started by farmers and may be accidental escapes from farm clearings. The debris caused by the hurricane is such that access and movement for firefighters is very difficult. Consequently, these fires are difficult to suppress unless they can be reached at a very early stage. Fire in broad-leaved forest may stimulate the regeneration of mahogany and cedar but more usually there is complete destruction of forest and replacement by persistent bracken, which is itself a fire hazard (Johnson & Chaffey 1973).

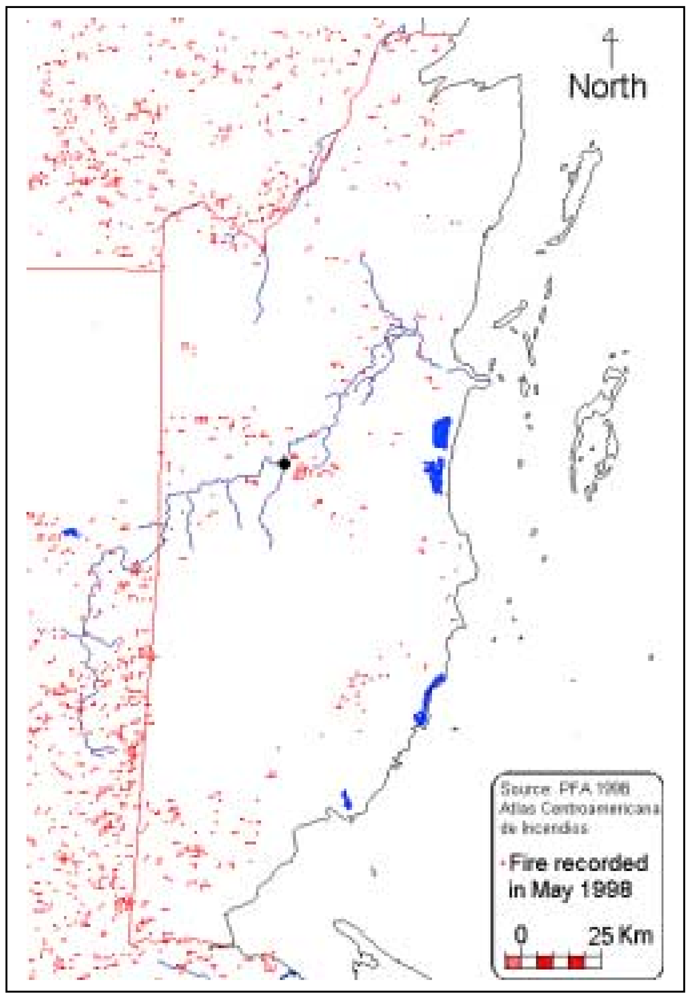


Figure 7. Fires in and around Belize in May 1998

For the same reason selective logging practices also create favorable conditions for the spread of wildfires. Not only do the discarded crown and branches provide fuel for fires, also the resulting scrubby growth following the opening of the canopy is usually more incandescent than the original forest.

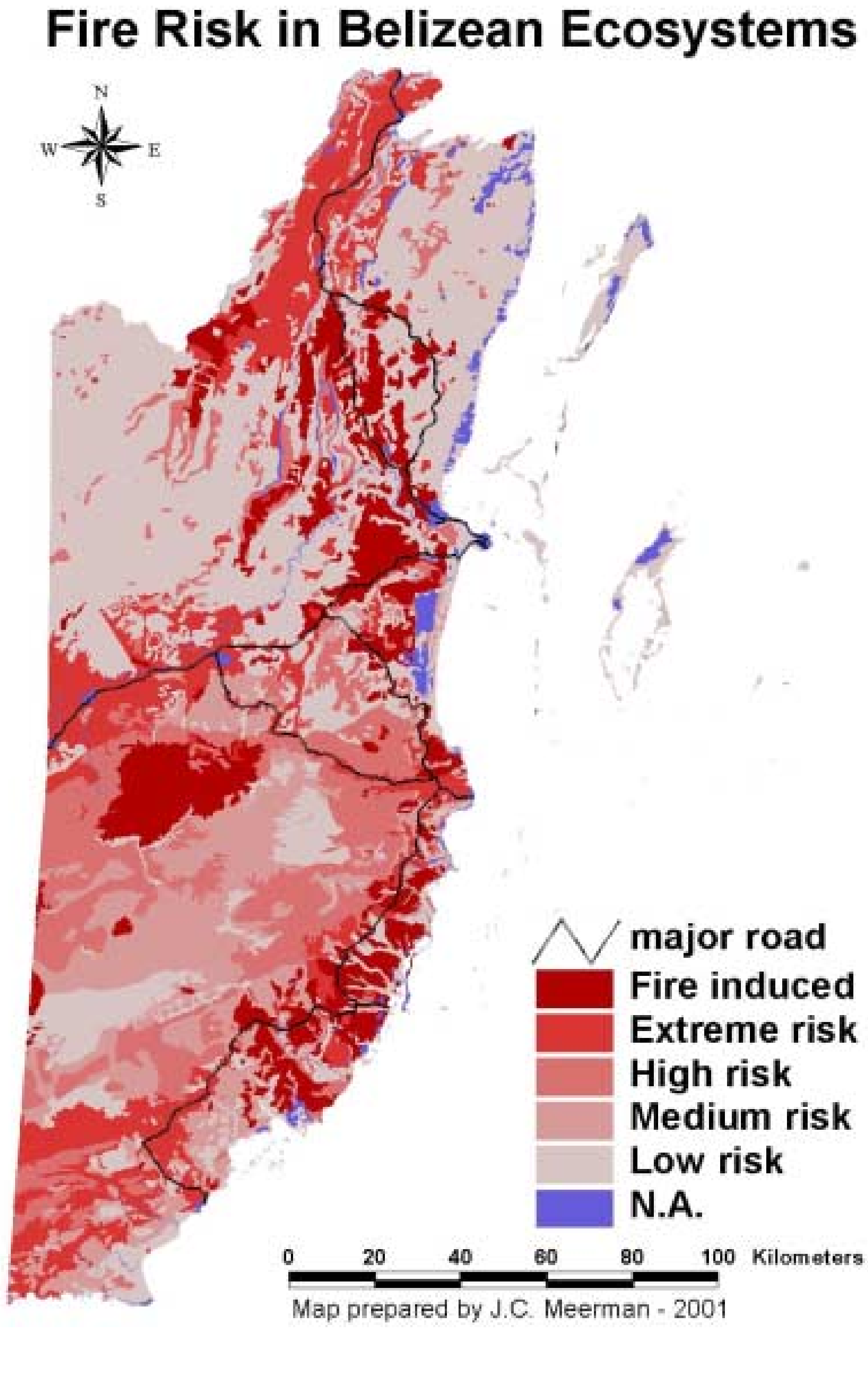


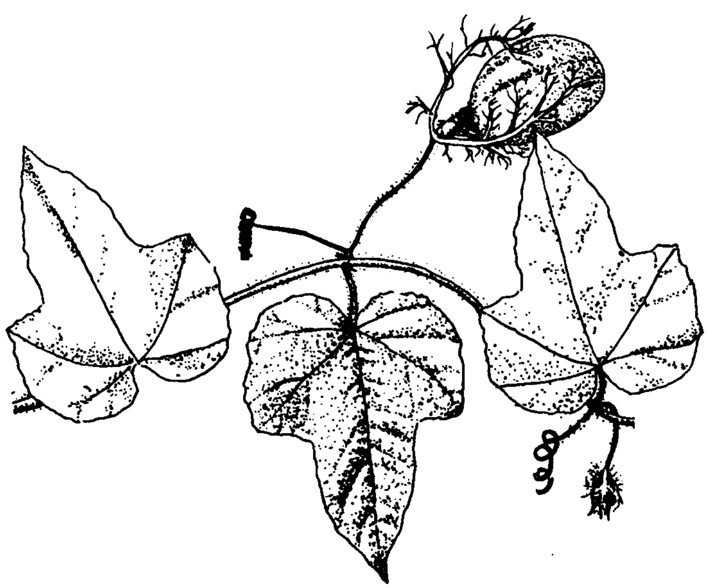
Figure 8. Fire risk in Belizean Ecosystems

More than anything, slash and burn agriculture has to be seen as the main culprit for fires in lowland broadleaf forests. In general the subsistence farmer has little consideration for the well being of the forest and most farmers do not take escaped "milpa" fires seriously. And the 1998 effort by PFA (1998) clearly shows that most fires occurred near human habitation (Figure 7), this map also shows that the fire intensity is higher in neighboring countries where the human pressure is higher.

Observations in the field show that burned hill tops are virtually always connected with agricultural clearings in at the foot of the same hill. The only noteworthy exceptions seem to be some fire damaged areas well away from any activity on a hillcrest of the Maya Mountains. Lightning strike is the most plausible explanation for these burned areas although agriculture is present at the feet of some of these same hills and fire-creep below the canopy remains a distinct possibility.

Using the characteristics of each ecosystem it was possible to produce a fire risk assessment map for Belize (Figure 8). This maps shows all the current fire-induced ecosystems (such as savanna and pine forest), but also shows the fire-risk for each ecosystem. In this case slope of the terrain is, important but also the proximity to human settlements and (slash and burn) agricultural fields.

Concluding, the importance of fire in the Belizean ecosystems has largely been downplayed but is probably of major, and increasing, significance. More investigations are needed to establish the actual impact and possible measures to prevent the damage caused.



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