PD-AAN-893

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THE TROPICAL FOREST ECOLOGY OF THREE WATERSHEDS IN THE REPUBLIC OF PANAMA

Contract Number
525-0191-C-00-1091-00

Project No. 525-0191

Project Title: Technical Assistance to RENARE

PREPARED FOR:

RENARE/USAID 525-T-049

PREPARED BY:

TROPICAL SCIENCE CENTER
SAN JOSE, COSTA RICA

JANUARY 1983

EXPERIENCE, INCORPORATED
MINNEAPOLIS, MINNESOTA 55402

The English language version of this report is a translation from the original in Spanish, Translated by Lucinda Tosi and Daniella Parré. San José, Costa Rica.

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INTRODUCTION

I. INTRODUCTION

The consultancy in "Ecology of the Moist Tropics" is part of the project denominated "Hydrographic Watershed Management, Panama", carried out under a contract between the government of Panama, through its General Direction of Renewable Natural Resources (RENARE), and the U. S. Government, through the Agency for International Development (AID).

The watersheds chosen for the project were: the watersheds of Gatún Lake (the Panama Canal) and of the Rivers La Villa and Caldera.

This project was assigned to the North American consulting firm, Experience Inc., which subcontracted the pertinent parts to the consultancy in Ecology of the Moist Tropics with the Tropical Science Center, in San José, Costa Rica.

To undertake this consultancy of 12-man months, the Tropical Science Center assigned the following individuals to the project:

Dr. Joseph A. Tosi, Jr.
Ing. For. León Isacc González P.
Ing. For. Vicente Watson C.
Ing. For. César Pérez Figueroa
Ing. For. Rafael Angel Bolaños M.

Objectives and scope of the study

In the RENARE/U.S.A.I.D./Experience, Inc. prime contract, the following general objectives are specified:

a) To strengthen the technical and administrative capabilities of RENARE;

b) To increase comprehension of the importance of the appropiate administration and conservation of Panama's renewable natural resources;

c) To establish programs for the appropriate use and preservation of the watersheds of the Panama Canal and La Villa and Caldera Rivers, which include the participation of each area's population in the integral development of that area.

The subcontract for the consultancy in Ecology of the Moist Tropics has the following terms of reference:

a) To delineate and adjust the ecological life zones of the watersheds of the Panama Canal and the La Villa and Caldera Rivers.

b) To prepare training programs in tropical ecology, in order to improve the capabilities of Panamanian professional personnel.

c) To identify typical ecosystems in each of the watersheds of the project.

d) To cooperate in the selection of forest species to be used in the watershed areas of the Panama Canal and the La Villa and Caldera Rivers;

e) To recommend and establish specific measures for the maintenance of the ecosystems in their unaltered natural state and for the recovery of those already altered.

f) To develope norms and laws to govern all agricultural, urban, sports, etc. activities in the different watersheds of the project, on land as well as in lakes and rivers.

In agreement with RENARE and in coordination with the other consultants of the Project, the terms of reference were adjusted and harmonized and the scope of this ecological study was set. In this way, plans were made to undertake the work in the time contracted for, given the facilities and means available.

The work finally consisted of:

a) The identification of the life zones, according to Holdridge's ecological classification (1947, 1967, 1978) in the three watersheds of the Project on a scale of 1:50,000. The final draft of the life zone maps was at a scale of 1:100,000 for the watershed of the Panama Canal and at 1:50,000 for the other two watersheds.

b) The development of a map of rural land use capability for each of the three watersheds, according to Tosi's system (1972, 1981), at a scale of 1:100,000 for watershed of the Panama Canal and at a scale of 1:50,000 for the other watersheds.

c) The identification of typical ecosystems, through a description for each life zone, of the most representative associations, or through a more specific identification of some of them from detailed plant and soil studies in selected areas covered by natural vegetation in the watershed of the Panama Canal.

d) The training of RENARE's personnel, according to the selection made by the General Director or by other RENARE officials.

The life zones constitute the basic units for determining potential-rural land use and for identifying, locating, and describing the natural ecosystems. In like manner, they can be considered as a base for recommending and elaborating the regulations stipulated in the terms of reference. They also may be useful, in the same way, for recommending and establishing specific rules for keeping specific ecosystems in their unaltered natural state and for the recovery of those ecosystems that have already been altered, as indicated by the aforementioned terms.

The identification of those ecosystems which should be retained in or restored to original natural vegetation requires application of a classification of land use capability based upon sustainable productive capability. Such a classification may indicate need to change land use,

in which case such a change is recommended unless zones of protected natural habitat or national parks have already been established as state policy, with all the goals and restrictions implied by those parks. In such a case, it follows that the use of these protected or national park areas and the maintenance of the natural vegetation should prevail over any other use determined by Tosi's classification system.

Tosi's system permits land to be classified in quantitative terms of major rural land use, as determined ecologically by the bioclimate, the most important physiographic and edaphic factors, and the agrotechnological management system to be used. Under this classification system, only rural land is classified. Therefore, in this study no recommendations for regulating activities other than farming, forestry, or environmental protection activities have been included. Thus, norms and laws for urban, sports, or other non-rural land using activities are not included, nor are norms and laws for the use of the lakes and rivers which, though normally included in the rural landscape, are not specifically considered under the classification system applied.

On the other hand, Tosi's system can be used as a basis for the formulation of watershed management plans and for territorial management in general, for which purposes it is specifically designed.

Although, in the terms of reference, maps of land use capability are not specifically requested, these were made to serve as a concrete and fundamental basis for the land management recommendations. It is necessary to keep in mind, however, that the precision of these maps could not be greater than the precision of the soil studies available for their formulation (CATAPAN, 1970).

As a homologous activity of the consultants, training was offered to RENARE personnel (counterparts in the study) in Ecology of the Moist Tropics, such as to acquaint them with new knowledge in the field and provide them with practical experience in the methodology used by the consultants in Panama.

Furthermore, personnel of the Forest Inventory Departament were added to the aforementioned RENARE personnel at the close of the consultancy to collaborate in vegetation studies using new methods in plant analysis with which they were unfamiliar.

The training of personnel was complimented and widened with a terminal seminar or training course on methodology used in the realization of this ecological study. This course included detailed explanations of Holdridge and Tosi's classifications systems and their practical aplications, as well as several methods for plant studies, and the presentation and analysis of the life zone maps and of land use in the three watersheds.

The requirement in the original terms of reference, that the consultants cooperate in the selection of tree species for watershed reforestation projects, has been complied with in only a general way as part of the recommendations on land use by life zones.

This selection had already been made in specific terms by the FAO-RENARE Project. In said Project, being run concurrently, an evaluation of the forest species used in Panama, in the different life zones and according to soil conditions, has been presented (Romero and Tapia, 1981). It was also considered that the selection of forest species for the reforestation of three watersheds was an objective more appropriate to the AID/Experience, Inc. consultancy in Tropical Forestry.

Therefore, the principal objective of this study can be summarized in the presentation of an ecological framework for the management plans of the three watersheds under consideration, through a classification of the ecological environment, according to the life zone, and the determination, according to the bioclimate, physiographic, and edaphic conditions, of major rural land use capability, according to Tosi's system. Such a classification is limited in its precision by the information on soils currently available for the consultancy.

Another important objective was the training of Panamenian personnel, related to the discipline of the consultancy, as well as those Technicians to be entrusted by RENARE with execution of the recommendations.

These objectives were achieved within the limitations on available facilities, in the period stipulated by the contract.

Responsibilities of the Personnel that participated in the proyect

The study was conducted by the personnel of the Tropical Science Center working together as a group, for a cumulative time of twelve man-months.

The distribution of responsibilities among the personnel that participated in the consultancy was:

Dr. Joseph A. Tosi Olin acted as General Director and Supervisor of the project.

- He oriented and directed the final elaboration of the life zone maps and of the major land use capability, as well as the correlation of data presented in the soil study of Catastro Rural de Tierras y Aguas de Panama (CATAPAN, 1970) and the values of the keys in the system elaborated by himself for the determination of major rural land use capability in Colombia (Tosi, 1972, 1981).

- He revised the maps of the life zones of the three watersheds made in the field. Together with the engineers Bolaños, González, and Watson, he directed and completed the maps of the life zones and of the land use of the rio Caldera Watershed.

- He participated as an instructor in the final training course of the Panamanian personnel, and,

- He revised, edited, and approved the present study.

While in Panama, the engineer César Pérez was in charge of the working group and represented the Tropical Science Center before RENARE.

- He oriented, organized, and supervised the field work, except that of the Caldera river watershed.

- He gave logistic expertise to the group and administrated the work in Panama, as well as being in charge of driving the vehicle assigned to this consultancy.

- In the field, he revised the information found in the CATAPAN study with the collaboration of the RENARE soils specialists, Ings. Víctor Ponce and Efraín Tapia.

- He designed, organized, and directed the vegetation and soil studies of the plots which were established for the purpose of characterizing some of the natural ecosystems in the Panama Canal watershed.

- He was in charge of field training the Panamanian counterpart personnel.

- He organized the final training course for the Panamanian personnel and participated, along with Dr. Tosi, as the instructor for the course.

- He developed the work plans and presented the advance reports of the completed study, and drafted the final report in Spanish.

The engineers Rafael Bolaños, León González, and Vicente Watson, along with Ing. Pérez, made up the crew of consultants for the field work during the two months of Pérez's first stay in Panama.

- They processed the climatological data provided by RENARE.

- They made the life zone maps of the three watersheds and their corresponding land use capability maps, through the interpretation of the CATAPAN data in the Tropical Science Center office in San Jose, under the direction of Dr. Tosi.

- They identified many of the tree species in the three watersheds in collaboration with the RENARE dendrologist, Lic. Aristides Martínez, and gathered some material for the herbarium and for subsequent identification.

- They wrote a work document as a basis for the final report.

Homologous personnel from RENARE

The homologous, or counterpart, personnel from RENARE was formed by the engineers Víctor Ponce and Efraín Tapia, specialists in soil identification from the Departament of Soils and Waters, Lic. Aristides Martínez, biologist specialized in dendrology from the Departament of Forestry, and Ing. Miriam Rivera, agricultura engineer from the Wildlife Section of RENARE's Departament of National Parks. The soils engineer, Víctor Ponce, acted as coordinator for the group.

The following individuals participated in the inventory of vegetation: the foresters Rodolfo Jaen, Juan de Dios Castillo, and Joaquín Díaz, all specialists in forest inventory in RENARE's Department of Forestry; the forester Matilde Barrios from the Watershed Management Project; the assistants Nicanor León and Alcides Ruiz, also RENARE employees, and Mr. Alvaro González, forest ranger of the Smithsonian Tropical Research Institute (STRI) in Barro Colorado. Lic. Aristides Martínez, mentioned above, acted as dendrologist.

Valuable collaboration on this report was given by RENARE personnel, Dr. Raisa Ruiz, Head of the Departament of Agronometeorology; Mr. Carlos Villareal, climatology technician from the same departament; Mr. David

Ríos, Head of the Department of Cartography; and Ing. Carlos Melgarejo, Head of the Department of Forestry. These three departments, along with the Departament of Waters and Soils, were the most related to this study.

Lic. Emma de Zamora, Head of the Department of Waters and Soils, participated in the organization and coordination of the Workshop Course on Methodology Used for the Ecological Study on the watersheds of the Panama Canal and the La Villa and Caldera Rivers.

Throughout most of the Work Project in Panama, Ing. Irving Díaz acted as General Director of RENARE, and Lic. Darío Tovar acted as Subdirector. Ing. Omar Peña acted as Coordinator of the Watershed Management Project.

Ms. Iraida Martínez, the secretary from the Watershed Management Project, acted as secretary for the group.

Distribution of the Consultants' Time and Chronology of Activities

The group of ecological consultants joined the project team during the week of April 12, 1982. On this date, Dr. Tosi arrived in Panama, on the 13th, Ing. César Pérez, and on the 14th, the engineers Rafael Bolaños, León González, and Vicente Watson.

Dr. Tosi had been in Panama earlier, on a matter related to the consultancy. On this occassion, he stayed a week and the rest of the personnel stayed until June 5, at which date the engineers, Bolaños, González and Watson returned to San Jose, Costa Rica. On June 6, Ing. Pérez travelled to San José, and re mained there for a week to attend to some administrative matters in the Tropical Science Center related to this consultancy, and to discuss with Dr. Tosi the work done in Panama and the work to be undertaken in July and August. On June 10th, Ing. Pérez returned to Medellín, Colombia, returning to Panama on July 2nd to continue with the consultancy until the end of August.

During the first week in Panama, necessary administrative arrangements were made. A meeting was held with Ing. Irving Díaz, Director of RENARE, to determine the scope of the work and the facilities and support services that RENARE would provide in the course of the project. At that meeting, the Director appointed the Panamanian counterpart personnel to the consultants in ecology. These counterparts were formally assigned to the project on April 20, 1982, in memorandum DIR-82-059 from the Administration. However, for various reasons, the originally assigned team of counterpart personnel was not incorporated into this project until May 3rd. Only Ing. Efraín Tapia participated from the beginning in the field work, accompanying the group from the beginning in the field work, accompanying the group under verbal orders of Ing. Díaz before the official memorandum stating his appointment came out.

During the first week, also, transactions were made with the Ministry of Foreign Relations for permission for the consultants to stay in the country more than 30 days, since all travelled to Panama on tourist visas. Ing. Pérez and Ing. Watson als needed to obtain a license to conduct motor vehicles from the National Headquaters for Land Transit of the National Guard.

Other administrative transactions related to the consultancy undertaken in that week were an accident insurance policy, a bank account in the name of the Tropical Science Center to cover daily operating costs of the consultancy, and a search for lodging for all the personnel. During this week, also, the heads of the RENARE Departament related to the ecological study were visited, informed of the work that was to be undertaken, and their support for it sought.

In the first and second weeks in Panama, several meetings were held with the other Project consultants, Dr. C. Buford Briscoe, in Agroforestry Systems, Dr. Waldemar Albertain, in Tropical Forestry, and Ing. Edward Finegan in Watersheds, as well as the counterpart personnel, Ing. Lovelia

de Castrejón and Ing. Vielka Garibaldi, to coordinate the consultancy work with other work in the Project.

During the following two weeks a general survey of the Panama Canal watershed was made. The RENARE are administrative areas were visited, recept Area 3, which was inaccessible because of difficulties in water transport. In each administrative area, projects underway were visited and the head of the area and auxiliary personnel were contacted to inform them of the objectives of the ecological study and to seek information useful to it. Visits were initiated to most remote sites first, in order to take advantage of the still-passable roads, since they rainy season was just starting.

During these first weeks, climatological information necessary to work in the Panama Canal watershed was obtained. Part of the information provided was processed, part of if had to be processed to calculate or verify the long term annual rainfall average as well as the annual average temperature at each different station. Based on the temperature data, corresponding biotemperatures were calculated.

During the first weeks it was necessary to buy the national topographic map sheets at 1:50,000 from the National Geographic Institute Tommy Guardia. These, along with other cartography material necessary for the work, was requested from the Cartographic Department of RENARE, through administrative channels set upo for the Project. However, due to RENARE's difficulty in obtaining the material, it was finally bought directly with Tropical Science Center funds.

The rainfall and temperature averages for each station were recorded on the topographic maps of 1:50,000, according to the official station coordinates. The exact site of each station was subsequently verified in the field and revised where necessary, as in those instances where the coordinates were incorrect.

During the first reconnaissance survey, life zone delimitations were made, as well as their transitions, and observations were made on plant life, soils, and land use.

In the weeks between the 3rd and the 10th of May, the entire consultancy and counterpart personnel actively participated in identifying and delimiting the life zones of the Panama Canal watershed, as well as in the revision of the CATAPAN map in the field.

Prior to the field work, the objectives and scope of the study, as well as the bases of Holdridge's life zones classifications system and Tosi's major land use capability system were explained to all conterparts participating. With the engineers Ponce and Tapia, we tried to determine the way to utilize the CATAPAN soils information in application of Tosi's system to classify land use capability.

The field work constituted a practical training experience in Holdridge's life zone ecological classification system for the RENARE counterpart personnel. Tosi's land use classifications proved to be interesting and novel for the RENARE soils specialists. They concluded that this system could be used as a basis for large-scale intervention in land use planning throughout Panama.

When transport conditions permitted, two teams were formed to cover the greatest area in the least time. However, this was rarely possible. The lack of a second vehicle for field work most of the time was one of the most serious inconveniences. On rare occassions we were able to use Ing. Efraín Tapia's personal RENARE vehicle, but for personal reasons on the part of Ing. Tapia, this was not normally possible.

Generally, team members were distributed in one group for the identification and delimitation of life zones and for the study of the natural vegetation, and in another group for soils and land use studies,

but there was some interchanging of personnel between groups so that soils specialists could accompany the group that delimited life zones.

On May 6, the team visited Barro Colorado Island. During the visit to the island, Dr. Donald Windsor, head of the Environmental Studies Project of the Smithsonian Tropical Research Institute (STRI), very cordially attended the ecological group. In his project, a micro-watershed covered with primary natural vegetation had been established in which a number of parameters of the environment have been measured with automatic high-precision instruments. The information is recorded in order to be easily transcribed in a computer program.

During the visit, a good deal of the island was covered, on permanent paths, and the magnificent primary natural forest was enjoyed and admired. This forest is becoming extinct worldwide and this island may be one of the few places where it might reamain inviolate for future generations. The Administration of the Smithsonian Institute attended the ecology team in a most cordial manner during their stay on the island.

During the week of May 10, the consultants began processing the Río La Villa watershed climatological data and premapping the life zones and their transitions. Some of the RENARE counterparts participated in this work to acquire practical experience in the technology.

On May 17, the entire team traveled to Los Santos to conduct the ecological study of the Río La Villa watershed. The team consisted of the ecology consultant group and the homologous, or counterpart, RENARE group, some in a vehicle assigned to the ecology study and some in Ing. Efraín Tapia's vehicle.

Before initiating the field work, the group met with Ing. Efraín Lao, head of the Río La Villa Watershed Management Project, to inform him of the objectives of the study and to coordinate the work. The group received extensive collaboration from Ing. Lao in the perfomance of their

work. Ing. José Domingo Rodríguez and Ing. Antonio Samaniego of his office were assigned as participating personnel and were taught the goals and methodology of the work. Ing. Rodríguez and Ing. Samaniego participated in part of the field work. The direct participation of technical personnel in the watershed study was one of the RENARE Director's requirements.

The head of the Río La Villa Project also assigned a vehicle for use in the field work, for at least a good part of the time insofar as fuel was available. In this way, the greater part of the time, it was possible to organize three work teams.

From the 10th to the 27th of May, almost the entire Río la Villa Watershed, with the exception of a few inaccessible areas, was covered. Life zones were identified and delimited and a field revision was made of almost all soil units included in the corresponding CATAPAN map, with comparison of data on the map and new data collected in the field. Wherever pertinent, the CATAPAN map was corrected.

Natural vegetation was also observed and some samples were taken in the few areas still covered by degraded forest vegetation. It was not possible to visit areas with undisturbed primary vegetation. Most of these did not actually fall within the limits of the watershed.

Although normally the rainy season starts a little later in this part of Panama, during the study group's visit there were heavy rains in the high places in the watershed, especially in the last days of their visit, which damaged the roads and made access to certain areas and taking plant samples difficult.

The work was very intensive and continuous, even on Saturdays and Sundays. During the stay in La Villa de Los Santos it was possible to go to Santiago for a day to obtain needed cartography from Bureau of Agrarian Reform of MIDA. The engineers Pérez, Ponce and Tapia, were in

charge of the choice and purchase of this material. The purchase was made with Tropical Science Center funds.

On the 28th of May, the group returned to Panama, passing again through Santiago to acquire other missing maps of the La Villa and Caldera watersheds.

During the first week of June, some complementary trips were taken to the Panama Canal watershed in order to fill in missing information on the life zone map. On this ocassion, we had counted on the use of a helicopter, as agreed with the Coordinator of the Watershed Management project, Ing. Omar Peña, to complete the field work, but this was not possible since RENARE does not participate in the National Guard's vigilance flights due to RENARE's lack of funds to contribute to flight costs.

During this week, a trip was made to San Juan de Pequeñí, where it had not been possible to go earlier due to the low water levels of the Río Pequeñí. Only part of the team made this trip due to limited space in the boat, although in the end the group had to walk anyway since the RENARE craft was damaged.

During the first week of June, the climatological data on the Río Caldera watershed was obtained and processed. Dr. Tosi had planned to arrive at this watershed directly from San José, Costa Rica, during the first or second week of June, in a Tropical Science vehicle, in order to conclude the work of the ecological study. A washout of the bridge over the Río Chiriquí prevented the team in Panama from joining hin there and the visit was postponed.

Due to difficulties of space in the Project office, as well as to lack of transportation for the whole group on some complementary trips in the Panama Canal watershed, Dr. Tosi decided to transfer the group to San José, at the end of the first week in June.

Before coming to Costa Rica, the group of ecology consultants presented a verbal report of the work done to Lic. Darío Tovar, National Subdirector of RENARE in charge at this time of the Administration. The meeting was attended by Dr. C. Buford Briscoe and Mr. Edward Finegan, Watershed Management Project (WMP) consultants, Ing. Omar Peña, Coordinator for WMP for RENARE; the RENARE counterpart personnel for WMP: Ing. Vielka Garibaldi, Ing. Lovelia de Castrejón, Ing. Víctor Ponce, and Ing. Efraín Tapia, and Lic. Aristides Martínez as well as Dr. Raisa Ruiz, Head of the Agrometeorology Department, Ing. Carlos Melgarejo, Head of the Forestry Service Department, and Lic. Gerardo Cáceres, Head of the Waters and Soils Department.

From June 15 to July 7, Ing. Bolaños, Ing. González, and Ing. Watson finished the life zone maps of the three watersheds and made the major land use capability maps in the Tropical Science Center offices, in San José, Costa Rica, under Dr. Tosi's supervision.

On July 8, Dr. Tosi and the engineers Bolaños, González, and Watson traveled by land in a Tropical Science Center vehicle, from San José to Boquete, Chiriquí, in the Río Caldera watershed. After staying in this watershed until July 10 to finish the field work related to the consultancy they returned the same day to San José.

Ing. César Pérez returned to Panama from Medellín, Colombia, as mentioned above, on July 2.

In the first days of July, and advance report was written on the work done from April 12 to July 12, 1982, and a work plan was presented for the months of July and August of the same year. This work plan was made after a meeting with Lic. Darío Tovar, Subdirector of RENARE and acting Director during this period.

Present at the meeting were: Ing. Víctor Ponce, RENARE counterpart personnel Coordinator for this consultancy. The aforementioned work plan was submitted for consideration and approval by the RENARE administration

and by Dr. C. Buford Briscoe, Project Consultant. The proposed work plan was also discussed with the consultant Mr. Edward Finegan, as well as with his counterpart, Ing. Vielka Garibaldi.

In the week from July 5 to 9, Ing. César Pérez wrote a document on the vegetation studies with the intention of using it in the identification of several of the more outstanding natural ecosystems in the Panama Canal watershed. Also made was a program for the completion of these studies which was discussed with the personnel of forest inventories of RENARE's Forestry Service Department, in particular, with the dasonomists Rodolfo Jaen, Juan de Dios Castillo, and Joaquín Díaz.

During the same week, from July 12th to 16th, and during the following two weeks, several days were dedicated to the localization of the plant sample parcels in Soberanía Park, Cerro Azul, and Barro Colorado. On July 19th there was a meeting with Dr. Gilberto Ocaña, Superintendent of the Smithsonian Tropical Research Institute (STRI) in Barro Colorado, to define some research to be carried out by RENARE in the Gigantito Península, as an experimental forestry area. This peninsula is part of the Natural Monument of Barro Colorado and is being utilized only as a protective belt for the island, which shelters the best known biological research center in the tropics.

The Agricultural Research Institute of Panama (IDIAP) and RENARE are the organizations directly responsible for this research. They will have the collaborations of STRI and the Agricultural Reseach and Education Center (CATIE) of Turrialba, Costa Rica. According to a suggestion from Ing. Irving Días, General Director of RENARE, some of the vegetation studies to be undertaken by the consultants for identification and characterization of the typical natural ecosystems of the Panama Canal watershed should be made in the aforementioned study area, as part of the research project previously proposed for the characterization of the area for forestry experimentation.

In addition to Dr. Gilberto Ocaña, from STRI, and Ing. César Pérez, for the Ecology Consultancy of the Watershed Management Project, the following people attended the meeting: Dr. Raisa Ruiz, Head of the Agrometeorology Dept. and coordinator of RENARE research, and the engineers César Isaza, Víctor Ponce, and Efraín Tapia, of RENARE's Department of Waters and Soils, and Ing. Carlos Malgarejo, Head of RENARE's Forestry Dept.

At this meeting it was agreed to conduct the vegetation and soil studies according to the proposed plan for this consultancy by the personnel specialized in forest inventories and in soil survey of RENARE's Forestry Department and Waters and Soils Department.

The STRI offered lodging and food in their facilities at Barro Colorado Island as w ell as transportation in Lake Gatún, the guiding personnel for reconnaisance of the area, as well as the permanent collaboration, during the vegetation studies in the entire watershed, of its forest ranger, Alvaro González, Moreover, STRI offered to provide a special helicopter flight, through the U.S. Air Force quartered in the Panama Canal area, to fly over the area of study, with possible extention of the flight to other points of interest in Parque Soberanía.

This helicopter flight took place on August 13 and the following people participated: Ing. Víctor Ponce, Ing. Efraín Tapia, Lic. Aristides Martínez, and the dasonomist Juan de Dios Castillo, all RENARE officials, as well as the ranger from STRI, Mr. Alvaro González, and Ing. César Férez of the ecological consultancy.

During the week of July 12-16, the necessary team was enlisted to complete the vegetation inventory. This team was provided by Ing. Elmo Montenegro, Director of the FAO Forestry Project at RENARE.

It was necessary for this consultancy to make a special effort to get RENARE to speed up its administrative transactions in order to provide

traveling expenses for its personnel who participated in these vegetation and soils ecosystem studies.

The studies were made in parcels located in Parque Soberanía, Cerro Azul, and Peña Blanca, an area neighboring the Natural Monument of Barro Colorado, and not in the Gigantito Península, as previously mentioned. Apparently it was agreed to undertake the studies in the former rather than the later area. Peña Blanca is also located in the Barro Colorado protection belt.

For the work in Cerro Azul, it was necessary to stay the night in a site neighboring the study area. For the work in Peña Blanca it was necessary to stay the night in the camp or in installations of Barro Colorado Island.

The vegetation studies were undertaken, as was mentioned, by the personnel of forest inventories of RENARE's Forestry Department with the help of other personnel. Layout of the plots and vegetation measurements, was done by the foresters Rodolfo Jaen, Joaquín Díaz, and Juan de Dios Castillo. Field notes were taken by Matilde Barrios, and tree identifications were made by Lic. Aristides Martínez. The helpers Mr. Nicanor de León and Alcides Ruiz collaborated in the field work. Mr. Alvaro González of STRI's vigilance corps also collaborated in the measurements. In some cases, as in Peña Blanca, we counted on the assistance of the field workers to open the trail in the inventory parcels and to make some of the soils pits.

Ing. Víctor Ponce and Ing. Efraín Tapia made the soils descriptions from pits located near each sample plot. Dr. Ruiz collaborated on the studies in Peña Blanca.

Mr. Pedro Acosta, Head of the STRI Vigilance Corps accompanied Ing. Pérez, Ing. Ponce, and Ing. Tapia in a reconnaisance of the Peña Blanca área for the selection of sample plot sites and collaborated in coordinating

water transportation to the work site and the acquisition of auxiliary personnel in the field.

The Ecological Consultancy's work consisted of the adoption and design of the sampling system and of its theoretical and practical explanation, as well as the selection of sites for the localization of the sample plots.

The vegetation inventory was conducted from July 19 to August 6. This was followed by information processing by the forest inventory personnel at RENARE's Forestry Department, as well as the completion of the missing names of some tree species.

Facilities and limitations in the completion of the study

RENARE and the Watershed Management Project provided some of the facilities for the completion of this study. Despite the desire of RENARE officials that the project proceed in the best possible way and with the least mishaps, there were no lack of difficulties that undermined its efficiency or that required appeal to authorities other than those assigned by RENARE in order to overcome them.

Most of the difficulties were of an administrative nature. Since the time allowed for field work was brief, the administrative transactions should have been made as swiftly as possible in order to attend to the four ecological consultants in such a short time period. Despite the RENARE administrative officials continual concern in speeding up those transactions, the administrative structure of RENARE as well as lack of funds, or the delay in turning them into each, often did not meet expectations.

During the ecological consultant's stay in Panama, we were able to count solely on the use of one camper-type vehicle, CJ-7, 1878 license

plates, from RENARE's Watershed Management Project. According to our contract, RENARE's Purchase Section was to regularly provided fuel which it did for the most part rapidly and efficiently. However, on four occasions, it was necessary to buy fuel with personal funds, not reimbursed by RENARE.

In general, fuel provision for the RENARE vehicles is one of the most critical or neuralgic points in the institution's functioning. Fuel is bought in advance, generally on a monthly basis, from a gas station, and the Purchase Section distributes it to the official vehicles through orders, according to their requirements, trying to economize or rationalize use. Normally, however, paperwork for the next purchase is not completed before the existing supply is used up.

When it is essential to buy fuel directly at a gas station, or when it must be purchased during a trip, the procedures to obtain refunding of the money from RENARE are so slow that it is preferable to avoid them and resign oneself instead to losing the money.

In spite of the many kilometers covered and the severe abuse to which the vehicle assigned to this study underwent on bad roads, indicating an urgent need to change the oil and the oil filter, this was only partly possible after a great effort. The oil was changed but not the filter. The limited availability and cost of filters on the Panamanian market, the uncommon characteristics of the vehicle's Diesel motor, and RENARE's trouble some administrative procedures did not allow us to make the change necessary to the good maintenance of the vehicle.

All the other vehicles of the Project were in the same condition, most of them with greater mileage and with an equal or greater work loads. The purpose of mentioning this is simply to exemplify the difficulties that RENARE field workers face and the consequent diminishing of RENARE's efficiency by administrative hindrances, which should be reviewed and corrected if a greater work perfomance is desired.

The delay caused by cumbersome administrative procedures for often simple work tasks was partly due to the lack of available funds due to budget cuts, and partly to the great number of cases which must pass from bottom to top and return.

The constant and direct efforts of the consultants, supported by the friendship and good will of the administrative officials at times tended to help speed up these procedures a little, but often these efforts represented a waste of the consultant's professional time.

Due to the size of the consultancy team, as well as that of the counterpart team, it was indispensable to have another vehicle for the fieldwork, but this was not normally possible. Several suggestions were made to resolve this problem but none was followed up. For part of the work, Ing. Efraín Tapia's vehicle was used, but due mainly to MIDA regulations on the supplying of fuel, there were many hindrances and restrictions on its use. The fact that it was a gasoline vehicle made its use of fuel too great and it was inefficient for the roads that had to be traveled. The lack of another vehicle that could have been used permanently in the fieldwork constituted the major obstacle to conducting the fieldwork in the best possible and most efficient way.

Another factor influencing efficiency of the work and limiting access to some of the areas in Panama Canal and Río La Villa watersheds was the rainy season, which impeded or considerably limited access on roads not transitable during this season.

A good part of the Panama Canal watershed, to the East as well as to the West, is in mountainous areas inaccessibley by land anyway, indicating the need for a helicopter. Yet, for reasons already mentioned, it was not possible to obtain this assistance, previously available to RENARE at low cost.

During the work in Río La Villa Watershed, Ing. Tapia's vehicle was used a good deal, and fuel was obtained for it in the regional offices of

of MIDA in Chitré. One of the vehicles of the Río La Villa Watershed Management Project was also partially used, until fuel ran out.

In the second part of the consultancy in Panama, a pick-up was made available by the Forestry Department for the vegetation studies. This vehicle, in poor condition and operating on gasoline, which made it very inefficient, was also open in back. Nevertheless, it was satisfactory in view of the relatively brevity of the work. Fuel difficulties were numerous and some of the selected sampling sites could not be visited.

For the plant inventory work in Peña Blanca we counted on transportation by water on the vigilance and personnel transport craft belonging to STRI in Barro Colorado. STRI provided all the facilities for lodging and food of personnel doing vegetation studies, as well as a helicopter flight over the study area. STRI collaboration was very extensive valuable, and efficient.

RENARE's technical departments in Agrometeorology, Cartography and Forest Service collaborated extensively in the fieldwork of this study, within the limitations of their resources.

Climatological data for the three watersheds was supplied, as mentioned earlier, by the Agrometeorology Department, either from their own records or those of other organisms as for instance, IHRE (Institute of Hydrology and Electric Resources) which has the greatest number of stations installed in the country, and the Canal Comission, which has a good network of very long-term stations.

In general the climatological data for the study areas is limited, much of it of being for short periods of register. For some, the reliability of the record is doubtful.

However, for the delimitation of the life zones on a map at a scale of 1:50,000, this data is satisfactory for most of the areas, inasmuch

as Holdridge's classification system allows one to infer life zones from observations of vegetation and other elements of the natural and cultural landscape.

For a more precise delimitation of the life zone transitions, it would be necessary to have more precise meteorological information and a greater geographical density of weather stations.

Temperature records are very limited in number and consequently the mean temperatures of most of the medium and high altitude places in the watersheds had perforce to be estimated on the basis of an approximate thermal gradient.

Due to the insufficiency of climatic data, to the inaccessibility of some areas, and to certain deficiencies in the available base maps, the life zone boundary locations are approximate, not withstanding the opportunity that Holdridge's system offers for their extrapolation from vegetation, and despite the relationship existing between the location and distribution of the life zones with the physiographic conditions, direction of winds, etc..

Part of the climatological material supplied was published in pamphlets or in special formats. Nonetheless, for the purpose of this study, it was necessary to revise the material and in some cases to reprocess it. Another part of the material had to be organized and processed from the beginning.

The Cartography Department was an organism that provided important support in this work. This department has a good collection of original drafts of the maps of the three watersheds and equpment and specialized personnel for their reproduction and adjustment. In spite of this, due to the volumen of work they have and to the limitations on funds to buy work elements, this department was unable to provide all the necessary material for this study. The available cartography, however, was supplied

in time and with efficiency. In spite of that, in some cases there were limitations due to a lack of paper to make heliographic copies and the Tropical Science Center had to buy it. In like manner, it was difficult to get some maps colored because of insufficient personnel or of colored pencils, which the TSC had to buy and its own consultants use. This department could not buy the maps it did not already have because RENARE funds were not available or the transactions for their adquisition were too slow. When this consultancy's work in Panama was finished, the RENARE check to buy the maps approved for the work had not even been issued.

Therefore, it was necessary to purchase, at the Tommy Guardia National Geographic Institue, all the sheets of the topographic maps on a scale of 1:50,000 and printed in color by the Institute for the watersheds.

In the same way it was necessary to buy, at the National Headquarters of Agrarian Reform of the MIDA in Santiago, heliographic copies of the CATAPAN soils maps on a scale of 1:20,000, and reductions on a scale of 1:50,000, of the Río La Villa and Río Caldera watersheds. These copies were reproduced from the original drafts at Headquarters.

In like manner, heliographic copies of the geological and geormophological maps, the land use maps, the slope maps, the life zone maps, and administrative area maps of the Río La Villa watershed, in the form of reproductions made from the original transparencies at the Río La Villa Project headquaters in Los Santos, had to be purchased by the consultants directly. All these purchase were made with Tropical Science Center funds.

RENARE's Dept. of Cartography made available copies of CATAPAN's soils map of the Panama Canal watershed on a scale of 1:100,000 as well as maps of the administrative areas, a basic map, and other maps of that watershed (on a scale of 1:100,000), plus a set of eight maps of different themes, of the Río Caldera watershed, and basic maps of all three watersheds, which were used as a basis for drawing definitive life zone maps and major land use capability maps. The Panama Canal map was on a scale

of 1:100,000; the other two on a scale of 1:50,000.

The Forestry Department cooperated on the vegetation studies, through the forest inventory personnel and coordinated and obtained all the additional RENARE personnel for this purpose.

The Department of Communication and Community Relations and the Dept. of Waters and Soils collaborated through their chiefs in the organization and development of the terminal Workshop-Course that was offered by this consultancy.

For the office work we counted on space in the large room assigned to the FAO/RENARE Project, in which the Director of that Project worked, as well as his secretary, the three permanent consultants of the Watershed Management Project, two officials from RENARE acting as Panamanian counterparts of two of the consultants, and one secretary from the same Project. Also working in this office was an official of the Fuelwood and Charcoal Project in Panama sponsored by CATIE in Turrialba, Costa Rica. With the arrival of the four ecology consultants and one counterpart person in this consultancy, which had offices assigned at the distant Parque Soberanía (other counterpart personnel had their desks or work places in other RENARE offices), the room proved to be even more inadequate when all the personnel was there together. There was only one available desk for ecology and when the consultants did not go into the field, it was impossible to work in this office unless other Project personnel did not happen to arrive due to being in the field or in other activities of their work.

At first, the Director of RENARE designated as office space an office adjoining the temporary dormitories in the headquaters of Parque Soberanía, in Summit, where the four Ecology consultants' desk were located. Nonetheless, the lack of ventilation in the office and the difficulties in communication between Summit and RENARE's offices, where it was necessary to conduct many activities, did not allow an efficient use of those facilities. Fortunatelly, fieldwork was done almost every day. When it was

nécessary to do some office work, it had to be done in the consultants' residences.

This difficulty, aggravated by the transportation limitations, forced Dr. Tosi to order the transfer of the personnel to San José, Costa Rica, some days before the anticipated return, as mentioned earlier.

Much of the office work, therefore, was done in San José by the three junior consultants. In the second part of the Ecology Consultancy when there was only one consultant, there was no longer an office problem.

Another great limitation for certain office tasks was the secretarial service. The one Project secretary had to attend to the three permanent consultants and two counterparts assigned to them by RENARE, there being little time left over for the ecology consultants. Despite her ability good will, and efforts to attend to all the Project personnel, it was not possible to type all documents written by this consultancy, and some reports and programs were greatly delayed.

The final draft of the Advance Work Report written by the Consultancy in Ecology on April 12, June 12, 1982 was typed by the FAO/RENARE Project Secretary: Ms. Giselinde González, because the Project Secretary did not have time, this thanks to the valuable collaboration that the Project Director, Ing. Elmo Montenegro, always gave the consultancy, and thanks to Ms. González's courtesy. The FAO Project Director also furnished the inventory team needed for the vegetation studies.

Xerox copies of the printed material produced or needed for the consultancy for purposes of the job, on RENARE's Xerox machine, were limited for lack of paper or time on the part of the girl in charge of running the machine. A good deal of this material had to be reproduced directly with Tropical Science Center funds, or that of the consultants. In the final part of the consultancy, we had some valuable help in the form of a donation of Xerox paper from the FAO Project.

The ecology consultant received ample assistance and support from Lic. Aristides Martínez, a RENARE dendrologist, assigned to the Seed Program of the Forestry Department. His knowledge of Panamanian arboreal vegetation, his responsibility in his work, and his gay spirit which made his company on the job very pleasant, even in difficult moments, was one of the greatest aids in conducting the fieldwork in this consultancy. Without Lic. Martínez's help, it would not have been possible to achieve the level of plant identification that was reached.

The soils identification and classification specialists, Ing. Víctor Ponce and Ing. Efraín Tapia, also helped the consultancy in valuable ways, such as in the localization and purchase of the maps, in the field revision of the CATAPAN maps, and in the description of soil profiles for each -- vegetation sample plot. Ing. Ponce collaborated with great good will in the general coordination of the relations between the consultancy and RENARE.

Without the collaboration of the inventory personnel of the Forestry Dept. of RENARE, it would not have been possible to conclude the vegetation studies that were undertaken.

In spite of the limitations in their budget ande the many problems - engendered by their administrative system, the entire RENARE staff involved in this consultancy cooperated to the outmost. This spirit of collaboration bypassed the difficulties and made the consultants'stay in Panama very - pleasant.

CHAPTER II

REVISION OF LITERATURE AND PREVIOUS STUDIES

II. REVISION OF LITERATURE AND PREVIOUS STUDIES

There are some antecedents to the present study. Some are of an ecological or environmental nature or relate to renewable natural resources and their availability, conservation, and use. Others relate to land use or to some of the bases for the determination of potential land use. Also, for each watershed, there are specific management projects. It is not our purpose here to make a bibliographical review of all of them, but rather to simply mention the projects and studies that preceded this one, above all those which were used in this study as sources of information.

Ecological Studies

In early 1955, Holdridge and Budowski (1956), conducted a reconnaissance of Panama and in a preliminary way delinated the life zones in the country, as well as their relationship to agriculture and forestry. The life zones were delimited on a map at a scale of 1:1,000,000. In general, in this work, some life zones present in the country were not included, and some that were delimited had to be corr ected subsequently by Tosi (1971) due to later refinements and changes in Holdridge's system (1947, 1953, 1967, 1978). The work was done at the request of the Panamanian government by the then Technical Cooperation Program of the OAS, under the Inter-american Institute of Agricultural Sciences of Costa Rica.

Subsequently, by way of a consultancy of Dr. Tosi for the UNDP/FAO Project with the Panamanian Government, denominated "Forest Inventories and Demonstrations" (FAO/SF/PAN 6), a revised and more detailed life zone map on a scale of 1:500,000 was produced and published along with a corresponding report (Tosi, 1971).

Dr. Tosi's consulting work was carried out from July 10 to Dec. 15

of 1967 and had as its purposes the preparation of an updated map of life zones in Panama, with information on the associations and stages of succession, to make a preliminary stratification of the forest areas required by the programs of forestry research, plantations, and forest inventories of the aforementioned project.

In the production of this map, the new refinements introducted in - Holdridge's system (1967, 1978) were applied, primarily relating to the determination of biotemperature in the Tropical and Subtropical lowlands and to the life zone transitions. In the report, as well as giving a detailed explanation of the basic aspects of Holdridge's system and of the methodology used, each association is described, for which its distribution and climatic limits, the listing or mention of characteristic tree species, predominant soils, actual land use, and recommendations for potential land use are established.

In some of the more important associations, seasonal patterns of moisture distribution, crop potential and limitations, different soil types are discussed and some species are recommended for forest plantation trials.

This work of Tosi's (1971) has been the basis for the classification of the Panamanian environment and a fundamental reference for all subsequent studies related to environment; as in the present study in which life zones are mapped at larger scale with only small changes and additions corresponding to the more detailed and specific nature of the work.

In Tosi's original study (1971), calculations are presented for the hydric balance using a method proposed by the author for a number of Panamanian weather stations, as well as a brief description of the procedure for that calculation. The study also contains some considerations on the climatology of Panama.

Soils and Land Use Capability

Another document that was used as a basis for the elaboration of the major land use capability maps in the three watershedes studies was one presented by Tosi for the classification of rural land in Colombia in 1972 and published by the Tropical Science Center in 1981.

By the way of this system, each unit of land can be classified in different uses, called "major" uses by Tosi, and their corresponding agro-technological management system, according to the limits established by the same author for 10 physiographical and edaphic factors, as they appear in codes he elaborated for each life zone in Colombia.

The five major land uses, or categories of use, in descending order from highest to lowest intensity of economic use are: clean-tilled crops (A), pastures (P), permanent crops (C), production forests (B), and protection (X).

The ten physiographical and edaphic factors are:

1. Slope (in percent and longitude: short slopes, under 50 m. and long slopes, greater than 50 m.)
2. Microrelief (in 4 classes)
3. Effective depth (in centimeters)
4. Texture (in 4 classes)
5. Stoniness and rockiness (in 5 classes)
6. Internal drainage (in 5 classes)
7. Inherent fertility (in 5 classes, determined according to laboratory analysis and a cumulative score referred to a fertility rating table of the Agustín Codazzi Geographic Institute of Colombia,

or by the pH, determined in field by colorimetric methods and by fertility estimates made by direct observation or on the basis of other information)

8. Extent of present erosion (in 5 classes)

9. Salinity (in 4 classes)

10. Risk of flooding or inundation (in 5 classes).

The categories of agrotechnological management systems ecountered or that could be developed in Colombia are:

Advanced, mechanized (M), Advanced, artisanal (A), Traditional (T), and Primitive (N).

Advanced, artisanal systems are not really present in Colombia as yet. They could be developed as a solution to land use problems in ecological situations that are more difficult than those appropriate for the Advanced, mechanized systems and as an "appropriate technology" solution to the general socioeconomic and ecological conditions in the country.

In Tosi's system (1971), it is considered that the appropriate land use category for an area with not lead to deterioration of the long-term or original productive capability of the soil resource. The classification also includes considerations of the external economic or social dangers that certain uses would induce.

Tosi's system therefore, is a conservationist system, based on conservation of the soil resource and on categories of use. It does not lead to the determination of specific crops, or classes or types of cattle or forest species for the classified land units. These would be chosen afterwards, based not only on soils and climatic conditions in each region, but also on economic and social considerations.

Among the basic criteria, the risk of soil erosion is taken into account, compared with the acceptable tolerance of soil erosion. To determine the maximum extent of tolerance of erosion according to the climatic and soil characteristics, the major use in relation to the technological management system that is used, the universal equation for the determination of soil loss by erosion is applied (Wischmeier and Smith, 1965).

A = R. K. L. S. C. P. in which:

A = Soil loss in (Tons/ha/year)
R = Rainfall erosion factor
K = Susceptibility of soil to erosion
L = Longitude of the slope in meters
S = Slope gradient in percent
C = Index of protective value of the vegetative cover
P = Index of protective value of the soil conservation methods used

If a maximum A of soil that could be lost is determined according to the soil that could be formed and the numerical values of R an K are known, the land uses can be determined, that is, the proper vegetation cover, according to the soil conservation methods used for each combination of slope gradient and length of slope. Tosi estimated the value of A for climatic association of each life zone based on soil formation rates given in the literature.

He also determined the R factor for each life zone, because a straight line relationship can be shown to exist. Factor R indicates the erosive force of rain. It is related to the cinetic energy of the rain when it fall to the ground (E) expressed in $kgm/m^2/mm$ multiplied by its intensity (I) expressed in mm/hour.

He related the K factor to 4 textural categories; this relation alone is not the best way to determine the K factor, since it is related to

a greater number of soil properties, but due to the lack of reseach in the tropical environment, as in Colombia, a simple relationship, though not precise, is the easiest way to give numerical value to factor K.

He related the vegetative cover with the 5 major land uses, and the conservation methods with the use or non-use of advanced agrotechnological management systems, these factors being considered for the climatic association of each life zone. For land used in clean-tilled crops, permanent crops, and pasture, in each life zone in Colombia, he estimated a numerical value and also estimated a certain percentage of decrease in that value when advanced agrotechnological management methods were used, whether mechanized or artesanal.

Other basic criteria used were: the degree of accelerated erosion present, the physical limits of terrain on operation of farm machinary, use of animal power, or use of human labor in cultivation and harvest, the special requirements of each agrotechnological management system in term of productivity for the different uses, based on the total of ecological factors and the technical feasibility of modifying one or more limiting factors as by engineering works, soil conservation methods, removal of stones, drainage, irrigation, liming, or fertilizing.

Tosi's system (1981) is a quantitative, objective, unambigous system, adequate for the ecological and socio-economical conditions not only of Colombia, but of other countries in Tropical America. It is presented as a valuable aid in the classification of potential land use in those countries and a better alternative to the agrological system of the Soils Conservation Service of the Department of Agriculture of the United States (1950), which has been used with or without modification in most of these countries.

Specific Studies

1. CATAPAN

To deduce the necessary data for the application of Tosi's system, the soil study by the rural Catastro of Lands, and Waters of Panama (CATAPAN, 1970) was used, this being the only source of information available, as explained in more detail under "Methodology Used" in the present report. This soil study was published in three volumes. Of these, the main source of information was chapter 6 of the first volume which deals with agricultural soils and site factors.

The soil classifications by CATAPAN employed the U.S. Dept. of Agriculture, Soil Taxonomy, at that time under development and called the "Seventh Approximation" (Soil Survey Staff, 1960, 1965).

Also consulted were the appendices which give the results of laboratory analysis by CATAPAN, in order to find information suitable for application to Tosi's keys according to the types of soils represented by the symbols that characterized the properties determined by CATAPAN for each soil unit in the three watersheds. The majority of the soil units in the CATAPAN maps of the three watershed, expressed by those symbols, were not found in those appendices, as it seems there was some information lost that was not included.

Other CATAPAN studies (1970) consulted were the maps that represented different geological, geomorphological, topographic, soils, and land use factors in the different watersheds, the majority of which are based on the CATAPAN study, some with certain modifications.

In the CATAPAN soils study (1970) the soil in the field and in the lab were differentiated in such a way that, according to the authors' purposes, in the final analysis all the soils in the project could be place in the categories of the Seventh Approximation, from soil order to soil series.

It was assumed that when the types of soil from Panama were studied in more detail, the application of the new classification used would not give rise to conflicting characteristics.

The differentiation was also designed in such a way that it would permit mapping the Panamanian soils in terms of taxonomic units that would have great significance in cartographic units that contained the primary differentiation used in the Seventh Approximation and that could be transferred subsequently to minor categories of the same classification except for the cases of the map generalization.

The legend on the CATAPAN soils maps presents a fractional code that includes, as described in more detail in the Methodology, in the numerator:

- epipedon (ócrito, úmbrico, mólico)
- endopedon (argílico, cámbico, óxico, and pan)
- drainage (in six classes)
- depth (in five classes) and
- texture (in eleven categories of textural families)

In the denominator the following appear in order:

- parent material (in 11 combinations of geological and lithological material, and generalized land forms, using this concept in partial form)
- slope in percentage gradient (six classes)
- degree of existing soil erosion (in two classes)
- stoniness (in three classes)
- land use capability (according to the eight agrological classes of the Agrological Classification System of the Soil Conservation Service of the U.S. Dept. of Agriculture)

The CATAPAN soils study (1970) is very generalized and does not include all the factors considered by Tosi in his keys for the classification of major land use capability. Nor does the general nature of the study allow for the separation of smaller areas included in larger areas of soil characteristics and different potential land uses. In the field, it was found precisely that, because of the scale, there are many important soils areas that do not seem to have been distinguished seperately while in inaccesible areas, often covered with arboreal vegetation, the same soils characteristics were portraved as extending over wide areas.

That study, however, was the sole source of soil data that could be consulted and applied to the determination of major rural land use capability in the three watersheds studied. This old study represents the only national soils survey and classification for Panama.

2. Río Caldera

Other important documents consulted were: the diagnostic for the Río Caldera watershed made especially for the watershed management project (MIDA-RENARE, 1980) and the Río La Villa Watershed Sub-Project, of the Watershed Management Project (MIDA-RENARE, 1981). It was not possible to consult the respective study for the Panama Canal watershed, as there were difficulties, including finding it in RENARE offices, and it was never possible even to examine it. The other projects were reviewed in their respective watershed sites and later XEROX copies were made of them for a more detailed examination.

The diagnostic of the Caldera River watershed (MIDA-RENARE, 1980) was carried out by 5 RENARE technicians representing different disciplines. It was headed by Lic. Jorge A. Mendieta, Director of the Río Caldera Watershed Management Project, and two employes of the French TEchnical Soils Conservation Mission in the Chiriquí Highlands, Dr. Remmy Oster, climatological geographer, and Ing. Vicente Ribier, agricultural engineer.

The said study also includes the generalities, antecedents, importance, justification, and objetives of the Río Caldera watershed management project, a physical description of the watershed, its biological resources, the socio-economic situation, land tenure, actual land use, and land use capability, as well as the legal situation for the management of the watershed and the management zones. Two apprendices and 13 maps on different themes are included, at a scale of 1:50,000.

In the physical description of the watershed, its geographical and political location, the geology, geormorphology, climatology, soils, and hydrology are outlined.

Under biological resources, the study considers the vegetation and, in relation to the vegetation, the life zones of the watershed, according to the ecological map of Panama (Tosi, 1971) amplified to a scale of 1:50,000. A general description is given of each life zone which includes climatic characteristics, limits and localization, soils and land use characteristics. A list of the principal existing arboreal species is also presented.

The list of plants is amplified by those presented in studies by Holdridge (1961), La Bastille (1973), and Díaz (1970). In the chapter on biological resources, some lists of wild animals in the watershed are presented, based on the work of Handley (1966), La Bastille (1973), and Charles Bennet, (without reference, cited by MIDA-RENARE, 1980), and considerations are made on the wildlife situation,habitats, and hunting. Also presented is a list of endangered species, as well as conclusions and recommendations as to biological resources.

Among the recommendations on biological resources, it is stated that more effort is needed to know them, for which an inventory should be made of these resources based on Holdridge's life zones, the limits of which should relate to the watershed more clearly than is shown in the maps that accompany the aforementioned diagnostic.

According to that diagnostic, the trees in the watershed's forests have been used primarily for lumber, and it is recommended that other uses be studied, such as medicinal, food, and ornamental uses, and that these possible alternatives in use also take into account the uses of the flora, the fauna, and the Guaymí indigenous community that lives in the zones neighboring the watershed. In the search for other uses for the wood of the forest species in the watershed, according to the diagnostic, the technological properties of the wood should be studied, as well as the silvical characteristics of the tree species as a guide to future forest management.

It is further recommended that the forest rangers be increased in number in order to better protect the forests, above all in the highlands over 1,800 m. where the main watersheds are located, these being subjected to strong pressure by farmers in search of land, bringing a destruction of forests that brings with it the destruction of the habitats of the forest fauna.

It is also recommended that the quality of Río Caldera's waters be studied to determine the effects of fertilizers and pesticides used in farming the watershed on its aquatic flora and fauna.

Under socio-economic situation, the survey covers several aspects of human settlement, demographic as well as educational and religious conditions of services and physical infrastructure, such as availability of electrical energy, potable water, and roads and, finally, basic considerations on production and marketing, with data on cooperatives, credit, agricultural products, cultivated areas, costs of production and commercialization, machinery and human labor used, and other agricultural inputs. This chapter offers abundant information on the socioeconomic aspects, essential to the management plans for the watershed, although presented in a disorganized manner.

The diagnostic used and actualized the CATAPAN study (1970) for the knowledge of land tenancy. It indicates that public land represents

14% of the surface of the watershed and that the vast majority (81%) of the properties and of the area they comprise have only rights of possession with 3% having registered title.

According to the data, small holdings predominate in the watershed, since 67% of the properties were less than 10 has. in extent, and only 9% were larger than 50 has. Among these, 4% were larger than 100 has., while 24% of the properties were between 19 and 50 has., and were located mainly in the middle part of the watershed. Large holdings, those greater than 100 has. in size, were located in the southern and northeastern parts of the watershed or in the lowlands (50-100 has. meters elevation). Small properties were located on the best soils, those derived from recent volcanic ash, and were planted in vegetables. Most of the vegetable farms were smaller than 1 ha.

The small farms represented only 7% of the total surface area of the watershed, which is 22,000 has., and the large (greater than 100 has.) represented 25% of that area. The medium ones, between 10 and 50 has. in size, represent 21% and those between 50 and 100 has., 14%. The remaining 33% of the area was included in public lands, national parks, and the like.

Actual land use, according to the Diagnostic, is related to the soils present in the watershed, that is, soils derived from recent or old volcanic ash or from basic igneous rocks are preferred for farming. Close to half the watershed area (47,4%) is still covered by primary forest or secondary vegetation of minor development; 15,7% by crops; 8% by permanent crops; 4,8% by vegetable crops; and 2,8% by variety of crops for domestic consumption.

The forests have been steadily destroyed, according to the Diagnostic, remaining only on the highest slopes in the northern, northeastern, and northwestern extremes of the watershed. Pastures, according to that information were distributed throughout the watershed, on the diverse types of soil, but mostly in the southern and western parts where the forest has

practically been eliminated. The area of pasture in part has been extended towards the highest, steepest lands, by way of the destruction of natural forest, causing severe environmental degradation.

Most of the pastures are composed of native species and have low productive capability, though according to the diagnostic there are programs for the introduction and improvement of pastures. In the Diagnostic, emphasis is placed on overgrazing and burning.

The vegetable crops, located on the best soils, extend to the northeast part of the watershed, according to the study cited earlier, but these have also extended to forest soils where some of the study plots are located, descending in small strips from Volcán Barú. Vegetable crops included potato, tomato, and various other vegetables, as well as small fields planted to flowers. The production of vegetables here has been very important for supplying Panama. Among the most prominent permanent crops in the watershed are coffee and, in a small extension, citrus; among those for domestic consumption are corn, sugar cane, and banana.

The farmers are very familiar with vegetable crops and they use mostly manual methods of cultivation, although in some cases they use oxen and, on the more level ground, tractors. Weeds are controlled with herbicides. In some cases, crops receive suplementary irrigation, by sprinkling with gravitational water.

However, as noted in the Diagnostic, soil conservation is not practiced and there has been a severe deterioration of the soils due to high rates of erosion and production of sediments. Therefore, it is recommended in the Diagnostic that strong measurements be taken to prevent erosion and to correct its effects where it has already taken place.

Farming with irrigation during the dry season or under cover, has proven to be profitable and is mentioned in the Diagnostic as systems that

should be practiced in order to protect and improve horticultural land.

In recent times, according to the Diagnostic, coffee growing, both with and without shade, has increased. Coffee groves have been established in areas previously covered by forest and high secondary vegetation. The technological level of this crop is generally low, except in the case of the large plantations.

According to the aforementioned Diagnostic, soil losses by erosion in properties of 40 m^2 on 35% slopes located in Boquete, at an elevation of 1,150 m. were between 55 and 182 Ton/ha/yr. in 1979. The lowest loss was in fields of cabbage, followed by beans, both crops planted on the contour and mounded. The greatest loss was in bare land followed by 79 Ton/ha/yr. in carrots planted on the contour, and then beans cultived up-and-down slopes. Pastures produced a loss of 35 Ton/ha/yr., but after the grass grew, the soil loss by erosion was minimal, being 0,05 Ton/ha/yr.. It appears that there was no grazing, though the Diagnostic does not mention this.

Coffee, probably grown without shade (though it is not specified), caused a loss of 77 Ton/ha/yr.. This was reduced to 1,4 Ton/ha/yr. after covering the soil with mulch. In covering bare soil with mulch, losses were reduced to 57 Ton/ha/yr..

The observations make evident the possibility of reducing losses in coffee groves and pastures to a minimum with good management, but nowhere is the effect of grazing mentioned. It is noted in the Diagnostic that in spite of the great force of the rains, when there is a good vegetation cover, like well managed forest, grass, or coffee, erosive effects are slight. On the other hand, in the fields grown to vegetable crops, the Diagnostic says that erosion is accelerated and the soil can disappear in just a few years. It also mentions that there are now fields in which the surface horizons have been totally eroded away, and fields that are no longer cultivated or which produce very little because of the past effects of erosion.

Observed in the field, signs of different kinds of erosion are evident in cultivated fields. Erosion is more evident where inappropriate types of agricultural machinery is used, such as rototillers in the El Salvador, Quiel, and Volcancito sites. The Diagnostic emphasizes the need to conserve soil in cultivated lands, where losses of 50-100 Ton/ha/yr. can not be tolerated; this would equal a sheet of soil 0,75 - 1,4 cm. depth.

It is further noted that in the lowlands of the watershed, in areas covered with grass, where soils are more clayey than in the highlands, mass movements predominate, like landslides, sheet flows, and bank collapse, plus compaction-terraces of cattle. In the highlands, where the soil is more permeable, landslides occur with less frequency, except in unusually rainy periods, as in 1970.

In the chapter on land use and erosion, the Diagnostic also mentions the problems of fires in the natural vegetation. These occur every year in the lowlands of the watershed, above all in the natural grasses, primarily due to farmers' carelessness when fields are burned prior to annual planting. In 1968, a fire of this nature spread into experimental plantations of trees species for reforestation, established in 1967 by FAO. If this area is considered as having the greatest quantity of potential land for reforestation, according to the Diagnostic, then it is of the greatest importance to protect the area from fires. In the highlands of the watershed, fires in the natural vegetation are minor or do not occur, except in several cases.

For the classification of land use capability, the Diagnostic used the methodology proposed by Sheng (1972) in Jamaica, designed for mountainous lands in the moist tropics. The Diagnostic mentions that this method concurs with most of the principles and assumptions that have been used in other classification systems of land use capability, among which are cited the most relevant for the Caldera watershed management project. According to the explanation in the Diagnostic, Sheng's classification

doesn't determine the capability of the soils for specific crops, but rather the major land use. The major land uses according to this system: arable land (C), prairie/meadow (P), forage trees and fruit trees (AF), and forest land (F).

The system is based on permanent limiting factors of a physical nature rather than on the chemical properties of the soils. Among the physical factors, the Diagnostic cites slope, erosion, and climate. In the table actually presented as a basis for the determination of major uses, however, only the combination of soil depth and the slope are given.

Soil depth is considered in three classes: deep soil (greater than 90 cms.), moderately deep (50-90 cms.), little depth (less than 50 cms.). The slope is divided into six classes: 0-12%, 24-36%, 36-48%, 48-60%, and greater than 60%. The cost of modifying the adverse factors do not affect the classification.

In accordance with this table, land may be used for cultivation given various combinations of depth and slope, depending on the soil conservation methods used; these appear in 4 categories, as sub-indices of Subcategory C, for arable land: (1) requiring few or no intensive conservation methods, such as windbreack in large fields, contour tillage, strip cropping, or wide terraces; (2) lands that require more careful conservation, such as drainage trenches or terraces. In this case, the conservation steps can be taken using machinery; (3) land which requires terraces, hilling, and contour trenches, constructions in which the possibilities for mechanization are very limited; (4) lands in which intensive conservation methods are needed and must be undertaken manually.

Grasslands for pasture should be improved and managed and should be limited to slopes of less than 48% and to lands that are not too moist, rotational grazing is recommended on all types of slope.

Cut forage grasses and fruit trees are located on slopes between

48-60%, but with the construction of terraces and planting in the contour of the orchards, as well as the construction of detour trenches and the use of a grass cover in intermediate places.

Forest land is on slopes greater than 60%, on deep or moderately deep soils, and on slopes of 48% on soils of little or very little depth.

According to the aforementioned, the deeper the soil, the more possible it will be to cultivate on steep slopes, but always with more intensive conservation methods. In like manner, as soil depth decreases or slopes become steeper, land use must be limited to less intensive uses.

When a soil seems too moist or too stony, or occasionally floodable, all of which prevents working the land, it must be classified for pasture use if the slope is less than 48%, or for forest use if the slope is greater than 48 percent.

Land dissected by gullies which prevent normal working of the land must be classified for forest use.

In general, land is classified according to the most intensive use possible without producing risk or prejudicial effects which would diminish its productive capacity. A less intensive use of lands classified for more intensive use is logically possible, from the point of view of soil conservation; however, it would not be logical from the economy or social perspective in most cases.

Land classified according to Sheng's system, ar mentioned in the Diagnostic, is in accord with its land use capability under moderate to high management intensity rather than with the actual agrotechnological management system in use at present. This classification does not include measurement of productivity nor profitableness. That economic factors should not be included in this type of cassification is stated in the Diagnostic.

The categories of capability are homogeneous only in relation to the degree of risk they represent for conservation with respect to the limitations in agricultural or forest use. Each category may include many different soil types. When the agrotechnological management system is changed or simply when new methods of farming are introduced or when important land recuperation work is done there should be a reclassification of land use capability, in accordance with this system.

In agreement with this classification system it was determined by the Diagnostic that 51,3% of the watershed area was of forest vocation, that 26,1% was suitable for cultivation under one of four different categories mentioned earlier, and that 14,1% were grazing lands. Only a small proportion, 0,6%, were classified in the Diagnostic for fruit or "forage" trees. The remaining 7,9% corresponds to urban and settlement sites, rivers, and infrastructural uses.

According to the classification made in the Diagnostic, the forest lands are located mainly over 1,800 m. of elevation. They are lands with slopes greater than 60% and a high rainfall, more than 2,000 mm. per year. These lands are very susceptible to erosion and landslides were frenquently observed, according to the Diagnostic.

On arable lands there can be clean cultivation or permanent crops. The Diagnostic does not establish a difference between these two categories of crops that constitute the two major land uses. Permanent crops are not to be found in the Diagnostic under fruit or "forage" tree use because this is called agro-forest use.

Among the arable lands are those with slopes of 0 to 50%, a range that includes different categories of arable land use. According to the Diagnostic, the soils included in this use-category vary. Among them are those derived from recent volcanic ash and those of old, weathered ash. The majority of land included in this type of usage, requires soil conservation measures.

According to the Diagnostic, grazing lands are located in the southern part of the watershed, beginning at the Cabezón Peak. These lands are of low fertility with a lot of stonieness in some cases, or very eroded. In general terms, there is concordance between actual use and that determined by this classification, except in the case of certain vegetable crops and pastures on very steep slopes. Nevertheless, soil conservation practices are recommended in all cases, even on well located crops.

A map of land use capability accompanies the Diagnostic. It indicates the space distribution of this use capability in the Caldera river watershed and it is very important to compare that made by the Tropical Science Center.

The Diagnostic makes a summary of the main Panamanian laws and decrees which have to do with the regulations on the use of natural resources: water, soil, forest, and wildlife, and also with the creation of the Barú Volcano National Park. A small synthesis of each is included.

To attain uniform management of areas with similar characteristics, four management zones were established in the Diagnostic, based on the topography, climate and soil characteristics, the complexity of the resource, the use, it's actual and potential activities, and the opportunities for development. Besides this, in each of these zones, small areas which are considered critical because of their advanced state of deterioration or in which the possibility of changes which could take place with serious effects on conservation were identified. These should be handled in a special way.

The four management zones that were outlined are:

(1) Protection zone

(2) Horticultural Production Zone

(3) Dairy and Permanet Crops Production Zone

(4) Forest and Grazing Zone

This classification was made based on consideration of both land use capability and actual land use, as determined by the Diagnostic.

The protection zone is located over 1,800 m of elevation and has very broken topography, slopes greater than 60%, soil derived from volcanic ash, high rainfall, almost permanent cloudiness covering primary natural forest, which has been altered in some places due to the "extraction of lumber", agriculture, or grazing. Land in this zone has been classified as of forest potential although it should have been protection. This is a very important water producing zone, and it's soils are very susceptible to erosion. Moreover, it has been declared a National Park, and its management should be subject to a special plan.

The horticultural production zone is located in the middle and West part of the watershed between Alto Boquete and 1,800 m. of elevation declining to 1,300 m on the East; it includes soils derived from volcanic ash with good drainage and high fertility; high rainfall (between 2,500 and 3,500 mm. annual). Actual land use is horticultural crops and in steeper parts permanent fruit crops. The Diagnostic recommends establishing a soil conservation program with an information team and technical assistance.

The permanent crops and dairy cattle zone is located in the middle and east part of the watershed, between aproximately 1,000 and 1,800mm. of elevation, with very broken topography, and slopes between 36% and 60%. It includes soils derived from old, weathered volcanic ash and used in permanent crops such as coffeee and pasture. The Diagnostic considers that the coffee is badly managed and that this should be improved, also that citrus fruits should be grown on the land using incentives and technical assistance, and that a pasture management program could be established usefully. It is considered in the Diagnostic that the land-use capability of this zone is grazing and permanent crops.

The forest and pasture zone is located in the southern part of the watershed, South of Cabezón Peak. It has gentle topography, not very fertile soils with a lot of stoniness and in some parts is very eroded. It also has high rainfall, close to 4,000 mm. Its actual use is intensive grazing with scattered remnants of natural forest. The Diagnostic recommends the reforestation of this zone, but with technical assistence and incentives, including a pasture improvement program. It recommends naming extension technicians for each zone; biologists, agricultural engineers, animal technicians, and forest engineers, whose specialities are related to the particular characteristics of the zone.

For special management effects, in areas where the deterioration or fragility of the environment indicates a need, six areas proposed as special management units: (1) The Quiel Bajo Ravine; (2) The Palo Alto river; (3) the slopes east of the Guarico and Gualas Peaks; (4) the beginning of the Hato Nuevo Ravine; (5) "The Grande Ravine"; and (6) the Horqueta Ravine.

The location of each area is mentioned and the land use problems which characterizes it, as well as recommendations for a more adequate management. In every instance the problems are caused by contraindicated land use, in most cases grazing on overly steep land. Some of these areas are in the National Park zone.

In this area landslide and erosion problems are serious and recuperation may not be easy. In many cases it would seem that a radical change in land use can not be attained because of tenancy conditions, therefore the Diagnostic recommends intermediate systems of use, such as agroforestry, to eliminate grazing completely. Nevertheless, it is not known if these systems are workable or advisable under such heavy rainfall conditions and on lands so steep. In other cases, the Diagnostic recommends timber production on lands where reforestation or protection might be better and where natural regeneration may be the best way. These recommendations are more than anything simply alternatives of the most

feasible use, and of course they should be evaluated before they are applied. Regarding the horticultural crops, the Diagnostic insists upon the need of using soil conservation methods.

Two annexes are included. The first contains an analisis of limitations for the development of the Caldera river watershed, the second contains an analysis of the forest subsector.

For the analysis of limiting factors in the development of the watershed, each of the parts studied and their respective divisions were taken into account. With regard to climate, different climatic factors and their effect on certain physical conditions or on productivity are considered; the limiting factors caused by the special characteristics of each climatic element of the watershed are not taken into account. In many cases, one of these limiting factors is the high rainfall, another is the steepness of the land. All of this contributes to limitations in land use and speeds up the erosive process. Some limiting development factors are a consequence of others.

Although it is mentioned that there are physical limitations such as climate and soil, there are also biological, institutional, economical, and legal limitations, and the actual land use to be considered. Social, economical, cultural, institutional, and legal factors are not taken into account. In general, this annex is a synthesis of considerations and recommendations which have been mentioned earlier in the study.

In general terms, the recommendations insist upon the need for a more detailed study of environmental conditions, many of which are not well known as in the case of the biological resources. It also insists on the need to use appropriate soil conservation methods to counteract the erosive effects of the high rainfall and steep slopes of the land along most of the watershed area.

Recommendations are also made about land use, such as zoning crops, introducing other promising ones, improving the management of others,

like coffee, intensifing others such as citrus crops and, above all, giving more technical assistance and offering greater incentives for those crops which are being promoted. Regarding reforestation, it is considered that this could include a large area of the watershed. Programs for improving pasture are also considered.

Constantly emphasized is the need to improve, increase, and set rules for vigilance on part of the forest rangers. One of the most important functions of vigilance is the protection of the valuable resource for water production. Also mentioned is finding other applications for timber and the need for studying the silvicultural and growth aspects of forest species which would enable a better use of forest resources.

The volume of the Caldera river is considered to be fairly regular, although there have been catastrophic floods, like the one in 1970. To maintain a regular volume and avoid as far as possible destructive floods, the Diagnostic emphasizes the need for protecting the natural forest and looking for the best possible land use.

In the appendix on the forest subsector, the Diagnostic presents an analysis of the forest situation in Chiriquí Province. This includes information on extraction and milling of lumber with statistics on the sawmills in this province, species of sawn lvmber production for 1979, labor force, and machinery used. Also presented is information on organized production groups and individual producers, production by species and groups of forest species, as well as the monthly timber production in the province during 1977, number of logs in cubic meters, and their value. According to this information, the timber produced in Chiriquí province in 1977 was 5,592 m^2 worth $10,992, mainly from mangroves used in the bakeries of David. The sawn wood production in the first 9 months of 1979 was about 6,428 m^3 worth $989,428.

To be able to fill future lumber demands, an estimate of the yield of Pinus caribaea in plantations, is included in the appendix. It is

estimated that an annual yiedl of 15 m^3/ha will have produced in 20 years 300 m^3/ha of which 178 will be usable as sawn lumber and the rest, product of three thinnings. This estimate also considers an annual rate of increase of 4.4% in national lumber demand. This represents some 28,200 m^3 in 20 years, in other words, 158 or 160 hectares reforested with this species can supply future demand in Chiriquí province.

The Diagnostic recommends these species for reforestation; Pinus caribaea, Pinus patula, and Pinus oocarpa, for constructions; Terminalia ivorensis and Eucalyptus sp. for fuel; Gmelina arborea for boxes, and Eucalyptus sp. for railroad ties.

The Diagnostic is a valuable study. It includes a lot of information about the watershed and it has even divided this area into different management zones. This information should be taken into account in all planning for the watershed. The maps attached to the Diagnostic present important cartographic information, some of which pertains to the present study.

3. La Villa River

The subproject Management of the Hydrographic Watershed of La Villa River (MIDA-RENARE, 1981) was developed by 12 RENARE professionals, headed by the engineer Ivanor Ruiz de León, with collaboration from a MIDA engineer and 4 auxiliary personnel of RENARE.

This study includes the same parts and structure of the earlier study of the Caldera watershed. Its objective is establishing the measures that should be taken to conserve, protect, and use in an optimum and scientific way the renewable natural resources of the watershed. In the study, a diagnostic is made so as to be able to formulate a management plan using the most realistic alternatives for solving the problems of the watershed. The recommendations that are given are outlined in the National Development Plan (1976-1980).

The study mentions the great importance of preserving the forests of the Canajuá Peak Area, some 66,865 ha. and that of the El Montuoso Forest Reserve, some 13,040 has. which are among the few forest areas that are still left in the Azuero Peninsula and where the main rivers of this peninsula start. The waters of these rivers are needed to guarantee the normal development of the different economic activities of the Peninsula. Also mentioned is the progressive degradation of the soils in two areas of 50,000 has. which are in grave danger of deterioration due to overgrazing and the indiscriminate felling and burning of the forests.

To justify the Management Plan of the La Villa river watershed, this study emphasizes that over 45% of the population of the Azuero Peninsula is located in this area. Their main activity is agriculture and cattle raising which require interaction with the forests, soil, and water. Also commented upon are the good perspectives for agroindustrial development in the region. This is still incipient and is the reason why it is necessary to conserve water and soil resources, these being essential for any such development.

Other aspects which have to do with the importance of this project are the need of supplying water from the La Villa river to various communities, among these, the cities of Chitré and Los Santos which are considered poles of industrial development in the Urbanization Plan. Water is also needed to irrigate the fertile soils of the extensive river terraces.

On the other hand, such agricultural land use in the watershed area destroys the land resource and causes serious erosion and sedimentation problems. This is why management programs for the watershed are so urgent. This would benefit the hydrological regimes of other rivers which have their head waters in the forest areas mentioned before. Some of these areas, or at least part of them, are not located in the La Villa river watershed itself but nevertheless should be included as management units in its Management Plan.

The general objectives of the study have to do with the rational use of renewable natural resources: maintaining the ecological balance, conservation and protection of flora and fauna, improving the quality of the water and hydrological regime, soil recuperation, and, finally, the population's standard of living by complete planning of natural resources use so as to satisfy the real needs of the people, the watershed, and the country.

More specific objectives are: rehabilitation, protection, and conservation programs for the high parts of La Villa river and its main tributaries; specific measures to reduce erosion, the control and reduction of sedimentation, and training of farmers in production alternatives.

To attain these objectives it is suggested that the watershed be divided into four administrative areas with an efficient working structure. Seven basic programs are suggested based on the judgement of the zoning technicians as to areas suitable for crops in agreement with land use capability and the traditional farming activities of the region. These projects are: (1) soil conservation; (2) improved pasture; (3) reforestation; (4) environmental education; and (7) marketing of forests products. Each program is briefly explained.

In the physical description of the watershed, its geographical and political location is indicated, there is brief mention of geology and geomorphology based on studies by CATAPAN (1970) and reference to the climate of the zone. No climatological data are provided.

Regarding the climate, precipitation, relative humidity, temperature, evaporation, evapotranspiration potential, hydrological balance, calculations of the Angot coeficient, and the probability of precipitation are covered.

Regarding hydrology, the limnographic and limnometric seasons and the periods of register are mentioned while existing information and the probable yields of the watershed are analyzed.

The physical description included in the study contains valuable information about the watershed. Part of this information has been used to complement the present description of the watershed based on the consultancy's ecological and land use study.

In the study of biological resources, flora and fauna are considered. Most of the chapter concerns the flora which is discussed in terms of the Holdridge life zones. The outlines of these zones, on one of the maps adjunct to the study with a scale of 1:50,500, were based on an amplification of this area taken from the ecological map of Panama (Tosi, 1971).

For each life zone, the study includes some of the scientific and common names of the forest species found in this area as well as some of the characteristics and uses of these species. Also mentioned is the location of these zones in the watershed and some of their land use characteristics, with suggestions for the study.

Also considered are some economical aspects of vegetation, especially the timber resources. The principal forest species of the region are mentioned as well as some others that are sold in the Bayano and Darién area. Also mentioned is the Azuero sawmills in the Azuero peninsula, as well as the production of charcoal, firewood, and poles and post used in agriculture.

The study analyses the soil deterioration caused by overgrazing on degraded areas, a deterioration caused by the replacement of the forest by pastures. The specific sites where this occurs are listed as are the effects this produces.

Finally, conclusions are drawn on the environmental impacts of bad land use, among which are cited the felling of mangroves causing the winds to increase and affecting the tides, felling of the open thorny forests near the coast where clayey and high carbonate or alkali soils

reflect solar radiation under exposed conditions.

Also mentioned is the effect forest felling has on the force of the trade winds in the coastal region. Without the protective barrier of the arboreal vegetation, these winds blow over the swamps, drying and crystalizing the minerals, which are then blown in land as dust clouds, damaging agricultural lands and contaminationg the air.

Regarding the forest fauna, a list is presented of some of the species, shellfish, reptiles, and mammals. In this study, the forest fauna is used as a life zone indicator. In each one, some of the animals are briefly mentioned, and are related to certain vegetational aspects.

Concerning the social-economical situation, the study includes abundant information about demographic, educational, health, and housing aspects as well as information about the economic activities of the Azuero Peninsula, this includes that of the agricultural sector and also refers to commerce, transportation, communication, and other services aside from the electrical energy situation and the highway infrastructure of the region. To conclude, the study presents an analysis of the macroeconomical behavior and conclusions are drawn that the Herrera and Los Santos provinces are highly agricultural, 65% of the former and 58% of the latter being dedicated to agriculture.

The growth of Chitré has been greater than that of Los Santos. Chitré has become a service center with the Los Santos province as its satellite.

Among the recommendations is that agroforestry should be promoted according to land use capability, inasmuch as these activities would be useful for conserving and exploiting renewable natural resources and also for attaining an integral development and formation of the human population. Development programs should aim for the stabilization of the population and an increase in income and employment levels, which would permit a

self sufficient and harmonious development and subsequent agroindustrial development using the raw materials provided by agroforestry activity.

Regarding the tenancy, information is provided for both Herrera and Los Santos provinces, more specifically, the La Villa watershed. This watershed includes 48.2% of the farms in Herrera and 45.2% of the total area exploited in that province.

According to this information, 14% of the farms had titles and represent 24.7% of the area in farms; 6.3 percent, representing 1.5 percent of the area were rented; 61.6% which represent 46.1% of tle land area were titled. Under the heading of a "mixed regime", the so called untitled properties, included 7.4% of the farms and 20% of the area.

Farms in the part of the watershed which corresponds to the districts of Herrera province, were predominantly small with between 10 and 50 has. These represent 42.3% of the area. Four point-nine percent were between 50 and 100 has. and make up 21.3% of the area, and only 2.1% of the farms are larger than 100. has. These, however, represent 25.24% of the area.

The farms in the part of the watershed which correspond to the districts of Los Santos province, represent 33.1% of the total and 27% of its area. According to the study, 10.7% of these or 16.2% of the total area had titles; 9.1% or 1.3% of the area, were rented; 58% or 44.7% of the area did have property titles, and 22% or 37.6% of the area was of a mixed property regime.

Regarding sizes, the study mentions that in the Los Santos province part of the watershed, small farms predominate; 59% of the properties representing 8.9% of the area were under 10 has.; 29.1% were between 10 and 50 has. or 34.4% of the area, and only 3.3% were over 100 has. but represented 29.2% of the area.

In summary, small developments or untitled properties predominate in the watershed area. Most of these are under 10 has. and some are even less than 1 ha., whereas more than one fourth of the area is controlled by less than 4% of the property owners. These considerations are very important for any land management plan or use that is proposed.

On the land, almost all properties (more than 99.5% representing more than 94% of the area) are privately owned. Societies, State Cooperatives, and peasant settlements represent only a very tiny fraction of the farms in the area.

With respect to actual land use, in comparison with 1953, forest is greatly reduced in area. This has led to serious soil deterioration. Because of this the Management Project for the Watershed of the La Villa river can no longer be postponed.

To determine actual land use in the watershed, the area was divided into 3 zones, high, medium, and low.

The high part includes remnants of primary forests and vegetation in the intial and later stages of secondary succession and by pastures in Llano de Piedra and other areas, shifting cultivation in the Chepe area and, on a smaller scale, by permanent crops in the Pitaloza, Chepe and other areas. The Montuoso Forest Reserve is in this high zone and even though it's a reserve the forest is very deteriorated. This reserve does not lie within the watershed, but is included in it for administrative purposes.

In the middle zone, extensive grazing predominates with grasses like "La Yaragua" (Hyparrenia rufa (Ness) Stap.) which covers practically the whole area, from Macaracas, continuing through Pozos to Pese. There are also a few remains of secondary forest and the offical forest plantation of the Macaracas communal forest.

In the low zone, the most extensive use is grazing and, second to

this, grain crops, as well as the sugar cane plantations of the Las Cobras refinery. To a lesser extent there are open-tilled crops on the alluvial soils and, near the coast, the mangrove area.

The study considers that the technological level of agriculture in the watershed has improved in the last years due to mechanization, fertilization and irrigation. Some statistical charts related to this are included. Nevertheless, the negative effects of the felling of forests and protective vegetation in the watershed and the use of burning as an agricultural tool are discussed and explained. These systems, still very much in use, have caused the destruction of extensive areas due to erosion and have presented serious problems to the hydrological regime.

To counteract these effects, more advanced pasture and grazing management system is recommended, with the introduction of more nutritious grasses, fertilization and control of mixtures, use of cut forage grasses, silage, and food supplements, as well as pasture rotation.

To determine land use capability, the study used the U. S. Department of Agriculture's soil conservation system adapted by CATAPAN for work done between 1965 and 1968.

According to the study, 1.6% of the watershed soils fall in Class II; 5.2% in Class III; 22.5% in Class IV; 8.7% in Class VI; 61.0% in Class VII, and 1.0% in Class VIII. The area of the watershed in 122,000 has.

This study also include a legal framework for the management of the La Villa river watershed, in which the main laws and decrees relating to management are summarized.

Finally, a Management Plan covering five management zones and four administrative areas is presented. The proposed management areas are: (1) The protection zone; (2) The Agro-forestry production zone; (3) The

annual and perennial crops and dairy production zone; (4) The horticultural production zone; and (5) The mangrove and coastal swamp zone.

The protection zone occupies the highest area of the watershed, with slopes of 45 to 75%, an average annual rainfall of 2,050 mm. and Class VII soils. The study recommends reforestation with native species for this zone.

The agroforestry production zone is found between 10 and 420 m. of elevation, with an average yearly rainfall of 1,350 mm., slopes from 8 to 45% and in a few cases from 0 to 3%, soil classes VII, VI, and IV. Reforestation and improved grass management is recommended.

The annual and perennial crops and dairy production zone is located in various areas within the lower part of the watershed, with an average yearly rainfall of 800 mm., slopes from 0 to 20%,sand soil Classes III and IV. Permanent crops and dairy production are recommended in this zone, where the study found annual crops, permanent crops and pastures.

The horticultural production zone is distributed over different areas by the river. It includes Class II soils, with slopes from 0 to 3%.

The mangroves and coastal swamps zone is near the coast, in the characteristic areas of this environment. According to the study, it should be left unused as a protection zone.

Six programs are described in the management plan: (1) organizational and technical administrative development; (2) social development; (3) reforestation; (4) grass management and improvement; (5) soil and water conservation, and (6) evironmental conservation.

A justification for each program is presented, as are the objectives and strategies to be used. Two models are included in the reforestation program, on agroforestry systems and another using conventional, commercial

forestry systems. The latter consists of the conservation of secondary vegetation as productive forest, with farmers efforts directed to produce transitory crops and eventual establishment of valuable forests under a type of "taungya" system. The former model embraces agroforestry systems in which the shade needed by perennial crops such as coffee or cacao is substituded or complemented by planted, timber species. The pasture improvement and management programs include "agro-silvo-pastoril" systems, which basically try to combine pasture and timber production on the same ground.

Four-year objectives are outlined for each program in this plan and the priorities of the program are set by administrative areas.

The Management Plan for the La Villa river Watershed present valuable information regarding certain aspects covered in the present ecological study.

4. The Chiriquí Highlands: Soil erosion

MIDA-RENARE (1980) together with the French Mission to Panama, presented a Technical Report on soil conservation in the Chiriquí Highlands, as a result of the investigations made in 1979 and 1980 in five runoff plots of 40 m^2, 9,3 m. of length downhill and 4.3 m. in width, with slopes of 35%. These study plots were located at 1,150 m. of elevation near Boquete, where soil losses were analized after each heavy rainfall.

The soils that were studied are similar to those in the area derived from volcanic ash with a surface horizon 30 cms. in depth, very rich in organic matter, followed by a transition horizon 15 cms. deep with a dark grayish brown color, 10% organic matter, and a C-horizon more than 45 cms. deep, brown in color, corresponding to weathered volcanic rock.

Soil texture was sandy loam of apparently very low bulk-density

and high permeability according to tests made with the Muntz infiltrometer. The five tests showed an average of 85 mm. rainfall equivalents infiltration in 10 minutes and 280 mm in 60 minutes. The infiltration was of 99.95% for plots with grass cover, leaving only less than 1 mm. of surface runoff from 3,000 mm. of precipitation

According to this data, these soils are extremely resistant to erosion; nonetheles, it is mentioned that they present a high weakness to runoff because of the lack of resistance to undermining.

Rainfall, in 1979 and 1980 in the plots was 3,846 mm. and 2,983 mm. respectively. This was compared to that registered at four neighboring stations of IRHE. Precipitation in the area is high and varied, being between 2,000 in Cerro Punta and 4,500 at Planta Caldera; it increases from the coast to the mountain range but reaches its highest amounts between 500 and 1,000 m. of elevation. Approximately 90% of the annual total falls between April and December; January and February are the driest months. In the dry months, as mentioned earlier, there are rains from the north, called "bajareque". These come from the Caribbean and reach 5 kms. towards the Pacific beyond the continental divide, representing 15 to 20 percent of the annual total, depending on the distance to this divide.

According to this report (MIDA-RENARE-French Mission, 1981) the heavy rains are intense, as precipitation may reach 60 mm. in 30 minutes, 100 mm. in an hour, and 350 mm. in a day; these intensities vary greatly from one place to another.

The R-Factor of the Universal Soils Loss Equation was 1,500 where the study plots were located.

In other places in the area, the R-Factor varied from 330 to 2,800, this last figure occurring at Planta Caldera, very close to the Río Caldera watershed. The variations from one year to another were notable, in

November of 1974 it was 0, and in November of 1975 it was 380; in April of 1978 it was 0, and in April of 1979 it was 225. The year 1979 was very rainy and precipitation surpassed 20% on the average; in 1980, on the other hand, precipitation was 10 percent below average.

The runoff for a heavy rain in the research plots covered with grass, a crop of carrots, or bare ground was 0.02 mm, 0.5 mm and 35 mm. which represented 0.03%, 6%, and 44% of the total rainfall.

Soil losses by erosion were determined in 5 plots: the first, where two vegetable plantings a year were made, the rows on the contour; the second, where plantings were made along the slope; the third with pasture; the fourth with coffee; and the fifth, bare ground. Losses were for 1979, respectively, 55, 80, 35, 77, and 183 Ton/ha., and for 1980, 80, 122, 0.01, 0.3, and 223 Ton/ha. Those results, translated to a loss of soil depth were, for each of the parcels in 1979, respectively, 18, 12, 5, 11, and 27 mm., and 12, 18, 0.001, 0.06, and 34 mm in 1980. Soil depth eroded was calculated from an assumed soil density 0.65 kg/liter, such that the loss of one Ton/ha. equalled a sheet of soil 0.15 mm. thick.

It is noted in the results that losses on plots in pasture and coffee decreased rapidly as these crops grew.

In another table, soil losses in the plots in pasture are presented as this grew, and its comparison with the plot free of vegetation and with that in coffeee, which, from 74.2% Ton/has/yr. if compared with unprotected soil, decreased to 3.1 Tons when the soil was covered with weeds and was weeded by machete or up to 0.3 Ton/ha/yr. when it a living cover and mulch and was weeded by machete.

The soil losses under short-term vegetable crops can become important, surpassing the limit considered permissable of 10 Ton/ha/yr for that type of soil. In the investigation, these losses were determined with relation to various crops and crop systems. The crop on contour with sidehilling of plants decreased the losses notably.

Recently turned soil resists erosion, because it presents better conditions of aeration and permeability, but this is temporary: after one or two strong rains it again forms an impermeable crust.

Plantings in September and October are dangerous because the heaviest rains then fall when the soil is least protected. A single heavy rain falling on unprotected soil can carry away more than 40 Ton/ha., as indicated in the aforementioned report, according to deductions made on small plots. On the large plots ploughed by tractors, the damage may be more serious. It caused losses of 100 and up to 200 Ton/ha., on plots of several hectares with slopes of 10% ploughed by tractor.

Early plantings are much less dangerous in terms of erosion, because the soil is quite dry. Losses were only 3 Ton/ha. for potatoes in 1979, and 6.2 Ton/ha. for Chinese cabbage in 1980, an especially rainy year.

Contour plantings turned out to be a system which protected soils quite well. Erosion was 5.5 times greater on a plot with cultivation running up and down the slope, as compared with a plot cultivated on the contour. In beans this difference was significant after side-hilling plants; in the nonhilled plots the difference was less; nonetheless, it was appreciable.

The research plots represent special conditions in terms of size and fixed slopes and therefore may differ from natural or actual conditions. On small plots the volumes of water are small. However, on plots of only 40 m^2, one may observe total volumes of 1,500 liters in less than 30 minutes. That is a run-off of 30 mm. which produced soil losses of 30 Ton/ha. On larger plots the volume of water accumulated is proportionaly greater and therefore run-off and damage are greater.

A common method of preparing soil on these lands is with a "rotavator" or "rotatiller". This produces great damages in soil erosion, such that it is considered in the aforementioned bulletin to be the number one enemy of soils in the highlands, especially on large plots. This apparatus

leaves the soil polverized on the one hand and compacted on the other hand, and consequently the run-off is said to be greater.

The bulletin (MIDA-RENARE-French Mission, 1981) presents in its second part a series of practical instructions on soil conservation with simple illustrations and explanations.

5. Canal Watershed

RENARE presents two informational brochures on Soil Conservation in the Canal Watershed (MIDA-RENARE-French Mission, 1981) and another on The Importance of Panama Canal Watershed Management (Isaza and Moran, undated).

In the first, consideration is given to the problem of the destruction of the protective vegetation by felling of trees and burning. The critical areas are mentioned and RENARE's role in dealing with the problems is made clear. This brochure is illustrated with several photographs of burned areas and of projects conducted by RENARE for the conservation of the watershed.

The pamphlet on The Importance of Panama Canal Watershed Management explains in detail what a watershed is and the consequences of irrational land use. Three maps on a scale of 1:500,000 of the Panama Watershed are presented to indicate its limits and extent and the proportions of land deforested in 1952 and 1976.

During five weeks, from April to May of 1980, a multidisciplinary team of seven experts on environmental resources and renewable natural resources made a review of environmental conditions and natural resources of Panama. The themes covered were: (1) deforestation and soil erosion, (2) loss of forest fauna and their habitats; (3) air and water pollution; (4) disposal of solid wastes, (5) noise pollution, and (6) impact of hydroelectric projects on the environment. The individual reports were put

together and edited as one document for a final report which presents the "Environmental Conditions and Natural Resources of Panama" (International Science and Technology - AID, 1980). This report has not yet been published.

The primary objectives of that review were to "evaluate the state of natural and environmental resources in Panama, identify the principal needs related to resource conservation and environmental management, formulate recommendations to prevent or reduce to a minimum unfavorable impacts on the environment as a result of plans, general development strategies, and projects, and provede specific information directed at environmental and natural resource activities in Panama, which can be used in planning and establishing priorities towards development. These objectives were established in a joint effort by the Panamanian Government and the Agency for International Development (AID) in Panama.

The study was carried out by the "International Science and Technology Institute, Inc." (1980) under contract Nº AID/PDC/-C-1251, in which the following people participated: Jeffrey Boyer, Leader of the Team and Environmental Planner; Random Dubois, Marine Ecologist; Gary Hartshorn, Silviculturist; Stanley Heckadon, Social Anthropologist; Edmund Ossio, Specialist in Pollution; Frank Zadroga, Hydrologist; and Goetz Schuehaltz, Forest Fauna Ecologist and National Parks Planner.

The study had the following objectives that were established in a joint effort with the Panamanian Government and the AID Mission On Panama.

(1) Evaluate the state of natural and environmental resources of Panama

(2) Identify the primary needs related to resource conservation and environmental management

(3) Formulate recommendations to prevent or reduce to the minimum the unfavorable impact on the environment, as a result of plans, general strategies, and development,projects, and

(4) Provide specific information directed at environmental

activities and natural resources of Panama, which can be used in the planning and establishment of priorities toward development.

The most critical problems related to environment and to renewable natural resources that the group identified were:

(1) spontaneous colonization

(2) deforestation

(3) soil erosion and deterioration of pasture land, and

(4) the destruction and contamination of marine life habitats.

It was found that the principal limitations to effective management of natural resources and environmental protection were:

(1) the lack of understanding of the environment

(2) actual development strategies

(3) the lack of centralization of authority in natural resource management and environmental protection

(4) the lack of basic information on natural resources and the environment, and

(5) the lack of technically qualified personnel.

To try to correct the problems found, a series of recommendations were made in the different areas of study.

For example, in the area of colonizaction and resource development, it is recommended, among other things:

- to establish a colonization policy
- to modify the program of access road construction to reduce to the minimum the environmental impact of such construction

- to provide technical assistance in the development projects so that environmental protection strategies be included
- to promote permanent forest plantings
- to protect the rights of minority groups that inhabit the forest areas subjected to colonization.

With regard to forest resources, it is recommended in the study:

- to legally establish national and communal forests, with adequate management and direction
- to initiate research projects on certain types of natural forests, emphasizing the multiple use of natural resources
- to implement the silvicultural programs for the cativo forests and mangroves
- to promote projects of forest plantation and agroforestry for the rehabilitation of degraded soils
- to evaluate the systems of forest concessions to replace the short term exploitation-and benefit system with other systems in order to maintain future long-term production
- to actualize the statistic on forest resources
- to realize forest inventories in areas threatened by the encroachment of agriculture and to develop plans for rational land use, based on soil capability.

With regard to the forest fauna resources and to national parks, it is recommended to:

- establish a conceptual plan for forest fauna and wildlife refuge areas
- design a sinecological and applied research program according to the aforementioned plan

- updated legislation on fauna and national parks to determine the applicability of that plan
- adopt a new classification for protected area to better indicate the characteristics and needs of each areaa
- initiate pilot projects in multiple land use and in commercial exploitation of certain forest fauna species
- establish a section on Outdoor Recreation in RENARE

For atmospheric and soil resources the following recommendations were made:

- Adopt the watersheds as the planning and administration unit for national development projects and give these an integrated multidisciplinary focus
- Undertake a study of the watersheds in Panama to identify critical problems, resources potentials, actual land use, and land use capabilities, for the purpose of establishing basic development priorities in each
- Protect all watersheds providing water to the municipalities and to hydroelectric plants
- Undertake studies specific on soil and water conservation and provide financial assistance to RENARE and IDIAP for their execution
- Initiate integrated, multiple-use projects of watershed development in which individual uses would be combined in accord with land use capability
- develop, at all levels of public education, programs for environmental education, and also educational programs and extension services which will satisfy the needs for administration of natural resources and environmental protection.

Other topics in which recommendations were made were those related to marine resources, water and atmospheric contamination, solid waste disposal, all of which have little relation to the present study and need no further mention herein.

The recommendations cited above, from the environmental profile study of Panama, are closely related to the present ecological study as a basis for the management of the three watersheds, and, therefore, should be taken into consideration in the recommendations of the present study.

In the aforementioned study, also, recommendations are made to the AID Mission in Panama, recommendations compatable with offical AID policy in environmental matters (Regulation 16:PD 63 and also authorization fo the Congress of the U.S. under he Protocol of Foreign AID, Sections 102, 103, 118, and 119) with respect to assistance to the Panamanian authorities in the protection and administration of natural resources. These recommendations are considered to be of the highest priority with regard to the administration and conservation of long-term resources productivity and should also be taken into account in the present study.

Said recommendations refer to general education, especially with respect to the evaluation of the environmental impacts of development projects and the implementation of measures for environmental protection as well as training of gobernment functionaries charged with administration and supervision of these activities.

Environmental education is recommended for all levels and more specifically for middle and upper levels of schooling. Is is further recommended that nationals who are trained ecologists be directly involved in the environmental evaluation of all development projects.

Amongst the recommendations are included, also, careful review of all development projects in Panama financed by AID, such that these conform to accepted norms of environmental protection and rational use

of renewable natural resources, strict supervision of all parts and steps in the development process in these projects and especially in those that involve significant environmental risks such as the construction of dams and highways, irrigation works, and fisheries projects.

Amongst the potential areas for development of projects on the part of AID and the Government of Panama, the Environmental Profile - mentioned recomends the creation of a National Commission for Environmental Protection, directly under the Presidency of the Republic , with sufficient authority and broad functions (to be specified in detail, related to the programs and activities of the ministries, semi-autonomus government and private agencies which have a relation to the environment).

A list of additional programs are also presented by the ministries and other institutions.

The actualization of forest inventories is emphasized, especially for forests with economic value and the forest being felled, as well as evaluation of deforestation rates in Panama.

Also recommended is a five-year pilot project of forest colonization, based on the concept of forest farms which might eventually become a model for more rational land use on the part of colonizers and which would replace the actual agricultural methods of felling and burning.

The study of the Environmental State and Natural Resources of Panama, (Environmental Profile) mentioned above, has ample and valuable information on various geographical, social, economic, and ecological aspects of the country.

Much of this information has been useful as a complement to the present report of the consultancy on the Ecology of the Moist Tropics of the Watershed Management Proyect.

The chapter of that study are as follows:

I. General conditions and characteristics of the environment and the economy

II. Colonization and resource development

III. Forest resources

IV. Resources of forest fauna and national parks

V. Marine resources

VI. Soil and water resources

VII. Air, water, and soil wates pollution

VIII. Mineral and energy resources

Appendixes.

CHAPTER III

METHODOLOGY USED

III. METHODOLOGY USED

A. Life zones

In making the ecological maps of the three watersheds, the World Life Zone System of Ecological Classification (Holdridge, 1947-1967) was used.

According to this system, life zones are equally-weighted divisions of the earths's bioclimate. Each has quantified critical limits of mean annual biotemperature, precipitation, and moisture, this last expressed as the relationship between potential evapotranspiration, as a function of biotemperature, and rainfall. For that reason, in order to delimit the life zones it is desirable to have as many reliable records of a reasonable time span for rainfall and temperature as is possible for the area under study. In the case of annual mean temperature, inasmuch as this may differ from the annual biotemperature, it is necessary to convert the former to the latter by way of an empirical formula, since the more precise calculations of biotemperature based on temperature per hour from thermograph records is a laborious task and not usually possible for lack of this data at most weather stations. The formula for mean annual biotemperature is:

$$T^{bio} = \frac{t^{bio} \text{ of the twelve months}}{12}$$

(1) t^{bio} (of one month with $t > 24$ degrees Celsius) = $t - (t - 24)^2$ (0.03 latitude)

(2) t^{bio} (of one month $t < 24$ degrees Celsius) = t

(3) t = mean monthly temperature in degrees Celsius

(4) t^{bio} = mean monthly biotemperature in degrees Celsius

(5) T^{bio} = mean annual biotemperature in degrees Celsius

The climatological information for this study, above all when referring to rainfall and to temperature, was provided by the Agrometeorological Department of RENARE for all or most of the stations located in the three watersheds. This data had been processed or was processed to find those parameters that would allow for premapification of the life zones and subsequent revision in the field.

The annual averages for the aforementioned parameters were first analyzed for stations with longer-term records, in order to later relate these to the averages of stations close-by having shorter periods of records and in this way obtaining a correction factor for the longer period. No statistical analysis of double mass was made to determine the reliability of the data.

Stations with temperature data were relatively few albeit sufficient for the most part for determing temperature in the lowlands of the watersheds, (except in Caldera); this was not the case for higher elevations where temperature had to be estimated by the calculation of an approximate thermal gradient. The gradient used is the one presented by Tosi (1971) in the delimitation of the life zones of Panama. According to this gradient, the different altitudinal belts present in the three watershed were theoretically determined.

Annual biotemperature and rainfall averages determined, as stated above, for each station were located on the topographic maps at 1:50,000 of the Tommy Guardia National Geographic Institute. Each station was located according to its published polar coordinates and its life zone identified from the data.

Based on the data points, premapification of the life zones was then concluded, keeping in mind the land formations and the influence of winds. This allowed for obtaining the approximate preliminary boundaries of the different bioclimates.

Once in the field and as the areas were traversed, boundary locations were confirmed or altered locally by interpretation, primarily of the natural vegetation, land use, crop conditions, and characteristics of the soils.

Under Holdridge's system, a life zone may be identified in the field according to the physiognomy of the vegetation and, inversely, the landscape's bioclimatic conditions can then be deduced. One great advantage of this system as compared to others is its suitability for deducing valuable climatic information for areas for which such information does not exist, or to correct information that does not correspond to what is indicated by the vegetation and other elements in the landscape.

In the course of the fieldwork, some errors were also corrected as to the location of weather stations.

During the field verification, an ample network was established of points corresponding to the limits of the life zones. Later those points were joined by a continuous line, except for the limits of the transitional bioclimates.

Due to conditions of accessibility, there were several places in the watershed which were impossible to reach. Since it was not possible to make the helicopter flight that was solicited to get around that problem, the life zones in those inaccessible areas were determined by extrapolating from known points, life zones according to a logical sequence are generally present in the distribution of life zones under given geographical conditions. To make this extrapolation more precise, other factors of a physiographical and atmospheric nature were taken into account.

One of the areas which was not possible to visit was the one that extends to the east of 79º 30' West Longitude in the Panama Canal watershed. This area, besides its inaccessibility, also lacks topographic maps, for which reason it was necessary to adapt some less accurate general

topographic maps to a scale of 1:100,000 and amplify these to a scale of 1:50,000 in order to match up the cartography for use in field mapping.

For the purposes of final presentation, a simpler base map, elaborated by RENARE's cartography section was used. The matrixes of this map are filed in that Department. For the larger, Panama Canal life zone map, the scale was reduced from 1:50,000 to 1:100,000 to fit the afore mentioned RENARE map. The life zone maps of the other two watersheds were presented finally at the original field scale of 1:50,000.

B. Methodology and System Used in Mapping Major Rural Land Use Capability

Major rural land use capability the the three watersheds was determined using Tosi's system (1972, 1981), which considers, as mentioned earlier, the life zone, the most important soil characteristics, and the agrotechnological management system utilized.

It was neither possible nor the purpose of this study, as time and resources could not have permited, to conduct a soil survey in the watersheds in order to obtain the values of the different physiographic and edaphic factors needed to apply Tosi's keys and determine, for each given soil unit, its major rural land use capability. It was necessary therefore, to utilize the only available source of information on this subject: tha CATAPAN study (1970) mentioned earlier.

In view of the general nature of that study, which includes most but not all the factors and factor-classes that Tosi requires for application of his system, it was necessary to make several adjustments and suppositions as explained below. Some of these adjustments or corrections were based on what could be done in the field, logically insufficient to make fundamental improvements in the CATAPAN study.

Therefore, the classification map presented here for major land use

capability could not be more precise or detailed than the basic CATAPAN study on which it was based. In spite of this, it is considered that these maps contain all the information necessary to identify the larger areas that can be defined as development poles in a future management of the watersheds.

For each soil unit of the CATAPAN study, and there are a large number of them in each of the three watersheds, especially in the Panama Canal watershed, the key corresponding to the life zone or zones in which it is located was applied.

Tosi's keys (1981), as mentioned earlier, include 10 physiographic and edaphic factors, and consist among other things of a series of lines with definite quantitative limits or classes of values for each of these factors. All the values of each factor of the soil unit considered must be included within the limits fixed on the given line if the unit is to be classed for the given use capability and the corresponding system or systems of management indicated for that line. If just one of the soil unit values that corresponds to a physiographic or edaphic factor is outside the permissible limits, then the interpreter passes on to the next line, which may or may not indicate the same major land use capability for the system of agrotechnological management in reference. If that line again does not agree in full with the conditions at the site, then succesively lower lines are consulted until the one that fulfills all the requirements is reached, indicating the acceptable major land use capability and system of agrotechnological management for the values of the site under consideration.

The usual case is that as one descends in order, the lines indicate less intensive major use capabilities and therefore less exacting values of physiographic and edaphic factors, finally reaching an exclusively protective land use.

The different parameters and their structure, as they appear in CATAPAN (except the consecutive numbering), is as follows:

1	2	3	4	5
O	X	M	CF	1
Ic	C	1	0	
6	7	8	0	

where

(1) (Epipedon)

(2) (Endopedon)

(3) Internal drainage

(4) Texture

(5) Soil depth (cm)

(6) Original material

(7) Slope category

(8) Erosion

(9) Stoniness

For further information, it is necessary to consult the key in the CATAPAN study.

Given below are the equivalents obtained; on the left are Tosi's values, on the right, CATAPAN's.

High (2) = 1. Inherent Fertility

$$\frac{BC}{Fa}$$

Medium-to-High (2-3) = $\frac{OC}{Fa}$ $\frac{BC}{Sc}$ $\frac{U^*}{Mb,\ Fa}$ $\frac{UC}{Ec}$

Moderate (3) = $\frac{UC^*}{Fi,\ Sa,\ Sc,\ Fa,\ Mc}$ $\frac{UX}{Sc}$ $\frac{OT}{Ie}$

Moderate-to-Low (3-4) = $\frac{UC^*}{Ie,\ Ft}$ $\frac{BX}{Sc}$ $\frac{OX}{Sa}$

Low (4) = $\frac{OX^*}{Sc,\ Ie}\ \frac{UX}{ft}\ \frac{OC}{Ie}$

The number in parenthesis corresponds to the symbol for the fertility class proposed by Tosi.

In the combinations indicated with an asterisk (*), the numerator may be combined with any one of the denominators separated by commas.

Other possible combinations that do not appear above, correspond to the low (4) or very low (5) fertility classes.

2. Internal drainage

A	(Excessive)	=	E	(Excessively-drained)
B	(Good)	=	W	(Well-drained)
		=	M	(Moderately well-drained)
C	(imperfect)	=	N	(Imperfectly-drained)
D	(Poor)	=	G	(Poorly-drained)
E	(Very poor)	=	V	(Flooded)

3. Texture

L	(Light)	=	S	(Sandy)
		=	Ks	(Shallow sand)
		=	F	(Fragmented)
		=	K	(Shallow loan)
		=	Kc	(Shallow clay)
M	(Medium)	=	Lc	(Coarse loam)
P	(Heavy)	=	Lf	(Fine loam)
		=	Sc	(Coarse sedimentary)
		=	Cf	(Fine clay)

MP	(Very heavy) =		CV	(Very fine clay)
	=		Sf	(Fine sedimentary)

4. Erosion

0	(Null)	=		
1	(Slight)	=	1	(Slight to moderate)
2	(Moderate)	=		
3	(Severe)	=		
4	(Extreme)	=	2	(Severe to very severe)

5. Stoniness

0	(Free or Slightly stony)	=	0	(Without stones to moderate)
1	(Moderately stony)			
2	(Stony)	=	1	(Severe stoniness)
3	(Very stony)			
4	(Extremely stony)	=	2	(Severe stoniness)

For the values of soil depth it was not necessary to adopt equivalents, since Tosi does not propose categories but direct numerical values, for which reason we worked with the original CATAPAN concepts in which:

Very deep soil	:	+ 152 cms.
Deep soil	:	91-150 cms.
Moderately deep	:	51- 90 cms.
Slightly deep	:	25- 50 cms.
Very slightly deep	:	0- 24 cms

In the case of slope, Tosi also does not propose categories but does evaluate slope in terms of short and long slopes, gradient being given in percent. The CATAPAN categories are considered as such, attempting to adjust their values to each of the ranges proposed by Tosi in each the keys;

however, according to field observations, it was decided to consider the CATAPAN categories as short slopes and long slopes were estimated based on that category-data.

CATAPAN presents the following slope categories:

A	0 - 3 %
B	3 - 8 %
C	8 -20 %
D	20 -45 %
E	45 -75 %
F	+ 75 %

Once the values were matched, we proceded to analyze each of the soil units recognized by CATAPAN and their use capability was determined in relation to the life zone or zones in which it fell. For this reason, a single soil unit might be sectioned in to different use capabilities, or in some cases some of those units might have a different use capability altogether than CATAPAN data indicated, due to the verification in the field of the fact that one or more of the factors expressed in the CATAPAN map was in error, and therefore we proceded to qualify these units based on observations in the field.

In order to take into account other factors considered in Tosi's methodology, not expressed directly in CATAPAN, it was necessary to obtain them indirectly, based on existing data in the CATAPAN study. These factors were: the pH, the salinity the macrorelief, and the danger of flooding (anegamiento).

The five categories of major land use capability that Tosi proposes are:

<u>clean tilled crops</u>: A
<u>pasture</u> : P

permanent crops : C

production forest:: B

protection : X

Nonetheless for this study, it was decided to add an additional category:

permanent tree crops: CF

This was to differentiate it from the permanent crops (C), since there are many areas with arboreal-type crop species, which require no soil tillage at all and which are not exacting as to fertility, primarily.

Two symbols were adopted to represent major land use capability on the map . One is a fractional code with numerator and a denominator indicating two alternatives in the use capability as, for instance, a "traditional" or "advanced, artisanal" technological system is employed. The other consists of only one letter, which indicates that major land use capability is identical at either technological level.

A hierarchical order is assumed with respect to the intensity of the different categories of use, for which reason they are called categories of major use capability. Intensity is basically a measure of the edaphic and bio-climatic requirements of each of the categories. For example, clean-tilled crops (A) are more exacting than pasture (P), and for this reason the latter category follows the former.

For this reason, it is considered normally possible to sustain on lands classed within a given category uses corresponding to all others that are less intensive. However, in the present study, some peculiar characteristics in the soils are presented which in a certain way limit the order of this hierarchy. In particular, this is true for the pasture (P) and permanent crops (C) categories. In each case, certain soil units do not enter the

less intensive restrictions on depth and fertility.

For instance, some areas which qualify as appropriate for pasture (P) are not recommended for permanent crops -- a less instensive use -- still suitable, alternatively, for permanent tree crops (CF), production forest (B) or protection (X).

The maps indicate cases in which the normal hierarchical order may be followed and in which it may not. In those cases where these two categories of maximum use capability appear together, separated by a comma (e.g., P, C), it means that both activities are permitted; that is the normal order is permitted, but when the letter P appears alone, it means that an alternative use in permanent crops is not recommended.

Originally, Tosi (1972, 1981) considered pasture (P) as a less intensive use than permanent crops (C). This has been changed as a result of soil erosion determinations under each category.

Below are expressed a few examples:

P, C/A : Means that in the unit so designated, both grazing and permanent crops and the categories below it in intensity (e.g., CF, B, and X), may be practiced, under a "traditional" management system. The A in the denominator indicates that if a more intensive management system is used, with certain methods such as organic fertilizing, soil conservation practices, and the like, that is to say an"advanced, artisanal" system of management, then that unit may be utilized for the production of clean-tilled crops (A) as well as all other less-intensive uses.

P/A : This case is similar to the above, but here it is not recommended to use permanent crops under traditional management systems, although it is possible to have: permanent

tree crops (CF), forest production (B) or absolute protection (X). The A indicates the same as in the previous example.

A : Means that the soil unit so classified can be farmed to clean-tilled crops under traditional as well as advanced, artisanal or mechanized management systems.

X/B : This symbol aappears frequently on the maps. It indicates that production forest use under traditional systems is not permitted, but may be accepted if advanced technology is employed, thus ensuring soil and forest conservation. Also, given the extent of these units, which were considered by CATAPAN in only a very generalized way, the symbol can be interpreted in another way. That is, in certain sectors of the unit where local conditions are above average, they can be used for forest production under traditional systems while in other sectors of the same unit, conditions being worse, that activity will not be permitted, not even under advanced technology.

In general, it does not seem advisable to recommend other than absolute protection for these units, due to the danger of implying that a more intensive use like forest production is possible throughout the area they occupy, even where it is indicated that such use requires application of advanced, more soil-conserving practices, these being not well known or understood in the country right now. Thus, the tendency could be to exploit forest with traditional systems, a very dangerous-change in land use.

The CATAPAN study's soil information is also to be found in maps on a scale of 1:50,000 which was used for the elaboration of major land use capability for the La Villa and Caldera river watersheds, but decreasing to 1:100,000 for the Panama Canal watershed.

Maps Nos. 1.1, 2.2, and 3.3, for the watersheds of the Panama Canal and the La Villa and Caldera rivers, respectively, and Appendix 4 showing the soil units identified by CATAPAN, with their respective major land use capability, according to Tosi's system.

CHAPTER IV

RESULTS

IV. RESULTS

A. GENERAL DESCRIPTION OF THE BIOCLIMATIC CONDITIONS

1. Rainfall:

The major part of the area studied is under the direct influence of the Pacific climatic regime, which has a single, well-defined dry period. Smaller areas are influenced by the Atlantic regime, characterized either by not having a dry period or by having only a very short one. The areas with an Atlantic climatic regime are located in the northeast of the Panama Canal watershed and on some highlands of the Río Caldera watershed. The Río La Villa watershed has a "monsoonal" type of rainfall distribution particularly in its low and middle elevational parts, there being between five to six effectively dry months each year, from December through May. At the higher elevations in that watershed, two to four months are dry. Something similar occurs in the case of the other two watersheds, but the dry period there is somewhat shorter while still being considered slightly "Monsoonal". The dry period lasts four to four and -a- half months per year, from December to April. However, an exception must be made in the case of the highest part of la Caldera's watershed and the northern and northeastern section of the Panama Canal watershed, where there are only two to three relatively dry months. In the Canal watershed the dry period decreases from South to North and from West to East, so there are sectors with climatic associations and others ranging to a wet-atmospheric type climate, with dry periods ranging from four months to only one month. Over the greater part of the area of the three watersheds, light rains start in April and it is in September and October that the highest rainfall totals for the year are recorded.

The ranges of average annual rainfall for the three watersheds of the Panama Canal and the Caldera River are similar, varying between approximately 2,000 and 4,500 mm., while for the Río La Villa watershed the range

is between 1,000 mm. and 4,300 mm..

In general, for these three watersheds, rainfall increases with elevation above sea level. Also, locally, it may increase or decrease in response to physiography and exposure. For instance, in the Río La Villa and Panama Canal watersheds, the highest rainfall occurs in the highest parts of the watersheds, giving rise to Premontane rain forest life zone, yet this does not occur in the Caldera watershed where phisiography and exposure cause the rainfall to be greater in the eastern sector than in the western sector; also in this watershed, the higher rainfall of mid-elevations begins to let up in the upper watershed in response to special conditions of topography and exposure.

In general terms, the pluviometric information in the greater part of the areas studied was sufficient for the purpose of the study, although the density of the recording stations in the more inaccessible regions was too low to permit a detailed delimitation of life zones there from the rainfall record alone.

2. Temperature and biotemperature:

Temperature records in the three watersheds indicate a normal variation, for the Tropical latitudinal region, in both monthly mean and extreme temperatures. Available data for the lower parts of the watersheds were sufficient for the purposes of the present study, but not for the upper regions, for which there is no data at all (except for the Caldera watershed). For this reason, in order to premap the life zones, it was necessary to find the altitudes -of- change between two altitudinal belts, Tropical basal and Premontane, by using a direct relationship between altitude and temperature, as mentioned previously.

The greater part of the territory studied has a mean annual temperature between 20 and 27ºC. The highest temperatures are recorded are in

Río La Villa, where the annual mean is 27.5ºC, with a mean-maximum of 32.6ºC, and a mean-minimum of 22.5ºC at Chitré. The lowest temperatures are in the Caldera River watershed, where the mean-minimum annual temperature should be about 8ºC at the highest elevations on Baru Volcano.

In Appendix 1, 2, 3, 1A, 2A, and 3A, there is a list of climatic data used in this study.

B. LIFE ZONES IDENTIFIED IN EACH WATERSHED

1. Panama Canal Watershed:

General characteristics:

The Panama Canal watershed is located between approximately 7º 39' 02" and 9º 21' 05" North latitude and between 79º 15' 00" and 80º 07' 14" West Longitude and lies in the central part of the narrow Isthmus of Panama, in the provinces of Panama and Colón.

The Panama Canal watershed is more appropriately the watershed of Gatún artifical lake, which is formed by an earth dam blocking the river. Gatún Lake has an area of 258 Km^2 or 25,813 hectares, according to Isaza and Morán (undated) or 425 Km^2 according to the Information Office of the Panama Canal Company (1980). For a long time, Lake Gatún was considered to be one of the largest artificial lakes in the world and even today, after the construction worldwide of large reservoirs, mainly for hydroelectric purposes, it continues to be one of the largest.

Another dam on the Río Chagres, above Lake Gatún, forms an artificial lake called Alajuela, or Madden, covering 52 Km^1 or 5,163 hectares (Isaza and Morán, op. cit.), which is used to regulate the level of Gatún Lake. These two reservoirs also supply water and some electricity for the third of the population of the country who live in Panama City and Colón. The

lakes occupy 9,4% (ibid.) of the area of the watershed.

The Panama Canal watershed is the most extensive of the three watersheds studied, occupying 326,255 has. (AID, 1978), that is, about 2.5 times (2.68) that of the La Villa watershed and 15 times (14.5) that of Caldera. It is also the most important watershed in Panama, since Lake Gatún is the one that supplies the water for the operations of the locks and constitutes close to 50% of the waterway of the Canal as well.

The annual average of water entering Lake Gatún has been calculated at 53 million cubic meters while the water used from it in the operation of the Canal is 18 million cubic meters, to which 8 million cubic meters in evaporation have to be added. The passage of each ship presupposes a loss of 90,000 m^3 (Creaciones Publicitarias Santanach, undated). This positive balance may be reduced in very dry years. Alajuela Lake has a maximum storage capability of some 579 million cubic meters and a useful capacity fo 428 million cubic meters (Isaza and Morán, op.cit.).

The Panama Canal watershed can be divided conveniently into two parts by the Canal. The eastern part of the watershed has an area of 103,150 has. (ibid) and a rectangular shape, limited by an extension towards the West of the San Blas Mountains and by the ridges projecting from this range toward the southwest and by Lake Gatún and the lower part of canal itself. From the San Blas Mountains, the rivers Gatún, Pequeñí, Boquerón, and Chagres wend toward the southwest. The length of this section is some 45 km. and the width some 58 km. It is also the section with the most pronunced slopes in the watershed and Lake Alajuela is located in it.

The western part of the canal has an area of 223,075 has. (ibid) and more than half of Lake Gatún is located in it. The base of this part is the same as the eastern part. It is constituted by the canal and its prolongation along the lake. This part of the watershed extends narrowly to the southwest and two parts may be recognized, one corresponding to the south of Lake Gatún through which a series of rivers run from south to

orth and a prolongation toward the south of the extreme southwest of the lake, which comprises the long, narrow watersheds of the Trinidad and Cirí rivers. These descend from the continental divide formed by a mountainous mass constituted of Gairal and other peaks, which is an elongation toward the east of the Central mountain range. The total width of these two smaller watersheds varies between 10 and 15 kilometers and their length, up to Lake Gatún, is some 35 kilometers. The length of the western part, running northeast to southwest, is some 40 kilometers and the width running northeast to southeast is some 28 km.

The rivers Palenque, Gatún, Agua Sucia, Agua Salud, and Frijolitos, among others enter Lake Gatún on the east. By way of the Chagres river, the rivers Boquerón, La Puente, Pequeñí, with its principal tributary, the San Miguel, and Indio, with its principal tributary, the Cascadas, make up Lake Alajuela. Above this lake, the Chagres receives the rivers Agua Clara, Palenque, Guatucillo, and Chilibre with its principal tributary, the Chilibrillo.

The rivers Cirí, with its principal tributary the Chutral, Trinidad, with its principal tributary the Cacao, Gigantillo, Las Hules, with its principal tributary the Linajones, Riecito, with its principal tributary the Zaíno, and Paja, among others, all enter Lake Gatún on the west.

The Panama Canal watershed extends onto the Atlantic slope, approximately to the north of the continental divide, which lies closest to the Pacific Coast that is, about 14 kilometers inland from it, although in some sectors it is much farther away. A good part of the Atlantic watershed is made up of lowlands at an elevation below 100 meters. The level of Lake Gatún is 26 meters above mean sea level.

To the north and northeast, lies the most important mountain range in the watershed, which is, as mentioned earlier, the elongation to the west of the San Blas range. This separates the watershed from the narrow coastal strip to which flow the rivers Cascajal, Cuango, Culebra, and

Mandinga, among others. This range, which is higher than 400 meters above sea level (except in the depression where the Boquerón River is born, which is about 200 meters), reaches its greatest altitude in Bruja Peak. From this peak, a branch goes southwest to separate the Río Gatún watershed from the coastal strip. This branch descends almost to Río Gatún. In the other, eastern extreme of the watershed, the range reaches a peak at 920 meters from which another ridge goes southwest to separate, in that direction, the Panama Canal watershed from those of rivers flowing to the Pacific Ocean on that side, among which are the Juan Díaz, Cabra, and Pacora. This branch reaches its greatest altitude on Jefe Peak, at 1,007 meters elevation. This is one of the highest peaks in the watershed and the highest in the western part of the watershed.

On the south and southeast, the watershed borders on the continental divide which is on the average, 15 km. from the Pacific coast. This divide is relatively low: rarely surpassing 200 meters in some places, as in Patacón Peak which is 215 meters. To the south of Alcalde Días and east of Las Cumbres, however, this small sierra rises to 445 meters at Peñón Peak. Towards the western part of the watershed, this small range continues in a more continuous way, wider in some places and narrower in others, until it rises to Almuerzadero Peak, at 597 meters and continues south by the Trinidad mountain ridge to Campaña Peak, outside the watershed. On Trinidad Peak, another of the highest points in the watershed is reached at 1,100 meters of elevation. Here, a small mountain with steep ridges of marked beauty is formed: the so-called Llorón mountain range, which divides the waters that go to Río Trinidad from those that go to Caimito and its tributary, the Perequete. This last flows into the Pacific. Also, on this mountain range, besides Trinidad Peak, are Valoli peak of 737 meters, Tusa of 796 meters, Llorón of 925 meters, and Los Monos of 893 meters.

From Los Monos Peak, the continental divide continues generally to the west to Chichibalí Peak at 907 meters elevation, passing along Peña Blanca Peak at the same elevation and separating the watershed of the Trinidad-Cacao from the waters that flow toward the Pacific by way of Río Chame. From Chichibalí Peak, the continental divide turns southwest

surpassing 1,100 meters with a series of apparently unnamed heights reaching 1,145; 1,112; 1,154; and 1,128 meters. The last of these peaks is located to the southwest of Pelado Peak at 1,185 meters of elevation, probably the highest point in the entire watershed. This range also divides the watershed of the rivers Cirí-Chutral that flow to Lake Gatún from the watersheds of the rivers María-Chame and Mata Ahogado, that flow to the Pacific.

Pelado Peak forms part of the same mountain mass that joins Gairal Peak at 1,185 meters of elevation and several others that constitute a sort of orographic star where a number of rivers that flow in different directions originate, among them the Cirí, the Indio, the Taobre-San Miguel, tha Zaratí, the Estancia, the Antón, the Farallón, the Las Guías, and the Mata Ahogado.

From Pelado Peak the western border of the Canal watershed continues a general south-north direction by way of a ridge that is more than 1,000 meters high and reaches its most mountainous at San Andrés Peak at 1,026 meters of elevation, a little displaced from the continental divide of the watersheds of the rivers Cirí and Indio-Terial, the latter flowing directly to the Atlantic.

A peak with no known name southeast of San Andrés, 1,054 meters in elevation, lies on the boundary of the Canal watershed there. This continues in a general south-north direction, descending almost to 400 meters and passing by Negra Peak at 458 meters, the hills called La Gloria and Nance at 350 meters, Tería Peak at 425 meters, the hill Mangle at 463 meters, El Tigre Peak at over 425 meters, and a series of unnamed peaks with heights of over 400 meters. Arriving South of the Las Petras summit at under 300 meters, one encounters the Tería Peaks, at 348 m., having the same name but different from the earlier mentioned peak, where the watershed boundary continues in a general northeast direction but with many curves passing by the La Encantada summit at 269 meters, Ajo Peak at more than 350 meters, and other heights of 365 meters which divide the Indio and

Ciricito watersheds and those of other rivers of minor importance that flow to Lake Gatún. The boundary of the watershed on that side finally reaches hills that are very close to the shores of Lake Gatún itself.

These small hills divide the lake from the streams that flow to the Atlantic, amongst which is the Río Lagarto. The same lake shores make up the northeast boundary of the watershed, which continues to the dam of the Chagres in the Gatún site and after this, in a northeast-southwest direction, passing by several military installations of the old Canal Zone to the south of Colón, reaching the northeast extreme of the lake where the boundary is the divide between Lake Gatún and the short streams that flow directly to the Atlantic, as mentioned earlier.

The southern and part of the eastern borders of the lake are more irregular than those of the northwest and form numerous entries and exits, or bays, inlets, and peninsulas. Also, on the lake there are several islands, made up of ancient peaks and hills that were isolated and surrounded by water. Among these islands are La Zorra, Juan Gallego, and the famous Barro Colorado, now declared a Natural Monument for being a natural reserve of tremendous scientific value and for its numerous and important natural science investigations.

Geologically, the Panama Canal watershed in its low part is made up of undifferentiated sedimentary rocks, mostly acillolites, limolites, and shales, sometimes mixed with calcareous tuff. In the western high part of the watershed, there are volcanic rocks with mixtures of undifferentiated sedimentary rocks, and in the southern part, volcanic formations with conglomerates, tuffs, lavas, and other meteorized mixtures. In the vicinity of Lake Alajuela, there are formations of calcium and calcareous shale (Comisión de Reforma Agraria, 1967).

The climate of the Panama Canal watershed is isothermic because of conditions imposed by its latitude, and, because of its low elevation in general, it is macrothermic, with median temperatures generally greater

than 24º and even 26º and 27º, as mentioned earlier. The rainfall, as mentioned, is between 1,500 and more than 4,000 mm. in annual averages, and for this reason constitute a humid to perhumid climate. Supermoist conditions and cooler temperatures characterize the higher parts of the watershed, which are the ones that generally receive the greatest rainfall. In those parts there are also large concentrations of clouds, producing characteristic "cloud forests", true wet - atmospheric associations. The identification and delimitation of the life zones, one of the primary objective of this study, characterize the climatic conditions of the watershed in detail.

In spite of the extensive area of the watershed, its climatic conditions are not very variable. For the most part, the climate corresponds to that of the Tropical moist forest life zone.

The natural vegetation, as will be discussed in more detail for each life zone, is comprised of different forest types and includes numerous species of broad leaved trees and lesser plants, including a great number of palms and tree strata of variable densities, height, and size, according to the different associations and life zones present.

Over the greater part of the area, the primary natural vegetation has been completely or considerable altered, being replaced largely by pasture, crops, and urbanized areas or areas otherwise altered by human activity. According to the information of Isaza and Morán, 47% of the primary vegetation in the watershed had been destroyed before 1976. Between 1952 and 1976 the deforested area went from 50,000 to 153,188 hectares, that is, from 12% to 47% , according to the same source. According to data from the Document of the Watershed Management Project (AID, 1978), however, the wooded area decreased from 83% in 1952 to 32% in 1978. That source estimated an additional deforestation of 7,000 hectares during 1978 and a total disappearance of primary forest by the year 2000 if the present rate of deforestation is maintained.

The deforestation of the watershed has been a consequence of the system of shifting cultivation, or felling, burning, and abandonment after a short crop cycle that has been practiced traditionally in the watershed, with severe soil deterioration and the production of sediment that is deposited in lakes Gatún and Alajuela.

In Lake Alajuela, the annual rate of sedimentation has increased by 200% in recent years and hydrological studies indicate that by the year 2040, 80% of its water storage capability will have been lost due to sedimentation (AID, 1978). Some areas within Lake Alajuela have been covered by sediments to a height of 6.60 meters, in 1979, probable date of the publication of the pamphlet of Isaza and Morán, with the consequent decrease of its water storage capability. For another thing, the conditions of eutrophication of the lake are between moderate and severe and those of Lake Gatún are definitely severe (Isaza and Morán, op.cit.).

The production of sediments in the entire Panama Canal watershed has been estimated at more than 9 million cubic meters per year (AID, 1978). With the increase of pasture land in the area, on steep slopes and with grasses such as the jaragua, the production of sediments will increase at a rate calculated to surpass 15 million cubic meters per year by the year 2000 (AID, 1978).

The extensive grazing on steep slopes that has replaced the natural or secondary forest, is therefore another land use intensifying deterioration of soil and, in general, of the environment. Due to the low yields in migratory agriculture, the tendency is to give the abandoned lands over to extensive grazing rather than to natural forest regeneration. The grass that is commonly planted is jaragua (Hyparrhenia rufa). This grass grows in the form of clumps rather than extending to form a continuous sward which would cover and protect the soil. Due to grazing that compacts the soil and reduces infiltration of rainwater, this type of grazing and this type of grass cause serious erosion, produce a great deal of surface

runoff and sediments , and notably decrease the productive capability of the soil. This system of cultivation of pasture is very much rooted in the culture of the population of certain regions in Panama, such as that of the Santeños. It has been described and its effects and cultural relationship has been widely discussed in several studies by Stanley Heckadon Moreno (1978, 1981).

People from the subhumid tropical zone of Los Santos and Herrera that have been deforested ever since the Colonial period under such a system, principally of extensive grazing following shifting agriculture, have subsequently spread out to other, more-humid regions in the country, including the Peninsula of Azuero, to which they have transplanted this cultural systmm of land use onto lands which are less appropriate for it. The consequence of this transferrence from subhumid to humid areas, has been the destruction of vast forest areas and their conversion to fields in the process of accelerated erosion where the productive capability has been lost. As a consequence, it has been necessary for them to repeat the same process in other forest areas with the same humid or even wetter conditions. There may be no stopping this process until total destruction of forests in Panama is reached, and until soil regenerative capability is lost and production under other uses more compatible with the environment, through more appropriate systems of agrotechnological management, is impossible. The most dynamic and aggressive ethnic group in this process of colonization has been the Santeño campesino, according to Heckadon (1979).

The uncontrolled colonization of originally forested areas in the humid tropical regions has been considered the most critical problem in Panama, with respect to environment (ISTI-AID, 1980). The colonization is carried out by campesinos from the "interior", that is, from the overly populated plains of the Pacific slope of the Isthmus, among others from the provinces of Herrera, Los Santos, and Chiriquí. The main areas of colonization have been the litoral region of the Caribbean in the provinces of Colón, Veraguas, Bocas del Toro, and the eastern region that

includes parts of the Pacific slope as well as the metropolitan region in which the Panama Canal watershed is located (ISTI-AID, 1980).

The colonization of the Metropolitan and Eastern regions started in the early 60's (McKay, 1971). The province of Los Santos lost 30 percent of its population between 1940 and 1960, through migration to the central part of Panama (C.G.T., 1965).

The causes of the colonization process are very complex (McKay, 1971), originating in a profound transformation of the Panamanian agrarian society during this century. The scarcity of lands originally used for grazing and for other types of agriculture in subhumid tropical life zones, and their depletion and deterioration by inappropriate and abusive use, as well as the tenancy systems originating in the Spanish colony, a population growth well-above the available natural resources, have all been causes of this migration, which has led not only to colonization of forest areas elsewhere but also to migration to the cities, especially to the Panama City and Colón Metropolitan areas, as well as to other small neighboring urban centers in the Panama Canal watershed (IISTI-AID, 1980).

The increase in the level of assistance in health,, education, and other services, and the formation of an internal market, especially for beef, have been other causes of these migrations (Heckadon, 1979). The construction of regional roads promoted by the government for the improvement of the standard of living of the poor campesinos, has contributed inmensely to the colonization process and to the destruction of the natural forest (ISTI-AID, 1980). A genuine consciousness of the value of forest resources does not exist in the country; the forest is actually considered a symbol of underdevelopment. Nor does a technology exist that would allow for taking advantage of the forest without degrading it. The public does not understand the significance of environmental quality nor the value of natural resource conservation. The development plans for the

country generally reflect this attitude (ISTI-AID, 1980).

The human population in the Panama Canal watershed has undergone drastic changes in the last 70 years, due to the construction of the Canal and to the growth of Panama City and Colón. However, the most rapid changes have taken place since the Second World War (ISTI-AID, 1978).

The greater part of the rural population in the Panama Canal watershed is mestizo, although there are some Chocóe Indians as well as blacks with a Colombian ancestry (AID, 1978). The greater part of the population is dedicated to farming in small private holdings under slash and burn systems; around 13 percent are cattlemen, and less than 5 percent live in organized settlements (AID, 1978).

a) TROPICAL MOIST FOREST

This is the life zone of greatest extent in the watershed, since it occupies 90.45% of the area or 285,070 hectares. It predominates over almost all of the lowlands, in terraces as well as in the hills, including the surroundings of the Canal and of Gatún and Alajuela Lakes.

The Tropical moist forest life zone is found in the watershed at elevations under 400 meters above sea level, except in some small hilly areas, where it may reach as high as 600 meters.

Where possible, the perhumid transition of this life zone, located, in the northern sector near Buena Vista and Río Gatún was differentiated on the map.

Bioclimatic conditions: this life zone has limits of average annual rainfall between 2,000 and 3,100 mm., and limits of biotemperature from 24º to around 25ºC.

Vegetation: the primary vegetation of this life zone has been considerably altered and over large areas completely destroyed, due to agriculture and grazing. The primary natural forest has three tree strata, the highest surpassing 30 meters, and the largest stem diameters are one meter or a little more. It is possible, however, to observe considerable differences in the physionomy and composition of the vegetation in the different edaphic associations. Such is the case of those found on soils derived from limestone rocks where the vegetation has an appearance that would correspond to the climatic association of a drier bioclimate. The greatest edaphic dryness (aridity) that this type of rock and these soils present is due to the greater speed of filtering by waters derived from it. On the other hand, the fine red clayey soils of some hills apparently retain more moisture, and therefore, the vegetation that grows there seems to correspond to a more humid bioclimate. The first case, of soils derived from limestone, is found in the vecinity of Lake Alajuela, and the second, of very fine textured soils, on the road to Agua Salud.

Among the native tree species characteristic of forests in this life zone are: Bombacopsis sessiles, Scheelia sp., Sterculia apetala, Apeiba tibourbou, Vochysia ferruginea, Hura crepitans, Genipa caruto, and Tabebuia rosea.

Upon the limestone soils, the following species, among others, are found: Bombacopsis quinatum, Parmenthiera sereifera, Calycophyllum candidissimum, Astronium graveolens, Cavanillesia platanifolia, and Triplaris sp.

Upon the hills of red clayey soils: Dipterix panamensis, Simarouba amara, Calophyllum sp., Luehea seemmannii, Turpinia occidentalis, Xylopia sp., Didymopanax morototoni, Enterolobium schombourgkii, and Luehea candida, among others.

In the vegetation studies undertaken in different parts of the Panama Canal watershed, among them some sites that correspond to this life zone, the characteristics of the primary, degraded, and secondary natural vegetation are described in more detail.

Land use: this life zone is suitable for a certain type of agriculture, above all for permanent crops wherever soils edaphic conditions are adequate. Under exceptionally good soil conditions, annual or clean-tilled crops continuously or in long-term rotation with production forest are possible. Grazing is normally harmful, except on very good soils and on only moderate-to-low slopes under intensive management.

Actual land use in the watershed in this life zone, is mostly extensive grazing of beef cattle. The grass is most often seen to be in bad condition, "jaragua" (*Hyparrenhia rufa*) predominates, and, because it is not stolonipherous, does not protect the soil well. Overgrazing is notorious, as is also grazing on very steep slopes.

The most common seasonal crops are corn, beans, rice, and yuca, which are produced in the traditional way using, for the first three, the system called "roce" or "roza", that is, felling-and-burning. Permanent crops are scarce, the principal ones being coffee and some fruits such as citrus, avocado, zapote, mango, guanabana, and marañon. RENARE has been encouraging the cultivation of marañon for the last few years, as part of its reforestation and arborization programs.

It is important to point out the harmful effects that the "gramalote" (*Saccharum espontaneum*) has and continues to cause in open terrain. This grass was introduced into the Canal area in order to stabilize the side slopes of highways and other engineering works. With time, this impalatable grass became wild, reproducing and spreading intensely, invading fields under cultivation, with serious damage due to competition. It is maintained by annual wildfire and is therefore almost impossible to control.

b) TROPICAL WET FOREST

Tropical wet forest life zone has an extension of more than 14,028 hectares, which represents 4.3% of the watershed's area. This life zone is located in the northeast sector of Lake Alajuela which includes the sources of the rivers Gatún, Boquerón, and Pequeñí, and comprises sierra formations between 400-800 meters elevation. The relief is largely broken to steep but there are sectors of considerable size that present a rolling topography.

Bioclimatic conditions: the estimated mean annual rainfall in this life zone in the watershed varies from 4,000 mm., in the least-humid area, up to 4,500 mm. in the most humid area, under the influence of the winds from the northeast which are the ones that bring most ot the rains in that region.

Mean annual biotemperature is over 24ºC, except in the transition from this life zone to the Premontane altitudinal belt, where it decreases to about 22ºC at the upper elevational limits of the life zone.

Vegetation: because this life zone is located in a region of difficult access, a large part of the area remains in primary forest, which is well-developed, with trees as high as 35 m. and with diameters of more than a meter. The forest contains more than 3 arboreal strata, with a certain degree of epiphytism and numerous species of palms. Among the principal species are the following: *Socratea durissima*, *Cespedezia macrophylla*, *Swartzia panamensis*, *Virola*, sp., *Apeiba* sp., several species of *Annonaceae* and *Sapotaceae*, *Bernoulia flammea*, *Quararibaea* sp., *Saccoglottis* sp., *Manilkara* sp., *Hyeronima* sp., *Lecythis* sp., *Sloanea* sp., *Guarea* sp., *Carapa* sp., *Veconcibea* sp., *Moraceae*, *Myrtaceae*, and *Welfia* sp.

Land use: in spite of the difficult access, many of the

lands of this life zone in the watershed have been opened up for cattle ranching and recently, with the opening of a road of low specifications, lumber extraction has begun. The cattle ranching activity is carried out in the form of extensive grazing in areas of undulating relief. Also, some crops for family consumption are produced, such as corn, rice, yuca, and banana or plantain, in terrain recently incorporated into the agriculture and cattle activities by the felling and burning of secondary as well as primary forest. Some of these lands are located upon terraces and small colluvial areas.

The Tropical Wet Forest is not a favorable bioclimate for either agriculture or grazing activities due to its heavy rainfall. This life zone is more adequate for well-directed forest production, an activity in which the best yields can be expected. Also, this life zone is very important due the large quantity of water it provides for the canal.

c) PREMONTANE WET FOREST

The typical Premontane wet forest life zone area is a small one in the watershed, but the area occupied by this bioclimate in its Tropical basal transition (Premontane wet forest, Tropical basal transition), is of considerable extent. It covers, in all, some 5.04 percent of the area or 16,442 has.

It is located on high hills and low mountains mainly at elevations between 100 and 800 meters above sea level. One large continuous area of this life zones is found in the southwest extreme of the water shed; another, near Azul Peak, and the largest of all to the East of Lake Alajuela.

Bioclimatic conditions: the rainfall limits of this life zone vary according to the biotemperature in the watershed; average

annual rainfall ranges from around 2,500 to 4,000 mm., for non-transitional areas, and biotemperatures between 22º and 24ºC. The biotemperature of the Tropical basal transition is between 24º and 25ºC, with rainfall between 3,000 and 4,000 mm., as long-term annual averages.

Vegetation: a considerable area of primary vegetation still exists in this bioclimate, primarily due to the predominantly steep slopes and low natural fertility of the soils where it occurs.

The natural vegetation in this life zone in the watershed is dense, with tall trees with diameters only slightly smaller than those of the Tropical wet forest life zone.

The principal tree species observed in the non-transitional areas were: Calophyllum sp., Chrysophyllum sp., Cordia sp., Croton sp. (schiedanus), Clethra sp., Saurauria sp., Lonchocarpus sp., Zanthoxylum sp., Vernonia sp., Terminalia amazonia, Vochysia ferriginea, Euterpe macrospadix.

The following occur in the transition (to Tropical basal): Terminalia amazonia, Quararibaea sp.,Terminalia oblonga, Terminalia sp., (bucidoides), Anacardium excelsum, Pouteria sp., Ficus sp., Lecythis sp., Bernoullia flammea, Socratea durissima, Oenocarpus panamanus, Tachigalia sp., Platypodium sp., and Cespedezia macrophylla.

Land use: lands covered with natural forests predominate; however, in places near populated areas, this life zone in the watershed is utilized for grazing of steers and for the production of subsistence crops, among them, some grains and root crops. In some places that have been in pasture for several years, signs of severe erosion and compaction can be observed. The land is covered with sparse grasses, is in a poor state of growth due to high rainfall, which limits land use for agriculture and grazing activities to small localized extensions with more favorable conditions, which are scarce in this life zone in the watershed:

lands used for grazing have generally steep slopes and inherently low soil productivity.

d) PREMONTANE RAIN FOREST

The area with this bioclimate is relatively small, approximately 685 hectares, which represent only 0.21 percent of the area of the watershed. It is located on the upper ridges of the mountains to the east of Lake Alajuela, at elevations greater than those of the Tropical wet forest life zone, that is from 800 to 900 m.a.s.l.. A great part of the land is very steep with slopes greater than 80 percent.

Bioclimatic conditions: The average annual rainfall in this life zone in the watershed is higher than 4,000 mm. and it was estimated that at its maximum point it reaches 4,500 mm. The biotemperature should oscilate between 22 and 21°C in the lowest and highest parts respectively.

Vegetation: this life zone's major area is covered with the original natural forest which is characterized by a very high tree density and a great deal of epiphytism. As in the Tropical wet forest, palms are very numerous. In certain sectors, the forest is dwarfed due to the slight depth of the soil.

The principal species are: Protium sp., Clusia sp., Vochysia jefensis, Clethra sp., Socratea durissima, Welfia sp., Euterpe macrospadix.

Land use: man has scarcely modified the natural conditions of this life zone in the watershed at all, partly because of its difficult access, and partly because of its low economic potential. For these reasons, the major part of the area is conserved as original vegetation, which should be protected to maintain the ecological equilibrium and thus to ensure good quality and regulated water production for the use of the Canal.

2. Río La Villa Watershed:

Six life zones were differentiated in the Río La Villa watershed (see Map Nº 2). Two of these are represented only by basal belt transitions Premontane dry forest, and Premontane moist forest. All the life zones identified belong to either the Tropical basal or the Premontane altitudinal belts. The former extends from 0 to 600 meters the latter from 600 to 918 meters above sea level which is, at the same time, the maximum elevation encountered in the watershed. There are four humidity provinces included: Subhumid, Humid, Perhumid, and Superhumid. The first three are well represented while the fourth is only a tiny fraction. In general terms, the lower part of the watershed is subhumid (dry) the medium part humid (moist), and the high part perhumid (wet).

General characteristics:

The Río La Villa Watershed is located in the eastern part of the Azuero Peninsula between 7º 34' 03" and 8º 00' 10" latitude north and between 80º 21' 09" and 80º 49' 04" longitude west. It has an elongated shape, with a narrowing in its lower part and a widening in its higher part. It occupies 122,000 has. in the provinces of Herrera and Los Santos.

The La Villa river has a length of some 108 kms; it originates on the eastern slope of the Western Azuero Mountains and flows into the Gulf of Parita. Its important tributaries are the Las Matas, Tebario, Estibaná, Gato, and Espiguita rivers. Río La Villa supplies water to the communities of Chitré and Los Santos, considered as development poles in the urban plan. More than 45 percent of the population of the Azuero Peninsula lives in the watershed of this river.

The La Villa river's watershed has a greater ecological diversity than that of the Canal river, in spite of the fact that it is smaller. It is located in the driest part of Panama, which lies near the mouth of Río La Villa and extends along part of the coast of Parita Gulf. Rainfall increases progressively toward the interior or upper part of the watershed.

The lower part of the watershed is a lowland plain of marine and alluvial deposits, recent or subsequent. Here the coastal and alluvial plains and, closer to the coast, the mangroves and beaches, stand out as the important landscape features.

On the alluvial plain, there are vestiges of abandoned river meanders, Behind the natural levee there are more or less extensive recent river terraces.

Low hills of tertiary origin, mainly sandstones, predominate in the middle part of the watershed. The hills are grouped, usually in chains, between the wide terraces of Río La Villa and its tributaries, or between the narrow valleys of those rivers. In some cases, two terrace levels can be observed.

The highlands are made up of low mountains of cretaceous sediments among them clay and siltstones, with a low degree of metamorphism. It is probable that thereare also limestone deposits. In certain areas, the igneous material from the center of the mountain chain crops out in the form of granitic or granodioritic rocks. Amongst the mountain chains, Canajagua Peak of terciary origin stands out. The interior valleys stretch out and extend far into the mountain chains.

Along with the quite active processes of deposition and erosion, volcanic and tectonic processes are also recognized to exist. Quema Peak, near but outside the limits of the watershed, is cited as an extinct volcano as is the so called Nuco de las Minas. The terrain has numerous geological faults.

The primary natural vegetation has been completely destroyed in almost the entire watershed. In the lower part there are still areas with mangroves and a short distance inland from the coast are the ramains of a forest, characteristic of the subhumid or semiarid life zones, which has

a number of dediduous species. In the upper part, there are still the r mains of primary vegetation, albeit degraded. Such is the case of the areas neighboring Canajagua Peak, Pitalosa Peak, and in the vicinity of Chepo de Las Minas, the last of these being located outside the watershed. The Montuoso Forest Reserve, 13,040 has, includes this place and, while located outside the watershed depends on the Río La Villa Project for administrative purposes.

The secondary forest has been reduced to isolated patches. Grasses constitute the predominant vegetation. These are generally spontaneous species that were introduced at some point to form pastures. There are areas with cultivated grasses, others mixed with native and spontaneous grasses and even with improved grasses. The grasses are normally mixed in different proportions with secondary forest vegetation in its earliest stages of succession. The invasion of secondary species indicates the state of neglect of pastures and the difficulty of keeping these weed-free in the humid and perhumid life zones. The felling of forests and fire have completely transformed the natural landscape of the watershed. This process, initiated a long time ago in the subhumid zones of the watershed to give the lands over to grazing, has subsequently encroached on the humid and perhumid zones, with severe consequences of erosion and alteration of the hydrologic regime

On the level subhumid parts with good soils there are, along with grasses, some clean-tilled crops, even intensive ones, such as vegetables, or mechanized ones, such as sorghum and corn. In the middle, more humid part, along with grasses, there are extensive crops of sugarcane on the terraces. This cane is processed in a local sugar mill. Part of the product is utilized for making a popular liquor in the region.

Some arboreal fruits, almost spontaneous, like the mango, grow on the roadsides, on some riversides, or along fences, or isolated between the pastures. Other fruit trees are cultivated in small family orchards,

along with several clean-tilled subsistence crops. In the highest and coolest part of the watershed, coffee is cultivated. Coffee cultivation has increased in the last few years, at the expense of the natural forest. Part of the coffee is grown beneath the trees of degraded primary forest.

Forest plantations are limited to small areas of an almost experimental or ornamental nature. Pinus caribea stands out the most and grows the best. There are also some parcels with teak, Tectona grandis, and melina, Gmelina arborea. The Community Forest of Macaracas is an interesting example. It contains several experimental plots for testing species-adaptation and growth in a number of timber species as well as being a natural vegetation reserve in an extensive area otherwise almost completely devoid of trees.

The results of this deforestation and grazing industry on the sloping lands of the humid life zones has been accelerated soil erosion and a high level of river sedimentation. The contamination of the La Villa river is serious also, due to agroindustrial and domestic waste disposal therein.

The La Villa river watershed is quite a characteristic example of a watershed with serious problems due to improper land use and the absence of a management plan. Due to its morphometric, geomorphological, soil, climatic and economic characteristics, as well as its medium size, the La Villa river watershed could be an excellent example for the formulation and application of a pilot plan of watershed management and territorial planning with ecological and socio-economic bases.

The above roughdraft of the watershed was based on field observations complemented with data from the "Watershed Management" project, "Río La Villa Watershed Management", Subproject, MIDA-RENARE, Los Santos, Panamá, 1981.

a) DRY TROPICAL FOREST

This life zone is located in the lower inland part of the watershed being separated from the ocean by a strip of land that corresponds to Premontane dry forest, Tropical basal transition. It covers approximately 39,729 has. which represents 32.56 percent of the total area of the watershed. The terrain, for the most part, is level. There are only a few hills from 100 to 220 meters above sea level in its transitional part to the Humid province.

Bioclimatic conditions: within the areas of this bioclimate there is only one representative meteorological station, Los Santos. The average annual rainfall at this station is 1,113 mm. and average annual temperature 27.5ºC, which corresponds to an average annual biotemperature calculated at 24.7ºC.

Rainfall has an abnormal distribution over the year. There are two marked seasons, one rainy and one dry; the latter is longer than is usual for this life zone, corresponding to monsoonal rainfall pattern.

The precipitación limits for this bioclimate vary between 1,000 and 1,500 mm. per year; the biotemperature is estimated as varying between 24.5 and 24.8ºC.

Vegetation: in the watershed, the original vegetation of this life zone has been totally destroyed. This was one of the first regions in Panama to be colonized by the Spaniards who employed native agricultural and imported grazing practices which entail the destruction of the primary forest. At present there remain only a few isolated trees from this forest, scattered over the vast cattle pastures. The principal species are: Copaifera aromatica, Pithecolobium sama, Bursera tomentosa, Clorphora tinctoria and Cocoloba sp.

There are also other arboreal species having a wider natural range of distribution, such as: Andira inermis, Guazuma ulmifolia, and Enterolobium cyclocarpum;

Land use: the principal land use is extensive beef cattle grazing, although sugar cane and some grains and vegetable such as onion, tomato, and sweet pepper are produced on a small scale.

This life zone, being subhumid, is ecologically appropriate for intensive use of the land, although such use is limited during the dry season without irrigation. Within the watershed, the existence of certain areas with level terrain and moderate but not excessive rainfall during part of the year endows the zone with a potential for the production of seasonal crops. This potential can be increased if a project of supplementary irrigation is established.

b) TROPICAL MOIST FOREST

This is the most extensive life zone in the watershed. It is located in the middle and upper sectors and covers 36.41 percent of the area, or 44,420 has. Landforms are mostly hills and low mountains at elevations between 200 and 600 meters above sea level, although there is a small sector of Tropical moist forest in the "cool" or Premontane transition, near Chepo de Las Minas, where this bioclimate reaches approximately 800 meters.

Bioclimatic conditions: as in the Panama Canal watershed, rainfall limits in this life zone are from close to 2,000 to 3,100 mm., annually, on average. It includes populations like Las Minas and La Mesa with rainfall records of 2,283 and 2,500 mm., respectively.

Biotemperature varies between 22 and 25ºC. A great part of this life zone includes an atmospheric association of the monsoonal type.

The rest is represented by the climatic association with respect to rainfall distribution characteristics. There are a series of edaphic associations as well, due to special soil conditions, such as those of the terraces.

Vegetation: Basically, the forest includes the same species cited for the Panama Canal watershed, except for those corresponding only to areas of limestone soils which were not observed in this watershed. Also, the species Dipterex panamensis was not found, possibly due to a somewhat longer dry season in this watershed as compared to Canal's for this life zone. Also in contrast to the Canal watershed, the palm Acrocomia vinifera occurs, although in an isolated and scattered form, since this palms appears more frequently in the Tropical basal belt transition of the Premontane moist forest life zone. In like manner, the incidence of Scheelea sp. is much less than in the Panama Canal watershed.

Land use: Land use is similar to that of the Panama Canal watershed in this same life zone, that is, extensive grazing and some subsistance crops. However, there are great problems appearing here in land productivity, and these will grow even worse in a few years, due to accelerated erosion occurring in the steep terrain that predominates. The greater part of the surface of this life zone area is not suited to grazing, nor for many types of farming, basically due to the overly steep slopes and to the low natural fertility of the soils.

c) PREMONTANE DRY FOREST

No typical areas of this life zone but only its Tropical basal belt transition are encountered in the watershed. This transition covers a small area, 2.92 percent or 3,562 hectares. Located in the lowest part, from sea level up to some 20 meters of elevation towards the

east of Chitré, the greater part of the lands it covers are flat, have poor drainage, and include mangrove swamps.

Bioclimatic conditions: it constitutes the sector with the least rainfall of the watershed and probably of all Panama. This should be slightly less than 1,000 mm. as an annual average. Although there is no representative weather station within the watershed, the climatic data was deduced from the Los Angeles station, located relatively nearby, which registers 980 mm. as an annual average. Biotemperature hardly varies in this bioclimate being in the order of approximately 24º C. Air temperature, conversely, is very high.

Vegetation: the primary forest vegetation has completely disappeared; only small clumps of secondary forest and isolated trees that have been left within pastures can be observed. Some of the species are common in the nearby life zone (Tropical dry forest); nonetheless, there are places with quite different taxa, due more than anything to special edaphic conditions, possibly to poor drainage and salinity.

The principal species observed were: Caesalpinia coriaria, Prosopis juliflora, and Acacia farnesiana; as well as Hypomane mancinella, Clorophora tinctoria, Guazuma ulmifolia, Sciadodendrom excelsum, and Genipa caruto.

In mangroves that have not yet been exploited, as in areas near the mouth of the La Villa river, trees some 10 meters tall and some 15 centimeters in diameter are found of Rhizophora mangle, Laguncularia racemosa, Avicenia nitida, Avicenia bicolor, Pelliciera rizophorae, and Conocarpus erectus.

Land use: a great part of the area, given its conditions of flat relief and poor drainage, is practically unused, except for salt evaporation pans and for commercial shrimp farms, in some places. The

part with the best drainage has fair conditions for conventional agricultural and cattle grazing, due to its fertility. Negative factors include a high ground water table and salinity. At present, these firm ground soil sectors are utilized for extensive grazing and in some cases for grain production.

d) PREMONTANE MOIST FOREST

The typical Premontane moist forest life zone is not found in the watershed either, but only its "warm" or Tropical basal belt transition, which has an extension of approximately 264.5 Km^2, or 20.80 percent of the total area. It occupies an intermediate position between the Tropical dry forest and the Tropical moist forest life zone. Geographically, it is located where the flat coastal lands end and where the climb to the uplands begins. Generally, the landscape is comprised of low hills or of the lower parts of the mountains that rise up slowly. The greater part of the area falls between 100 and 200 meters above sea level.

Bioclimatic conditions: Average annual rainfall in the areas of this life zone in the watershed oscillates between 1,560 and 2,000 mm. The distribution of the rainfall throughout the year is not normal, the dry season being longer than the 3 1/2 months that would be considered normal in this case. For this reason, the area has a characteristically atmospheric-type or monsoonal association. The average annual biotemperature is greater than 24ºC and probably reaches 25ºC.

Vegetation: As in the entire La Villa river, watershed, the original forest vegetation has been completely destroyed. The only forest that remains is the one called "Communal Forest of Macaracas", which is small, has suffered a great deal of human intervention, and is located on shallow soils.

The dominant trees in this forest have a maximum height of 22 meters and diameters up to 100 cms. The principal species are: Dalbergia sp., Enterolobium cyclocarpum, Astronium graveolens, Ficus sp., Spondias mombin, Crataeva tapia, Licania arborea, Sciadodendron excelsum, Cedrela mexicana, and Bursera simarouba.

Other arboreal species observed in this same life zone were: Hymenea courbaril, Albizzia caribea, Luehea candida, Platymiscium pinnatum, and Acrocomia vinifera.

Land use: land use is similar to that of the Tropical dry forest life zone although, due to the topography which in this transition is more uneven, cattle grazing predominates even more. There is also grain production by transitional systems and very few plots of garden vegetables. The bioclimatic conditions of this life zone are quite favorable for agriculture and cattle production; however, in this particular case, soil fertility -varying between low and moderate- restricts its potential. Also, the slopes -from moderate to steep- limit grazing and annual crops. If the mild climate is combined with the edaphic and topographic conditions, it could be said that an adequate use for the greater part of this zone's area are permanent crops, primarily of an arboreal type.

e) PREMONTANE WET FOREST

This life zone is found in the upper part of the watershed. It has a small extension, convering 6.21 percent of the watershed area, or only 7,576 hectares. A small sector is of a "warm" transitional nature and covers a few additional kilometers. This bioclimate, including the transition, is located on terrain of abrupt topography, in hills as well as mountains. The elevations vary between 450 and 800 meters above sea level.

Bioclimatic conditions: the typical life zone, as well as the transition area, have similar rainfall limits in this watershed. These limits are between 3,000 or 3,100 and 4,000 mm., annually. With regard to the biotemperature, it is different in each case. For the transition, it is between approximately 24 and 24.5ºC, while for the non-transitional life zone area the limits can vary between 22 and 24ºC. as an annual mean.

Vegetation: the vegetation is similar to that of the Panama Canal watershed, although it is worth noting that the species *Weimmania pinnata* was found here. Also, this life zone in the La Villa river watershed was the only place that the native conifer *Podocarpus* sp. was observed, a species that possibly exists in the Río Caldera wastershed as well.

Land use: as mentioned previously, the areas with steep slopes have pronunced limitations for agricultural and grazing use, because of the danger of erosion to which these soils are especially vulnerable, under three of four meters of rain per year. Consequently, clean-tilled crops and grazing should be excluded where such topographic and climatic conditions prevail. Such uses are even more restricted by the low fertility of these soils and, in general, by the soils of most of the watershed.

In spite of these limitations and the grave damage produced by grazing, as in all the aforementioned bioclimates, this activity continues to predominate.

f) PREMONTANE RAIN FOREST

Due to its extension, this life zone is of little importance and is found only in a small sector in the highest part of the watershed at elevations of 700 to 900 meters, some 260 hectares, or 0.21 percent of the watershed area.

Bioclimatic conditions: the rainfall in this life zone in the watershed may range between 4,000 and 4,300 mm annually and the biotemperatures between approximately 21 and 23ºC.

Vegetation: the vegetation is similar to that described for the same bioclimate in the Panama Canal watershed.

Land use: Ecology dictates that lands in this life zone be reserved totally to protective use under native natural vegetation.

3. Río Caldera Watershed:

The Caldera River Watershed is located in the northwestern part of the province of Chiriquí, in the district of Boquete, between 8º 37' and 8º 53 latitude north and between 82º 21' and 82º 33' longitude West.

The Caldera River watershed forms part of the Chiriquí river and has an extensión of 22,000 hectares (MIDA-RENARE, 1980) extending from approximately 230 meters where the Caldera river enters the Chiriquí, up to 2,500 meters, according to the AID report (1978) or up to 3,457 meters, which is the elevation of Volcan Barú, on whose eastern slope its sources are found, if one considers the volcano to be within the watershed.

The watershed has an elongated shape that extends approximately south-north to the elevation of Boquete, from which point it deviates approximately in a eastwest direction. In its lower part, it is quite narrow, with a width of less than 2 kms; it then widens in its middle and upper part to 10 km. The total length from northwest to southeast is some 29 kms., and the length of the double arc formed by the river's course, without counting its meanders, is some 38 kms.

The Río Caldera watershed can be considered as being divided into three main parts: low, middle, and high. The low part is made up of old terraces dissected by relatively deep canyons, with almost vertical side slopes and cliffs, as well as by alluvial fans with volcanic influences (MIDA-RENARE, op.cit.), In this part, Caldera river flows against its right bank from which enter several small tributaries that flow through narrow canyons or "callejones" as they are known locally. These terraces are continued in the same way outside tha watershed towards the Río Cochea, Río Papayito, and Río Papayo watersheds, forming a well-defined landscape, of a wide terrace. On the left bank in this lower part, the Caldera river receives the waters of the Agua Blanca river, which runs from south to north, and its tributary, the Las Negras and others of minor importance that descend from the Guarico and Guacas peaks and flow to the Las Negras ravine by way of riverbeds shallower than those entering the right bank of the Caldera.

Inside the low part, some hills stand out, among them Guarico, Guacas, and Cabezón, with steep but short slopes, which separate the watershed of the Agua Blanca river from that of the Jaramillo and from several other streams of minor importance and of slight length that flow into the Caldera in its low end on the right bank.

The middle part of the watershed is made up of a small enlargement of the Caldera river canyon, as well as of its terraces and of the alluvial fans of the Palo Alto, the Grande, and the San Agustín rivers. In this enlargement is located the town of Boquete, which is the most important population center in the watershed, and which lies at an elevation of 1,100 meters above sea level. This middle part rises to the watershed limits on the east and north in the form of steep ridges. These form a division of waters beteween the Pacific and the Atlantic, the so-called "Cordillera de los Andes". This division separates the provinces of Chiriquí and Bocas del Toro. In them, the Pate Macho Peak stands out, with a height of about 2,200 meters. In this middle part, the rivers Palo Alto Pianista, and Palomo, between Palo Alto, Panista, and Horqueta peaks,

flow into the Caldera river on its right bank. These rivers join to flow into the Caldera above Boquete, and form an extensive watershed of steep mountains. On the eastern most side of the watershed, in this middle part, the San Agustín, Grande, and Aserrío, rivers flow into the Caldera. These streams rise in less-steep and lower areas than those entering on the right bank which rise in mountains of intermediate elevation. Some of the canyons through which these streams run are, however, quite deep and steep, like the canyon of the Grande river.

The upper part of the Caldera watershed begins at the mouth of Horqueta stream on the left-hand bank, and of El Velo stream on the right bank. In this part, the Caldera river has a course that runs approximately west-east from its source on the slopes of Volcán Barú, to change slightly to the southeast at Boquete. This high part is formed, by deep, steep canyons seperated by narrow ridges.

According to the MIDA-RENARE study (1980), the Río Caldera watershed is made up of igneous rocks, intrusive or extrusive, with a predominance of basalts and andesites. The volcanic deposits and marine sediments were submerged in the Pacific Ocean up to the Oligocene, at the time of orogenic formation of the mountain chain continuing up to the Pliocene, when there was pronunced volcanic activity, the intrusion of igneous rocks, and the fracture of these rocks as well as of the marine sediments. In the Quaternary, volcanic activity continued, the terciary sediments of the piedmont sank, and subsequent erosion led to the deposition of deep alluvium on these sediments. In the present epoch, there has been a decrease in volcanic activity, and the formation of entrenched streams through the dissection of terraces and alluvial fans and, finally, the evolution of the present-day landforms, such as Volcán Barú, the hydrovolcanic fans, and the associated cones and alluvial terraces (MIDA-RENARE, op.cit).

The massif of Volcán Barú has steep slopes of basaltic and andesitic rock dating principally from the Pleistocene and covered in good part by more

recent volcanic ash from which the soils have developed. Within this mountain mass there are a number of major peaks and deep canyons. To the east and north of the Caldera river, the basalts and andesites that crop out are more ancient than those of Volcán Barú and are overlain by poorer, more lixiviated soils, except above 1,200 meters of elevation, where a recent volcanic ash cover has rejuvenated them.

The ash deposits are found only in the upper part of the watershed, in the vicinity of and southwest of Volcán Barú. Ash deposits are related in location to the prevailing winds which, in this case, are the trade winds (idem),blowing from the east and northeast to west and soutwest.

The hydrovolcanic fans consiste of massive deposition of alluvial and volcanic materials in the form of fans and colluvium with a sandy or gravelly texture. The alluvial fans located above Boquete have been covered recently by volcanic ash and have given rise to very fertile soils. The most recent fans, below Boquete, have not been covered by ashes and have coarse textured, gravelly and stony materials. The soils derived from these materials are lithosols used only for extensive grazing. The rivers have carved deep vertical-walled canyons between the alluviums through which they flow (idem). The geomorphological, geographical, and geological characteristics mentioned are described in the MIDA-RENARE (1980) study cited and on the map of the watershed that accompanies it.

The climate of the Caldera river watershed is determined by its low-latitudes location as well as by the influence of the mountains. It is an isothermic climate, without variation or with slight variations in monthly mean temperature during the year (no more than one to three degrees Centigrade), and with differences in mean annual temperature due only to the range in elevations above sea level that exist in the watershed. Oscillations in daily temperature are less than 10ºC during the rainy months and between 10-20ºC in the dry months. Minimum temperatures are lower in the dry months, from December to February. Below-freezing temperatures may occur above approximately 2,300 meters and frosts at

ground level above 2,000 or 2,100 meters. The few stations that record temperature, records for other regions of Panama, and calculations for other countries with climatic conditions similar to those of the watershed, indicate an approximate change of 0.59ºC for each 100 meters change in elevation (idem).

The precipitation in the Caldera River Watershed is quite high, with variations in quantity and distribution related to the influence of topography and of altitude. The average long-term annual values vary between 2,000 and 5,000 mm., depending on the site. In the piedmont or outliers of the Volcán Barú massif, rainfall totals increase with elevation; at lower elevations, closer to the Pacific Ocean, in the province of Chiriquí, precipitation is on the order of 2,000 to 2,500 mm annually. It increases a little toward the interior, reaching above 2,800 or 3,000 mm, decreases to less than 2,000 in the lower part of the watershed, and then increases with elevation towards, the upper part, reaching above 2,000 and even 4,000 mm. in the northern part (idem).

The life zones of the ecological map of Panama (Tosi, 1971) and of the ecological map of this study offer very precise information on the maginitude and special distribution of the rainfall in the watershed, as well as of the variations in the average annual temperature. Suggesting higher rainfall than is indicated in the MIDA-RENARE, report, cited (1980).

In the diagnostic of the watershed (MIDA-RENARE, op.cit) there is some data on rainfall for stations located in or near the watershed, and analyses of its variation in elevations are made. In like manner, other climatic analyses are made, such as the rainfall variation coefficient, which is 0.22 for a 12 year period in the Bajo Boquete station and of 13-years at Finca Lérida.

The rainy season depends, as in all humid tropical and equatorial regions, on the passage of the intertropical convergence zone of low pressure over the region, which occurs from May to June and from September

to October, a period in which the most rain falls. However, according to the MIDA-RENARE study (op.cit), there are no synoptic documents of the regions to study the climatology of the area.

During the months from January to March, a high pressure zone lies above Panama, the intertropical convergence zone lying well to the South over the Amazon. For that reason, the northeast trade winds blow strongly and persistently, causing drought in the Pacific lowlands and light orographic rains on the exposed Atlantic mountain slope. The latter also affect the upper most parts of the Pacific slope. In this way, the dry season is from December to April and the rainy season from May to November over all but the upper parts of the watershed. In July and August, a slight decrease in the rains can be observed. This is called a "veranillo de San Juan". It occurs when the intertropical convergence zone moves to the north of Panama. The driest month is usually March and the rainiest month usually October, followed by May or June (idem).

In the diagnostic of the Caldera watershed (idem), there is a graph of the rainfall regime at the Planta Caldera station for a period of 18 years and in which the median frequency appears for the upper and lower cuartile. The regime and the frequency with which the values of 200, 400, and 600 mm. are exceeded in four years, in five years, once in two years, and once in five years, respectively, are presented on that graph. These data indicate the relative reliability of the regime which characterizes the entire Pacific slope of Chiriquí Province and, for that reason, of the Caldera river watershed, except on a strip of land about 5 km into the watershed from the division of waters with the Atlantic slope, where there are orographic rains, characteristic of the high parts of that slope, during the months of the dry season. This type of rain, generally not very strong, is called "bajareque" or "norte" in the region. This effect is apparent in the record for the Bajo Grande station, located 2.5 km. from the division of waters, and at Finca Lérida, at 4.5 Km. It is hardly perceptible at Boquete, at 9 Km. The December to January rains represent 19 percent of the total in Bajo Grande, 10 percent in Finca Lérida, and 3 percent in Boquete (idem).

The previous phenomenon allows for cultivation in areas such as those located at the height of Bajo Grande and Finca Lérida where there are substantial rains during what is normally the dry season in the rest of the watershed, but not in lower areas like Bajo Boquete or to the South of it, where these rains are insignificant or non-existent. According to the farmers, it seems that this phenomenon has increased in the last few years at mid-year, but there is no data to confirm or negate this affirmation (MIDA-RENARE, 1980).

According to the data at Bajo Boquete, there is great variability in the amount of rain from one month to another. The months with the greatest variations seem to be September, May, and April. October is more reliable, according to the graph of the star of frequencies for the Planta Caldera station (idem).

Rainfall intensity varies a great deal from one place to another; it is greater in the lower than in the higher parts of the watershed. In the low parts, intensities greater than 130 mm. per day and 60 mm. per hour are common one or more times a year; in the high parts, intensities of even 30 mm. per hour are less common. This data allowed for a calculation of the R factor of the universal equation for the determination of the soil losses by erosion (Wischmeir and Smith, 1965), which indicates the intensity of the rains, which concurs with the diagnostic of the watershed (idem) of R = 330 in Bajo Grande, at 2,300 m of elevation and of R = 2,800 at Planta Caldera, at 920 meters elevation with an intermediate value of R = 880 for the Los Naranjos station at 1,200 meters of elevation.

According to the diagnostic of the Río Caldera watershed (idem), direct solar radiation at the Bajo Grande station was 1,600 hours per year on average for the years 1982-1987, with minimum monthly values of 90 hours in June and July and a maximum of 220 hours in March. December, January, and February have values of 150, 170, and 190 hours, respectively, and the rest of the months of between 100 and 110 hours. El "bajareque" logically decreases the number of hours of direct sunlight because the

sky remains cloudy. At the Planta Caldera station, solar radiation is 2,000 hours per year, and in David, outside the watershed and closer to the sea, 2,400 hours (idem).

There is no reliable data (idem) on evaporation; this is logically greater in the dry season in which there is greater insolation and stronger winds. In the aforementioned diagnostic (idem) the possibility is mentioned of calculating the potential evapotranspiration solely on the basis of temperature; some estimates are made of the value of 60 mm. for the rainy months and of 120 mm for the dry months at an elevation of between 1,000 and 1,500 meters with an average value of 1,000 mm. These values seem low when compared to those if Holdridge's formula (1978) is used, a formula based only on biotemperature and through which it is possible to calculate that value with a great deal of precision.

According to the data cited by the Diagnostic of the watershed (idem), the Caldera River has quite a constant volumen of water flow. The relationship between the average maximum volume and the average minimum volume in 7 years (1963-1969) was only 2.1. For this reason the seasonal flow of water of the Caldera River is not characterized by a pronounced drawdown. This rather constant water volume is due to the permeable nature of the volcanic ash soils in the higher parts of the watershed and to the protection, afforded by the natural primary vegetation that the watershed still retains in these high parts.

The Boquete hydrological station that functioned during the years from 1963 to 1969 registered the data of a watershed of 10,900 has., indicates an average volume of 8.3 m^3 per second for those years, with an average minimum of 5.3 m^3 in March and a maximum of 11.2 m^3 in December. The average yield per unit of surface was, for that period, 76.1 m^3/second per square kilometer and a runoff equal to 2,400 mm. of precipitation as an average for the entire watershed (idem).

Since October of 1974, the station has been located upriver from the terminal of the Estrella Los Valles Hydroelectric Plant, with a drainage basin of 13,600 has. In the diagnostic of the watershed (idem) there is a graph of the Caldera's runoff along with that of the rainfall at Bajo Boquete and Finca Lérida, during the period 1975-1977. This graph shows that the peak runoff was in December of 1975, with a value of about 550 mm., while the minimum was in April of 1976, with about 110 m..

In spite of the constant volumen of the Caldera river, especially during the low-water period, there are still pronounced high water events, some of them disastrous such as that of April 1970 which produced great havoc. Because it is a torrential mountain river, it is difficult to measure these peak flows. Nonetheless, it is considered (idem) that the maximum instantneous water volume is over 400 m^3/second and was possibly more than 1,000 m^3/second in April of 1970.

An instantaneous volume of 4,000 m^3/second was calculated as the 100 years flood for the Estrella Los Valles Hydroelectric Plant. The highest flood peaks occur in the months between December and April, when the nort-eastern orographic rains fall. Serious flood events are also created by the occassional damming of the river by tree trunks and landslides.

The soils of the watershed are highly related to the parent material,to the topography, the climatic conditions of the region, and the age of those soils. On the slopes of Volcán Barú to Boquete, soils derived from recent volcanic ash predominate. The soils are deep, highly permeable, well-drained, of a granular structure, black -at least on the upper horizons- with abundant organic material, and of high fertility; they are the most fertile soils in the watershed, although they present problems of insolubility of phosphorus, like all soils derived from volcanic ash. Since they are the soils most cultivated with little care, they show signs of erosion, very marked in some cases. These are the soils whose management and conservation deserve the greatest priority because they are the most utilized,

productive, and valuable in the watershed. These soils have been classified as "Typic Dystrandepts" (MIDA-RENARE, op. cit).

To the east of Boquete, the predominant soils are also derived from volcanic ash, but ancient ash. These soils are deep, permeable, although in some cases they remain saturated with water due to the high, humidity of the climate. They are soils of steep slopes with stony phases in small areas. Near the rivers, the soils are superficial, since the original soils are buried beneath a shallow and less fertile alluvial deposit. The predominant soils are grayish-black to dark gray in the upper horizons; of granular structure, and of loamy or silty-loam texture. Their middle (B) horizon has silty-clay texture and a subangular structure; in the lower (C) horizon, they have a clay-loam texture, are without structure and of a light grayish-black color. They are soils that have lost part of their organic material and original fertility due to leaching over time and under the action of climate. They belong to the Andept suborder in which part of the organic material has separated from the alophane to become mineralized. They are classified as "Andic Humitropept" (idem) under the U.S. Soil Taxonomy.

In the lower part of the watershed, to the south of Cabezón Peak, soils derived from basic hydrovolcanic material predominant. In general, these are slightly or only moderately-deep or superficial soils, in part eroded, of a gray or grayish-red color, granular structure and loamy texture in the A-horizon, overlying a clay horizon with red an white mottles here and there. The soils to the east of Río Caldera are the oldest in the watershed, have very low fertility, and are very impoversihed by leaching and erosion; in places, they have stony phases. To the west of the Caldera river, in this southern part of the watershed, the hydro-volcanic deposits are more recent and have given rise to more fertile soils than those on the eastern side; however, they are very stony and difficult to mechanize. In general, the soils of the southern part of the watershed have been classified as "Oxic Dystropept" (idem).

The actual land use in the Río Caldera watershed was discussed previously, in the revision of literature in this ecological consultancy. There, it was mentioned that close to half of the watershed is covered by either primary or secondary forest vegetation, 36.5 percent by pastures without or mixed in different proportions with trees and brush, and 17.7 percent by crops, of which 8 percent are permanent crops, 4.8 percent horticultural crops, and the rest diverse crops for farm family subsistence.

Horticultural crops predominate in the upper part of the watershed, occupying the good soils under intensive cultivation. These horticultural crops constitute an important source of production for Panama, along with other high areas in Chiriquí province which, because of their climates, are the most favorable and almost the only areas for this kind of production in the country. Permanent crops, especially coffee and citrus, predominate in the middle part of the watershed toward the west; toward the east, pastures for dairy cattle. The pastures extend throughout almost the entire watershed in different conditions of maintenance and for either dairy cattle or beef cattle breeding stock, primarily. The upper part of the watershed is covered with primary forests where Volcán Barú National Park is located, as well as degraded and secondary forests (idem).

In 1970, the population density of the watershed was 34.4 people per square kilometer, less than in 1960, when it was 36.9 (idem). This decline in the population may be due to the floods of 1969 and 1970 (AID, 1978). In 1970, the population of the watershed was approximately 8,000 inhabitants, concentrated primarily along the river course (AID, 1978). The 34.5% of the population residing in the watershed live in populated places of more than 1,000 inhabitants; the population of Bajo Boquete was 2,614 people in 1970 (MIDA-RENARE. op.cit). The standard of living of the population in the watershed is a little higher than in other rural areas of Panama; the major source of income is coffee, although potatoes, vegetables, and fruit, as well as cattle, also represent important sources of income for the population; horticultural crops are grown on small plots, often smaller than 5 hectares (AID, 1978).

The Caldera river watershed, in addition to being an important region for horticultural, dairy, and coffee production, is important because Estrella Los Valles Hydroelectric Plant is located there. Due to steep slopes in many parts of the watershed, the high rainfall, and the intensive use of the land in certain parts, a watershed management program emphasizing soil management and conservation is vital to the rational use of this energy resource.

a) TROPICAL WET FOREST

This life zone is located in the lower part of the watershed, occupying 20.45% of its area. Its limits of average annual rainfall are approximately 4,000 and 4,500 mm. and biotemperature is estimated to be between 22 and 24.3ºC; these limits include the transition to Premontane or "cool" transition of the life zone which is found at 500 to 900 meters elevation.

In general, this life zone has conditions that are inappropriate for agriculture or grazing use, due to high rainfall, low fertility, and the moderate to steep slopes, as well as stoniness in many places. This condition of stoniness is in a certain way, favorable, since it facilitates infiltration of rainwater and to a great extent minimizes surface run-off. In spite of this decrease in the run-off, there is a sector in the lands bordering the Agua Blanca river where serious problems of erosion have been occassioned by the wrong use of soil. This sector includes part of the Premontane Wet Forest life zone, in its Superhumid transition as well. Possibly to correct or prevent these problems of erosion, small plantings of pines have been made in some places in this area; these don't seem to have responded very well to the desired objectives.

In some parts of this bioclimates there are remnants of natural forest, mostly exploited, however, the predominant activity is extensive grazing.

Among the most distinctive species are: Acrocomia vinifera, Tabebuia rosea, Cordia alliodora, Cedrela mexicana, Curatella americana, Byrsonima crassifolia, and Xylopia aromatica.

The natural vegetation has characteristics of the vegetation from much drier climates, possibly due to the monsoonal climate in this area, as well as to the excessive rates of infiltration and low water-holding capacity of the soil.

b) TROPICAL PREMONTANE WET FOREST

This bioclimate has great importance since the majority of the population living in the watershed are settled in it. This life zone is the major area of agricultural and cattle production in the watershed, coffee and vegetables are cultivated, and dairying is quite an important activity. Soils conditions are favorable for agriculture in spite of the high rainfall.

The limits of average annual rainfall vary between 2,300 and 4,000 mm. for the typical life zone; while the superhumid transition includes areas with from 4,000 to 4,500 mm. Biotemperature varies between 17 and 22ºC. There is also another transition in the lower extreme of the watershed that corresponds to the Tropical basal transition, with rainfall between 3,500 and 4,000 mm. and biotemperatures between 24 and 24.5ºC, as annual averages. The elevations of this life zone vary according to the transitions, and, for that reason, it ranges from 250 to 1,600 meters elevation. This life zone is the most extensive of those found in the Caldera river watershed, covering 40.39 percent of its total area.

Very little natural vegetation remains in this bioclimate, in the watershed. Among the most common arboreal species are: Calophyllum sp. Ulmus mexicana, Mauria heterophylla, Rapanea sp., and Citharexylum sp. In the "warm" or Tropical basal transition, among others, are the following

species: Guazuma ulmifolia, Acrocomia vinifera, Cordia alliodora, Xylopia aromatica, Cedrela mexicana, Curatella americana, Byrsonima crassifolia, and Tabebuia rosea.

c) TROPICAL LOWER MONTANE WET FOREST

The Lower Montane Wet forest life zone covers approximately 39.11 km^2, which represents 17.78% of the watershed area. It includes part of the lands located on the ridges to the northeast,as well as those of the Volcán Barú massif, between 1,520 and 2,500 meters elevation.

Average annual rainfall varies from 2,000 to 4,000 m. The mean annual biotemperature, which in this case is equal to the mean annual temperature, ranges between 12 and 17ºC.

In general, the terrain is very hilly but there are some sectors with rolling terrain where the slopes are less steep. In the very hilly parts the original vegetation has been preserved, but in those parts with less slope, the original vegetation has been very altered or destroyed, although the custom is to leave quite a lot of trees in the pastures.

The trees reach heights of 17 meters and diameters of 70 cms., the principal species observed in the field were: Cedrela tonduzii, Ulmus mexicana,Turpinia occidentalis, Didymopanax pittierei, Inga sp., Sapium sp., Quercus sp., Panopsis sp., Pouteria sp., Banara sp., Styrax sp., Annona sp., and some species of the Moraceae and Myrtaceae families.

The sectors with more favorable slopes are used for dairy cattle or for the production of vegetables. Primarily, the grass, "Kikuyo" (Pennisetum clandestinum Hochst), and Holstein cattle are used.

The area in this life zone has soils of volcanic origin, of moderate fertility, although like all soils derived from volcanic ash, they tend to retain phosphorus. Bioclimatic conditions, although they are not the best due to the high rainfall, permit the production of dairy products and vegetables because of the ameliorating effect of the volcanic soils.

Areas with these conditions are very scarce in Panama. On the other hand, the majority of the land is hilly with often very abrupt slopes, as well as relatively high rainfall, which makes the soils very susceptible to degradation. Given the importance of the activities undertaken there, and the fragility of the environment, it is recommended to introduce and apply advanced, artesanal systems of agrotechnological management in land use. Under such systems, the areas with more favorable slopes would be used for the production of vegetables or for dairy cattle while these with steeper slopes would be used for forest production or, in some cases, would be maintained unused under protective natural vegetation.

d) TROPICAL LOWER MONTANE RAIN FOREST

The Lower Montane rain forest life zone occurs where an intermediate strip of high rainfall lies between the two sections of Lower Montane wet forest life zone. That strip is found on a low point of the northeast ridge, which concentrates passage of clouds and very heavy rains in that sector.

Annual rainfall must be close to 4,200 mm. and mean annual biotemperature between 12 and 17ºC.

This life zone is found in places with very steep slopes (over 100 percent gradient). For this reason, the forest is low compared to other life zones, reaching heights of 15 meters and diameters of 50 cms..

Some species that are found are: Ulmus mexicana, Heliocarpus appendiculata, Quercus sp., Clethra sp., and others in the Myrtaceae and Lauraceae families.

The area belonging to this bioclimate, because of the difficult physical conditions for economic utilization, has been retained largely in forest. Its use should be primarily for protection under natural vegetation: economic exploitation of the forest is not adviseable, not only because of the high rainfall, but also because of the topography. The area of this life zone is only 35.49 km^2.

e) TROPICAL MONTANE RAIN FOREST

The Montane Rain Forest is found at the highest elevations, above 2,500 meters, Volcán Barú, the only high peak in the watershed. It reaches from there to the summit, at 3,320 meters. The terrain is extremely steep and the soil little developed. Also, this area is subjected to very strong winds.

There is no weather station in this life zone, but by extrapolating from vegetation and information of weather stations below, it is estimated that the average annual rainfall must range between 3,000 and 4,000 mm. and the mean annual biotemperature between 8 and 12ºC.

The vegetation is mostly of a shrublike nature, reaching heights of about 4 meters. It is composed of the following species, among others: Buddleia sp., Escallonia sp., Wiemmannia pinnata, and Quercus sp.

This area lies within Volcán Barú National Park and from the point of view of major land use capability, should be retained under absolute protection.

This bioclimate covers approximately 11.55 Km^2, which represent 5.25% of the watershed area.

C. MAJOR LAND USE CAPABILITY

1. Clean-tilled crops (A):

This is the most intensive category of use, since it is very demanding in terms of soil, slope, and climate.

Given the characteristics of the area under study, lands in this category of use turned out to be the most scarce, especially in the Panama Canal watershed, where low soil fertility was the decisive factor in lowering land capability ratings for all lands, in spite of the fact that considerable areas exist with good physical and bioclimatic conditions otherwise.

In the Río Caldera watershed, the area classified for this use was negligible. Here the limiting factors are varied, the most important being stoniness, steep slopes, and wet bioclimates.

In the Río La Villa watershed a proportionally more extensive area for seasonal crops exists. The units are located primarily on the alluvial terraces of the La Villa River and on some of those of its tributaries. As in the Panama Canal watershed, a large area with good bioclimatic and physical conditions for the production of annual crops cannot be utilized in this activity due to inherently low soil fertility, unless advanced, artesanal agrotechonological management systems are introduced and adopted by farmers.

In general terms, all units classed for this use-category have moderate to high natural fertility, level to slightly-sloping relief, good natural drainage, basic to moderately-acid soil pH, no accelerated, man-induced erosion, no stoniness, moderate-to-deep soils, and light-to-heavy, textured soils. Also they have generally favorable bioclimatic conditions.

2. Grazing (P):

The area falling in this second most intensive land use category is greater than that for clean-tilled crops, because this activity can be maintained economically and technically on sites too infertile for the clean-tilled production of seasonal crops. Therefore, due to that minor requirement,this activity would occupy the units that were not classified for the production of clean-tilled crops, ordinarilly because of low fertility or excessive stoniness. However, the land units selected as appropriate for grazing activity do not include those with moderate or steep slopes due to the danger of soil destruction, especially on heavy-textured soils which are widespread in all the areas studied. The lands selected for this activity are usually level to slightly-undulating, of moderate-to-low fertility, and moderate-to-deep in soil depth; other edaphic factors vary. If an advanced, artesanal system is adopted, land units with slightly greater slopes or with very limited total soil depth would be added to the total area.

Under traditional systems, the area having grazing as its most-intensive recommended use is large only in the La Villa and Caldera river watersheds,however, it is insignificant there when compared to the area actually being used for that activity, which is usurping much of the area having permanent crops, tree crops, or forest production as the recommended use. There are, as a consequence, many sectors in the process of accelerated soil degradation.

3. Permanent crops (C):

The area recommended for this activity (see Maps) is relatively small, although a great deal of the land recommended for grazing could be utilized alternatively for the production of permanent crops. Where this possibility exists it has been indicated on the map. Furthermore, there

are many units appropriate for the production of permanent tree crops, especially if an advanced, artesanal technology is used; this last alternative is discussed separately in the following section (4).

The category of grazing with alternatives for permanent crops basically obeys an ecological order of priority, since it is considered in general that grazing use is more demanding of favorable slope and soils conditions than is permanent crop use, even though the latter will ordinarily be more lucrative than cattle production itself. The area designated for clean-tilled crops could also be used for permanent crops (or for grazing) but is not economically attractive inasmuch as seasonal crops are in general much more lucrative than any other activity. Considering that the area suitable for clean-tillage is scarce, it should be utilized up to its maximum permitted intensity.

The physical conditions limiting use to permanent crops, once the more intensive and site demanding use-areas (A, P) have been chosen, will be those corresponding mostly to humid and perhumid bioclimates or even subhumid bioclimates, with moderately steep slopes and high to moderate fertility, on deep soils and with good internal drainage, Other edaphic factors may be more variable. Places with the above conditions but with low fertility and high soil acidity prevented the inclusion of many land units in this category, some of which were classified for forest production with an option of permanent, aboreal-type crops (CF) if an advanced, artesanal agrotechnological management system is employed.

4. Permanent tree crops (CF):

Arboreal-type permanent crops constitute a new alternative in major land use capability, a refinement in Tosi's system designed to fit in between the categories of permanent crops and of production forestry. Included in this category are such strictly arboreal type crops as cashew,

mango, soursop, citrus fruits, peach palm, and plantations of trees for timber. This kind of crop allows for an increase in land use intensity on soils with a low fertility problem and, at the same time, can be established under more severely limiting site conditions,. because such crops are not "cultivated" in the sense of soil disturbance while, because of their arboreal habit preventing soils erosion to a great extent. The category is applied only for an advanced, artesanal agrotechonological management system however, because commercial plantations of these crops do not exist traditionally within the area and, if their establishement is desired, a special development program will be necessary.

Included in this category were a large part of the lands that, under traditional agrotechnological management systems were classified as suitable only production forestry (from naturally regenerated stands). Such lands, in general, have slopes between 20 and 40 percent gradient, soils of a heavy or very-heavy texture, and humid or wetter bioclimates. In the Panama Canal watershed, some land in this category is found in nearly all sectors.

Among the areas appropriate for this use, Cerro Cama and Buena Vista stand out particularly. At present the latter site is being used for extensive grazing of beef cattle, a use which is producing severe soil erosion. In these areas, grains are also cultivated by the traditional systems of felling and burning. Among the RENARE programs, the cultivation of cashew and peach palm is being promoted, and fall, appropriately, in this major use capability category.

5. Production forestry (B):

The area classified for production forestry constitutes a vast majority of the total area studied. It is located on hilly and broken terrain as well as on relatively flat terrain. The principal reason for which lands are included in this category are: steep slopes, very humid-to-

wet bioclimates, or soils of very low fertility. Some sectors, included in the Panama Canal watershed, are the mountains to the east of Lake Alajuela,Cacao's, the series of low hills located by Cerro Cama and in its vicinity, and the hills on the eastern side of Lake Gatún. In the La Villa river watershed there are lands suitable only for forest production in almost all the places with a landscape of hills or mountains and, while the area is small, the mangroves.

In the Caldera river watershed the same situation exists but lands with even moderate slopes are also included, where these have been badly eroded.

In the Panama Canal watershed,there is a large sector located to the west of Lake Alajuela that still retains its original forest. This is the only place within the area studied, where natural forest management could be undertaken at present. Such management must be made a priority project, because impending deforestation here will not only destroy the forest but its management potential as well.

In general, some production forestry area could be used for the production of permanent tree crops were advanced, artesanal agrotechnological management systems to be adopted. In these cases, however, the use of this type of management would be indispensable and should not be confused with other systems that premeditatively or not might be adduced to exploit the forest in an inadequate way and destroy it with severe environmental consequences. For this reason, it appears to be more advisable, for the present, to permit only a production use under natural forest vegetation, or absolute protection.

6. Protection:

The units classified for absolute protection are located mostly in the upper most parts of the watersheds where slopes are abrupt and the

bioclimates are perhumid or superhumid. This pattern is found in all three of the watersheds studied.

In the Panama Canal watershed, the most important area of protection is found in the northeast part where there are many sectors of steep terrain with shallow soils in the Tropical wet forest, Premontane wet forest, and Premontane rain forest life zones. Fortunately, the major part of this area still retains its natural forest, but unless there is an effective and inmediate control on deforestation, the woody plant cover will completely disappear, in which event a series of ecological problems will occur; among them, and the most serious for the Canal, a significant increase in sedimentation of the lakes. In this watershed there is also a series of small units, classified for protection, due to different causes such as rocky soil, poor drainage, and extremely steep slopes.

In the La Villa river watershed there are areas classified for protection because of poor drainage, made up of lowland swamps near to the sea, and the mangroves. In general, the area for protection in this watershed is very small. Of the three watersheds studied, this has relatively the least area in this category of major land use capability.

The Caldera river watershed has, proportionally the largest area requiring absolute protection. In it, three large land units are classified in this category, due to both the steepness of the terrain and high rainfall. Within this class are included almost all the canyon walls and sideslopes of the principal river and its tributaries which, in this watershed, are very deep and long with slopes greater than 100 percent. The other important sector classified for protection is that lying above about 1,600 meters alture sea level, where the slopes are extremely abrupt and the life zones correspond to Montane rain forest and Lower Montane rain forest. The excessive rainfall of these life zones limits any activity that implies the elimination of all or part of the original plant cover.

CHAPTER V

APPENDIXES

APPENDIX 1

CANAL ZONE WATERSHED

List of Meteorological Stations - Precipitation

Station	Elevation m.a.s.l.	Latitude	Longitude	Years of record	Period	Average Annual Precipitation mm.
Chame	30	8º 35'	79º 53'	10	71-80	1532
Chimián	30	7º 42'	78º 38'	7	74-80	2857
Altos Pacora	400	9º 15'	79º 20'	6	75-80	2935
Utivé	80	9º 09'	79º 20'	10	71-80	2602
Río Ipetí	60	9º 01'	78º 31'	10	71-80	1786
El Cacao	180			10	71-80	2374
Cirí Grande	200	8º 46'	80º 03'	10	71-80	2415
Fort Sherman, C.Z.				6	71-76	2888
Aeropuerto Paitilla	10	8º 58'	79º 31'	10	71-80	1605
Chilibre	80	9º 09'	79º 37'	10	71-80	2055
Cerro Azul	620	9º 10'	79º 25'	10	71-80	3769
Agua Clara	100	9º 17'	79º 54'	10	71-80	3084
El Caño	34	9º 04'	79º 50'	11	70-80	2179
Howard Z.C.	132	8º 55'	79º 36'	13	68-80	1767
Cristóbal	12	9º 12'	79º 54'	10	70-79	3100
Tocumen (agronomía)	10	9º 03'	79º 22'	10	70-79	1873
Tocumen (T.C.)	20	9º 03'	79º 23'	10	70-79	1842
Gamboa	34	9º 07'	79º 41'	10		2068
Hodges Hill		9º 04'	79º 41'	10		2077
Loma Bonita	100	9º 10'	79º 15'	6	75-80	2207
Las Cumbres	200	9º 05'	79º 32'	10	71-80	1914
Boca de Pacora	2	9º 02'	79º 17'	5	76-80	1697
Capira	117	8º 45'	79º 52'	10	71-80	1635
Ing. Felipillo	12	9º 04'	79º 18'	5	76-80	1975
Zanguenga	100	8º 58'	79º 53'	10	71-80	1928
Caimito	180	8º 40'	79º 57'	7	74-80	1990

Station	Elevation m.a.s.l.	Latitude	Longitude	Years of record	Period	Average Annual Precipitation mm.
La Mitra	60	8º 50'	79º 47'	10	71-80	1743
Sajalices	40	8º 41'	79º 52'	10		2183
La Polvoreda	90	8º 57'	79º 40'	10		1876
Ciento	38	9º 18'	79º 45'	10	71-80	2784
Gatún	29	9º 16'	79º 55'	10	71-80	2596
Represa Alajuela	40	9º 12'	79º 37'	80	00-80	2367
Barro Colorado	64	9º 10'	79º 50'	55	26-80	2534
Pedro Miguel	33	9º 01'	79º 37'			2025
Chico	122	9º 16'	79º 31'	20	61-80	2145
Guacma				13	68-80	2119
El Chorro	43	8º 58'	79º 59'	33	48-80	2245
Monte lirio	85	9º 14'	79º 51'	73	08-80	2337
Altos de Balboa	30	8º 57'	79º 33'	75	06-80	1998
Fort Clayton	122	8º 58'	79º 35'	17	60-76	2005
Escandalosa		9º-26'	79º 36'	10	71-80	2958
Salamanca	82	9º 18'	79º 35'	10	71-80	2109
San Miguel	515	9º 27'	79º 30'	10	71-80	3429
Candelaria	100	9º 23'	79º 32'	48	34-81	2991
Las Raíces	34	9º 06'	79º 59'	10	71-80	2004
Agua Clara	30	9º 22'	79º 43'	10	71-80	3196
Peluca	107	9º 23'	79º 34'	43		2958
Caño	34	9º 04'	79º 50'			2113
Guacha	36	9º 11'	79º 51'			2041
El Chorro	43	8º 58'	79º 59'			2201
Balboa Docks	9	8º 58'	79º 34'			1852
Alajuela	76	9º 12'	79º 37'			2209
Cerro Jefe	975	9º 14'	79º 23'	17	41-57	3521
Los Cañones de Capira	100	8º 57'	80º 04'	11	48-58	3038
Rosario	30	9º 02'	80º 06'	13	36-48	2814
Morán	37	8º 53'	80º 03'	11	48-58	3031
Ciri Grande	1120	8º 39'	80º 05'	18	41-58	3107

APPENDIX 1 - A

CANAL ZONE WATERSHED

List of Meteorological Stations - Temperature

Station	Elevation m.a.s.l.		MONTHLY TEMPERATURE (°C.)												Temperature Year
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Tocumen	14	$M\bar{X}$	31.7	32.4	32.6	32.7	31.2	30.0	30.7	30.3	29.7	29.5	29.9	31.3	31
		$\bar{X}$	26.2	26.6	27.2	27.4	27.0	26.6	26.7	26.6	26.3	26.2	26.2	26.2	
Balboa	31	$M\bar{X}$	31.9	32.8	33.7	33.7	32.3	31.5	31.2	31.4	31.1	30.9	30.9	31.7	31.9
		$\bar{X}$	26.8	27.4	27.8	28.0	27.3	26.7	27.1	27.0	26.7	26.5	26.6	26.7	
Gatún	29	$M\bar{X}$	29.7	29.7	30.2	31.0	30.7	30.4	29.7	30.0	30.5	30.2	29.6	30.0	30.1
		$\bar{X}$	26.8	26.9	27.2	27.7	27.2	27.1	27.1	26.8	27.0	26.6	26.0	26.3	26.9
Cristóbal	12	$M\bar{X}$	28.7	28.6	28.7	29.0	29.3	29.2	28.8	28.5	29.0	28.9	29.5	28.7	28.8
		$\bar{X}$	27.2	27.2	27.5	27.3	27.1	27.0	26.6	26.8	26.5	26.5	26.9	26.9	
Buena Vista	70	$M\bar{X}$	30.0	30.3	31.0	31.0	30.8	30.2	30.1	29.9	30.2	29.7	29.4	30.0	30.2
		$\bar{X}$	24.8	25.2	25.3	25.7	25.4	25.8	26.8	25.2	26.0	25.9	25.7	25.4	25.6
Alajuela	76	$\bar{X}$	25.9	25.5	26.9	27.6	27.4	27.3	26.7	26.5	27.2	26.8	25.8	25.8	

$M\bar{X}$: Mean maximum temperature

$\bar{X}$: Mean temperature

APPENDIX 2

LA VILLA RIVER WATERSHED

List of Meteorological Stations - Precipitation

Station	Elevation m.a.s.l.	Latitude	Longitude	Years of Record	Period	Average Annual Precipitation mm.
Llano Piedra	150	7º 39'	80º 34'	10	71-80	2152
Macaracas	80	7º 44'	80º 33'	25	56-80	1617
La Mesa	180	7º 38'	80º 37'	14	67-80	2500
Los Santos	10	7º 57'	80º 25'	16	65-80	1113
Atalayita	50	7º 52'	80º 32'			
Pesé	80	7º 54'	80º 37'	10	71-80	1382
Pitaloza Arriba	380	7º 38'	80º 40'	10	71-80	2244
Parita	30	8º 00'	80º 31'	14	67-80	1214
Llano de Los Reyes	80	7º 54'	80º 40'	13	68-80	1715
Llano de la Cruz	60	7º 57'	80º 38'	10	71-80	1494
Las Minas	350	7º 47'	80º 44'	21	60-80	2283
Valle Rico	173	7º 37'	80º 21'	10	71-80	2346
Los Angeles	32	7º 53'	80º 21'	10	71-80	981
Las Cruces	84	7º 49'	80º 26'	14	67-80	1257
La Tranca	150	7º 44'	80º 22'	10	71-80	956
La Miel	220	7º 33'	80º 20'	10	71-80	1724
Quebrada La Llana	60	7º 30'	80º 33'	14	67-80	2569
Las Tablas	50	7º 46'	80º 16'	22	59-80	1151
Ocú	130	7º 57'	80º 43'	4	77-80	1569
Pan Azúcar	320	7º 44'	80º 41'	4	77-80	1705
Los Pozos	260	7º 47'	80º 39'	13	68-80	1710

APPENDIX 2-A

LA VILLA RIVER WATERSHED

List of Meteorological Stations - Precipitation

Station	Elevation m.a.s.l.		MONTHLY AIR TEMPERATURE (°C.)												Temperature Year
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Set.	Oct.	Nov.	Dec.	
Los Santos	16	$M\bar{X}$	32.7	33.2	33.6	33.9	33.1	31.8	31.9	32.0	31.6	31.6	31.6	31.8	32.6
		$\bar{X}$	27.4	28.1	28.3	28.7	28.3	27.4	27.3	27.3	26.8	26.7	26.6	26.6	
		$MIN\bar{X}$	22.0	22.2	22.7	23.5	23.3	23.0	22.6	22.3	21.9	23.1	21.5	21.5	22.5
Atalayita	50	$\bar{X}$	26.4	26.7	27.5	27.7	27.7	27.1	27.1	26.8	26.6	26.6	26.3	25.7	26.8

$M\bar{X}$: Mean maximum temperature

$\bar{X}$: Mean temperature

$MIN\bar{X}$: Mean minimum temperature

APPENDIX 3

CALDERA RIVER WATERSHED

List of Meteorological Stations - Precipitation

Station	Elevation m.a.s.l.	Longitude	Latitude	Year of Record	Period	Average Annual Precipitation mm.
Concepción	270	8º 32'	82º 37'	10	71-80	3562
Potrerillo Arriba	930	8º 41'	82º 31'	14	67-80	4616
Hornitos (Gualaca)	1020	8º 44'	82º 14'	24	59-80	4051
La Cordillera	1200	8º 44'	82º 16'	18	63-80	3608
Fortuna	1040	8º 44'	82º 15'	10	71-80	3543
David (Aeropuerto)	27	8º 24'	82º 55'	13	68-80	2653
Cerro Punta	1830	8º 52'	82º 35'	18	63-80	2108
Nueva California	1400	8º 47'	82º 39'			2909
Caisán Arriba	1150	8º 46'	82º 44'	10	71-80	4186
Bajo Grande Caldera	2300	8º 51'	82º 33'	10	71-80	2509
Gómez Arriba	380	8º 34'	32º 34'	10	71-80	4029
Santa Cruz	670	8º 39'	82º 46'	10	71-80	4228
Cuesta de Piedra	1000	8º 41'	82º 37'	10	71-80	5828
Finca Lérida	1700	8º 48'	82º 29'	10	71-80	2680
Caldera	350	8º 39'	82º 23'	18	63-80	4091
Los Naranjos	1200	8º 47'	82º 27'	10	71-80	2399
Bajo Boquete	1060	8º 46'	82º 26'	11	70-80	3526
Planta Caldera	920	8º 43'	82º 28'	23	58-80	4357

APPENDIX 3-A

CALDERA RIVER WATERSHED

List of Meteorological Stations - Temperature

Station	Elevation m.a.s.l.		MONTHLY AIR TEMPERATURE (°C.)												Temperature Year
			Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Set.	Oct.	Nov.	Dec.	
Paja de Sombrero	388	$M\bar{X}$	29.6	30.2	31.2	31.6	30.4	29.6	29.7	29.3	28.9	28.3	28.7	29.3	29.7
		$\bar{X}$	24.7	25.4	26.4	26.2	25.2	24.5	24.8	24.6	24.4	24.0	24.2	24.2	24.9
Planta Caldera	920	$\bar{X}$	20.5	20.7	21.2	20.9	20.3	19.6	29.8	19.7	19.6	29.5	19.8	20.1	20.2
Los Naranjos	1200	$\bar{X}$	19.6	20.7	20.2	20.7	20.8	20.5	20.6	20.6	20.3	20.3	20.2	19.9	20.3
Hornitos	1340	$\bar{X}$	17.9	17.5	17.9	18.5	19.5	19.4	19.3	19.5	19.7	19.6	19.2	18.5	
Bajo Grande	2300	$\bar{X}$	12.8	12.5	13.4	14.1	14.6	14.6	14.5	14.6	14.5	14.3	14.2	13.2	13.9

$M\bar{X}$: Mean maximum temperature

$\bar{X}$: Mean temperature

APPENDIX 4

CATAPAN Units with their equivalent major land use capability classification by life zones and under two technological systems of management: Traditional (T) and Advanced, artesanal (A) for each of the three watersheds.

CUENCA DEL CANAL

UNIDADES	bh-T		bmh-P	
	T	A	T	A
OCWLf1 / Fa B10	A	A	A	A
OCNCf1 / Fa B10	A	A	A	A
BCNCf1 / Sc B10	A	A	A	A
OCWCf1 / Fa B10	A	A	C,P	A
BCMKc3 / Sc B10	A	A	C,P	A
BCNCf1 / ScA10	A	A	C,P	A
UCNCf1 / Fa A10	P	A	P	A
UCGCf1 / Fa A10	C,P	A	P	A
ONCf1 / Fa A10	P	A	P	C
OCNCf1 / Fa B10	C	A	C	A
BCMKc4 / Sc B10	C	A	B	C
BCMKc4 / Sc C10	C	A	C	C
OXWCf1 / Sa B10	P,C	P,C	P,C	P,C
OXWCf1 / Fa B10	P,C	P,C	P,C	P,C

UNIDADES	bh-T		bmhP	
	T	A	T	A
OXMCf3 / Ft B10	P	C	P	C
OXWCf1 / Ie B10	P	C	P	C
OXWCf3 / Sa B10	P	C	P	C
OXMCf1 / IB10	P	C	P	C
OXWCf1 / Sa C10	P	C	P	C
OXWCf1 / Ft B10	P	C	P	P
OXWCf1 / IC10	P	C	B	C,P
OXWCf1 / Ft C10	P	C	B	C,P
OXWCf1 / Ie C11	P	CF	B	CF,P
OXMKc3 / Sa C10	C	C	C	C
BXWCf3 / Sc B10	C	P	C	P
UXMKc3 / Sa C10	C	P	C	P
OXMCf3 / Sa C10	C	C	B	C
OXWCf3 / Ie E12	B	B	B	B

UNIDADES	bh-T		b-h-P	
	T	A	T	A
OCWCf3 / Sa B10	P,C	P,C	P,C	P,C
OXWCf1 / I B10	P	C	P	C
OXWCf3 / Ft B10	P	C	P	C
OXWCf3 / Sa E10	B	B	B	B
OXWCf3 / Ie E10	B	B	B	B
OXWCf3 / Ie E11	B	B	B	B
OCWCf3 / Ie E10	B	B	B	B
OCWCf4 / Ie D20	B	B	B	B
OXWKc3 / Sa E11	B	B	B	B
OXWCf3 / Ie E10	B	B	B	B
OXWCf1 / Ie E12	B	B	B	B
OXWCf1 / Ie E11	B	B	B	B
OXWCf1 / I E10	B	B	B	B
OXWCf3 / I E10	B	B	B	B
OXWCf3 / I E11	B	B	B	B

UNIDADES	bh-T		b-hP	
	T	A	T	A
OXWCf1 / IE 11	B	B	B	B
OXWCf3 / Sa E11	B	B	B	B
OXWCf3 / Ft D10	B	B		
OXWCf3 / Sa D10	B	B		
UXWCf3 / Sa D10	B	B		
OXWCf3 / Sc D10	B	B		
OCWKc4 / Sa D10	B	B		
OXWKc4 / Ie D11	B	B		
OXWCf4 / Sa D10	B	B		
OXWCf4 / Ie D11	B	B		
BCWKc4 / Sa D10	B	B		
OCWCf3 / Sa D10	B	B		
OXWKc3 / Sa D11	B	B		
OXWCf3 / Sa D11	B	B		
OXWCf3 / Ie D10	B	B		

UNIDADES	bh-T		bmh-P	
	T	A	T	A
OXWCf3 Sa E10	B	B	B	B
BCMKc4 Sc D10	B	B	B	B
UXWCf3 Ie D11	B	B	B	B
UXWCf3 Ie D11	B	B	B	B
OXWCf3 Ie D11	B	B		
OXWCf3 Sa D10	B	B		
OXWKc3 Sa D11	B	B		
OXWCf3 Sa D11	B	B		
OXWCf3 Ie D10	B	B		
UXWCf3 Ie D11	B	B		
OXWCf3 I D10	B	B		
UCMKc4 Sc E10	B	B	B	X
UCMKc4 Sc D10	CF	B	B	X
UCMKc4 Sc C11	C	B	B	B
OXMCf3 I C10	B	CF	B	B

UNIDADES	bh-T		bmh-P	
	T	A	T	A
UXWCf3 Ie D11	B	B		
OXWCf3 I D10	B	B		
OCWCf3 Sa D10	B	B		
OXWCf3 Ft C10	B.	CF	B	CF
OCWCf3 Ie C10	B	CF	B	CF
OXWCf3 Sc C10	B	CF	B	CF
OXWCf3 I C10	B	CF	B	CF
OXWCf4 Sc C10	B	CF	B	CF
OXWCf3 Ft D10	B	CF	B	CF
OXMKc4 Sa C10	B	CF	B	CF
OXWCf3 Sa C10	B	CF	B	CF
OXWCf1 F D10	B	CF	B	CF
OXWCf1 I C11	B	CF	B	CF
OXWCf1 Ie C10	B	CF	B	CF
OXWCf1 Sa D10	B	CF		

UNIDADES	bh-T		bmh-P	
	T	A	T	A
OCMKc4 / Sa C10	B	CF	B	CF
OXWCf1 / Ie D12	B	CF	B	CF
OXWCf1 / Ie D10	B	CF	B	CF
OCWCf3 / Ie D10	B	CF	B	CF
OXWCf3 / I D10	B	CF	B	CF
OXWCf3 / Ie C10	B	CF	B	CF
OXWCf4 / Ie E11	B	X	X	X
OXWCf4 / Ie E10	B	X	X	X
UXWCf4 / Ie E10	B	X	X	X
UXWCf4 / Sa E10	X	B	X	B
OXWCf4 / Sa E10	X	B	X	B
OXWKc4 / Ie E11	X	B	X	B
UXWCf4 / Ie E11	X	B	X	B
OCMKc4 / Sa E10	X	B	X	B

UNIDADES	bh-T		bmh-P	
	T	A	T	A
OXWCf1 / I D10	B	CF		
OXWCf1 / I D11	B	CF		
OXWCf1 / Ie D11	B	CF		
OXWCf4 / Ie E12	B	X	X	X
Xr	X	X		
OCWKc4 / Ie F12	X	X		
UCWKc4 / Ie F12	X	X		
OXWCf3 / Sa F11	X	X		
OCWCf4 / Ie	X	X		
FP	X	X	X	X
UXWCf4 / Ie F12	X	X	X	X
OXMKc4 / Sa E11	X	B	X	B
OXWKc4 / Ie E12	X	B	X	B
UCWKc4 / Ie E11	X	B	X	B

UNIDADES	bh-T		bmh-P	
	T	A	T	A
OCWCf4 / I E10	X	B	X	B
UCMKc4 / Sa E10	X	B	X	B
OXWCf3 / Sa E10	X	B		

UNIDADES	bmh-T		bp-P	
	T	A	T	A
OCWCf3 / Ie. E10	B	B	X	X
OCWCf3 / Ie D10	B	B		
OCWCf4 / Ie D20	B	B		

CUENCA DEL RIO LA VILLA

UNIDADES	bs-T		bs-P		bh-P	
	T	A	T	A	T	A
UCMCf1 Fa A10	-	-	A	A	A	A
UCNCf1 Fa A10	A	A				
UCMCf1 Fa A10	A	A				
UXMCf1 Ie C10	P	A				
UCNCf1 Ie C10	P	A				
OXNCf1 Sa B10	P	A				
OCGCf1 Fa A10	P	A				
OXMCf1 Sa C10					C,P	A
UCWKc4 Sa C10					C	A
UXNCf1 Ft C10	P	P				
OXMCf1 Ie C10	P	P				
UXMCf1 Ft C10	P	P				
OXMCf1 Sc C10					P	P
OXMCf1 Sc C20					P	P

UNIDADES	bs-T		bs-P		bh-P	
	T	A	T	A	T	A
OCWCf4 Ie B10	P	P	P	P	P	P
OXMCf1 Ie B10			P	P		
OCNCf4 Ie C10			P	P		
UNLc1 Mb A10	P	C				
OXMCf1 Ie C10	P	C				
OCVCf1 Fa A10	P	C				
OXWCf1 Ie E11	P	C				
UCMCf1 Fa A10	P	C				
UCNCf1 Fa A10	P	C				
OXWCf1 Ft B10	P	C				
UXMCf1 Ft A10	P	C				
OXNCf1 Ie B10	P	C				
OXNCf1 Ft A10	P	C	P	C		
OXNCf1 Ft B10			P	C		

UNIDADES	bs-T		bs-P		bh-P	
	T	A	T	A	T	A
OXMCf1 / Sc B10	P	C	P	C	P	C *
OXMCf1 / Sa C10					C	P *
UCWCf4 / Ie C12	C	P				
OXMCf3 / Ie C10	C	P	C	P		
UXWCf3 / Ie C10	C	P				
UCWCf4 / Ie B10	C	P				
UXWCf4 / Ie C11	B	P				
UCWCf4 / Ie C11	B	P				
UCWCf4 / Ie C10	B	P				
OXWCf3 / Ie D11	B	CF				
UXWCf3 / Ie D11	B	CF				
OCWKc4 / Sa D11	B	CF				
UCWCf? / Sa D10	B	CF				
OXWCf1 / Ie E11	B	CF				
OCWKc4 / Sa D11	B	CF				

UNIDADES	bs-T		bs-P		bh-P	
	T	A	T	A	T	A
OCWCf4 / Sa E11	B	B				
OXMCf1 / Ie E12	B	CF				
UXWCf4 / Ie D11	B	CF				
OXMCf1 / Ie D11	B	CF				
OXWCf1 / I E10					B	B
OXMCf1 / Ie E10					B	B
UCWKc4 / Sa E11	B	B	B	B	B	B
UXWKc4 / Sc E11	B	B				
UCWCf4 / Sa E11	B	B				
OCVCf1 / Fa A10	B	B			B	B
OCWKc4 / Sa E11	B	B	B	B		
UXWKc4 / Sa E11	B	B				
Mm	X	B			X	B
Mb			X	B		
ML	X	X	X	B	X	X

UNIDADES	bh-P		bh-T		bmh-P		
	T	A	T	A	T	A	
OXMCf1 / Ft C20			C	C			
OXWCf1 / Ft C20			C	C			
OXMCf3 / Ie E11			B	CF	B	CF	
OXWCf1 / Ie D10			B	CF	B	CF	
OTWCf1 / Ie D10			B	CF			
OTWDf1 / Ie E10			B	B			
OXWCf1 / I E10					B	B	
OXWCf1 / Ie E11			B	B	B	B	
OXMCf3 / Ie E11			B	B			
OXWCf1 / Ie E11	B	B	B	B	B	B	**

* También está en el bh-T

** También está en el bs-P

CUENCA DEL RIO CALDERA

UNIDADES	bmh-P		bmh-T		bmh-MB		bp-MB		bp-M	
	T	A	T	A	T	A	T	A	T	A
UCWLc1 * Ec C10	A	A								
UCWLc1 * Ec C10	P,C	A								
UCWLf1 Ec B10	P,C	A								
UCWLc1 Ec D10					P,C	A				
OCMLc2 * I A10	P	A								
OCMLc2 * I A10	C	P								
UCMLf2 * FI B12	P	A	P	A						
UCNLc1 Fa B10	P	A								
OCWLf1 I B10			P	P						
UCWLc1 Ec B10	P	P								
UCMLf2 * FI B12	P, CF	P, CF	P, CF	P, CF						
UCMLc1 Ec/IC20	C	C								
UCWLc1 Ec C10	C	P								
UCNCf1 Ec/IC10	C	P			C	P				
UCWLc1 Ec D10	B	C								

UNIDADES	bmh-P		bmh-T		bmh-MB		bp-MB		bp-M	
	T	A	T	A	T	A	T	A	T	A
UCGLc1 / E/IC12	B	C			B	C				
OCMLf3 / I D20			B	CF						
OCMLf3 / I C20			B	CF						
OCWLf2 / I C20			B	CF						
OCWLf1 / I C10			B	CF						
OCVLf2 / I C21	B	CF	B	CF						
OCWLf2 / I D21	B	CF	B	CF						
OCMLf2 / I C11 *			B	CF						
OCMLf2 / I C11 *	C	P								
OCMLf3 / I D11	B	CF								
OCMLf1 * / I C10	B	CF								
OCMLf1 * / I · C10	C	P								
UCWLc1 / Ec E10	B	CF			B	CF				
UCGCf1 / Ec/IE10	X	B			X	B	X	B		
UCGNCf1 / Ec/Ic10	X	B					X	B		
XV	X	X	X	X	X	X				
UCMLc2 / Jc/F12					X	X	X	X	X	X

* Son unidades que tienen diferente Capacidad de Uso conforme cambia la Zona de Vida. Observare que en algunas otras tienen la diferente Capacidad de Uso dentro de la misma Zona de Vida pero esto es porque se de-

Best Available Document

APPENDIX 5

INFORMATION ON SOIL SAMPLE SITES
(Description of Profiles)

MINISTRY OF AGRICULTURE AND CATTLE DEVELOPMENT
NATIONAL OFFICE OF RENEWABLE NATURAL RESOURCES

Ecological Studies of Watersheds

- Description of Soil Profile -

I. INFORMATION ON THE SAMPLING SITE

a) Profile Nº:	1
b) Location:	Peñas Blancas, wooded area to the West of Barro Colorado Island-Gatún Lake, Province of Panama
c) Date of the observation:	August, 6, 1982
d) Describers:	E. Tapia and V. M. Ponce
e) Altitude:	50 m.a.s.l.
f) Land form:	
1) Physiographic position:	System of low hills with sedimentary formation
2) Form of the surrounding terrain:	Hilly, dissected by small streams entrenched in ravines
3) Microtopography:	Small alluvial terrace - Slope 3-5%
g) Climate:	The mean annual rainfall is approximately 2,800 mm., with a dry season from the end of December to April. There are sporadic rains in that interim

II. GENERAL INFORMATION ON SOILS

a) Parent material:	Sedimentary, sandy/sandstone
b) Drainage:	Moderately good

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c)	Conditions of humidity in the profile:	Good
d)	Depth of ground water layer:	Below the profile at all times
e)	Presence of stones on the surface or rocky outcrops:	Class 0, without stones
f)	Evidence of erosion:	There are no evident traces of anthropic erosion in the observation site, however, geological erosion has caused some gullies in the natural drainage
g)	Presence of salts or alkalis:	Not detected
h)	Human influence:	On the site there are trees over 150 years in age; nevertheless, the forest appears to have been interferred with and stripped of its most valuable timber trees. Also observable are many footpaths used by poachers

BRIEF DESCRIPTION OF THE PROFILE

This soil, which occupies a narrow fluvio-alluvial terrace, is deep and well drained but has a good capacity for retaining moisture. It shows good physical conditions for deep root development, with a notable biological activity, above all in the first horizons. Abundant undecomposed plant residues can be observed on the surface layer.

DESCRIPTION OF THE PROFILE

A_1 0-18 cms. Dark reddish-brown (7.5 YR 3/2), moist, clayey, limey, weak medium subangular block structure; brittle, sticky, slightly plastic; abundant fine, medium, and large pores; abundant fine, medium and large roots; notable biological activity; net limit, undulated.

A_2 18-39 cms. Yellowish-red (5YR 4/6) moist; light clay; weak medium

angular blocks; brittle, sticky, slightly plastic, abundant fine medium and large pores; abundant fine and medium roots; gradual limit, undulated.

B_2 39-75 cms. Reddish-brown (2.5 YR 4/4) moist, clayey, weak, medium columnar structure; brittle; sticky, and slighth plastic; abundant fine and scarce medium pores; abundant fine, moderate, medium and thick roots; diffuse limit; undulated.

B_3 75-150 cms. Reddish-brown (2.5 YR 3/6) 95% moist, variegated with dark red (10YR 6/4.5%) clayey, weak medium columnar structure; slightly firm, sticky, and slightly plastic; abundant fine pores; abundant fine and scarce medium and thick roots.

MINISTRY OF AGRICULTURE AND CATTLE DEVELOPMENT

NATIONAL OFFICE OF RENEWABLE NATURAL RESOURCES

Ecological Studies of Watersheds

- Description of soil profile -

I. INFORMATION ON THE SAMPLE SITE

a) Number Profile:	2
b) Location:	Peñas Blancas, woody area to the west of Barro Colorado Island-Catún Lake, Province of Panama
c) Date of observation:	August 6, 1982
d) Describers:	E. Tapia and V. M. Ponce
e) Altitude:	70 m. a. s. l.
f) Form of the terrain:	
1) Physiographical position:	System of low hills, predominantly sandstone
2) Form of surrounding terrain:	Inclined, dissected by shallow-to-deeps ravines
3) Microtopography:	Inclined hillsides. Slope of 40%
g) Climate:	The total annual rainfall is about 2,800 mm, with a dry periodo extending from the end of December to the month of April. There are sporadic rains during the interim

II. GENERAL INFORMATION ON SOILS

a) Parent material:	Sedimentary (sandstone)
b) Drainage:	Good
c) Conditions of humidity in the profile:	Good tendency to humidity
d) Depth of the friatic layer:	Under the profile in all seasons

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e) Presence of stones on the surface or rocky outcropping: Class 0, without stones

f) Evidence of erosion: There are no traces of anthropic erosion in the observation site; however, geological erosion has caused some gullies in the natural drainage waterway in adjacent sites

g) Presence of salts or alkalis: None have been detected

h) Human influence: In the site, trees of over 150 years age can be found; nonetheless, the forest shows signs of interference by stripping of its most valuable species. Poachers also operate in the area

BRIEF DESCRIPTION OF PROFILE

Although in forest, its position on the hillside has caused a superficial/ shallow soil, with a very thin upper horizon, in the lower part, very wathered parent material which permits root penetration can be observed. In general the soil is well-drained, appearing to be quite permeable to water.

DESCRIPTION OF PROFILE

A_1 0-13 cms. Reddish-brown (5YR 4/4) moist; clayey, large angular block structure; moderate; firm, sticky, and plastic; abundant fine and medium pores; abundant fine an medium roots; net limit, undulated.

B_2 13-28 cms. Yellowish-red (5YR 5/6) moist, cayey, large angular block structure, moderate; slightly firm, sticky, very plastic; abundant fine and medium roots; b sque limit, undulated.

C_1 28-49 cms. Yellowish-red (5YR 4/8), 60 % moisture; variegated skeletal clay texture, medium-to-strongly prismatic structure; very firm, sticky, and plastic; a few fine pores; abundant medium and fine roots; difusse limit, undulated.

C_2 49-130 cms. Reddish-brown (2.5YR 4/4), 50% moisture, variegated with red (2.5 YR 4/8) 50%, parent material semi-meteorized, interspersed with clay; few medium roots.

MINISTRY OF AGRICULTURE AND CATTLE DEVELOPMENT

NATIONAL OFFICE OF RENEWABLE NATURAL RESOURCES

Ecological Studies of Watersheds

- Description of Soil Profile -

I. INFORMATION ON THE SAMPLE SITE

a) Number of profile:	3
b) Location:	Peñas Blancas, woody area to the west of Barro Colorado Island-Gatún Lake, province of Panama
c) Date of observation:	August 6, 1982
d) Describers:	E. Tapia and V. M. Ponce
e) Altitude:	90 m.a.s.l.
f) Landform:	
1) Physiographical postion:	System of low hills, predominatly sandstone
2) Form of surrounding terrain:	Hilly, dissected by shallow-to-deeps ravines
3) Microtopography:	Peak of hill slightly level, slope of 5 - 10%
g) Climate:	The total annual rainfall is aproximately 2,800 mm. with a dry period extended from the end of December to the month of April. There are sporadic rains during the interim

II. GENERAL INFORMATION ON SOILS

a) Parent material:	Sedimentary (sandstone and claystones)
b) Drainage:	Good

c)	Con itions of moisture in the profile:	Good
d)	Depth of ground water layer:	Below the profile in all seasons
e)	Presence of stones on the surface or rocky outcropping:	Class 0, without stones
f)	Evidence of erosion:	There are no traces of anthropic erosion in the observation site, but because of prevailing ecological conditions, it is assumed that it will be intense when the actual forest is eliminated.
g)	Presence of salts or alkalis:	None have been detected.
h)	Human influence:	The soils has not suffered deterioration due to nman's interference, since they have remained continously under forest cover, although the latter has been stripped of its most valuable tree species.

BRIEF DESCRIPTION OF THE PROFILE

A moderately deep soil, abruptly becoming rocky. It is well-drained with notable integration of the organic material in the first horizon. The greater part of the roots extend to horizon B_2. There is a good tendency to retain moisture in the upper layers.

DESCRIPTION OF PROFILE:

A_1 0 - 15 cm Dark brown (7.5 YR 3/2) moist; clayey-limey; weak medium-angular block structure that grades to medium granular structure; brittle, sticky, and plastic; abundant fine, medium, and large pores, abundant fine, medium, and large roots; net limit, undulated.

A_2 15-29 cms. Yellowish-red (5 YR 4/6) moist; clayey; weak medium sub-angular block structure; brittle to slightly firm, very

sticky, and plastic; abundant fine, medium, and scarce large pores; moderate, fine, medium and large roots; gradual limit, undulated.

B_2 29-60 cms. Reddish-brown (2.5YR 4/4) moist; clayey; weak, medium prismatic structure; brittle to slightly firm; very sticky and plastic; abundant fine and scarce medium pores; few fine and medium roots; abrupt limit, undulated.

R83-180$^+$cms. Altered substrata of clay stone and sandstone of a reddish grey tonality.

APPENDIX 6

LIST OF PLANT SPECIES IDENTIFIED IN THE STUDY AREAS

1. Las Cruces
2. Agua Salud
3. Altos de Pacora
4. Cerro Azul
5. Gigantito

SPECIES IDENTIFIED AT "CERRO AZUL"

a) Large trees (greater than 10 meters):

Terminalia amazonia
Vochysia ferruginea
Calophyllum longifolium
Virola sp
Dialyanthera sp
Cespedezia macrophylla
Simarouba amara
Jacaranda copaia
Ceiba pentandra
Copaifera sp
Zanthoxylum sp
Anacardium excelsum
Couratari panamensis
Unonopsis sps
Coccoloba sp
Andira inermis
Chrysophyllum caimito
Protium sp
Xylopia aromatica
Xylopia frutescens
Ochroma lagopus

b) Small trees and bushes

Rapanea sp
Myrica cereifera
Vismia ferruginea
Vismia baccifera
Hampea micrantha
Cecropia peltata
Cecropia sp
Trichospermum mexicanum

b) Small trees and bushes

Heisteria longipes
Gustavia superba
Moaguitoxylum jamaicense
Astronium graveolens
Cecropia peltata
Terminalia sp
Protium sp
Swartzia simplex
Spondias purpurea
Lonchocarpus spp
Dialyanthera sp
Cochlospermum vitifolium
Hasseltia floribunda
Banara guianensis
Erythoxylum sp
Apeiba tibourbou
Miconia spp
Miconia borealis
Zanthoxylum sp
Inga spp
Cedrela fissilis
Tabebuia ochraceae
Tabebuia guayacan
Cassia maschata
Rauvolfia littoralis
Sauravia sp
Nectandra spp
Croton sp
Genipa americana
Pothomorphe peltata

c) Palms

Astrocarium alatum
Elais oleifera
Scheelea rostrata
Oenocarpus panamanus

d) Second growth species

Cecropia peltata
Cochlospermum vitifolium
Jacaranda copaia
Apeiba aspera
Trichospermum sp
Guaruma ulmifolia
Ochroma lagopus

e) Species natural regeneration

Ceiba pentandra
Vochysia ferruginea
Zanthoxylum sp
Dialyanthera sp
Gustavia superba
Scheelea rostrata
Cedrela fissilis
Tabebuia sp
Psychotria sp
Ceiba pentandra
Ochroma lagopus
Didymopanax morototoni
Anacardium excelsum

SPECIES IDENTIFIED AT "LAS CRUCES"

a) Large trees (greater than 10 meters):

Anacardium excelsum
Calophyllum longifolium
Cabanillesia plataneifolia
Terminalia lucida
Triplaris americana
Spondias mombin
Pterocarpus sp.
Bursera simarouba
Bombacopsis quinatum
Luhea semanii
Vochysia ferruginea
Sciadodendron excelsum
Didymopanax morototoni
Byrsonima sp.
Enterolobium ciclocarpum
Enterolobium schomburgikii
Dipterix panamensis
Phithecolobium saman
Ceiba pentrandra
Swietenia macrophylla
Hymenaea courbaril
Pseudo bombax septunatum
Albizzia caribaea
Cordia alliodora
Jacaranda copaia
Hura crepitans
Ficus insipida
Chrysophyllum caimito
Unonopsis sp.

SPECIES IDENTIFIED AT "AGUA SALADA"

a) Large trees (greater than 10 meters):

Schizolobium parahybum
Albizzia adinocephala
Leucaena multicapitula
Ochroma lagopus
Coumarouna oleifera
Dialyanthera sp
Rheedia edulis
Pourouma aspera
Lecythis sp
Poulsenia armata
Cespedezia macrophylla
Vochysia ferruginea
Zanthozylum sp
Calophyllum longifolium
Ceiba pentandra
Anacardium excelsum
Ficus insipida
Xylopia aromatica
Xylopia frutescens
Enterolobium ciclocarpum

b) Small trees and bushes

Trema micrantha
Turpinia paniculata
Hampea micrantha
Cordia alliadora
Trichospermum mexicanum
Vismia baccifera
Vismia ferruginea
Solanum sp
Cecropia peltata

Croton sp

Anona sp

Inga panamensis

Inga hayessi

Inga laurina

e) Palms

Socratea durissima

Welfia georgi

Oenocarpus panamanus

Euterpe sp

Sabal sp

d) Second growth species

Trichospermum mexicanum

Hampea michrantha

Trema micrantha

Schizolobium parahybum

Ochroma lagopus

Jacaranda copaia

Zanthoxylum sp

Trema micrantha

Leucaena multicapitula

Cecropia peltata

e) Species in natural regeneration

Schizolobium parahybum

Jacaranda copaia

Calophyllum longifolium

Zanthoxylum sp

Xylopia sp

SPECIES IDENTIFIED AT "ALTOS DE PACORA"

a) Large trees (greater than 10 meters)

Terminalia amazonia
Vochysia jefensis
Vochysia ferruginea
Cespedezia macrophylla
Virola koschnyii
Dialyanthera sp
Podocarpus oleifolius
Symphonia globulifera
Rheedia edulis
Calophyllum longifolium
Pourouma aspera
Achras zapota
Couropita sp
Couratari panamensis
Simarouba amara
Sacoglottis sp
Guarea aligera
Sloaena sp
Jacaranda copaia
Aspidosperma melagocarpum
Lacmellea panamensis
Couma macrocarpa
Anona sp
Cordia alliodera

b) Small trees and bushes

Inga spp
Heisteria longipes
Vismia ferruginea
Vismia bacafena
Marila macrophylla
Vismia guianensis

Vismia latifolia

Casearia silvestras

Rapanea sp

Roupala montana

Cecropia peltata

Coussapoa sp

Miconia spp

Solanum arboreum

Pithecolobium sp

Clusia sp

Miconia borealis

Erythrina sp

Simarouba amara

Mabea occidentalis

Cecropia sp

Ficus sp

Hampea sp

Cordia alliodora

Ochroma lagopus

Trema micrantha

Ocotea spp

c) Species in natural regeneration

Podocarpus oleifolius

Jacaranda copaia

Cecropia sp

Cespedezia macrophylla

Pourouma aspera

Simarouba amara

d) Palms

Socratea durissima

Welfia georgi

Euterpe sp

*Dos no identificadas

Nectandra sp
Eugenia sp
Solanum asperum
Inga sp
Apeiba tibourbou
Croton sp
Astronium graveolens

e) Palms

Euterpe sp
Socratea sp

SPECIES IDENTIFIED AT "GIGANTITO"

a) Large trees (greater than 10 meters):

Dipteryx panamensis
Virola sp
Dialyanthera sp
Castilla fallax
Pithecolobium sp
Pterocarpus officinalis
Zanthoxylum sp
Anona sp
Luehea candida
Bombaconsis sessilis
Ceiba pentandra
Pachira acuatica
Terminalia amazonia
Pseudobombax septunatum
Didymopanax morototoni
Cordia alliodora
Sweetia panamensis

Spondias mombim
Apeiba aspera
Sterculia apetala
Anacardium excelsum
Vochysia ferruginea
Triplaris americana
Sapium sp

b) Small trees and bushes

Tabebuia pentaphylla
Inga sp
Cecropia peltata
Heisteria longipes
Lonchocarpus sp
Geniga americana
Gustavia superba
Croton sp
Miconia spp
Protium sp
Banara guianensis
Vismia ferruginea
Spondias purpurea
Protium sp
Quasia amara
Herrania sp

c) Palms

Scheelea rostrata
Euterpe sp

d) Second growth species

Guazuma ulmifolia

Apeiba aspera

Apeiba tibourbou

Trichospermum mexicanum

Luhea seemani

Cecropia peltata

Heliocarpus popayanensis

Miconia sp

Didymopanax morototoni

Vismia sp

e) *Species in young regeneration*

Zanthoxylum sp

Gustavia superba

Pterocarpus sp

Spondias mombim

Dialyanthera sp

Virola sp

Apeiba sp

APPENDIX 7

FIELD DATA FOR EACH OF THE STUDY PLOTS
(Not included: on file with RENARE)

Study of the vegetation

In order to identify and characterize some of the principal terrestrial ecosystems of the watershed, vegetation studies were conducted on 1/10 ha. sample plots 100 meters long and 10 meters wide, subdivided into subplots 15 meters long. On each plot, all trees were identified where possible , including the palms 10 or more centimeters in diameter (DAP). Tree diameters were measured at breast height as well as total heigh and height to the first large branch.

These vegetation samples were made on different sites in the Panama Canal watershed, as indicated for each one of the parcels. Most of these were established in secondary forests, some of which had been in a process of recuperation for many years, as was the case of the plots taken in Parque Soberanía where apparently the natural vegetation was cut or interfered with in the times of the construction of the Panama Canal or earlier; although since that time there had been no major human intervention. In some other areas, as in the vicinity of Cerro Azul, the vegetation is apparently primary.

One of the areas where a more intensive sample was taken was in the vicinity of Barro Blanco in the area called Peña Blanca. In this area, as indicated earlier, the establishment of an experimental station is planned by RENARE and IDIAP with the colaboration of STRI and CATIE. One of the projects for this area is its characterization from the physical, biological, and ecological point of view, with the purpose of determining the feasibility of the area for the establishment of that station and for defining the possible lines of short and medium term forest investigation to b e undertaken.

The field data on the parcels are included in the corresponding folder in the archives of RENARE.

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