Land resource assessment of Northern Belize (NRI Bulletin 43, Volume 1 of 2)

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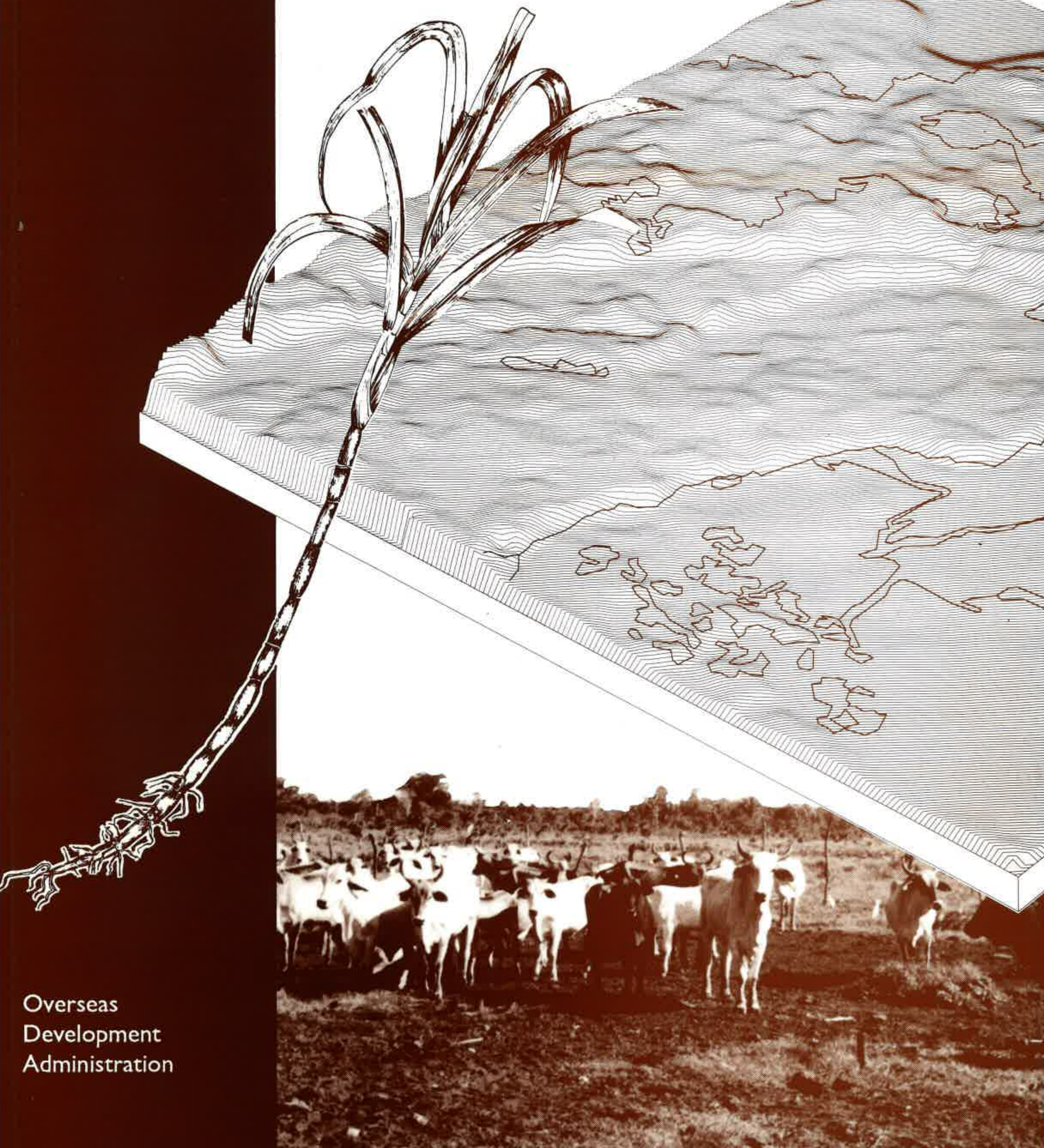
LAND RESOURCE ASSESSMENT OF NORTHERN BELIZE

Volume I



Overseas Development Administration

N.B. The following maps are included with this digital document as attachments:

Map 1a - Land Systems

Map 1c - Land Systems

Map 1d - Land Systems

LAND RESOURCE ASSESSMENT OF NORTHERN BELIZE

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The scientific arm of the
Overseas Development Administration

The Natural Resources Institute (NRI) is the scientific arm of Britain's Overseas Development Administration. NRI's principal aim is to increase the productivity of renewable natural resources in developing countries through the application of science and technology. Its areas of expertise are resource assessment and farming systems, integrated pest management, and food science and crop utilization.

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Summaries

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The land resource assessment was undertaken from July 1989 to June 1990 by the Natural Resources Institute (NRI) of the Overseas Development Administration (ODA), assisted by Mr. A. C. S. Wright, and Dr. M. Holder of Central Farm. The survey team consisted of:

R. B. King	Land resource specialist (team leader)
I. C. Baillie	Soil scientist (seconded from the Polytechnic of North London)
J. R. Dunsmore	Agronomist
J. H. Pratt	Economist
T. M. B. Abell	Forester
H. Versey	Hydrogeologist
D. A. Gray	GIS specialist
A. C. S. Wright	Soil adviser
M. Holder	Belize Ministry of Agriculture representative

The main object of the survey was to produce an updated land suitability assessment of Orange Walk, Corozal, Belize and Cayo districts which had not already been surveyed by Jenkin *et al.* (1976) and King *et al.* (1989). In addition, this survey would provide a land suitability assessment for the Belize Valley based on the soil mapping of Jenkin *et al.* Thus, together with the land resource assessments of Toledo and Stann Creek districts (King *et al.*, 1986, 1989 respectively), a land suitability assessment for the whole of Belize is now available.

Use of report

1. In addition to the generalized information, background, comment and recommendations given in the sections on Climate, Geology, Hydrology, Vegetation, Forestry, Human Resources, Transportation, Agriculture Institutions, Current Land Use, Farming Systems and Crop and Livestock Enterprises, the soils and land suitability information is provided at various levels of detail.

2. A descending hierarchy of land regions, land systems and subunits is mapped in four sheets (Maps 1a, 1b, 1c and 1d). The key accompanies Map 1c. The land system, an area with a recurring pattern of landform, soils and vegetation is the principal unit of classification. Land systems with similar characteristics are grouped into land system types, indicated by a common second letter in the land system map symbol. Soils are classified into suites and subsuites based on Wright *et al.* (1959).

3. Very basic landform information is incorporated into the name of each land system. More information is provided in the Land Unit Description section, summarized in Tables 8-16. Basic information on soils is given in the Soils section summarised in Table 17. More information is provided in Appendices 2, 3 and 4.

4. The location of each soil examination site is shown on Map 1. The soil type at that locality is given in Appendix 4. Elsewhere the soil type is indicated by the 'main soil type' column for that particular mapped subunit or land system in the table accompanying Map 1c and Appendix 1.

5. Land systems in Appendix 1 and Map 1c are listed within land regions from north to south and west to east as one would read a book. At any particular location, say Orange Walk town, the land suitability for that particular location is determined first of all by reference to the land system and subunit on the map - land system 0Z, subunit U for Orange Walk town. The suitability of that location for citrus is determined by finding 0Z in the first column of the table, U in the third column, and reading along the row as far as the 'Citrus suitability' column, viz S2nm–S3nm, i.e. moderately to marginally suitable with nutrient and moisture limitations.

6. One cm^2 on the map represents 100 ha or 247 ac. One in^2 represents 1594 ac. The side of one 50 ac lot measures 0.177 in (4.5 mm) on the map or approximately 3/16 in.

7. Generalized developmental considerations are provided in the following sections of this summary and in the various sections of the main report. They are relevant to the time of the

investigation: 1990. A discussion on the possible future development of the Western Uplands land region is provided in the Land Unit Description section of the report.

8. Agricultural and conservation values and land suitability assessments are indicated for each land system and its subunits in the table accompanying Map 1c and in Appendix 1. Where the soil type can be recognized, a more relevant assessment is indicated in Table A2.3 in Appendix 2, but which does not necessarily take into account slope and access.

9. Provisional recommendations for each subunit are indicated in the table accompanying Map 1c and Appendix 1, but any proposed development would need a detailed feasibility study, including an assessment of current costs and prices.

10. Map 2 shows land use both in 1969-72 and 1987-8.

Water

11. The distribution of rainfall during the year is extremely variable in Northern Belize. Little reliance can be placed upon the start or duration of the wet or dry seasons or how much rain can be expected.

12. The lack of adequate water during the dry season is the most serious factor limiting development throughout much of the project area, but use of groundwater could reduce that deficiency in many places. Further study is needed of the economics of different crops on different soils and land units.

Soils

13. The agricultural quality of the soils commonly changes abruptly within quite small areas, so that large-scale agricultural development projects requiring a uniform product ripening cannot be guaranteed.

14. The best soils in the project area are found in the Cayo Floodplains land system. Most of the rest of the soils tend to be shallow, compact or poorly drained, which limits their potential for perennial agriculture.

15. Most of Northern Belize is in the Northern Coastal Plain with shallow stony limestone soils, mantled in places by siliceous material of varying depths. The deep dark clays are the preferred agricultural soils, with or without some admixture of fine siliceous material. However, the extensive red Calcareous clays in Corozal District also have considerable potential for a range of crops. The soils of the Bravo Hills land region (in the west) include many stony or rocky shallow dark clays.

16. Most of Southern Cayo (i.e. that part of the Cayo District in the project area) consists of shallow soils on a rugged limestone landscape (most of Western Uplands and Central Foothills land regions), shallow soils on steep slopes over siliceous metasedimentary parent materials (most of the Maya Mountains land region) or acid soils over granite (Mountain Pine Plateau land system).

17. Mountain Pine Plateau and Coastal Plain soils derived entirely from siliceous parent materials (mostly found in the August Pine, Puletan and Belize plain land systems) are almost invariably difficult to farm. They have low natural fertility, are strongly acid and often have a highly mobile toxic aluminium content. Their natural vegetation is sparse and the land can often be acquired cheaply; but the development and maintenance of these soils requires such expert technical manipulation and high annual cash inputs that they are unlikely to provide an economic return.

18. Soils derived, or associated with, calcareous parent materials, are more fertile, usually supporting high forest in their natural state. The land is more expensive to purchase but development costs, apart from drilling for water, are relatively low.

19. Most of the soil samples were analysed at NRI. Some were sent to Central Farm. The range and capacity of the analytical facilities at Central Farm need upgrading, in order to meet the growing need for soil and fertilizer advice.

Conservation

20. Currently the only noticeable population pressure on agricultural land is in northern Corozal District. Now is the time to produce a national land development and conservation plan, which should have the support of local communities.

21. A Southern Cayo protection zone is indicated on Map 2d to indicate those areas which, because of steep slopes, water catchment role or special conservation value, should be left under protection forest.

22. The major vegetation types outside forest reserves are listed, and suggested reserves to maintain biodiversity are indicated.

23. An accurate database of the state of forest on private land should be compiled.

24. Natural forest should only be replaced by cattle ranching where there is an assurance that ranching will be under a semi-intensive management system.

25. When the current forest inventory of the Mountain Pine Ridge reserve is finished, a working plan should become available, which should indicate protection and production zones.

26. Future logging within the Chiquibul Forest Reserve should be limited to the Main Felling Series, until such time as population pressure might necessitate a strict agricultural development plan as indicated in the section on the Western Uplands in the Land Unit Description section.

27. Mangrove clearance is increasing in scale, although there is legislation to regulate clearance. Coastal mangrove must be protected to prevent coastal erosion, hurricane damage and depletion of fish, shrimp and lobster resources.

Land use and human resources

28. Most farmers have holdings of 5–50 ac (2–20 ha), but a greater total area of land is held by those farming more than 50 ac (20 ha). With few exceptions, land on estates (>1000 ac (400 ha)) is seriously under-utilized. Land taxation should be used to stimulate rational development of idle land with a high agricultural value, while fiscal or other financial incentives could be used to protect land with a conservation value.

29. The Mennonite communities are rapidly expanding their land for cultivation and pasture. Their agricultural production plans should be monitored, and production surpassing the capability of the local markets should be channelled to export. Their expansion programme should comply with the national development plan to determine whether they should be encouraged to grow export crops, or conversely whether expansion should be discouraged in order to conserve the natural forest. Maybe some efforts should be made to incorporate them more into the nation's political and administrative framework.

30. Many rural employers rely on non-Belizean migrant labour. The existing controls on temporary migrants should be maintained and strongly enforced.

31. The rural economy of Northern Belize is based on sugar cane, which is not usually rotated with other crops. Food crops, which contribute substantially to families' standard of living, continue to be based on a modified 'milpa' system, dependent on short-term fallow for the maintenance of soil fertility, which is becoming increasingly inadequate for all crops. The possibility of employing alternative systems should be investigated, particularly those involving a combination of legumes and mixed cropping.

32. Intensification of productivity for various enterprises mostly depends upon greater use of non-labour inputs, many of which must be procured outside the country and, in a number of instances (e.g. irrigation), are inevitably capital intensive.

33. A commission should investigate the reason for female rural unemployment in Corozal District.

Sugar cane

34. Sugar cane cultivation is the principal farm enterprise in Northern Belize. The average margin per dollar spent has exceeded all other enterprises, and the risk of failure has probably been lower than in other enterprises.

35. The sugar industry has improved substantially over the last few years with rising prices, replanting of smut-affected areas, better husbandry of ratoon crops, and favourable weather.

36. Growers have survived periods of low prices due largely to extensive methods of production, based on long-established cultivars. Unlike other crops, sugar cane can withstand temporary neglect, yet still provide a harvestable yield; but the current level of production could be obtained from a much reduced area by growing high-yielding disease-resistant cultivars, suitable for specific soil types, with advice on economic fertilizer regimes. The Sugar Cane Board should consider the following issues concerning intensification: grower's caution, appropriateness of new cultivars for a particular soil type, provision of soil and foliar analysis facilities, drainage requirements, provision of guidance on harvesting dates and possibly 'reaping schedules', provision of incentives for payment according to sugar yield, credit provisions, and the support that will be needed from government, board, Belize Sugar Industries (BSI) and the Cane Growers Association.

37. The economics of irrigation for establishing a new crop in the dry season, and starting a ratoon crop after harvest, should be investigated.

38. The price paid by Petrojam is marginally below the farmer's cost of production. Farmers would need to be paid more to provide incentives to produce more.

Diversification

39. Sugar cane is well suited to conditions in Northern Belize and farmers are familiar with it, but concern over the future of the sugar industry in the mid-1980s led to the establishment of a diversification programme out of sugar. Over the last few years, external quotas have varied from year to year but prices have risen slightly, and there is little incentive to diversify. However, given the uncertainties of the external sugar market, the diversification programme must continue. Belize Agribusiness Company (BABCO) should be given full support to establish a demonstration of farming capability. In addition to specific crops, investigations should be broadened to consider farmers' situations, farming systems, resources, credit conditions, and farmer experience.

40. BABCO should receive long-term financing from donors for research and development.

41. A vertically integrated operation for producing fresh papaya for export has made an encouraging start. Standards of production need to be uniformly high and irrigation is essential. Mediterranean fruit fly could affect the crop.

42. The 'sugar loaf' pineapple grows well, but trials on Cayenne material from Mexico (for producing fresh fruit for export) show a high proportion of unthrifty plants, many of which fruited prematurely. The future of this aspect of diversification is thus uncertain, and BABCO should be given full support to expand its trials particularly into fruit induction at different times. The 'sugar loaf' season (for the local market) should be extended, to the grower's advantage, by using chemicals to induce flowering.

43. Carambola trials are still in their early stages. Vegetative growth is encouraging, but careful selection for fresh fruits for commercial juice production will be essential because of the heterogeneity of the material.

44. Vegetative growth in small trials of yellow passion fruit appears encouraging, but the extent of fruit set has been low.

45. Winter vegetable production for the USA market is proving to be risky with little prospect of high returns, mainly because of competition from other suppliers.

Beans

46. Red kidney beans are a preferred item in the local diet and are the most popular type grown, despite uncertainty of yields due to weather and disease. The Mennonite community of Little Belize has expanded production considerably over the last three years and could be taking the lead in developing a useful export industry. This potential would be strengthened if the new CIAT *Phaseolus vulgaris* hybrids (red kidney crossed with black bean) prove less susceptible to the vagaries of the weather than the red kidney bean.

47. Environmentally, Northern Belize is suitable for soya beans, which could be a valuable import substitute for animal feed and vegetable oil. It is best suited to the larger mechanized farms, but development of this crop will depend heavily upon assured arrangements for harvesting and marketing.

Cacao

48. Cayo is the only district in the project area with sufficient rainfall for cacao; but at current prices, it remains only a low input system. If this crop could be linked to a livestock project, cacao growing might become more economic.

Cashew

49. Cashew grows and fruits well on the Crooked Tree soil subsuite, found mostly within the Crooked Tree Plain land system. Yields and kernel size appear satisfactory, but estate development would probably be uneconomic due to high labour costs. Government should start selecting seed stocks. Farm family enterprises, based on existing stands show more promise, particularly if linked to a small-scale decorticating machine, such as the one under test at NRI. The future of the industry depends on the cost-effectiveness of the decorticating machine.

Citrus

50. Citrus can be grown on some of the brown and red limestone soils of the Louisville and Xaibe Plains and the sandier soils of the Lazaro Plain in Orange Walk and Corozal districts, but most of northern Belize is at an uneconomic distance from the present processing factories in Stann Creek District. The Cayo Floodplains are, of course, very suitable for growing citrus.

Coconuts

51. Coconuts are still grown on a household scale for fresh nuts and oil, for the home and local market. Further development as an import substitute for vegetable oil or livestock feed is mainly constrained by the unattractive price offered to growers. The future of the crop is also threatened by the forecast that lethal yellowing disease will reach Belize in the near future. For this reason, replanting should use hybrid seedlings, even though the nuts are less desirable for household use.

Coffee

52. Very little coffee is grown. Robusta coffee has been grown commercially in the past and might still be tried in Cayo District as an import substitute.

Cotton

53. The first year trials in Orange Walk and Corozal districts of the high quality Sea Island cotton are encouraging, but the weather may have been unusually favourable. Strict monitoring is required to prevent abuse of pesticides.

Groundnuts

54. Groundnuts do not grow well on calcareous clay soils, and the local market for the various products of confectionery nuts (roasted nuts, peanut butter, salted nuts) is small.

Mango

55. Well-grown mango trees are found throughout the project area. Fruit set is highly irregular and, in addition, the viability of an export market for fresh fruit to the USA will not be apparent for several years: fruit flies may prove to be an adverse factor.

Oil-seed

56. Recent commercial developments in oil-seed production in neighbouring countries should be reviewed, particularly those of the Yucatan peninsula of Mexico.

Onions

57. Irrigated onions could be produced on certain soils (using high chemical inputs) on an increasing scale to meet the demands of the local market.

Irish potatoes

58. Many farmers would like to meet the demand for Irish potatoes, currently imported in considerable quantities, and trials are in progress.

59. Seed potatoes have been imported without adequate assessment of their suitability. Advice on suitable cultivars should be sought from the International Potato Centre in Peru.

Cattle

60. The structure of the national herd is unknown.

61. The quality of cattle stock has recently improved, and some good pasture has been established, but extensive grazing of natural pastures with little controlled breeding of livestock is the most widespread practice. Pastures are generally not managed with adequate care.

62. Initial investigations indicate a slender local market margin for beef cattle ranching, regardless of whether it is extensive or intensive. The costs and returns of cattle breeding should be researched in detail by the Belize Livestock Development Project (BLDP). Commercial viability of ranching on newly felled land requires adoption of an intensive system of pasture management. There is a potential market for carcase or boneless meat.

63. A principal requirement to gain owner's confidence is to develop a marketing system and gain acceptance of long-term government policy.

64. There should be legislation for the continuation of free local markets in beef cattle and meats, and a dismantling of export controls.

65. The growth rate of all imported steers should be recorded. Trials of imported steer fattening on small farms should be arranged by the BLDP, with a view to developing a cattle fattening project for smallholders.

Pigs

66. Pig products have been an important complement of peoples' diet for a long time. Whereas Belize is self-sufficient in fresh pork meat, processed products are imported. There are no large scale breeding or fattening units. Improved housing and the greater use of locally produced low-cost feed could improve profitability and possibly increase the quantity of pigs raised. During the dry season, adequate supplies of clean water often limit pig rearing.

Bees

67. Northern Belize has been ideally suited to beekeeping, and was the major centre in the country. The industry was well supported by a vertically integrated co-operative organization, but in the last two years it has been devastated by the arrival of the Africanized honey bee, the eradication of which is impracticable. The future therefore depends on introducing methods of managing this new arrival, including production from hybrid bees.

Mariculture

68. The feasibility of growing shrimps in Belize has been technically demonstrated, but there should be greater and stricter planning by developers, who should also budget for contingency costs.

Communications

69. The Cane Farmers' Association should experiment with radio communication to improve scheduling of cane deliveries to the Tower Hill factory.

70. The Hummingbird Highway should be fully rehabilitated.

71. An all-weather road should be built from Hill Bank to Belmopan.

Credit

72. There should be close co-operation between the Development Finance Corporation (DFC) and the Ministry of Agriculture and Fisheries extension service, to re-inforce the effectiveness of DFC's project monitoring, especially for smallholders.

73. The cost of maintaining DFC's field staff for monitoring projects needs subsidizing.

74. The proposed credit scheme of BLDP should be monitored.

75. The National Development Foundation of Belize (NDFB) should be considered for intermediate lending of World Bank funds to farmers.

76. The cause of the widening of the spread of interest rate of commercial lenders should be identified.

Survey operation

77. Land system boundaries were satisfactorily determined by interpretation of satellite and airphoto imagery, and examination of geological maps, supported by fieldwork for six of the seven land regions.

78. For the seventh, the Northern Coastal Plain, there was less correlation between landform and soils. Land system boundaries depend more upon the soil survey alone, and as indicated in the boundary clarity column of Tables 8-16 of the report, many of them are diffuse.

79. Airphoto interpretation revealed most of the landforms indicative of soil type, erosion hazard and differing drainage conditions, which were used as criteria to subdivide the land systems into agriculturally significant subunits.

80. Within each land system, the range of main soils (at suite and subsuite level) were ascertained by field inspection of accessible areas.

81. The average time spent per land system on soil survey in the field was 3 days, which was more than for Toledo District but less than Stann Creek District, which indicates the relative reliability of the three surveys.

82. The land systems and subunits are probably about 80% reliable in their indication of the likely soils. With the transfer of these boundaries into a Geographical Information System (GIS), they can be updated as more information is obtained.

83. The land suitability assessments are expected to have a corresponding approximately 80% level of reliability.

Resúmenes

RESUMEN DE LAS CONCLUSIONES Y RECOMENDACIONES

Con la asistencia de Mr. A. C. S. Wright y del Dr. M. Holder de Central Farm, el Instituto de Recursos Naturales (NRI), de la Administración para el Desarrollo Ultramarino (ODA), llevó a cabo, entre julio de 1989 y junio de 1990, una evaluación de los recursos de las tierras. El equipo encargado del estudio se hallaba constituido por:

R. B. King	Especialista en recursos de las tierras (líder del equipo)
I. C. Baillie	Pedólogo (procedente de la Escuela Politécnica del Norte de Londres)
J. R. Dunsmore	Agrónomo
J. H. Pratt	Economista
T. M. B. Abell	Silvicultor
H. Versey	Hidrogeólogo
D. A. Gray	Especialista del GIS
A. C. S. Wright	Asesor sobre suelos
M. Holder	Representante del Ministerio de Agricultura de Belice.

El objetivo principal del estudio fue producir una evaluación actualizada de la adecuabilidad de las tierras de los distritos de Orange Walk, Corozal, Belice y Cayo, que no habían formado parte de los estudios de Jenkin *et al.* (1976) y King *et al.* (1989). Además, este estudio proporcionaría una evaluación de la adecuabilidad de las tierras para el Valle de Belice, basado en la cartografía de las tierras de Jenkin *et al.* De este modo, junto con las evaluaciones de los recursos de las tierras producidos para los distritos de Toledo y Stann Creek (King *et al.*, 1986, 1989, respectivamente), se cuenta hoy día con una evaluación de la adecuabilidad de las tierras para el entero Belice.

Empleo del informe

1. Además de la información de carácter general, antecedentes, comentarios y recomendaciones proporcionados en las secciones relativas al clima, geología, hidrología, vegetación, silvicultura, recursos humanos, transporte, instituciones agrícolas, uso actual de las tierras, sistemas agrícolas y empresas agrícolas y ganaderas, se proporciona información más o menos detallada sobre la adecuabilidad de suelos y tierras.

2. Se ha realizado, en jerarquía descendente y en cuatro hojas (mapas la, 1b, 1c y 1d), la cartografía de regiones de tierras, sistemas de tierras y subunidades, acompañando la clave al mapa 1c. El sistema de tierras – zona con vegetación, suelos y formaciones recurrentes – es la principal unidad de clasificación. Sistemas de tierras con características similares se agrupan en tipos de sistema de tierras, lo cual se indica mediante una segunda letra común en el símbolo cartográfico de sistemas de tierras. Siguiendo a Wright *et al* (1959), los suelos de clasifican en juegos y subjuegos.

3. Dentro del nombre de cada sistema de tierras, se incorpora información muy básica sobre formaciones terrestres, proporcionándose mayor información en la sección relativa a Descripción de Unidades Terrestres, cuyo resumen aparece en las Tablas 8-16. En la Sección sobre Suelos, resumida en la Tabla 17, se suministra información básica sobre suelos, con información adicional en los Apéndices 2, 3 y 4.

4. En el Mapa 1, se presenta la ubicación de cada punto de examen de tierras, presentándose en el Apéndice 4 el tipo de suelo en cada localidad. En otras partes, se indica el tipo de suelo mediante la columna 'principal tipo de suelo' para la subunidad o sistema de tierras cartografiado, en la tabla que acompaña al Mapa 1c y Apéndice 1.

5. Los sistemas de tierras del Apéndice 1 y Mapa 1c se enumeran dentro de regiones de tierras de norte a sur y de oeste a este, de la manera como se leería n libro. En una ubicación específica, digamos, por ejemplo, la ciudad de Orange Walk, la adecuabilidad de las tierras para dicha ubicación concreta estará determinada, en primer lugar, mediante referencia al sistema de tierras y subunidad en el mapa del sistema de tierras OZ, subunidad U para la ciudad de Orange Walk. La adecuabilidad de dicha ubicación para los cítricos se determinará encontrando OZ en la primera columna de la tabla, U en la tercera columna y leyendo a lo largo de la hilera hasta la columna

'Adecuabilidad para cítricos', a saber, S2 nm–S3 nm, es decir, moderada a marginalmente apropiada, con limitación de humedad y de elementos nutritivos.

6. En el mapa, l cm^2 representa 100 ha o 247 acres. 1 in^2 (pulgada cuadrada) representa 1594 acres. El lado de una parcela de 50 acres mide 4,5 mm en el mapa o, aproximadamente, $^3/_{16}$ pulgadas.

7. En las secciones siguientes de este resumen, así como en diversas secciones del informe principal, se proporcionan consideraciones generalizadas de desarrollo correspondientes al momento de la investigación: 1990. En la sección del informe que hace referencia a la Descripción del empleo de las tierras, se examina el posible desarrollo futuro de la región de las Teirras Altas Occidentales.

8. En la tabla que acompaña al Mapa 1c y en el Apéndice 1 se indican, para cada sistema terrestre y sus subunidades, evaluaciones sobre los valores agrícolas y conservacionistas, así como de adecuabilidad de las tierras. En aquellos casos en que es posible reconocer el tipo del suelo, se indica una evaluación más apropiada en la Tabla A2.3 del Apéndice 2 si bien no se toman necesariamente en cuenta la pendiente y el acceso.

9. Si bien en la tabla que acompaña al Mapa 1c y al Apéndice 1 se indican recomendaciones provisionales para cada subunidad, cualquier desarrollo propuesto necesaría un estudio detallado de viabilidad, incluyendo una evaluación de precios y costes actuales.

10. En el Mapa 2 se presenta el empleo de las tierras en 1969-72 y en 1987-88.

Agua

11. La distribución de las precipitaciones durante el año en la región septentrional de Belice es extremadamente variable, sin que sea posible confiar en el comienzo o duración de las temporadas húmeda o seca o en la pluviosidad que puede esperarse.

12. La falta de un volumen de agua adecuado durante la temporada seca es el factor límite más crucial para el desarrollo en una importante parte de la zona del proyecto, aunque el empleo de aguas freáticas podría reducir dicha deficiencia en muchos lugares. Se requerirán nuevos estudios sobre la economía de diversos cultivos en distintos suelos y unidades de tierras.

Suelos

13. Por regla general, la calidad agrícola de los suelos cambia abruptamente dentro de zonas relativamente pequeñas, por lo que no es posible garantizar proyectos de desarrollo agrícola en gran escala, que requieran una maduración uniforme de los productos.

14. Dentro de la zona del proyecto, los mejores suelos se encuentran en el sistema de tierras de las planicies aluviales de Cayo. La mayor parte de los suelos restantes tienden a ser de escasa profunidad, compactos o con pobre avenamiento, lo cual limita su potencial para una agricultura perenne.

15. La mayor parte de la región septentrional de Belice se encuentra en la Planicie Costera Septentrional, caracterizada por sus suelos de piedra caliza y escasa profunidad, recurbiertos, a veces, por material silíceo de profundidades diversas. Los suelos agrícolas preferidos son las arcillas oscuras profundas, con o sin cierta mezcla de material silíceo fino. Sin embargo, las vastas arcillas calcáreas rojas del Distrito de Corozal poseen asimismo considerable potential para cultivos diversos. Las tierras de la región de Bravo Hills, al oeste, se hallan constituidas, principalmente, por arcillas oscuras de poca profunidad, con rocas o piedras.

16. La mayor parte de la zona meridional de Cayo (es decir, la parte del Distrito de Cayo que cae dentro de la zona del proyecto) está constituida por suelos poco profundos en un escarpado paisaje de caliza (la mayor parte de las Tierras Altas Occidentales y de las Estribaciones Centrales), suelos poco profundos en agudas pendientes sobre materiales madres metasedimentarios silíceos (casi toda la región de las Montañas Maya) o suelos ácidos sobre granito, en el sistema de tierras de la meseta de Mountain Pine.

17. Los suelos de las meseta de Mountain Pine y de la planicie costera, derivados por entero de materiales madres silíceos, (encontrados, principalmente, en los sistemas de tierras de August Pine, Puletan y planicie de Belice), son de explotación difícil, de manera casi invariable. Se trata de tierras con una fertilidad natural baja, fuertemente ácidas y, a menudo, con un elevado contenido móvil tóxico de aluminio. Su vegetación natural es escasa y, con frecuencia, estas tierras pueden adquirirse económicamente. Sin embargo, su desarrollo y mantenimiento requiere un nivel tal de manipulación técnica experta y aportaciones anuales de capital tan elevadas que no es probable proporcionen beneficios económicos.

18. Los suelos que se derivan o que se encuentran asociados con materiales madres calcáreos son más fértiles y, en general, soportan bosque alto en su estado natural. Y aunque la adquisición de las tierras es más costosa, los gastos de desarrollo – dejando aparte las perforaciones para la obtención de agua – son relativamente bajos.

19. La mayor parte de las muestras del suelo fueron analizadas en el NRI, si bien algunas se enviaron a Central Farm. Tanto la gama como la capacidad de las instalaciones analíticas disponibles en Central Farm requieren mejora, de forma que sea posible hacer frente a la creciente necesidad de asesoramiento sobre tierras y fertilizantes.

Conservación

20. En la actualidad, la única presión demográfica apreciable sobre tierras agrícolas se encuentra al norte del Distrito de Corozal. Este es el momento de producir un plan nacional de conservación y desarrollo de tierras, que debería contar con el apoyo de las comunidades locales.

21. En el Mapa 2d, se muestra una zona de protección de Cayo Sur, indicándose aquellas zonas que, como resultado de sus agudas pendientes, papel de captación de aguas o valor especial de conservación, deberían dejarse bajo bosques de protección.

22. Se enumeran los principales tipos de vegetación fuera de las reservas forestales y se sugieren reservas para mantener la biodiversidad.

23. Debería compilarse una base de datos precisa sobre la situación de los bosques en tierras privadas.

24. Solamente deberían sustituirse los bosques naturales por explotaciones ganaderas, cuando exista seguridad de que dichas explotaciones se encontrarán dentro de un sistema de gestión semiintensivo.

25. Una vez que se concluya el inventario forestal actual de Mountain Pine Ridge, debería disponerse de un plan de trabajo, que indicara zonas de protección y de producción.

26. Las futuras operaciones de explotación forestal dentro de la Reserva Forestal de Chiquibul deberían limitarse a la Serie Principal de Tala, hasta que llegue el momento en que la presión demográfica pueda requerir un plan estricto de desarrollo agrícola, según se indica en la sección sobre las Tierras Altas Occidentales y en la sección sobre Descripción de Unidades de Tierras.

27. El despeje de los manglares va en aumento, a pesar de la legislación que regula dichas actividades. Se hace necesario proteger los manglares costeros, para impedir la erosión de las costas, los daños de los huracanes y el agotamiento de los recursos de peces, camarones y langosta.

Uso de las tierras y recursos humanos

28. Aunque la mayor parte de los agricultores cuenta con propiedades de 5-50 acres (2-20 ha), un total aún mayor de tierras de halla en manos de quienes explotan más de 50 acres (20 ha). Salvo algunas excepciones, las tierras de las propiedades (>1000 acres (400 ha)) se encuentran seriamente infrautilizadas. Deberían utilizarse los impuestos sobre las tierras a manera de estímulo de un desarrollo racional de tierras ociosas con elevado valor agrícola, mientras que cabría emplear incentivos fiscales o financieros de otro género para proteger tierras con valor conservacionista.

29. Las comunidades menonitas,están extendiendo rápidamente sus tierras para cultivo y pastos. Habría que supervisar sus planes de producción agrícola, encaminando hacia la exportación aquella producción que sobrepase la capacidad de los mercados locales. Su programa de expansión debería adaptarse al plan nacional de desarrollo, para determinar la posibilidad de fomentar entre los menonitas el cultivo de productos para la exportación o si deberían ponerse obstáculos a su expansión, para conservar los bosques naturales. Tal vez debieran realizarse esfuerzos para conseguir una mayor incorporación de dichas comunidades en el marco político y administrativo de la nación.

30. Son muchos los patronos rurales que dependen de mano de obra de inmigración no nacional. Los controles en vigor relacionados con emigrantes temporeros deberían mantenerse y cumplirse con firmeza.

31. La economía rural de la región septentrional de Belice está basada en la caña de azúcar que, en general, no se somete a rotación con otros cultivos. Los cultivos alimenticios, que contribuyen sustancialmente al nivel de vida de las familias, continúan estando basados en un sistema 'milpa' modificado, que depende del barbecho a corto plazo para el mantenimiento de la fertilidad del suelo, que está siendo cada vez más inadecuada para todos los cultivos. Debería investigarse la posibilidad de emplear sistemas alternativos, particularmente, sistemas que lleven consigo una combinación de leguminosas y de cultivos mixtos.

32. La intensificación de la productividad para distintas empresas depende, en gran parte, de un mayor uso de factores no relacionados con la mano de obra, muchos de los cuales deben obtenerse fuera del país y que, en determinados casos (por ejemplo, el riego), requieren, inevitablemente, una elevada inversión de capital.

33. Una comisión debería investigar la razón del desempleo rural femenino en el Distrito de Corozal.

Caña de azúcar

34. El cultivo de la caña de azúcar es la principal empresa agrícola en la región septentrional de Belice. El margen medio por dólar invertido ha superado al de todas las demás empresas, mientras que el riesgo de fracaso ha sido, probablemente, más bajo que en cualquier otro tipo de empresa.

35. Durante los últimos años, la industria azucarera ha mejorado sustancialmente, como resultado del aumento de los precios, replantío de zonas afectadas por el tizón, una mejor gestión de la soca y condiciones meteorológicas favorables.

36. Los agricultores han sobrevivido períodos de bajos precios, debido, en gran parte, a métodos extensivos de producción, basados en cultivares bien establecidos. Contra lo que ocurre con otros cultivos, la caña de azúcar puede soportar períodos de abandono y proporcionar un producto cosechable. Sin embargo, el nivel actual de producción podría obtenerse con una zona de cultivo mucho menor, mediante el empleo de cultivares de alto redimiento resistentes a las enfermedades, apropiados para tipos específicos de tierra, con asesoramiento sobre regímenes económicos de fertilizantes. La Junta para la Caña de Azúcar debería considerar los factores siguientes relacionados con la intensificación: precaución del agricultor, adecuabilidad de nuevos cultivares para tipos específicos de suelos, provisión de equipo para análisis foliar y de suelos, requisitos de avenamiento, provisión de orientación sobre fechas de la recolección y, posiblemente, 'programas de maduración', provisión de incentivos para pago de acuerdo con el rendimiento del azúcar, provisiones de crédito y el apoyo que se requerirá del gobierno, Junta, Belize Sugar Industries (BSI) y Asociación de Cultivadores de Caña.

37. Debería investigarse la economía del regadío para el establecimiento de un nuevo cultivo en la temporada seca y comienzo de un cultivo de soca después de la cosecha.

38. El precio pagado por Petrojam es marginalmente inferior al coste de producción del agricultor. Sería necesario pagar más al agricultor, como incentivo para una mayor producción.

Diversificación

39. A pesar de que la caña de azúcar es un producto bien adaptado a las condiciones de la región septentrional de Belice y de que los agricultores se hallan familiarizados con el mismo, las preocupaciones sobre el futuro de la industria azucarera a mediados de la década de 1980 llevaron al establecimiento de un programa de diversificación. Durante los últimos años, los cupos externos han variado de un año a otro, aunque con un ligero aumento en los precios, siendo escaso el incentivo hacia la diversificación. Sin embargo, dadas las incertidumbres del mercado azucarero exterior, el programa de diversificación deberá seguir en pie. Debería proporcionarse un apoyo incondicional a Belize Agribusiness Company (BABCO) para el establecimiento de una demostración de la capacidad agrícola. Además de cultivos específicos, sería necesario ampliar las investigaciones para tener en cuenta las situaciones del agricultor, recursos de los sistemas agrícolas, condiciones de crédito y experiencia del agricultor.

40. BABCO debería recibir de los donantes apoyo financiero a largo plazo para investigación y desarrollo.

41. Una operación verticalmente integrada para la producción de papaya fresca par la exportación ha tenido un comienzo alentador. Es necesario que los niveles de producción sean uniformemente elevados y el riego es esencial. El cultivo podría verse afectado por la mosca mediterránea de las frutas.

42. Aunque la piña 'pan de azúcar' se desarrolla bien, las pruebas realizadas con material Cayenne de México (para la producción de fruta fresca para la exportación) muestra una elevada proporción de plantas 'despilfarradoras', muchas de las cuales dieron fruto prematuramente. En consecuencia, el futuro de este aspecto de la diversificación es incierto. Debería proporcionarse a BABCO apoyo completo para ampliar sus pruebas, particularmente, para la inducción de frutas en distintos momentos. Habría que extender la temporada del 'pan de azúcar' (para el mercado local) de manera ventajosa para el agricultor, utilizando productos químicos para inducir la floración.

43. Las pruebas de carambola se encuentran todavía en sus etapas iniciales. Y aunque su desarrollo vegetativo es alentador, será esencial una selección cuidadosa de frutas frescas para la producción comercial de jugos, habida en cuenta la heterogeneidad del material.

44. El desarrollo vegetativo de la fruta de la pasión amarilla en pequeñas pruebas parece alentador, si bien el índice de cuajado de la fruta ha sido bajo.

45. La producción de verduras invernales para el mercado estadounidense está demostrando ser arriesgada, con escasas perspectivas de elevados beneficios, debido, particularmente, a la competición de otros proveedores.

Judías

46. La judía roja es un artículo favorito de la dieta local, siendo el tipo más popular cultivado, a pesar de la incertidumbre de su rendimiento, como resultado del clima y de las enfermedades.

Durante el último trienio, la comunidad menonita del Pequeño Belice ha ampliado considerablemente la producción y podría hallarse a la cabeza en el desarrollo de una útil industria de exportación. Este potencial se vería fortalecido, caso que los nuevos híbridos *Phaseolus vulgaris* CIAT (cruce de judías rojas con judías negras) demostraran ser menos susceptibles a los avatares del tiempo que las judías rojas.

47. Desde un punto de vista ambiental, el norte de Belice es apropiado para el cultivo de la soja, que podría ser un valioso sustituto de importaciones de aceite vegetal y piensos para el ganado. Aunque más apropiado para grandes explotaciones mecanizadas, el desarrollo de este cultivo dependerá, en gran manera, de la adopción segura de medidas para su recolección y comercialización.

Cacao

48. Cayo es el único distrito dentro de la zona del proyecto con suficientes precipitaciones para el cultivo del cacao. Sin embargo, a precios actuales, sigue siendo solamente un sistema de baja entrada. Caso que este cultivo pudiera enlazarse con un proyecto ganadero, el cultivo del cacao podría resultar más económico.

Anacardo

49. El anacardo crece y furctifica bien en el subjuego de suelos de Crooked Tree y se encuentra, sobre todo, en el sistema de tierras de la planicie de Crooked Tree. Aunque tanto el rendimiento como el tamaño de la nuez parecen satisfactorios, es probable que el desarrollo de haciendas no resultara económico, debido a los elevados costes de la mano de obra. El Gobierno debería comenzar a seleccionar existencias de semillas. Las empresas agrícolas familiares, basadas en plantaciones ya existentes, muestran mayor promesa, particularmente, cuando se cuenta con una pequeña máquina descascarilladora, tal como la que está siendo sometida a prueba en el NRI. El futuro de la industria dependerá de la rentabilidad de la máquina descascarilladora.

Cítricos

50. Los cítricos pueden cultivarse en algunos de los suelos de caliza marrón y roja de las planicies de Louisville y Xaibe, así como en los suelos más arenosos do la llanura de Lázaro, en los distritos de Orange Walk y Corozal. Sin embargo, la mayor parte del norte de Belice se encuentra a una distancia económicamente no viable de las fábricas actuales de elaboración, situadas en el Distrito de Stann Creek. Por supuesto, las planicies aluviales de Cayo son muy apropiadas para el cultivo de los cítricos.

Coco

51. El coco sigue cultivándose a escala doméstica por su aceite y nueces, para el hogar y mercados locales. Todo desarrollo adicional como sustitutivo de importanciones de aceite vegetal o pienso para el ganado se ve constreñido, principalmente, por los bajos precios ofrecidos a los cultivadores. El futuro del cultivo se ve asimismo amenazado por las predicciones de que la enfermedad letal del amarilleo llegará a Belice en un próximo futuro. Por esta razón, todo intento de replantío debería utilizar plantas-semilla híbridas, a pesar de que las neuces sean menos deseables para uso doméstico.

Café

52. El café cultivado es muy escaso. El café Robusta, cultivado en el pasado a escala comercial, podría probarse en el Distrito de Cayo como importante sustitutivo.

Algodón

53. Las pruebas de primer año realizadas en los distritos de Orange Walk y Corozal con el algodón de alta calidad Sea Island son alentadoras, si bien es posible que el tiempo haya sido particularmente favorable. Se requerirá una vigilancia estricta para evitar el abuso de los pesticidas.

Cacahuete

54. El cacahuete no se desarrolla bien en tierras arcillosas calcáreas. Al mismo tiempo, el mercado local para los distintos productos derivados (cacahuetes tostados, mantequilla de cacahuete, cacahuetes salados) es reducido.

Mango

55. Existen mangos bien desarrollados por toda la zona del proyecto. El cuajado de la furta es altamente irregular y, además, la viabilidad de un mercado de exportación de fruta fresca a los EE.UU. no se pondrá en evidencia por varios años. Es posible que las moscas de la fruta resulten ser un factor adverso.

Semillas oleaginosas

56. Deberían examinarse recientes desarrollos comerciales en la producción de semillas oleaginosas en países vecinos y, en particular, los llevados a cabo en la península mexicana de Yucatin.

Cebollas

57. Mediante la aplicación de productos químicos, sería posible producir cebollas de regadío en ciertas tierras, a escala cada vez mayor, para dar satisfacción a las exigencias del mercado local.

Patatas blancas

58. Son muchos los agricultores que desearían cubrir la demanda de patata blanca que, en la actualidad, está siendo importada en considerables cantidades. Se están realizando pruebas con este producto.

59. Se han importado patatas de siembra sin una evaluación apropiada de su adecuabilidad. Debería solicitarse asesoramiento sobre cultivares aptos del Centro Internacional de la Patata, ubicado en Perú.

Ganado

60. Se desconoce la estructura de la cabaña nacional.

61. La calidad del ganado ha mejorado recientemente y se han establecido algunos pastos de calidad, si bien la práctica más generalizada es el pastoreo extensivo de pastos naturales con escasa cría controlada del ganado. En general, la gestión de los prodos es inadecuada.

62. Investigaciones iniciales parecen indicar que existe un ligero margen en la explotación del ganado para carne para el mercado local, tanto bajo gestión intensiva como extensiva. El Proyecto para el Desarrollo Ganadero de Belice (BLDP) debería estudiar detalladamente los costes y beneficios de la cría de ganado. Viabilidad comercial de la gestión ganadera. Existe un mercado potencial de carne en canal o deshuesada.

63. Un requisito de importancia para ganarse la confianza del propietario es el desarrollo de un sistema de comercialización, junto con crédito para su puesta en práctica, en apoyo de la política gubernamental.

64. Debería contarse con legislación para la continuación de los mercados locales libres en carnes y ganado para carne, junto con el desmantelamiento de los controles de exportación.

65. Se requiere un registro del índice de desarrollo de todos los novillos de importación. El BLDP deberiá organizar en pequeñas explotaciones pruebas de engorde de novillos de importación, con vistas al desarrollo de un proyecto de engorde de ganado para pequeños terratenientes.

Ganado porcino

66. Desde hace tiempo, los productos procinos han venido siendo un importante complemento de la dieta de la población. Mientras que Belice es autosuficiente en carne de cerdo fresca, se importan productos elaborados. No existen unidades de engorde o cría en gran escala. Una mejor estabulación y un mayor uso de piensos de bajo coste localmente producidos podrían mejorar la rentabilidad y, posiblemente, incrementar la cantidad de cerdo criados. Durante la temporada seca, la cría de cerdos se ve, a menudo, limitada por la disponibilidad de agua limpia.

Abejas

67. Ideal para la apicultura, la región septentrional de Belice ha sido el principal centro del país. Aunque la industria se hallaba bien apoyada por una organización cooperativa verticalmente integrada, en los dos últimos años se ha visto devastada por la llegada de la abeja africanizada, cuya erradicación no resulta viable. En consecuencia, el futuro depende de la introducción de métodos de gestión de dicha abeja, incluyendo la producción a partir de abejas híbridas.

Maricultura

68. Aunque la viabilidad de la producción del camarón en Belice ha quedado técnicamente demostrada, debería existir una mayor y más intensa planificación por parte de las empresas explotadoras, cuyos presupuestos deberían tener en cuenta costes accesorios.

Comunicaciones

69. La Asociación de Cultivadores de Caña de Azúcar debería experimentar con el empleo de comunicaciones por radio, para mejorar la programación de las entregas de caña a la fábrica de Tower Hill.

70. Se necesita una rehabilitación completa de la carretera Hummingbird Highway.

71. También se requiere la construcción de una carretera transitable en todas las épocas del año, desde Hill Bank a Belmopan.

Crédito

72. Se requiere una estrecha cooperación entre la Corporación para Financiación del Desarrollo (DFC) y el servicio de extensión del Ministerio de Agricultura y Pesquerías, para reforzar la eficiencia de la vigilancia de proyectos por parte de la DFC, particularmente, par pequeños agricultores.

73. El coste de mantenimiento del personal sobre el terreno de la DFC para vigilancia de proyectos requiere subvención.

74. Debería vigilarse el propuesto programa del BDLP.

75. La Fundación Nacional para el Desarrollo de Belice (NDFB) debería considerarse para provisión de préstamos intermedios de fondos del Banco Mundial al agricultor.

76. Existe necesidad de identificar la causa del ensanchamiento de la gama de tipos de interés de los prestamistas comerciales.

Realización del estudio

77. Los límites de los sistemas de tierras fueron satisfactoriamente determinados mediante interpretación de imágenes obtenidas por satélite y fotografía aérea, junto con el examen de mapas geológicos y trabajos sobre el terreno para sies de las siete regiones.

78. Para la séptima región – Planicie costera septentrional – hubo menos correlación entre las formaciones y los suelos. Los límites del sistema de tierras depende más del estudio de sueles solamente y, tal como se indica en la columna de claridad de límite de las Tablas 8-16 del informe, muchos de ellos son difusos.

79. La interpretación de las fotografías aéreas reveló la mayor parte de las formaciones indicativas del tipo de suelo, peligro de erosión y condiciones de avenamiento, que fueron utilizadas como criterios para subdividir los sitemas de tierras en subunidades agriculturalmente significativas.

80. Dentro de cada sistema de tierras, se estableció la gama de suelos principales (a nevel de juego y subjuego), mediante inspección de las zonas accesibles.

81. El tiempo medio invertido por sistema de tierra para el estudio de suelos sobre el terreno fue de 3 días, tiempo superior al requerido en el Distrito de Toledo, pero inferior al del Distrito de Stann Creek, lo cual indica la relativa confiabilidad do los tres estudios.

82. Los sistemas de tierra y subunidades poseen, probablemente, una confiabilidad aproximada del 80% por cuanto a su indicación de los suelos probables, mediante la transferencia de estos límites a un Sistema de Información Geográfica (GIS), será posible ponerlos al día, a medida que se obtenga nueva información.

83. Se espera que las evaluaciones de adecuabilidad de las tierras posean un nivel de confiabilidad correspondiente del 80%, aproximadamente.

Addenda

Part 1

Introduction

PROJECT BACKGROUND

Belize has a land resource assessment (Wright *et al.*, 1959), which has been updated for the Belize Valley (Jenkin *et al.*, 1976) and Toledo and Stann Creek districts (King *et al.*, 1986, 1989 respectively). During the survey of the Stann Creek District in 1988, the Government of Belize requested the Overseas Development Administration (ODA) to fund and provide technical co-operation for a land resource assessment of the rest of the country: Corozal and Orange Walk districts, part of Belize District not covered by the Belize Valley and Stann Creek District surveys (which latter survey included Belize District south of latitude 17°15'N), and the southern part of Cayo District – south of the area covered by the Belize Valley survey. The ODA agreed to this request and asked their Natural Resources Institute (NRI), who had done the previous land resource assessments (albeit under different names), with the exception of Wright *et al.* (1959), to undertake this one.

TERMS OF REFERENCE

The survey is required to provide a rapid appraisal of the nature, potential and present use of renewable natural resources in Corozal, Orange Walk, Belize and Cayo districts in the light of local possibilities and development aims of the Government of Belize, and at a level of detail appropriate to assist directly the Government of Belize in its general planning and development strategy. The survey is also required to update information on land potential published in Wright *et al.* (1959).

The survey will identify development opportunities, constraints and areas that should be left under protective forest. It will also investigate the feasibility of a Geographic Information System (GIS) for Belize.

1:100,000 scale maps of land systems and land use, similar to those produced for Stann Creek and Toledo districts, will be produced. In addition, a GIS database will be compiled so that specific maps answering specific information requests can be generated.

PROJECT DESCRIPTION

The project began in July 1989. The most recent aerial photography and satellite imagery were obtained, comprising:

(i) 1988 1:42,000 scale aerial photography

(ii) 1979, 1980 and 1987 Landsat MSS and TM imagery

(iii) 1987 and 1989 SPOT imagery of the extreme southern part of the project area

(iv) 1981 Shuttle radar imagery

(v) 1978 Seasat radar imagery

In order to investigate the extent to which the forest had been replaced by cultivation during the last twenty years, the above 'remote sensing' imagery was compared with aerial photography from 1969-70 (1:48,000 scale) and 1972 (1:39,000 scale).

The satellite imagery was ordered in the form of computer-compatible tapes (CCTs). The Landsat and SPOT imagery were processed at NRI and the National Remote Sensing Centre (NRSC) to produce contrast-enhanced 1:100,000 scale high-resolution colour laser prints. High resolution prints of the radar imagery were produced by Hunting Technical Services Ltd.

The first provisional land system boundaries were demarcated on to the satellite imagery, using the graphics of the GEMS image processor at NRI. Photographs were taken of the demarcated imagery portrayed on the screen, and prints were taken to Belize.

There were two fieldwork seasons: mid-July to mid-September, 1989; and mid-February to mid-June, 1990. The first field season was primarily a rapid soil characterization of the project area, but development opportunities and constraints and environmental concerns were also identified. The feasibility of establishing a GIS in Belize was also investigated.

After the first field season, a revised second set of provisional land system boundaries were demarcated onto one set of the high resolution colour laser prints, and copied onto overlays and prints at the 1:100,000 mapping scale to provide a provisional mapping base for the second field season. An automated classification of the area under cultivation and mangrove was determined from the Landsat TM imagery, using the GEMS and ERDAS image processors at Edinburgh University.

A more thorough and detailed soil characterization was executed in the second field season, towards the end of which and based on its findings, a revised third set of provisional land system boundaries was demarcated from the satellite imagery on to 1:100,000 scale overlays. Subunits from each land system were listed. This compilation was used as a basis for discussion with local extension workers and advisers about the suitability of the various land units for a variety of crop types.

The extent of cultivation and mangrove, as determined from the automated classification, was checked against visual interpretation of the satellite and airphoto imagery and in the field. Climatic, hydrological, agricultural, economic and forestry investigations were also carried out during the second field season.

At the end of the second field season and soon after leaving Belize, a final demarcation of land system boundaries and their subunits was put on to 1:100,000 scale overlays, from a detailed interpretation of aerial photography supported by information gained in the field, and additional information indicated by the satellite imagery. On request from the Ministry of Industry and Natural Resources, this final demarcation also included the Belize Valley, based on information provided by the remote sensing imagery and Jenkin *et al.* (1976). The team did not undertake any additional fieldwork in the Belize Valley. Final editing of the current land use and mangrove maps, as checked against the aerial photography, satellite imagery and fieldwork information, was delineated; and the extent of land use and mangrove in 1969 and 1972, as determined from the aerial photography of that time, was also demarcated.

Two 1:100,000 scale maps (each covering four sheets) were produced, indicating land use potential (Map 1), and extent of current land use and mangrove in 1987-9 and 1969-72 (Map 2). Map 1 was based on land suitabilities (and their subunits), assessed according to land suitabilities for beans, cacao, cashew, citrus, coconuts, coffee (Robusta), cotton, groundnuts, mechanized maize, milpa shifting cultivation, papaya, pasture, pineapple, mechanized rice, root crops, shrimp mariculture, sorghum, sugar cane and timber. Agricultural and conservation values and provisional recommendations were also determined.

Part 2

Environmental and human factors

LOCATION

The project area is 10,870 km^2 comprising Corozal, most of Orange Walk, southern Cayo and parts of Belize districts. Ambergris Cay is also included, but all other cays are excluded. The project boundary is indicated on Figure 1 and Maps 1 and 2. The project area borders Mexico and Chetumal Bay in the north, Guatemala in the west, Toledo and Stann Creek districts in the south, and the Caribbean Sea in the east.

Figure 1 demonstrates the dimidiated nature of the project area. The northern more developed part will hereafter be referred to as Northern Belize, and the southern under-developed part, excluding southern Belize District, will be referred to as Southern Cayo. The use of capital letters for Northern and Southern will distinguish the specific definition outlined here, i.e. northern Belize would be a more vague description.

All of Corozal and most of Orange Walk and Belize districts lie on the Northern Coastal Plain, bounded in the west by an escarpment which rises up to the Bravo Hills of western Orange Walk District. Most of Southern Cayo is in the Maya Mountains, but the western part lies on limestone with a more variable karst topography, called here the Western Uplands. It includes the area referred to as the Vaca Plateau – a name rejected in this study because of its unclear location and misleading description of the landscape. The term 'karst' is frequently used in this report, and refers to the characteristic steep tower and hollow topography produced by solution drainage rather than overland flow. Except for the forest management of the Mountain Pine Plateau, the only developed part of Cayo District within the project area is along the Hummingbird Highway, the valleys it crosses and Barton and Roaring creeks, all of which lie in the Central Foothills.

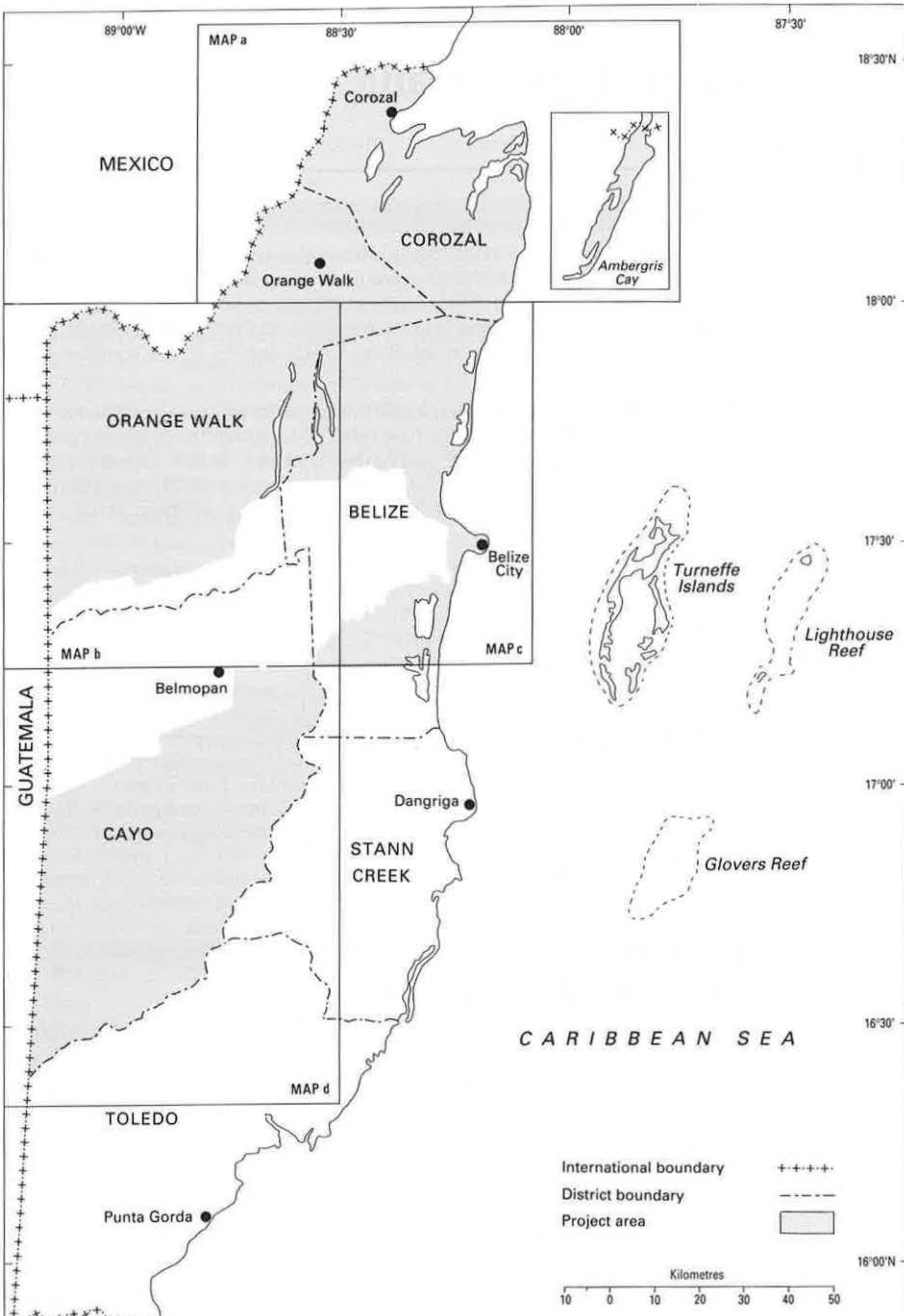
CLIMATE

Meteorological stations and records

Within the project area there are now only eight functioning meteorological stations: three in the south of Cayo District, two in Orange Walk, two in Corozal, and one in Belize District (Figure 2). Records from older stations were compiled by Walker (1973) and some of these were continued for a few years after 1970 (his cut-off date) before being closed. There are therefore records, of varying quality, from just over 30 stations. At most of these, only rainfall was measured but some included temperature and humidity and at one or two, wind speed and direction, and pan evaporation were also measured.

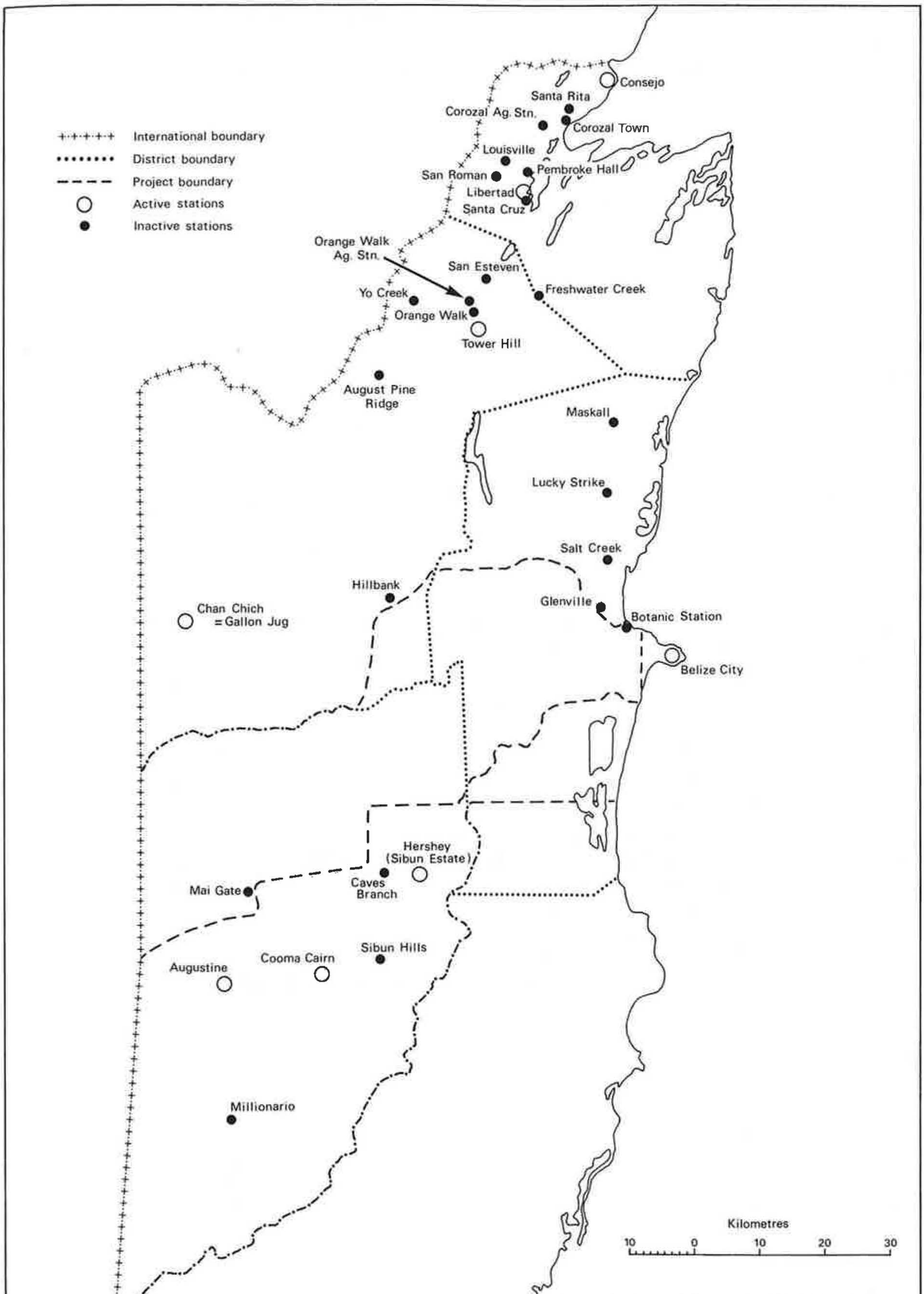
Reliance on old records from stations long closed (and in some cases operated for only a few years) is risky. We do not know whether the station was satisfactorily sited (or sited so as to give cumulative mismeasurements) or whether there was any change in instrumentation or recording methods. Where a station is the only one in a large area (e.g. Millionario and Freshwater Creek in Cayo and Orange Walk districts respectively), its trustworthiness becomes crucial in any water budgeting, and can never be demonstrated if it has been abandoned.

Figure 1



89°00'W
88°30'
88°00'
87°30'
18°30'N
18°00'
17°30'
17°00'
16°30'
16°00'N
MAP a
MAP b
MAP c
MAP d
MEXICO
Corozal
COROZAL
Orange Walk
Ambergris Cay
ORANGE WALK
BELIZE
Belize City
Turneffe Islands
Lighthouse Reef
Belmopan
GUATEMALA
CAYO
Dangriga
STANN CREEK
Glovers Reef
CARIBBEAN SEA
TOLEDO
Punta Gorda
International boundary
District boundary
Project area
Kilometres
10 0 10 20 30 40 50

Figure 2



International boundary
District boundary
Project boundary
Active stations
Inactive stations
Consejo
Santa Rita
Corozal Ag. Stn.
Corozal Town
Louisville
Pembroke Hall
San Roman
Libertad
Santa Cruz
Orange Walk Ag. Stn.
San Esteven
Freshwater Creek
Yo Creek
Orange Walk
Tower Hill
August Pine Ridge
Maskall
Lucky Strike
Salt Creek
Hillbank
Glenville
Botanic Station
Chan Chich = Gallon Jug
Belize City
Hershey (Sibun Estate)
Mai Gate
Caves Branch
Sibun Hills
Augustine
Cooma Cairn
Millionario
Kilometres
10
0
10
20
30

Table 1

Wind speed, evaporation and sunshine hours per day from Belize City (BC) and Central Farm (CF)

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
Wind speed (m/s)													
BC	1.16	1.55	1.94	1.97	1.91	2.03	2.11	1.74	1.48	1.30	1.39	1.50	
CF	0.43	0.58	0.86	1.05	1.61	0.98	0.81	0.69	0.58	0.47	0.41	0.74	
Pan evaporation (mm/month)													
BC*	102	107	165	175	189	160	173	165	130	126	107	102	1701
CF	87	103	157	175	189	160	157	150	130	110	99	87	1604
Sunshine (hours/day)													
BC	6.2	7.2	8.4	8.6	8.2	6.4	7.5	7.5	6.1	6.1	6.2	6.0	
CF	5.1	6.0	7.0	8.1	7.6	5.8	6.1	6.8	5.1	5.4	4.8	5.2	

* International Airport

An immediate improvement in the network in Northern Belize would be effected if stations could be operated at Sarteneja, Crooked Tree, Maskall and Blue Creek. The first two are in legally protected areas; there are police stations at the other two: reliable personnel should therefore be available and continuity need not be a problem. Certainly if conservation and management of water resources ever become a national concern, more rainfall stations will be needed, especially if, for example, irrigation is developed, which draws heavily on the available water.

Only short-duration measurements of wind speed and pan evaporation have been made within the project area, and in some cases these data have not been processed consistently. We have not calculated averages from these short and discontinuous records and values calculated for the International Airport and Central Farm have been used instead (Table 1).

During the winter months, cold air streams from anticyclonic weather systems to the north regularly enter the country. These cold 'northers' are usually accompanied by air turbulence and brief but heavy showers, together with rapid lowering of the air temperature. Papaya, plantain and banana crops are usually affected. These brief but damaging northers are not shown clearly by the meteorological records, but farmers claim they have been more frequent over the last ten years. They also have greater stength, and are likely to happen both earlier (September) and later (April or May) than formerly.

Northern Belize

RAINFALL

There are only four active rainfall stations in Northern Belize of which two: Libertad and Chan Chich (Gallon Jug) are new. There are 24 years of records from Tower Hill, and 11 from Consejo. Two of the stations included by Walker (1973) were continued for some years after his study before being closed. Monthly averages for all stations past and present (but omitting the two new ones) are shown in Table 2.

There are two noteworthy features of the rainfall pattern. One is the line of stations in the east having a higher annual rainfall than the rest of Northern Belize. The line extends from the former Botanic Station (and the nearby International Airport) to Freshwater Creek and includes Glenville, Salt Creek, Lucky Strike, and Maskall. Whether this is related to proximity to the coast cannot be confirmed.

Table 2

Mean monthly rainfall (in mm) in Northern Belize

Station	J	F	M	A	M	J	J	A	S	O	N	D	Total
C1	75.5	34.3	30.2	34.1	138	249	174	166	206	194	111	89.7	1502
2	67.6	33.4	20.9	39.4	117	237	175	151	240	160	102	73.6	1417
3	58.0	34.3	38.8	41.6	91.6	211	168	132	213	158	88.0	74.1	1308
4	61.8	38.1	29.7	33.8	98.6	219	171	144	168	174	129	51.3	1318
5	82.6	36.4	40.4	40.9	146	204	213	174	266	184	161	101	1649
6	50.8	35.3	34.1	40.2	61.0	241	198	157	235	185	56.4	84.1	1378
7	95.6	27.7	22.6	24.1	105	245	199	128	230	116	124	76.8	1394
8	73.5	32.8	29.2	36.9	137	220	169	147	218	192	90.0	56.9	1402
9	68.9	32.3	23.4	36.6	143	210	180	136	217	134	100	68.6	1350
OW1	67.4	44.6	43.5	19.9	96.4	230	199	151	244	169	84.9	93.3	1443
2	86.4	45.5	30.5	37.9	126	231	186	174	222	192	93.3	90.0	1515
3	67.1	53.6	15.2	26.9	76.5	208	190	151	222	157	92.3	81.3	1341
4	116	67.9	35.8	41.4	175	282	263	199	319	223	150	120	1992
5	68.7	40.1	35.2	19.7	134	192	176	149	228	168	70.7	94.3	1376
6	90.5	32.5	26.7	39.1	139	259	182	168	296	311	101	109	1754
7	43.7	63.3	49.8	46.3	88.0	199	200	149	184	205	90.5	56.9	1376
8	75.2	42.2	28.7	47.0	92.0	252	254	137	193	162	123	97.6	1504
9	111	30.8	81.8	36.4	109	256	225	190	289	142	91.8	64.1	1627
B1	99.4	48.6	54.9	46.3	119	214	226	152	277	245	145	105	1732
2	88.7	63.3	25.2	38.9	159	234	217	159	241	243	136	102	1707
3	87.7	47.5	31.3	41.7	106	240	221	135	223	249	137	113	1632
4	64.6	42.5	38.4	28.0	142	271	399	234	329	274	112	128	2062
5	148	50.8	42.7	39.1	105	170	138	146	192	256	221	143	1652
AC	96.1	49.1	33.3	26.2	86.7	148	105	86.2	187	195	164	117	1294

Corozal District (C)
1. Corozal town
2. Corozal Agric. Station
3. Consejo
4. Santa Rita
5. Santa Cruz Estate
6. Santa Cruz (BSI)
7. San Roman Agric. Stn
8. Louisville Estate
9. Pembroke Hall

Orange Walk District (OW)
1. Tower Hill
2. Orange Walk town
3. Orange Walk Agric. Station
4. Freshwater Creek
5. Yo Creek
6. San Estevan
7. August Pine Ridge
8. Gallon Jug
9. Hill Bank

Belize District (B)
1. Maskall
2. Lucky Strike
3. Salt Creek
4. Glenville
5. Botanic station

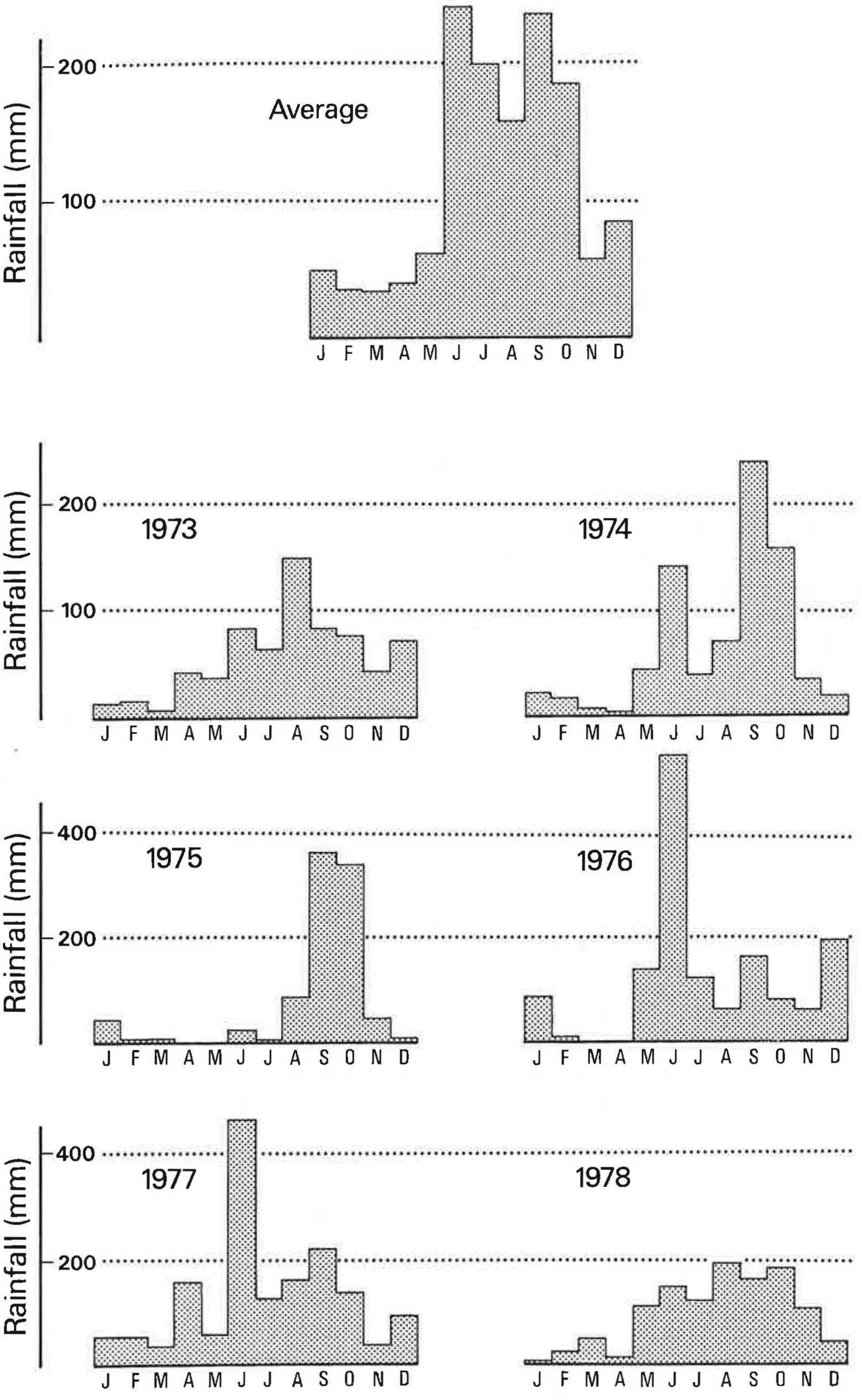
Ambergris Cay (AC)
San Pedro

The other feature of the rainfall distribution is the uniformity throughout Corozal District and extending to Orange Walk, Yo Creek, August Pine Ridge and even to Gallon Jug. The three-month dry season and double-peaked wet season is typical of most of the country; but it is interesting to see how abstract a concept is the average year. In Figure 3 the mean rainfall year at Santa Cruz (BSI) station is compared with six successive actual rainfall years at that station. Not one of the actual years looks like the average rainfall year; in fact they look as though they could have come from different regions altogether. This extreme variability must be taken into consideration when the agricultural implications of meteorological variations are being examined. A farmer who decides to plant because "the rains start about the middle of May around here" or who is confident that his crops will be well watered because "we always get 'x' inches in October" is at least as likely to be wrong as right.

Total annual rainfall is also highly variable. At Corozal Agricultural Station the annual rainfall between 1936 and 1970 ranged from 748-2095 mm with a mean of 1417 mm and a standard deviation of 350 mm. The much shorter record at Tower Hill gives extremes of 920 mm and 1750 mm, an average of 1443 mm and a standard deviation of 216 mm. The highest monthly rainfall on record occurred in June 1906; 902 mm in Corozal and 820 mm in Orange Walk. The highest daily rainfall recorded was 262 mm in June 1909 at Corozal (Walker, 1971).

Although the dry season from February to April is a climatic feature throughout the country it is more severe in the north than elsewhere. Daily records from

Figure 3


Rainfall (mm)
200
100
Average
J F M A M J J A S O N D
1973
1974
1975
1976
400
1977
1978

Santa Cruz show that the period of markedly deficient rainfall usually lasts over 140 days with small falls aggregating 90-150 mm within that time. In 1975 only 124 mm of rain fell in the eight months between the end of the previous November and the first week of August: this is probably about as bad as it is ever likely to get. Every couple of years there are daily falls of 15-25 mm to break the severity of the drought, but only rarely are these falls sufficiently heavy to exceed the storage capacity of the soil.

Because of the variability, probability estimates are only useful for long-term projections; for anything else they should be regarded as tentative. However, the following figures are reasonable first estimates based on the records from Corozal Agricultural Station. They refer to the three months February-April, although the drought can start earlier and last longer. The total rainfall will be less than 75 mm every two years, less than 50 mm once in every 4 years and less than 25 mm once in every 14 years. The growth of most crops will be impossible with such a low rainfall.

If the soil moisture storage capacity is low or if the plant is sensitive to drought, an individual dry spell, if sufficiently long, can kill a crop in a season which is generally quite wet. Using the daily rainfall record of the present Santa Cruz Station, which covers the last thirteen years, the duration of each dry spell longer than ten days was noted (ignoring rainfall of 3 mm or less). Over ten years, 77 ten-day dry spells can be expected, 30 twenty-day dry spells, 15 thirty-day dry spells, 6 forty-day dry spells and 3 fifty-day dry spells. Between the first heavy rains at the end of the dry season and the last heavy rains at the start of the next, 27 dry spells of ten days or longer can be expected (half of those occurring in November and December) in a ten-year period.

TEMPERATURE AND HUMIDITY

Long-term temperature measurements have been made at Santa Cruz (over 13 years). Monthly average maximum and minimum temperatures and monthly extreme maxima are given in Table 3. The hottest months reach a mean maximum of 32.9°C while the highest recorded temperature is 37.5°C. The average daily range is between 8-12°C while the range of daytime temperature throughout the year does not exceed 5°C. According to daily records from Yo Creek, one day in six will reach 29°C and one in 14 will reach 32°C.

Values of mean relative humidity at Corozal and Yo Creek Agricultural Station were 80-88% with San Roman rather higher.

EVAPOTRANSPIRATION

The empirical method suggested by Thornthwaite (1948) for calculating potential evapotranspiration was used to estimate the extent to which rainfall fails to meet the needs of growing plants. Potential evapotranspiration is the amount of water that a full cover of actively growing plants will use if there is no shortage, i.e. it is the amount of rainfall and supplementary irrigation to maintain maximum growing rate. Plants do not use the same amount of water at different

Table 3

Monthly mean maximum and minimum, and mean extreme maximum temperatures at Santa Cruz (°C)

	J	F	M	A	M	J	J	A	S	O	N	D
Mean maximum	29.1	30.7	31.3	32.3	32.9	31.8	32.1	32.6	32.2	31.4	30.4	28.8
Mean minimum	17.3	17.7	20.1	20.7	22.7	23.3	22.5	22.6	23.1	22.0	19.6	18.0
Mean extreme maximum	31.9	32.6	34.8	34.7	35.8	34.7	34.2	35.0	34.5	33.8	33.4	32.3

growth stages, and there may be good reason to deny a crop the water that it could use; but the concept of potential water use by plants is invaluable in trying to quantify rainfall deficiency and in examining how much it constrains agriculture.

The potential evapotranspiration (in mm), as estimated by the Thornthwaite formula, for the temperatures and latitude of Corozal are:

Jan	76	May	144	Sept	153
Feb	86	June	167	Oct	122
Mar	105	July	171	Nov	96
Apr	133	Aug	167	Dec	70

If we compare these figures with the mean monthly rainfall, there is no deficiency in the summer months (except for a small one in August) and indeed the whole deficiency is concentrated in February, March and April; but this is just another example of the way averages can mislead. A mean of say 200 mm of rain in June will certainly represent some years with 500 and some with 50, and during the drier Junes the crops will suffer if the deficiency is not made good in some other way – i.e. by irrigation. The month by month water deficiencies at Corozal Agricultural Station are indicated in Table 4. They are calculated by taking the mean potential evapotranspiration values given above, and subtracting the rainfall. An entry in the table was made only where this left a positive figure greater than 10 mm. We can see from this table that in many years there is water deficiency during the wet season. It arises because, as noted above, the high mean rainfall conceals many years when the fall is quite low, and also because the water needs of the crops are much greater during the summer months when the temperatures are higher and the days are longer. We see from the table that there is an average need for additional water of 494 mm. Nearly half of this is needed during the dry season, but a quarter is needed between June and August.

Southern Cayo

RAINFALL

There are three active stations and five discontinued ones in that part of Cayo District which lies in the project area; their monthly rainfall means are shown in Table 5. There is a clear reduction in rainfall from east to west with the highest annual fall in the Sibun Hills.

If we accept the four-year mean from Millionario as typical, there is also a marked decrease from Augustine southward. The wet season has the usual two peaks, with 40% of the annual fall making up the second (from September to November). In 1979 this season was particularly wet with 3460 mm falling between September and December at Augustine, and 320 mm in three successive days of November, which would have caused damaging floods in all the rivers draining the Western Uplands.

The dry season (February-April) provides only 12% of the annual total. The combined fall for these three months was less than 50 mm in only one year of the 41-year record at Augustine and less than 75 mm in only three.

TEMPERATURE

Extreme maximum and minimum temperatures for Cooma Cairn, monthly for 13 years, are listed in Table 6. Maxima at Augustine are consistently higher by 4-5°C, the absolute maximum being 39°C compared with 34.5°C at Cooma. Further east, temperatures are similar to those at Cooma but the highest single record is from Sibun Hills in April 1969, an astonishing 42.5°C. The annual range of monthly mean temperatures is about 7°C whereas the daily range is about 13°C. Analysis of daily records for Cooma, extrapolated to cover Augustine, indicates that during the months of March to June, the hottest temperature will exceed 29°C at Cooma (33°C at Augustine) one day in four; and 32°C at Cooma

Table 4

Rainfall deficiency (mm) at Corozal Agricultural Statation

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1936	–	–	101	71	–	–	–	13	–	–	–	65	250
1937	–	38	53	88	–	–	–	25	–	–	–	27	231
1938	41	23	105	120	–	60	124	–	–	–	–	63	536
1939	22	65	77	113	13	–	91	84	–	85	14	51	615
1940	–	82	73	78	–	–	–	42	–	59	–	–	334
1941	46	86	101	129	–	132	74	56	–	–	38	–	662
1942	18	76	101	129	–	44	–	–	–	72	–	–	440
1943	–	30	49	84	–	12	133	50	41	–	53	–	452
1944	30	62	28	124	130	–	–	–	–	27	17	68	486
1945	53	44	105	133	20	116	28	–	–	–	–	–	499
1946	–	11	76	105	91	37	56	–	–	–	–	–	376
1947	–	51	87	130	122	136	–	–	10	–	–	–	536
1948	28	80	105	63	56	–	–	–	–	74	–	–	406
1949	–	61	101	133	82	129	121	109	–	–	71	–	807
1950	23	39	58	133	127	–	110	87	–	–	75	36	688
1951	42	75	105	109	110	–	27	61	–	53	60	24	666
1952	15	72	60	66	79	–	–	63	–	–	–	14	369
1953	62	71	91	79	–	130	–	89	–	–	80	53	655
1954	–	81	102	109	–	–	–	–	–	–	50	24	366
1955	37	23	101	133	144	134	–	–	–	–	–	11	583
1956	68	57	72	133	–	–	51	107	–	44	72	21	625
1957	–	–	77	132	114	–	152	87	–	33	19	23	637
1958	58	59	89	104	na	–	–	103	–	–	–	na	na
1959	11	54	77	107	78	123	67	–	98	–	78	51	744
1960	47	79	103	82	–	–	–	–	–	–	–	30	341
1961	39	20	81	30	44	75	–	21	62	19	–	–	391
1962	–	78	77	74	–	–	75	107	22	20	20	32	505
1963	67	33	99	103	112	150	–	101	–	–	71	66	802
1964	–	84	101	133	70	–	–	61	–	71	–	–	520
1965	–	24	105	108	–	–	87	67	–	–	–	–	391
1966	46	–	35	55	–	–	15	–	–	–	45	52	248
1967	–	71	95	–	144	72	–	–	–	–	10	29	421
1968	–	57	105	133	–	–	72	108	–	–	35	44	554
1969	–	75	69	109	–	–	–	–	–	–	–	70	323
1970	46	–	105	133	–	–	–	–	–	–	58	32	374
1971	67	86	91	25	94	–	–	–	74	54	–	–	491
1972	–	68	na	133	124	–	–	29	–	18	na	na	na
1973	12	62	90	–	71	–	85	–	–	–	–	–	320
1974	13	48	105	128	–	–	98	57	–	–	57	38	544
1975	–	71	na	133	134	155	133	76	–	–	23	na	na
1976	–	65	100	125	–	–	33	93	–	–	23	–	439
1977	–	28	67	–	64	–	85	41	–	62	–	–	347
1978	25	38	46	na	na	na	35	40	–	–	30	53	na
1979	–	86	46	61	144	–	–	49	–	–	–	–	386
1980	62	33	99	57	144	–	22	49	65	na	18	na	na
Mean	22	52	84	96	54	34	39	42	8	16	23	24	494
%	4	11	17	19	11	7	8	9	2	3	5	5	

Table 5

Mean monthly rainfall, Southern Cayo (mm)

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
A	95.1	70.7	53.7	53.7	113	202	155	166	260	262	185	143	1759
CC	144	97.9	67.8	66.6	82.6	210	193	148	237	271	256	192	1966
M	108	59.0	65.3	68.4	153	169	191	93.3	155	177	111	159	1509
SH	319	103	105	52.6	129	315	269	276	365	274	423	215	2846
MG	99.4	69.1	60.0	67.4	71.2	203	166	136	215	194	228	93.5	1603
CB	157	96.3	73.0	74.7	129	349	441	232	279	238	225	170	2464
SE	151	86.2	91.3	75.2	167	349	426	253	313	235	267	175	2589
H	101	153	40.7	66.8	151	364	470	339	325	287	97.7	173	2568

A Augustine　　MG Mai Gate
CC Cooma Cairn　　CB Caves Branch
M Millionario　　SE Sibun Estate
SH Sibun Hills　　H Hershey's
SE and H are the old and present station in the same place

(36°C at Augustine) one day in ten. The mean monthly minimum temperature and extreme low are 15°C and 5.5°C respectively at both stations. Mean relative humidity ranges between 69-72% in May, and 86-92% in January. During the dry season, air temperatures fall by up to 5.5°C during the nights producing moisture condensation as dew. Farmers maintain this small nightly addition of extra moisture significantly helps plants under moisture stress – especially pastures and young arable crops.

Table 6

Extreme maximum and minimum temperatures at Cooma Cairn, to the nearest 0.5°C

Year	J	F	M	A	M	J	J	A	S	O	N	D
1973	27	26	33.5	34.5	33.5	31.5	30	29.5	30.5	30	26	26.5
	8	9	13.5	16.5	17.5	17.5	17.5	17.5	17.5	17	13.5	8
1974	24.5	31	32	33.5	36	32	29.5	29	30	25.5	25	24.5
	14	10	13.5	16.5	16.5	17.5	17	17.5	15.5	13.5	12.5	11
1975	29	28.5	31	33.5	34.5	34	30	30.5	28.5	31	26.5	26
	9	10	15.5	17	17.5	17.5	17	17	14.5	15.5	9.5	11
1976	25	24.5	29.5	31	34	30.5	31	30.5	30	29.5	27.5	27
	8	9.5	14.5	14.5	17.5	17.5	17.5	16.5	13.5	15.5	13.5	11
1977	26	27	31	31	31	30	29	31	30.5	30.5	29	26.5
	9	10	15.5	14	17.5	17.5	17.5	17.5	18.5	14	12	9
1978	27	27.5	33.5	31	35	33.5	29	30	30.5	30	26.5	27.5
	10	8.5	13.5	10	19	19	17.5	17.5	17.5	14.5	16.5	12
1979	28.5	30	30	33.5	34.5	33	32	31	31	30	29	25.5
	10	11	13.5	17	18.5	17.5	19	17	17	17.5	12	11.5
1980	26.5	29	na	33.5	34.5	27.5	29	31	29	27.5	26.5	23.5
	12	12.5	na	14.5	19.5	17.5	18.5	17.5	19	16.5	12	10
1981	26.5	26.5	29.5	31	32	31	28.5	29.5	31	27.5	na	17.5
	9	12	17.5	17.5	17.5	19	17.5	17.5	22.2	16.5	na	13.5
1982	27.5	27.5	29.5	31	31	33.5	29	29	30.5	29	26.5	26
	10	15.5	12	17.5	17.5	18.5	17	17.5	17	15	13.5	12
1985	25.5	27	29.5	30.5	31.5	28.5	28.5	29	27	26.5	29.5	25.5
	8.5	7	15	10.5	15.5	17	16	17	16.5	16.5	12.5	12
1986	21	27.5	31.5	28.5	30	28.5	29.5	27.5	28.5	27.5	26.5	25.5
	7	10	27	14.5	16	14.5	15	14.5	15.5	15	12	14
1987	26.5	29.5	35	30	32	30.5	28.5	28.5	25.5	25.5	27	na
	9.5	9.5	10	9	16	17	23	16.5	17.5	14.5	12.5	na

GEOLOGY

Three-quarters of the project area are underlain by limestone, decreasing in age from the hard often dolomitic Cretaceous limestone of the Western Uplands in the south-west, to the soft Pleistocene–Holocene coral limestones in the north-east. Most of the Maya Mountains consist of Santa Rosa Group metamorphic rocks: mainly argillites, but there is a belt of metavolcanic rocks in the extreme south. There are a number of granitic intrusions, the most extensive of which underlies most of the Mountain Pine Plateau. The lowland Pine Ridge deposits are considered to be Pleistocene alluvium.

Santa Rosa Group

Most of the rocks of the Late Palaeozoic (Late Carboniferous to Permian) Santa Rosa Group are fine-grained, mostly steeply dipping, metasediments, comprising phyllites, slates and mudstones. They are the dominant rock type of the Maya Mountains, and the parent material for the Ossory Suite of soils.

The group also contains the Bladen metavolcanics consisting of metamophosed, mostly alkaline rhyolitic lavas, pyroclastics and volcanic sediments. Their extent is indeterminate, and has been demarcated as such on Map 1d, using airphoto interpretation and the geological map of Bateson and Hall (1977), as subunit 'v' in the Richardson Peak Mountains land system. They are the parent material for the Richardson Suite of soils.

Metamorphosed conglomerates, sandstones and quartzites are commonly found in the northern part of the Copetilla Mountains land system, and in the eastern part of the Mountain Pine Plateau in the high plateau and high valleys subunits. Arenaceous beds are also found within the more common argillaceous beds elsewhere.

Margaret Creek Formation

The latest provisional geological map of Belize (Cornec, 1986) indicates a shaly sandstone formation between the Santa Rosa Group and the limestones to the north that outcrops between the Sibun River and Dry Creek which, on the basis of its stratigraphic position, and in comparison with Mexico and Guatemala, Cornec considered to be Jurassic–Lower Cretaceous. The formation is clearly recognizable on the aerial photography east of Dry Creek outside the project area, where it was described by King *et al.* (1989) as dipping northwards and conforming with the overlying limestones. The outcrop is not so clearly evident in the project area, although the argillaceous rocks of the Grano de Oro Hills may belong to this formation.

The formation was described by Dixon (1956) as consisting of a 1 m-thick limestone seam overlain by 370 m of dark grey or black shales, 210 m of micaceous sandstone, 60 m of dark brown mudstone, and capped with a thinly bedded lightly coloured sandstone which Dixon considered Cretaceous. As in King *et al.* (1989), the area occupied by the outcrop is mapped as part of the Ossory Plain with Hills land system, because the soils appear sufficiently similar to those derived from the Santa Rosa Group, although many are covered by limestone hillwash (subunit 'xP').

Coban Formation

The Western Uplands land region and the Toledo Foothills land region in the extreme southern tip of the project area are underlain by Coban Formation. These thick-bedded and massive Cretaceous (Neocomian to Turonian) limestones and dolomites produce the most striking karst topography in the country (represented by the "K" subunit symbol), particularly in the southern part of the Western Uplands, where there are several large cave systems, including the second largest chamber in the world, and an impressive natural arch (Puente Natural) over the Chiquibul Branch.

The formation contains a thick sequence – about 700 m (Viniegra-O, 1971) – of limestones and dolomites with evaporites in the lower part (Baldwin, 1986). It is the parent material for the Vaca soil suite, and one of the parent materials for the Chacalte Suite. The term "Hill Bank Formation" has been used by the Gulf Oil geologists for a clayey microcrystalline dolomite at the base of the Coban Formation. The Coban Formation often has interbedded shale and is sometimes sandy (Geology and Petroleum Office, 1986).

Campur Formation

The Xpicilha Hills with Plains and Hummingbird Plain with Hills land systems within the Central Foothills land region appear to be on the Senonian (late Cretaceous) Campur Formation limestone (Baldwin, 1986). The formation is about 850 m thick and is very fine-grained (Vinson, 1962). It dips gently northwards, and is one of the parent materials for the Chacalte soil suite.

Yalbac and Barton Creek formations

The Yalbac Formation is the northern facies equivalent of the upper Coban and lower Campur formations. The Barton Creek Formation is the northern facies equivalent of the upper Campur Formation. The Yalbac Formation is a sequence of anhydrite-carbonate alternatives, whereas the overlying Barton Creek Formation consists of limestones, dolomitic limestones and marls. "Chert is found in the upper part" (Geology and Petroleum Office, 1986).

The Yalbac and Barton Creek formations are mapped together by Cornec (1986) as occurring in three main locations within the project area:

(i) In the Gallon Jug Plain with Hills land system, below the escarpment at Cedar Crossing, in the mostly undulating plain north-west of Gallon Jug.

(ii) Below the Booth's River Escarpment in the extreme western part of the Hill Bank Plain land system.

(iii) In the extreme eastern part of the Hill Bank Plain land system and the extreme south-eastern part of the Shipyard Plain land system along the border of the New River Lagoon, including Indian Church.

The Barton Creek Formation would also appear to underlie the Neustadt and Blue Creek Plain land systems since the Jolja soil Subsuite found in those land systems appears to be derived from the upper chert band. The Yalbac and Barton Creek formations are one of the parent materials for the Yaxa Suite of soils.

Cayo and Doubloon Bank

The Cayo and Doubloon Bank groups are mapped by Cornec (1986) as underlying most of the Bravo Hills land region, and most of the Hill Bank, Shipyard and Jobo Plain land systems. The older Cayo Group contains limestone and dolomite, whereas the younger Doubloon Bank Group contains limestone with flints. The Yaxa soil suite is found in the Hill Bank and Shipyard plain land systems, whereas the Altun Ha soil suite, containing flints, is found in the Jobo Plain land system. The Jobo Plain land system therefore seems to overlie the Doubloon Bank Group, although borehole logs show the limestones are soft with clay interbedding, whereas the outcropping limestone is hard. The group may have a thick carapace. The older Cayo Group seems to be the more common rock type of the Hill Bank and Shipyard Plain land systems. The two groups are considered Early Tertiary in age (Cornec, 1985).

Tower Hill Formation

The name Red Bank Group was originally proposed by Flores (1952) to describe a series of clays and marls. Cornec (1985) has since described it as consisting of clays, gypsum and sand, and ascribed it to the early Neogene. It would appear to relate to Versey's (1972) Tower Hill Formation, which he described as consisting "mainly of sandy chalks, the detrital component being a fine to very fine, pure, quartz sand". This description is a fair approximation to the rock type found beneath the Lazaro Plain land system, and which appears to be the parent material for the Guinea Grass soil Suite.

These 'sandy chalks' are more commonly called 'marl' or 'sascab' when weathered. Following Johnson (1983), the term 'sascab' is used in this report to describe soft unconsolidated limestone, since unlike marl, which is considered by some authors to denote a freshwater calcareous clay, the term 'sascab' has no genetic implications.

Quinones and Allende's (1974) microscopic examination revealed sascab is "made up of a fine detritus of coral remains mixed with great quantities of the remains of ostacodes". They also noted sascab is highly valued for plastering and paving in Mexico. Darch (1981) described the sascab she investigated in Belize as being "a white- to cream-coloured unconsolidated deposit of silty fine sand texture, consisting primarily of calcite and quartz". She found "layers of silty fine sand, fine sand, silt and coarse gypsum crystals... in the profiles examined". Sascab varies both vertically and horizontally, but most of the samples taken by Darch had a low clay content. She concluded sascab is produced by deep weathering – the "gypsum horizons were formed in an earlier drier climatic period with low sea-levels".

Orange Walk Group

The late Neogene to Pleistocene Orange Walk Group contains sascab, interbedded with clay, and commonly with a lithified carapace. Quinones and Allende's (1974) X-ray fluorescence spectrometry analysis revealed both the sascab and the carapace contain calcite with a low magnesium content: "values around 1% of magnesium carbonate prevailing", which supports Friedman's (1964) contention that limestones originally rich in aragonite and calcite with a high magnesium content are transformed into limestone low in magnesium when exposed to soft water under subaerial conditions. "In the course of these changes a process occurs whereby the original minerals are substituted and the pores are filled with secondary calcite... The cementation in the surficial part of the original sediment which produces the carapace has been interpreted as the result of the increasing impermeability of the material owing to the progressive refilling of the pores. There would be an increasingly greater retention of moisture near the surface, with the consequent dissolution of calcite and recrystallization *in situ*" (Quinones and Allende, 1974). Darch (1981) considered the carapace "has occurred in the drier environmental zones where a seasonal water deficit occurs, either today, or in the past."

The Orange Walk Group underlies most of the Louisville and Xaibe plain land systems, and is probably the parent material of the Pembroke soil suite.

Pleistocene – Recent limestones

The youngest coral limestones are found around the northern coast, particularly under the Consejo Plain and Corozal Saline Swamps land systems, and at Ambergris Cay. They are hard, rubbly, porous and cavernous, and are the parent material for the Bahia soil Suite and the Shipstern and Ambergris Subsuite.

Alluvium

Alluvium is the parent material for the P (excluding MP), F, W, B, M and Y land system types (see section on 'Land Unit Description'). It underlies the Central Coastal Plain (within the project area) and a significant part of the Northern Coastal Plain.

The oldest alluvial deposits appear to underlie the P (excluding MP) land system type and are the parent materials for the Puletan and Revenge soil suites. Their age is indicated by their relatively elevated position in the landscape, often scattered occurrence, and degree of pedogenesis: all suggesting a Pleistocene age. They mostly seem to occur in a converging north-south alignment, i.e. east of north in the west, and west of north in the east. The western deposits, particularly of the August Pine and Crooked Tree Plains, are dissected by a parallel drainage system transverse to the alignment of the deposit. Some of the deposits in these drainage lines are derived from calcareous material (the Sennis soils), but most of them appear to be reworked and redeposited old alluvial soils (Haciapina soils). The two main western deposits along the eastern flanks of the Booth's and New river drainage systems, slope very gently to the west, and have an occasional degraded scarp on their eastern side. The deposit along the eastern flank of the New River system appears to have an extensive deposit of Haciapina soils along its western downslope edge.

Wright *et al.* (1959) considered these deposits were brought down by Pleistocene rivers draining the Maya Mountains. "The northward trend of the main river, meeting the south-trending sea current, would shape the area of deposition..." The position and alignment of the deposits between the New River and Northern Lagoon drainage systems combined with the current alignment of the middle reach of the Belize River support this hypothesis, but it is difficult explaining the location of the westernmost deposit flanking the Booth's River. The alignments of the easternmost deposits in the Tok Plain indicate old strand plains, presumably deposited by the south-trending sea current. Since Wright *et al.* envisage a late Pliocene or very early Pleistocene shoreline along the current

Hondo-Booth's River depression, the westernmost deposit along the Booth's River may be a remnant of an old strand plain. The deposits may have originally been carried north by the northward-flowing rivers and then redeposited by southward longshore drift along this old strand line, although the northward thinning out of the deposit argues against this hypothesis. The deposit itself indicates a direct southern provenance, but the absence of any sign of old alluvium between it and Belize Valley is difficult to explain.

King *et al.* (1989) referred to a ferricrete-capped marine terrace at about 15 m above sea-level on the Belize Plain land system. This marine terrace is mapped in this study as the middle plain subunit. It has scattered deposits of ferruginous gravel (Figure 4), and appears to correlate with Dixon's (1956) 15 m marine terrace. It is the parent material of the Bocatora soil subsuite. King *et al.* (1989) also found considerable evidence of a marine terrace at 40 m above sea-level, which appears to correlate with laterised alluvial fans (their subunit "gP") along the inward edge of the Central Coastal Plain. Gravels are also found outside the project area of the present study near La Democracia at about 40 m above sea-level. It is mapped in this study as the high plain subunit. There therefore appear to be two distinct marine terraces in addition to the low plain near sea-level.

Practically all the floodplain land systems are in Southern Cayo, giving rise to the Melinda soil suite. Northern Belize has very few floodplain deposits due to the porosity of the limestone. Even the flat alluvial-looking plain below the escarpment at Blue Creek does not have any alluvial deposits except where the Blue Creek immediately debouches from the Bravo Hills. There are, however, many slopewash deposits of local origin, mapped as the "W" subunit in the upland land systems.

Evidence of the currently active southward current is provided by the bar along the east coast of Ambergris Cay (Ambergris Strand Plain land system) and the intermittent thin bars along the eastern coast of Northern Belize. Strand plain deposits produce some of the Turneffe soil Suite. The 1987 Landsat TM imagery revealed the presence of a new bar since the 1968 aerial photography, which has

Figure 4

Ferruginous gravel on the middle plain subunit in the Belize Plain land system. Medium relief karstic hills of the Hummingbird Plain with Hills land system in the background extended the coast north of Condemned Point (latitude 18°15'N). It was probably created during a hurricane. Remnants of an old strand plain along a Pleistocene (?) coastline are indicated by the Matamore Strand Plain land system.

Granite

Granite is the rock type of much of the Mountain Pine Plateau (subunit symbol 's') and the few occurrences of the Stopper Plain with Hills land system. It is the parent material for the Stopper Suite of soils. According to Bateson and Hall (1977), it is mostly medium-grained, non-porphyritic and leucocratic. "Quartz is in excess of 10%... and the potash feldspar is much more abundant than plagioclase. Apatite and magnetite are the commonest accessory minerals". Biotite is usually in excess of muscovite. There are two localities of fine-grained acidic porphyries north-west of Baldy Beacon (17°01'N, 85°45'W), mainly within the Copetilla Mountains land system (subunits 's' and 'os'). The quartz ridge subunit (s) of the Mountain Pine Plateau is strictly an aplite dyke consisting almost entirely of granular quartz and feldspar (Bateson and Hall, 1977). Bateson and Hall dated the Mountain Pine Granite at 310-330 million years (Late Carboniferous).

Tectonics

Belize lies on the edge of the North American Plate; the boundary between the North American and Caribbean plates bisects the Gulf of Honduras. Northern Belize lies within the Corozal Basin structural province, whereas most of Southern Cayo is part of the Maya Block. The Northern Boundary Fault separating the Santa Rosa Group of the Maya Block from the Margaret Creek Formation and younger limestones of the Corozal Basin is at an approximate latitude of 17°05'N.

Bateson and Hall (1977) considered the overall structure of the Maya Mountains to be "an uplifted fault block consisting of a synclinorum trending east-north-east and plunging to the west at about 10°... The majority of the bedding planes dip steeply, and it is therefore probable that the sediments of the Santa Rosa Group are tightly folded" (Figure 5). The uplift took place in the Eocene (Geology and Petroleum Office, 1986).

Figure 5

Steeply dipping metasediments on the Navel Road on the Mountain Pine Plateau

The sediments in the Corozal Basin have a gentle dip, but the western part has a number of straight to arcuate north to north-easterly trending fault scarps, all with downthrown blocks on their eastern to south-eastern side, often with swamps or lines of sink holes at their base – the latter particularly in the Belize Valley outside the project area. The most prominent fault scarp, the Booth's River Escarpment, which joins the Rio Bravo Escarpment in the north, marks the boundary between the Bravo Hills and Northern Coastal Plain land regions, and is portrayed on the cover of this report. The faulting can be dated as post-Eocene, since it displaces the Cayo Group.

The arcuate nature of the fault scarps could be due to:

(i) Scarp retreat;

(ii) Lateral corrasion;

(iii) Slumping (Baldwin, 1986).

The lack of overland flow argues against scarp retreat, although there is some evidence of re-entrant valleys typical of retreating escarpments. There is evidence of lateral corrasion in the Rio Hondo Valley north of Blue Creek in Mexico; but the prevailing direction of concavity toward the east–south-east, the direction of downthrow and the evidence of backward rotation in the Belize Valley, all suggest slumping. The step-like nature of the faulting and slumping suggest marginal faulting along a rift system, probably associated with the late stages of the opening of the Cayman Trough between the Yucatan Peninsular and Honduras.

Hartshorn *et al.* (1984) described the Mountain Pine Plateau as a Middle Cretaceous planation surface. The plateau slopes from the south-east to the north-west, and the plateau remnants of the Palmasito and Chapayal land systems may be part of the same surface. King *et al.* (1989) also described a tilted dissected plateau north of the Stann Creek Valley Road which they also considered part of the same Middle Cretaceous surface. The tilting of this surface may be a cymatogenic deformation (King, 1961) associated with the rifting of the Cayman Trough. Hartshorn *et al.* referred to the limestones west of the plateau preventing drainage after the plateau was dissected. Dixon (1956) also referred to gravels deposited by westward-draining rivers being held up by a limestone barrier preventing the rivers from cutting down into the Santa Rosa Group below.

It has already been suggested that the parent material of the Pine Type of land systems (excluding the Mountain Pine Plateau) is Pleistocene alluvium. As indicated in the Alluvium section, there is some evidence of a degraded escarpment on the eastern side of the western deposits, as well as tilting toward the west, suggesting further tectonic activity in late Pleistocene times. There is also evidence of drainage reversal south-west of San Felipe, where the rivers drain south-westwards toward the Booth's River swamp, but are captured by the Booth's River to drain northwards, suggesting recent northward tilting.

Spanish Creek provides the most spectacular drainage reversal. Firstly, instead of continuing into Western Lagoon, it breaches the interfluve to drain towards Northern Lagoon, but then reverses direction completely to drain south through Black Creek to join the Belize River at Compass Point.

Drainage reversal is expected where tectonics appear to have been active until very recently. The Belize River itself, outside the project area, changed direction from a north-eastern to a south-eastern direction, but this is probably due to southward longshore drift.

The New River, Western, Northern and Progresso 'Lagoon' complexes in Northern Belize appear to be tectonic features, i.e. drowned fault scarps. The saw-tooth northern coastline seems similarly tectonically controlled. Additional tectonic activity is indicated by the approximate north-south trending escarpments traversing the Louisville Plain, producing *inter alia* co-linear series of swamps, e.g. Pulltrouser.

The Hondo Swamps land system abuts a fault scarp along most of its north-western side, which appears to be a tectonic continuation of the Booth's River Escarpment. The land surface above the escarpment at Neuendorf is 120 m above sea level rising to 140 m. The hills over the Mexican border also rise to 140 m. Northwards, Mexico overlooks Belize: the Mexican land surface dropping in altitude to 80 m opposite San Antonio and to 40 m opposite the extreme northern part of the project area. Since it cuts across Early Tertiary rocks and since the Hondo shoreline seems to have been in place in Late Pliocene or early Pleistocene times (Wright *et al.,* 1959), the surface may be Late Tertiary.

The circular lagoons in eastern Northern Belize are likely to be the product of limestone solution, as are the large circular depressions forming the Neustadt Swamps land system in the Bravo Hills land region. The NE-SW alignments in eastern Northern Belize, e.g. of Shipstern Lagoon, may be tectonic as they follow the same tectonic trend as western Northern Belize, but they may also be re-inforced by longshore drift along old shorelines.

Back *et al.* (1984) proposed an hypotheses to explain the coves, caves and crescent-shaped beaches along the Yucatan coast – a coastline similar in appearance to the eastern coastline of Northern Belize. They suggest seaward-flowing groundwater is channelled along dominant fracture zones. "The major flow, and therefore, the major dissolution, occurred along fractures with the widest openings" leading to incipient coves. "The area of discharge and groundwater flow pattern became a self-perpetuating mechanism that expanded the area of dissolution to form a branching network of subsurface solution channels that coalesced to form a cave system... As the dissolution continued, it removed support for the 1-2 m thick slab of limestone, the bottom of which is the cave roof and the top of which is the land surface".

There have been many fluctuations of sea-level in the Caribbean. Darch (1981) referred to Bartlett and Barghoorn's (1973) palynological analysis in Panama, which indicated "a very rapid rise in sea-level from 35,000 years B.P. to 8500 years B.P.", after which there was a slow rise to 2000 B.P. when it had reached its present level.

Old shorelines are indicated by the trend of the Tok Plain deposits. This trend is cut by the Belize and Sibun valleys and associated deltaic deposition; but the old shorelines appear again south of the Sibun River along the western shore of the Northern Lagoon and similar north-south trending features toward the coast.

"In recent geological time the area of and around Ambergris Cay has alternated between being a shallow sea floor and being exposed as dry land... The oldest rocks... are Late Pleistocene and Holocene in age" (Woods *et al.*, 1988). According to Woods, the reef from which Ambergris Cay was formed, was deposited 125,000 years ago in 6-8 m of water.

LAND UNIT DESCRIPTION

Three hierarchical levels of land unit are mapped, described and listed in the table accompanying Map 1 and in Appendix 1. The highest level, the land region, groups land systems with similar topography, lithology, soils, vegetation and hydrology. It is similar to the geographers' physiographic region, and is a unit to which local people can easily relate, and the characteristics of which they can remember. Land system outliers can occur in more than one land region. The land system is the prinicipal mapping unit, defined by Christian and Stewart (1953) as an "area, or group of areas, throughout which there is a recurring pattern of topography, soils and vegetation". It is classified according to certain parameters (King, 1970).

The land facets which make up the land system are usually sufficiently homogeneous to have a consistent agricultural or conservation potential, but are mostly too small to be mapped at a scale of 1:100,000. 'Subunits' were mapped instead. They distinguish either:

(i) Areas within the land system with distinctive angle of slope or local relief, e.g. rolling from undulating plain, low from high karst;

(ii) Land facets large enough to be mapped at 1:100,000 scale, e.g. floodplain benches and terraces in the Floodplain Type of land systems;

(iii) Areas with a dominant soil type, e.g. Cooma and Pinol on the Mountain Pine Plateau.

Remote Sensing and base maps

The prime base material for determining the main land units was the 1988 1:42,000 scale aerial photography, the 1:100,000 scale high-contrast colour laser prints of the 1987 30 m resolution Landsat Thematic Mapper (TM), 1980 80 m resolution Landsat Multispectral Scanner (MSS) imagery, and the soils fieldwork.

The colour composites used to compile the TM laser prints were made by ascribing a blue colour to band 3 (representing the red part of the spectrum), a red colour to band 4 (representing the near infrared part of the spectrum), and a green colour to band 5 (representing the short-wave infrared part of the spectrum). The colour composite used to compile the MSS print was formed by ascribing a blue colour to band 5 (the red part of the spectrum) and green and red to bands 6 and 7 respectively (representing the near infrared part of the spectrum).

These choices of colour composites and the degree of contrast enhancement were determined by experimentation on the NRI GEMS image processor: primarily to enhance landform and vegetation types. The TM combination is a standard one for revealing the three main components of information contained in the TM system (visible, near infrared and short-wave infrared). The MSS combination is weighted toward the rear infrared part of the spectrum to avoid the atmospheric scattering commonly associated with short-wave visible bands (blue and green) in the humid tropics.

The land system boundaries were mainly defined from the Landsat imagery and the soils fieldwork. They were subsequently modified and most of the subunits demarcated by reference to stereoscopic examination of the aerial photography, although the actual boundaries were put onto overlays of the Landsat imagery, not the aerial photographs. The subunits of the Corozal Saline Swamps land system were determined almost entirely from the Landsat TM imagery. Examination of the Landsat imagery was also used to confirm and sometimes correct the airphoto interpretation of subunit boundaries.

Gaps in the aerial photography particularly along the borders with Mexico and Guatemala, were compensated by scanning the 1969-72 1:48,000 scale aerial photography. A 1979 Landsat MSS image was used to determine land system boundaries of areas obscured by cloud on the TM image. The SPOT imagery were used to aid interpretation of the southern part of Southern Cayo. The soil maps of Wright *et al.* (1959) were mainly used to determine land system boundaries, where access proved impossible within the time constraints of the project.

Base map material was provided by the 1973-1982 1:50,000 scale map series, which was also used as field maps, although their access information was frequently out of date. Most of the recent access routes were located on the 1988 aerial photography and 1987 Landsat TM imagery, which information, in addition to that found in the course of fieldwork, has been transferred to Maps 1 and 2. Additional maps used by the team were the 1980 1:250,000 scale map series and the geological maps of the Geology and Petroleum Office (1986) and Bateson and Hall (1977).

Land regions

Within the project area, there are two coastal plain land regions (Northern and Central), distinguished mainly on the basis of hydrology; four limestone karst land regions (Bravo Hills, Central Foothills, Western Uplands and Toledo Foothills) distinguished on the basis of ruggedness and altitude; and one mountainous land region developed on siliceous rocks (Maya Mountains).

NORTHERN COASTAL PLAIN

The Northern Coastal Plain contains most of the flat to undulating land in Northern Belize and the Belize Valley. It is distinguished from the Central and Southern coastal plains of Stann Creek and Toledo districts respectively, which are narrow and backed by a mountain or hilly front at 15 km or less from the sea. The boundary between the Northern and Central coastal plain is however rather arbitary; and part of what was called the Central Coastal Plain in King *et al.* (1989) – the Belize Plain land system – is now considered part of the Northern Coastal Plain, because of the Belize Plain's wide extent within the Belize Valley. The boundary between the two land regions is taken along the boundary of land systems more typical of the respective land region. Belize Saline Swamps, Belize Swamps and the Puletan Plain land systems have all been allocated to the Central Coastal Plain land region. Further inland the western boundary interdigitates with the more hilly land regions of the Central Foothills and Bravo Hills. In Orange Walk District, the Booth's River Escarpment forms the western boundary.

The mean annual rainfall ranges from 1300-2000 mm and the altitude ranges from sea-level to 20 m, with local maxima of 40 m. Most of the plain is underlain by Cenozoic limestone, decreasing in age and hardness from the south-west to the north-east. Most of the north is cultivated. The natural forest over limestone is semi-deciduous broadleaf forest, but there are also large areas of pine forest and orchard savanna over leached soils from Pleistocene alluvium.

BRAVO HILLS

The Bravo Hills are found along the Guatamalan and Mexican borders from the Belize Valley in the south to Blue Creek in the north, with Albion Island occurring as a northern outlier west of Orange Walk town. The Booth's River Escarpment is its eastern boundary. Most of the land region is underlain by faulted hard Cretaceous and early Palaeogene limestones, which give rise to a stepped landscape of plains and karstic hills. The altitude ranges from 20 m at the base of the Booth's River Escarpment to 301 m at Chasquitan on the Guatamalan border (latitude 17°38'N).

The mean annual rainfall is around 1500 mm, and most of the land region is under semi-deciduous broadleaf forest. Land use within the project area is limited to the area used for pasture, maize and sorghum by the Mennonite communities in the north (and sugar cane on Albion Island), and a little pasture and mixed cultivation at Gallon Jug. Most of the Rio Bravo Conservation and Management Area lies within this land region.

CENTRAL COASTAL PLAIN

Most of the Central Coastal Plain is in Stann Creek District. As indicated above, it has a rather arbitary boundary with the Northern Coastal Plain, but it is wetter than the Northern Coastal Plain – the mean annual rainfall of Belize City is 2094 mm. Most of the vegetation is orchard savanna, swamp and mangrove. The mangrove stands are taller and more extensive than in the Northern Coastal Plain. Most of the soils are swampy or leached sands, suggesting its most suitable uses are conservation, tourism and shrimp mariculture. Some of the leached sands date back to the Pleistocene and appear to be marine terraces which interdigitate into the Hummingbird Plain with Hills land system of the Central Foothills land region, which forms its south-western boundary. The altitude range is from 0-20 m above sea-level.

CENTRAL FOOTHILLS

The Central Foothills are formed by the hard Cretaceous and early Palaeogene limestones that separate the Maya Mountains and Western Uplands from the Northern Coastal Plain. They stretch from the Guatamalan border almost to the sea. They form a distinctive karst landscape, partially submerged by alluvium in the east in the Hummingbird Plain with Hills land system. The mean annual rainfall is around 2600-2700 mm, and the natural vegetation is moist high broadleaf forest, but the valleys represented by the Cayo Floodplains land system, are used extensively for tree crops and pasture.

WESTERN UPLANDS

The Western Uplands land region covers the area occupied by Cretaceous limestones in western Southern Cayo. It is bounded by the Central Foothills in the north, and the Maya Mountains in the east and south. It includes the area demarcated as the Vaca Plateau on the 1:250,000 and 1:50,000 scale topographical maps. It replaces that term because the area includes some of the most impressive karst in the country, making the term 'plateau' inappropriate. The landscape generally varies from undulating plain with low karst, to high karst; with local relief varying from 20-200 m. As indicated in the Geology section, it also includes several large cave systems, including the second largest chamber in the world.

The altitude ranges from 180 m in the north to 700 m in the south. The mean annual rainfall appears to be around 1500-2000 mm, but the internal drainage of the limestone makes for little water availability, which in turn discourages settlement. The natural vegetation is semi-deciduous subtropical broadleaf forest.

The virtually unpopulated Western Uplands of today are at a similar stage of development to the northern part of the Northern Coastal Plain two hundred years ago. Current development is confined to exploitation of forest products (pine timber extraction for the lumber industry, rosewood birl collecting for cabinet-making etc.), collecting medicinal herbs, spices, resins and other minor products; and hunting game for local consumption.

Current recommendations for the Western Uplands are for conservation, but future land pressure may necessitate developmental considerations. Traditional milpa farming (see Farming Systems section) should not be practised, but the need for a disciplined approach to agricultural development does not mean the land should be opened up exclusively to large landowners, because the soil pattern is varied and intricate to such a degree that a small farmer is more likely to achieve satisfactory production from each soil variant, be it a mottled or gleyed patch of soil in a small depression, or a shallow, gravelly soil on a small convex elevated rise. The large landowner with mechanical resources can only farm to suit average soil conditions, although an average soil may hardly exist. Consequently the large landowner would get low yields from non-average wet or dry, deep or shallow soil variants. Pastoral farming would be more appropriate for the large landowner; whereas a small farmer with his greater sensibility to soil variation, can adjust his crop management practices to suit the local environment. Small farmers will find patches of soil suited to cacao, citrus, coffee, melons, pineapples, plantains, vegetables and small berries.

This does not mean the Western Uplands should immediately be opened up for small farmers. Control and policing of lands needs to be tightened, not loosened. Any programme of agricultural development in the Western Uplands should follow:

(i) Selection of the most suitable subunits for the proposed development;

(ii) A thorough investigation of the available water resources;

(iii) Surveying of road alignments for selected areas;

(iv) Construction of some major roads.

It might take from five to ten years to establish a system, or systems, of agriculture suitable for one or two blocks of about 2000 ha (5000 ac) each. To safeguard the Western Uplands from invasion by unauthorized persons seeking to pre-empt farm locations, the upland areas not designated for forest or natural vegetation resources should be given protected status, *pro tempore*, perhaps designated as the 'Western Uplands Agricultural Development Reserve'.

MAYA MOUNTAINS

The Maya Mountains cover most of Southern Cayo, particularly the eastern, and remote southern parts. The Santa Rosa Group metasediments and granitic intrusions are the main rock types. The very hard metasediments produce the highest and most inaccessible terrain in the country. Altitudes ranges from 120 m at the base of the Boundary Fault in the north to 1124 m at 'Doyle's Delight' in the extreme south on the Main Divide. Local relief ranges from about 20 m on the plateau subunits of the Mountain Pine Plateau to 400 m in the Roaring Creek and Sibun gorges. Slopes vary from gentle in parts of the Mountain Pine Plateau to steep in most of the Richardson Peak Mountains land system. Mean annual rainfall appears to range from 1700-3000 mm, and the vegetation is mostly subtropical montane wet broadleaf forest with pine-oak savanna on the Mountain Pine Plateau.

TOLEDO FOOTHILLS

The extreme south of Southern Cayo lies in the Toledo Foothills land region (King *et al.*, 1986). The Toledo Foothills also lie on the hard Cretaceous limestone that surrounds the Maya Mountains. That part of the land region that lies within the project area is mainly undulating plain with low karst.

This remote part of the land region was not visited and there are no climatic stations in the vicinity. The local relief is generally about 20 m, and the altitude ranges from 780 m on the Guatamalan border to 880 m where it abuts the Maya Mountains. The vegetation appears to be mainly a low transitional broadleaf forest.

Land systems

As with King *et al.* (1989), land system names are either:

(i) Identical to those in Stann Creek and/or Toledo districts (e.g. Richardson Peak Mountains);

(ii) Given a general name, usually after the main soil type, if is found scattered throughout the country (e.g. Sibal Swamps (SW));

(iii) Named after the local main soil type (e.g. Louisville Plain);

(iv) Given a local name to distinguish it from other land systems in the same land system suite (see later) (e.g. Corozal Saline Swamps).

In Appendix 1 and the land suitability table accompanying Map 1c, land systems are listed within the six main land regions in the project area, primarily in the order north to south, and secondly west to east. Land system symbols are based on those of Toledo and Stann Creek districts (King *et al.*, 1986, 1989 respectively), i.e. land systems identical to those described in those districts are given the same land system symbol, although they may be given a more appropriate name for the project area (e.g. TY is called Belize Saline Swamps in this report, Stann Creek Saline Swamps in King *et al.* (1989), and Toledo Saline Swamps in King *et al.* (1986)). Where a land system is of *similar* type to a land system in Toledo or Stann Creek district, it is given the same second letter in the land system symbol, but a different first letter to indicate it is a variant of that land system, e.g. BW for Belize Swamps to distinguish it from TW and SW. However for this study it was found that there was too much variability within districts to limit the first letter of the symbol to stand for a district. Many of the first letter symbols in this study are therefore taken from a local place or farm. This variation on a common theme suggested a different approach to describing the land units to that of King *et al.* (1986, 1989). Land systems are grouped here into *types* based on a common second letter of the land system symbol (Table 7). Each land system type is described, accompanied by a table indicating the main parameters of each land system within the type.

The following abbreviations are used in Tables 8-16 for the dominant geomorphic process operating on the land system:

PROCESS

A	Anthropogenic erosion
Ad	Alluvial deposition
F	Faulting
K	Karst
M	Marine erosion
Md	Marine deposition
Pn	Peneplanation defined as the 'slow flattening of divide slopes' resulting in 'multi-convex profiles' (Wooldridge and Morgan, 1959)
V	Valley incision

Table 7

Land System Types

Land system type	Characteristics	Location
Rugged (R)	Slopes greater than 25°	Maya Mountains
Plateau (L)	Plateaux at 500-1000 m altitude with broadleaf forest	Maya Mountains
Karst (X)	Karst hills or rolling limestone landscape	Bravo Hills, Central Foothills, Western Uplands and Toledo Foothills
Yalbac (K)	Flat to undulating plain with 10-100 m local relief	South-western part of Northern Coastal Plain, northern Bravo Hills and western Central Foothills
Plain (Z)	Flat to undulating plain with generally less than 10 m local relief	Northern Coastal Plain and western Central Foothills
Xaibe (I)	Shallow soils on flat plain	Northern Coastal Plain and Ambergris Cay
Glady (H)	Forest-savanna or low marsh-forest mosaic with forest dominant	Eastern Northern Coastal Plain and northern Bravo Hills
Backshore (N)	Savanna-forest mosaic with savanna dominant	Eastern Northern coastal Plain and Ambergris Cay
Pine (P)	Pine savanna or pine forest	Northern and Central coastal plains and Maya Mountains
Floodplains (F)	Floodplain benches and terraces	All land regions except Bravo Hills and Toledo Foothills
Waterlogged (W)	Poor drainage	Northern and Central coastal plains and Bravo Hills
Strand Plain (B)	Coastal sand	Northern and Central coastal plains and Ambergris Cay
Saline swamps (Y)	Saline Swamps	Northern and Central coastal plains and Ambergris Cay

MAIN SOIL TYPES

BV prefix indicates soil types defined by Jenkin *et al.* (1976).

DRAINAGE DENSITY

Drainage density classifications are defined with reference to Figure 6. Using the 1:50,000 scale maps the terms defined are:

very low: <1 km/km^2; low: 1-2 km/km^2; medium: 2-4 km/km^2; high: 4-8 km/km^2; very high: >8 km/km^2.

LOCAL RELIEF

Local relief is defined as the height difference between the valley bottom and the nearest adjacent intervalley crest.

DOMINANT SUBUNITS

The two most dominant subunits are listed in Tables 8-16 unless the second one occupies less than 10% of the area of the land system.

SLOPE

Slope terms are defined as:

slightly undulating: <1°; undulating or gentle: 1-5°; rolling or moderately sloping: 5-25°; steep: 25-35°; very steep: GT35°.

BOUNDARY CLARITY

a abrupt; c clear; d diffuse; g gradational.

RUGGED TYPE (R)

The Rugged Type contains two land systems: Richardson Peak Mountains (TR) and the Copetilla Mountains (CR). (The 'C' stands for Cayo District.) The Richardson Peak Mountains land system was first described from Toledo District (King *et al.*, 1986) as "densely dissected steeply sloping mountains" on Santa Rosa Group metasediments and metavolcanics. It was extended into Stann Creek District "to represent all the steep mountainous slopes in the Maya Mountains", i.e. including granitic slopes (King *et al.*, 1989); and divided into lithological subunits, mainly to identify the more erodible granitic slopes.

The Richardson Peak Mountains land system in the current project area has included a metavolcanic hills subunit so as to distinguish the area covered by the soils of the Richardson soil suite. The resistant quartzite bands demarcated for Stann Creek District, were not apparent on the remote sensing imagery of Cayo District and were therefore not discriminated.

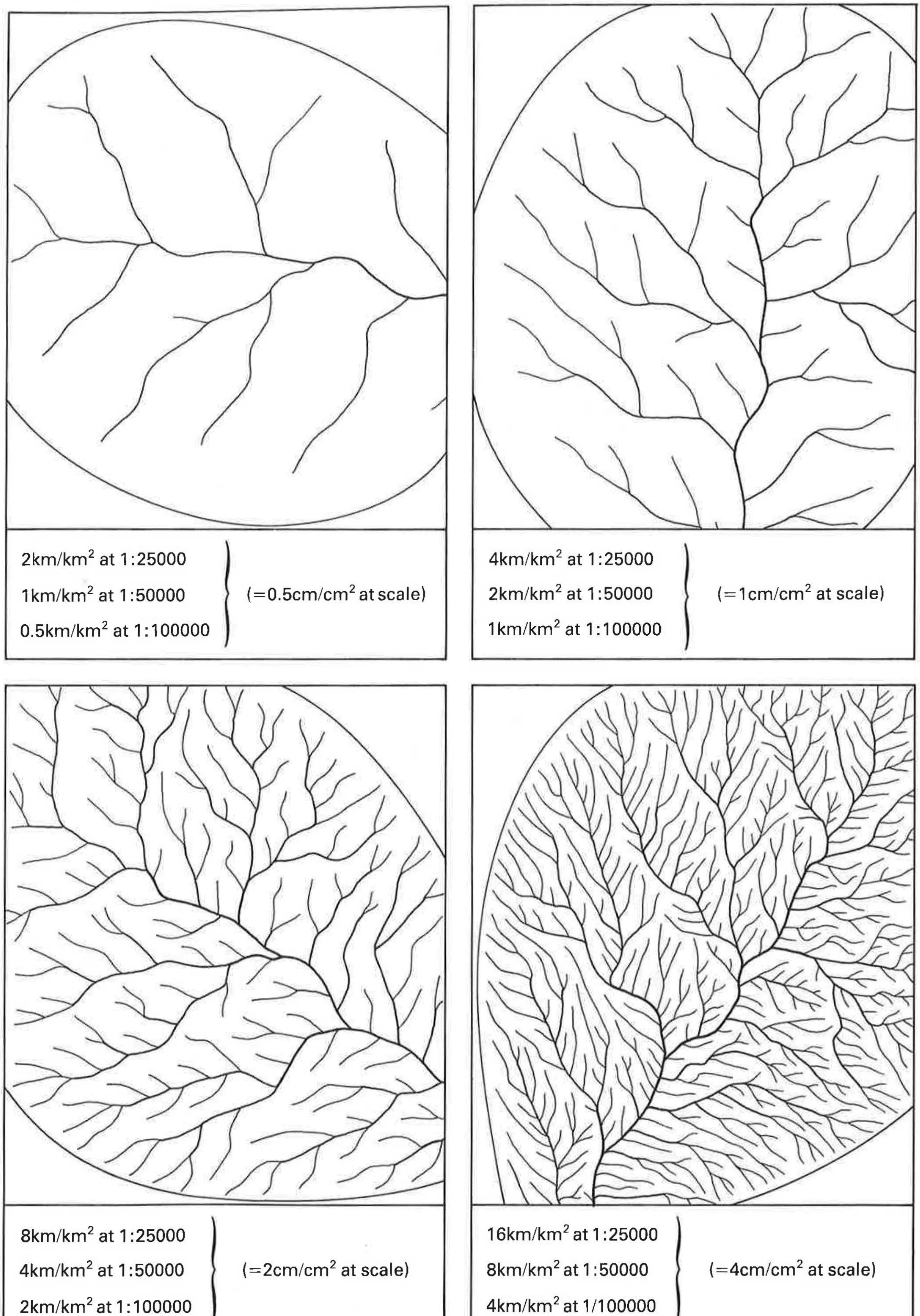
The Copetilla Mountains land system was distinguished from the Richardson Peak Mountains land system because the vegetation overlying the Copetilla Mountains land system is a mosaic of pine, grassland and broadleaf forest (Figure 7), and the soils appear to have characteristics of higher altitude soil subsuites (e.g. Cooma, Baldy, Pinol).

PLATEAU TYPE (L)

The Palmasito Plateau land system (TL) was recognized in Toledo District as isolated dissected plateaux in the Maya Mountains. The Chapayal Plateau land system (VL) has been distinguished in Cayo District as a lower altitude plateau, where the original overlying limestone has only recently been eroded away, and where remnants are still found. (The 'V' prefix stands for Vaca local variant.)

Figure 6

Drainage Density



(after R.B. King)

Figure 7

Copetilla Mountains land system, with the high plateau subunit of the Mountain Pine Plateau land system in foreground and background

VALLEYS IN THE MAYA MOUNTAINS

The above two land system types are particularized in Table 8, which for convenience also includes the Ossory and Stopper Plain with Hills land systems, originally designated from the Eastern Foothills land region in Stann Creek District, but also found as metasedimentary (Ossory) and granitic (Stopper) moderate slopes in the Eastern Branch and other valleys within the Maya Mountains.

KARST TYPE (X)

The Karst Type contains six limestone land systems. The Xpicilha Hills with Plains land system (TX) covers a large part of Cayo District in the Western Uplands and Central and Toledo foothills land regions. In the Toledo District survey it represented all land overlying limestone. In the Stann Creek District survey, two land systems represented limestone areas: one where there is a generally flat alluvial floor – the Hummingbird Plain with Hills land system (BX); the other, the Xpicilha Hills land system, was reserved for areas with higher local relief.

In the current project area, the Hummingbird Plain with Hills land system is found mostly in the eastern part of the Central Foothills. As in the Stann Creek District project area, the flat alluvial plain contains riverine alluvium of different ages, the youngest of which (Quamina Subsuite) is highly to moderately suitable for most forms of agriculture, but the oldest belongs to the agriculturally unsuitable Puletan Suite of soils. It was not possible to distinguish the different soils on the aerial photography or satellite imagery, and the flat alluvial plain subunit consequently has a varied nature. Where the flat alluvial plain forms an integral part of the Cayo Floodplains, it is allocated to that land system, including the instance where it represents an old course of the Caves Branch. The slightly undulating plain subunit (SU) consists mostly of the older Puletan Suite. The very poorly drained basins (subunit 'B') surrounding the residual limestone hums, described by Wright *et al.* (1959) as the product of limestone solution, are well displayed along the new Belize-Dangriga road (Figure 8). The karst soils belong to the Chacalte Suite.

Table 8

Rugged (R), plateau (L) and valley land systems in the Maya Mountains

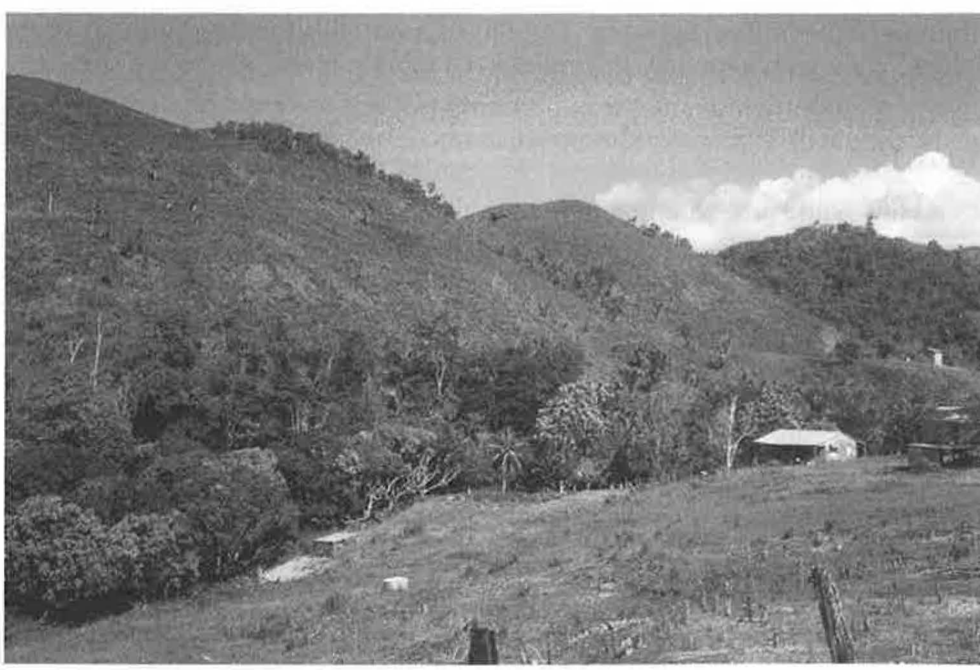
Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
TR	Metasediments	V	Ossory	Very high	60-400	120-1124	Metasedimentary hills	Montane moderate-high broadleaf forest	High	CX: a TX: c CR: g L: c SO: g MP: c
CR	Metasediments	V	Cooma	Very high	50-250	400-960	Metasedimentary hills Bare hills	Pine, grassland and montane moderate-high broadleaf forest	Moderate	TR: g MP: g MF: c TX: c
TL	Metasediments	V	Palmasito?	High	20-100	800-1000	Rolling plateau Undulating plateau	Montane moderate-high broadleaf forest	High	TR: c
VL	Metasediments> hard limestone	V	Granodoro	Low	20-60	550-650	Rolling plain Undulating plain	Moderate-low broadleaf forest>(dumb cane & tiger bush)	Low	TX: d TR: c
SO	Metasediments	V	Ossory	Very high	20-80	400-700	Rolling plain Undulating plain	Moderate-high broadleaf forest	High	CF: a TR: g TX: d
SS	Granite	V	Stopper?	Very high	50	350-400	Rolling plain Undulating plain	Moderate-high broadleaf forest	High	TR: g CX: a MP: c CR: g

Figure 8

Medium karst hills of the Hummingbird Plain with Hills land system, surrounded by a very poorly drained solution basin

Figure 9

Medium karst and rolling plain subunits of the Xpicilha Hills with Plains land system west of Barton Creek



The Xpicilha Hills with Plains land system covers most of the rest of the Central Foothills within the project area (Figure 9), and the southern part of the Western Uplands. The soils mainly belong to the Chacalte Suite with some Vaca Suite soils. As in the Stann Creek District project area, it represents the areas with the highest local relief, but also includes other varieties of karst landform, including those influenced by siliceous inliers (indicated by the 'S' subunit prefix symbol, as in Toledo District), formed where the limestone has been almost completely stripped away to reveal the underlying metasediments. Erosion from remnant limestone hums provide calcareous slopewash, which becomes mixed with the underlying weathered products of the metasediments, some of which may also be redeposited as slopewash. The more widespread presence of undulating and rolling plains within this land system in Cayo District has suggested an alteration to the name of the land system to Xpicilha Hills with Plains. All of the plain subunits may contain the odd isolated hill; so the 'HSU' subunit designated on the Toledo District side of the border, continues as 'SU' in Cayo District.

As in Toledo and Stann Creek districts, the very steep karst hills are subdivided on the basis of local relief into high karst (HK) with local relief greater than 75 m, medium karst (MK) with local relief between 25-75 m and minimal gentle footslopes and low karst (LK) with local relief less than 25 m and significant to extensive flat to gently sloping alluvial footslopes.

The northern part of the Western Uplands has been designated Vaca Hills land system (CX), because of its distinctive landscape and preponderance of Vaca Suite soils. The Vaca Hills contain high to medium karst (Figure 10) with remnant plateaux (possibly of the Middle Cretaceous planation surface), and narrow valley bottoms where there is current agricultural expansion.

The greater part of the Bravo Hills land region consists of the Gallon Jug Plain with Hills land system (OX) developed on limestones (early Tertiary Cayo Group) mostly younger than the Cretaceous limestones further south. (The 'O' stands for Orange Walk District.) The karst is not so prominent, and most of the land system consists of undulating to rolling plain (Figure 11), albeit interrupted by fault scarps represented by 'S' (steep) and 'R' (rolling) subunit symbols according to the angle of slope of the escarpment. The soils mainly belong to the Yalbac Subsuite.

The Wamil Plain with Hills land system (HX) represents the scattered patches of mostly degraded karst on the Hill Bank Plain. (The 'H' prefix stands for Hill Bank local variant.) The soils include Chacluum and Ramgoat Subsuites in addition to the Yalbac Subsuite. The Pilar Camp Hills land system (LX) in the Belize Valley with generally low relief karst mainly giving rise to the stony and

Figure 10

Vaca Hills high karst. Mountain Pine granitic plateau in foreground

Figure 11

Undulating plain subunit of the Gallon Jug Plain with Hills land system. Medium karst in background

gravelly soils of the Piedregal Series of the Yalbac Subsuite has been included in this land system type. (The 'L' prefix stands for the Spanish Lookout local variant.) It is the rolling uplands unit landform (IIa2) of the Escarpment and Plain landform system in Jenkin *et al.* (1976).

Three other hilly limestone land systems are included with this type, although they have not been given the 'X' symbol because of their distinctive location or characteristics. Albion Island Plain with Hills land system (OA) is a local name for the hilly land between the Rio Hondo and the unnamed tributary passing through San Antonio and San Roman. Geomorphologically it is part of the Mexican Plateau east of the Rio Hondo, and has been ascribed to the Bravo Hills land region. The soils mainly belong to the Yalbac Subsuite.

The prominent escarpment at Neuendorf separating the Bravo Hills from the Northern Coastal Plain, has been designated the Neuendorf Escarpment land system (OD). It is mostly steeply sloping but includes the Blue Creek Valley with its dissected terraces, valley-side slopes and occasional floodplains.

Most of the Karst Type has internal drainage, but parts of the Yalbac Hills have distinct valleys dissecting a dipslope behind a fault scarp, to form what is termed a 'dissected cuesta'. The land system is called the Yalbac Dissected Cuesta (OQ). The valley incision suggests the rock type is probably dolomitic limestone of the Barton Creek Formation. The landform consists of valleys formed by the dissection, a remnant undulating plateau (the dipslope) and the steep slope of the fault scarp.

YALBAC TYPE (K)

There is little difference between the Yalbac Type and the Plain Type (Z) which follows, although the Yalbac Type has greater local relief. As the name suggests, the Yalbac land system type generally contains land systems on the Yalbac Subsuite of soils; but it has been extended to include a land system with similar landform but containing soils of the Jolja Subsuite (Neustadt Plain) and a land system in the Belize Valley with similar landform but containing soils of the Vaca Suite (Belmopan Plain). The type has also excluded a couple of land systems

Table 9

Karst Types of land system

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
TX	Hard limestone Dolomite	K	Chacalte> Ossory	Very low	20-200	120-170	Medium karst High karst	High broadleaf and semi-deciduous forest with many quamwood and cohune	Very low	TR: c CX: g BX: g CK: c IF: a
CX	Hard limestone Dolomite	K	Vaca	Very low	100	180-560	High karst Medium karst	High broadleaf semi-deciduous forest	Very low except in VB	TX: g MP: a TR: a SS: a
BX	Hard limestone Alluvium	K + Ad	Chacalte Quamina	Very low	<75	15-160	Medium karst Flat alluvial plain	High broadleaf semi-deciduous forest with many quamwood and cohune	Low	TX: g BP: g BF: c CF: c
OX	Hard limestone	K + F	Yaxa	Very low	<100	20-301	Undulating plain Rolling plain	High broadleaf semi-deciduous forest with sapote, mahogany and cohune	Low	W: a NK: c OD: g HZ: a ZY: a HX: g
HX	Hard limestone	K	Yaxa	Very low	<50	40-150	Low karst Undulating plain	High broadleaf semi-deciduous forest with sapote, mahogany and cohune	Low	HZ: g OX: g
LX	Hard limestone	K + V	Yaxa	Low	<100	200-360	Rolling plain Undulating plain	High broadleaf semi-deciduous forest with sapote, mahogany and cohune	Moderate	LW: a OX: g IK: g CZ: a
OA	Sascab	K	Yaxa	None	20-60	20-60	Undulating plain Rolling plain	High broadleaf semi-deciduous forest with sapote, mahogany and cohune	Moderate	OW: a SW: a
OD	Hard limestone	V	Yaxa	Low	80	40-160	Steep slope	High broadleaf semi-deciduous forest with sapote, mahogany and cohune	Low	OX: g OK: a NK: a
OQ	Dolomite Hard limestone	V	Yaxa	Low	<60	100-200	Moderately sloping valley Undulating plain	High broadleaf semi-deciduous forest with sapote, mahogany and cohune	Low	HZ: c OX: c HX: g CZ: a

which contain Yalbac soils, but whose landforms are gentler than the surrounding land systems.

The characteristic landform of the Yalbac Type of land systems is dominantly undulating plain, but containing characteristic isolated and/or degraded karst: Relief is gentler than local equivalents of the Karst Type, and greater than local equivalents of the Plain Type.

Only two land systems are prominent in the project area – both in Northern Belize. The Shipyard Plain (OK) is the representative land system of the Yalbac Subsuite of soils in the Northern Coastal Plain (within the project area). It is mostly a flat plain (Figure 12) becoming an undulating plain in the south (Figure 13) with the occasional isolated hillock.

The Neustadt Plain land system (NK) (Figure 14) – the 'N' prefix stands for the Neustadt local variant – is contained within an area of the Bravo Hills land region with significantly less karst (only degraded karst represented by the rolling plain subunit) than the Gallon Jug Plain with Hills land system to the south-east. It contains mostly soils of the Jolja Subsuite.

The Beaver Dam Plain land system (BK) is mostly in the Belize Valley, but the southern edge is in the project area (Map 1d). It is the gently undulating areas unit landform (IIf1) of Jenkin *et al.*'s (1976) Escarpment and Plains landform system. It is seen along the Western Highway east of Belmopan between Cotton Tree and Nancy Porter Creek. It is mostly a flat plain with broad and shallow valleys.

The Spanish Lookout Plain land system (LK) west of Belmopan is Jenkin *et al.*'s "undulating areas adjacent to Spanish Lookout" unit landform (IId1) of their Escarpment and Plains landform system. Despite overlying the Cayo Group limestone and dolomite, the undulating plain is dissected by moderately sloping valleys whose erosion provides floodplain deposits downstream. This evidence of overland flow suggests the bedrock may be dolomite rather than limestone. The land system includes the Spanish Lookout Mennonite settlement, where there is extensive soil erosion in the valleys.

Figure 12

Flat plain subunit at the northern edge of the Shipyard Plain land system on the Orange Walk – Yo Creek Road

Figure 13

Undulating plain subunit of the Shipyard Plain land system on the San Felipe – Hill Bank road

Figure 14

Undulating plain subunit of the Neustadt Plain land system

The large areas of the Cuxu Subsuite (Vaca Suite) of soils in the Belize Valley, which are on mostly undulating plain rather than the surrounding Xpicilha Hills with Plain land system, are ascribed to the Belmopan Plain land system (CK). They are the very gently undulating areas unit landform (Ic1) of Jenkin *et al.*'s Southern Uplands landform system.

The Ramonal Hills land system (IK) – 'I' stands for the San Ignacio local variant – represents the occurrences of undulating and rolling plain overlying Yalbac Subsuite soils in the Western Branch Valley. They are the "gently undulating areas adjacent to the upper Belize River" unit landform (IId3) of Jenkin *et al.*'s Escarpment and Plain landform system.

PLAIN TYPE (Z)

The Plain Type contains land systems with low relief which have not been allocated to any other land system type. They are mostly on undulating terrain (Figure 15) shaped by subaerial erosion of limestone (peneplanation), and contain the main areas of sugar cane cultivation.

The Louisville Plain land system (ZZ) is defined as covering the area occupied by the Louisville and Concepcion soil subsuites. The first Z symbol indicates Corozal District. The Lazaro Plain land system (OZ) is defined as covering the area occupied by the Guinea Grass soil suite, and unlike the Louisville Plain land system to the north and Shipyard Plain to the south, it has distinct drainage lines (Figure 16). The Hill Bank Plain land system covers the area occupied by the Chacluum and Ramgoat soil Subsuites, although it also includes soils of the Yalbac Subsuite (Figure 17).

In the upper part of the Belize Valley, there is a series of cuestas developed on rotated slump blocks (see Tectonics section). The upper well-drained parts of their dipslopes have been ascribed to the Round Hole Plain land system (CZ). It is the "very gently undulating dipslope" part of Jenkin *et al.*'s "escarpment with occasional incised streams" unit landform (IIb1) of their Escarpment and Plains landform system.

The Hermitage Plain land system (IZ) represents the Yalbac Subsuite soil outliers within the Vaca soil suite in the upper Belize Valley. It is found in both the Ic1 (very gently undulating areas of the Southern Uplands landform system) and IId3 ("gently undulating areas adjacent to the upper Belize Valley" of the Escarpment and Plains landform system) unit landforms of Jenkin *et al.*

Figure 15

Lazaro Plain land system looking towards Shipyard from the San Felipe road

Table 10

Yalbac land system types

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
OK	Hard limestone	Pn	Yalbac	None	<20	15-86	Flat plain Lower slope	High broadleaf semi-deciduous forest with many cohunes	Moderate	ZY: a OZ: d HZ: d SW: a P: c
NK	Chert Limestone	Pn	Jolja	Very low	30-100	60-180	Undulating plain	Variable broadleaf semi-deciduous forest> Broken Pine Ridge	Low	OX: c NH: c NW: c
BK	Sascab	Pn	Beaver Dam	Very low	10	5-70	Flat plain Undulating plain	Low broadleaf semi-deciduous forest	Moderate	LK: g CK: d BP: c OX: a LW: g
LK	Sascab	Pn + V	Spanish Lookout	Very low	20	60-90	Undulating plain	Low-medium broadleaf semi-deciduous forest	High	X: a LW: c CK: d IF: c IK: g
CK	Hard limestone	PN + K	Vaca	Very low	20-40	60-120	Undulating plain	Low broadleaf semi-deciduous forest	Moderate	BK: d TX: g IF: c LK: d
IK	Hard limestone	Pn + K	Shallow Yalbac	Medium	30	80-240	Undulating plain Rolling Plain	Secondary thicket	Moderate	IZ: d TX: c IF: c LX: g

Figure 16

Drainage lines in the lower slope subunit of the Lazaro Plain land system

Figure 17

Undulating plain of Hill Bank Plain land system. Hillock in background

Jenkin *et al.* mapped some areas of Butcher Burns Series (part of the Haciapina Subsuite) on the right bank of the Belize River on the other side of the river from the international airport. Wright *et al.* (1959) allocated their Haciapina soil set to "pine ridge colluvium... collected in a badly drained spot", but these areas appear to be local topographic high spots. Unsure of their nature, they have been designated to a small separate land system: Belize River Plain (BZ). They are part of Jenkin *et al.*'s very gently undulating areas unit landform (IVa4) of their Coastal Deposits landform system.

Table 11

Plain land system types

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
ZZ	Sascab	Pn	Louisville Concepcion	None	5-10	<20	Undulating plain Lower slope	High broadleaf semi-deciduous forest with many cohunes	Low	ZY: a OZ: d ZI: d OW: a SW: a
OZ	Sascab Sand	Pn	Guinea Grass	Very low	5-10	<50	Undulating plain Lower slope	High broadleaf semi-deciduous forest with many cohunes	Low	ZZ: d OK: d SW: a OW: g
HZ	Hard limestone	Pn	Ramgoat Chacluum Chucum	Very low	5-10	3-120	Flat plain Undulating plain	High broadleaf semi-deciduous forest with sapote and santa maria	Low	ZY: a OK: g HX: g OX: a SW: a
CZ	Hard limestone	Pn	BV: Piedregal BV: Chorro BV: Tambos	Very low	5	130	Undulating plain	Medium broadleaf semi-deciduous forest	Low	LW: g OX: a
IZ	Hard limestone	Pn + V	Yalbac	Medium	40	80-200	Undulating plain Rolling plain	Low to medium broadleaf semi-deciduous forest and secondary thicket	Low	IK: d IF: c TX: c
BZ	Alluvium?	Pn	BV: Butcher Burns	None	<5	<5	Flat plain	Transitional broadleaf forest and thicket	Very high	BP: d BF: g SW: a

XAIBE TYPE (I)

The Xaibe Type of land systems contains shallow soils over recent limestone and occupies most of Corozal District. The Xaibe Plain (ZI) is the most extensive (Figure 18). It is characterized by the Xaibe, Puluacax and Remate soil subsuites. The Consejo Plain land system (JI) ('J' stands for Consejo local variant) occurs around Chetumal Bay. It is characterized by the shallow soils of the Bahia soil suite. The North Ambergris Plain land system (AI) ('A' stands for Ambergris local variant) is a flat plain with shallow undeveloped soils of the Shipstern Subsuite (Figure 19).

JOBO PLAIN

The Jobo Plain land system (BJ) could be considered the Belize District equivalent of the Xaibe land system type, since it also represents limestone hinterland. However the limestone is older, harder and flinty. The land surface is also pitted with small sinkholes of about a metre average diameter.

GLADY TYPE (H)

The Glady and Backshore land system types contain intergrade land systems, and as such may have biodiversity inplications. The Northern Bulkhead Plain land system (ZH) is an intergrade between the Xaibe Plain and Corozal Saline Swamps land systems. The vegetation consists of savanna glades, indicative of intermittent saline swamp conditions, within low broadleaf semi-deciduous forest. The Estevez Plain (BH) is an intergrade between the Jobo and Tok plains. The vegetation is a similar mosaic to the above; but the savanna is as common as the forest, and mostly overlies soils of the Tok Subsuite. The Blue Creek Plain land system (NH) contains a mosaic of low marsh forest, high marsh forest, and broadleaf semi-deciduous forest of variable height, where it has not been cleared, below an undulating plain (Figure 20).

Figure 18

Cabbages on the Xaibe Plain

Figure 19

North Ambergris Plain land system

Figure 20

Undulating plain of the Blue Creek land system

BACKSHORE TYPE (N)

The land systems in the Backshore Type occur in the immediate hinterland of the eastern coast of Northern Belize and on Ambergris Cay. The Shipstern Plain (ZN) is an intergrade land system similar to the Northern Bulkhead Plain, but contains more savanna and even some mangrove. The Maskall Plain (BN) is a similar intergrade land system with the same subunits as the Shipstern Plain, but is a coastal variant of the Jobo instead of the Xaibe plain. The West Ambergris Plain land system (AN) is an intergrade between the North Ambergris Plain landform and soils, and the Corozal Saline Swamps land system. Its vegetation is a mosaic of dwarf mangrove savanna and beach forest.

PINE TYPE (P)

All land systems with characteristic pine forest and orchard savanna ('Pine Ridge') belong to the Pine Suite. As indicated in the Geology section, they are all derived from old (Pleistocene?) alluvium, with the exception of the Mountain Pine Plateau; and are mostly unsuitable for agriculture. The characteristic landform is flat to undulating plain with accumulations of redeposited old alluvial wash (producing Haciapina Subsuite soils) in topographic depressions.

The August Pine Plain (OP) can be considered the modal land system of the suite in Northern Belize. It is found in two main localities: west of Booth's River; and on the interfluve between the New River and Western-Revenge lagoon drainage systems. Characteristic soils belong to the Boom Subsuite of the Puletan Suite, with its characteristic sandy topsoil over a finer textured compact subsoil. Characteristic vegetation is pine savanna (Figure 21), and the characteristic landform is undulating plain dissected by parallel drainage lines containing either calcareous alluvium of the Sennis Subsuite or redeposited old alluvial wash of the Haciapina Subsuite.

The San Felipe Plain land system (FP) ('F' stands for San Felipe local variant) is developed on old alluvium overlying sascab (soft limestone), producing soils with characteristics ranging from the Boom Subsuite to the Pixoy Subsuite of the neighbouring Lazaro Plain land system. It often adjoins the August Pine Plain land system, but there is also a wide band trending north-west from San Felipe to east of Yo Creek. The vegetation is transitional from Broken Pine Ridge through pine and oak savanna to open savanna with palmettoes (Figure 22). Characteris-

Figure 21

August Pine Plain land system

Table 12

Xaibe, Glady and Backshore land system types and Jobo Plain

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
ZI	Limestone of variable hardness	Pn + K	Xaibe Puluacax Remate	None	<5	<20	Flat plain Lower slope	Low broadleaf semi-deciduous forest with sapote, mahogany and cohune	Low	ZZ: d JI: d ZY: a ZH: g ZN: g
JI	Gypsiferous limestone of variable hardness	Pn + M	Consejo	None	<5	<10	Flat plain	Low broadleaf semi-deciduous forest with patches of marsh forest	Low	ZI: d ZY: a
AI	Hard limestone	K + M	Shipstern	None	<5	<5	Flat plain	Beach forest	Low	ZY: g AB: c AN: g
BJ	Hard flinty limestone	K	Altun Ha	None	<5	<10	Flat plain	Moderate broadleaf semi-deciduous forest	Moderate	P: c ZY: a ZI: d SW: a
ZH	Limestone of variable hardness Alluvium	K	Xaibe Puluacax Ycacos	None	<5	<5	Flat plain	Savanna glades in low broadleaf semi-deciduous forest	High	ZY: g ZI: g BJ: g
BH	Hard flinty limestone	K + Pn	Altun Ha Tok	None	<5	<5	Flat plain	Savanna glades in moderate broadleaf semi-deciduous forest	High	BJ: g QP: g
NH	Chert Limestone Alluvium	Ad>Pn	Jolja Yalbac Chucum	Very low	<5	40-80	Low marsh forest plain Undulating plain	Low marsh forest and variable broadleaf semi-deciduous forest	High	NK: c
ZN	Alluvium Limestone of variable hardness	Md>K	Ycacos Xaibe Puluacax	None	<5	<5	Glady forest plain Clumped tree savanna	Savanna with patches of low broadleaf semi-deciduous forest	High	ZY: g ZI: g
BN	Alluvium Hard flinty limestone	Md>K	Ycacos Altun Ha	None	<5	<5	Glady forest plain Clumped tree savanna	Savanna with patches of moderate broadleaf semi-deciduous forest	High	BJ: g ZY: g
AN	Hard limestone Alluvium	K + M	Shipstern Ycacos	None	<5	<5	Flat plain	Mosaic of beach forest and mangrove	Low	ZY: g AI: g

Figure 22

San Felipe Plain land system showing gradation from Broken Pine Ridge in background to open savanna in the foreground

Figure 23

A young cashew plantation on Crooked Tree Subsuite soils

tic soils belong to the Felipe Subsuite, and the characteristic landform is undulating plain.

The Crooked Tree Plain land system (KP) ('K' stands for Crooked Tree local variant) overlies old alluvium, which is mostly sandy to a depth of 50-250 cm (Crooked Tree Subsuite soils). The characteristic vegetation is pine savanna often with a dense cover of tall pines and large oaks (Figure 23). It is usually found on interfluve crests surrounded by the August Pine Plain land system. It is also found between the Western-Revenge and Northern Lagoon drainage systems, where there are both plantation and wild cashew plantations. The sandy soil usually has a high reflectance on the remote sensing imagery which has been used to indicate other unvisited localities, particularly within the Belize Valley. However, the reliability of their extent is very uncertain.

The characteristic landform is undulating plain, but the apparent indication of its existence in the lower Belize Valley, on the basis of its high reflectance on the aerial photography, suggests it is also found on the low marine terrace and pitted plain subunits associated with the Belize Plain land system.

The Tok Plain land system (QP) ('Q' stands for Tok local variant) is found in eastern Northern Belize, mostly in Belize District. Characteristic soils belong to the Tok Subsuite which seem to be developed on old strand plain deposits (see Geology section) overlying hard limestone. The characteristic landform is a flat plain with many depressions and small lakes (Figure 29). Characteristic vegetation is open savanna with few pines and oaks (Figure 24).

The first 'Pine Ridge' land system mapped in Toledo District (King *et al.*, 1986) was called Puletan Plain land system (TP) after the characteristic Puletan soil suite. In the Stann Creek District survey, King *et al.* (1989) distinguished three Pine Ridge land systems:

(i) Puletan Plain (TP) similar to that mapped in Toledo District;

(ii) Stann Creek Coastal Plain (SP) distinguished from the Puletan Plain by being generally better drained and having Broken Pine Ridge vegetation rather than Pine Ridge;

(iii) Belize Plain (BP) distinguished from the Stann Creek Coastal Plain "by the ferricrete-capped imperfectly drained plain".

In this survey, the Puletan Plain has been reserved for the flat coastal more waterlogged part of the Pine Ridge, including the saline plain subunit, also found in the Puletan Plain in the Stann Creek District project area. The pitted plain subunit containing the very poorly drained limestone solution basins described

Figure 24

Tok Plain land system. Waterlogged depression in middle ground

Figure 25

Middle plain subunit of the Belize Plain land system. Low plain subunit in the valley in the middle ground. Hummingbird Plain with Hills land system in the background

in the Karst Type section, occurs in both the Puletan and Belize plain land systems.

The Belize Plain occurs in the south-eastern part of the project area (Figures 4 and 25), but its greatest extent is in the Belize Valley. Marine gravel terraces remain characteristic. The one demarcated in the Stann Creek District survey was found to be more scattered in distribution, and has been mapped here as the middle plain subunit. A higher gravel terrace has been mapped in the Belize Valley as 'high plain'. It is on Jenkin *et al.*'s (1976) Colonel English and gravelly Santos Pine Ridge soil series and is on the undulating areas unit landform (IVa1) of their Coastal Deposits landform system. The same unit landform contains Jenkin *et al.*'s Rough Mile Series, which is mapped in this report as the undulating plain subunit.

Most of Jenkin *et al.*'s very gently undulating areas unit landform (IVa4) at the lowest altitudes is either mapped as 'pitted plain' or 'low plain'. A braided plain subunit distinguishes an area of braided drainage pattern between Freshwater and Tum Tum creeks. Areas mapped as 'Erindale (plus Rough Mile)' soil series in Jenkin *et al.* (1976) have been mapped here as the flat plain subunit. The slightly undulating plain subunit described under the Hummingbird Plain with Hills land system is also found within this land system.

The Mountain Pine Plateau land system (MP) is a dissected undulating plateau within the Maya Mountains land region (Figure 26). It is mostly developed on granite, contains mostly leached soils, and includes most of the Mountain Pine Ridge Forest Reserve. Other smaller plateaux with apparently similar soils are also included in the land system.

The subunits are distinguished by rock type, angle of slope and vegetation. The undulating granitic plateau (Figure 26) is the dominant subunit. Granite tends to be the rock type of the more subdued relief, but there is also an undulating to rolling metasedimentary plateau subunit. The plateau slopes up from the north-west to the south-east. Resistant metasedimentary rocks form the south-eastern plateau edge, producing the metasedimentary moderately to

Figure 26

Mountain Pine Plateau land system

Figure 27

Altiplanation terraces on the high plateau subunit of the Mountain Pine Plateau land system

steeply sloping valleys subunit with characteristic dumb cane and tiger bush – also found as a westward-draining valley in the north of the land system. Westward-draining valleys dissect the granitic plateau to produce the granitic (mostly moderately sloping) valleys subunit.

In the eastern part of the plateau, where the altitude rises to 1020 m at Baldy Beacon, the vegetation becomes very sparse (Figures 7 and 27). Two subunits are distinguished: high plateau and high (moderately sloping) valleys. The high plateau is mostly undulating with superimposed altiplanation terraces (Figure 27) formed by soil creep.

FLOODPLAINS TYPE (F)

Most of the Floodplains Type in the project area is found in Southern Cayo, because overland fluvial erosion is only possible on non-carbonate rocks. Most of the drainage of Northern Belize is provided by underground solution because of the widespread limestone bedrock.

The Cayo Floodplains (CF) is the most widespread and important land system of the type within the project area. It is found in the Central Foothills land region and represents the valleys of mainly siliceous alluvium derived from the Maya Mountains. The land system contains a number of benches and terraces, but they can be grouped into the low floodplain bench, high floodplain bench, and terrace sequence similar to that found in the Stann Creek Coastal Floodplains land system (King *et al.*, 1989). The low floodplain bench at 1-4 m above the river is flooded either annually or every few years (see Hydrology section). The high floodplain bench (Figure 28), 3-6 m above the low floodplain bench, or 5-10 m above the river, is rarely flooded, only after exceptional storms about every twenty years. The terrace is 3-10 m above the high floodplain bench and is only flooded after very exceptional climatic events that occur with a frequency of about a thousand years.

The Cayo Floodplains land system is distinguished from the Stann Creek Coastal Floodplains land system by the presence of calcareous alluvium (in addition to the dominantly siliceous alluvium) giving rise to calcareous variants of the floodplain bench and terrace subunits. The calcareous variants produce Quamina Subsuite soils. There are also some old Hattieville soils on the high floodplain bench and terrace subunits. The old course of the Caves Branch before it was diverted underground, appears to have deposited mostly Hattieville series and Quamina Subsuite soils according to the remote sensing imagery. It is

Figure 28

High floodplain bench subunit of the Cayo Floodplains land system at Barton Creek. High karst of the Xpicilha Hills with Plains land system in the background

Table 13

Pine land system types

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
OP	Old alluvium	Pn	Boom	Low	<5	5-25	Undulating plain Redeposited old alluvial wash	Pine savanna	Moderate	SW: a FP: g KP: d OK: c HZ: c
FP	Old alluvium/sascab	Pn	Felipe	Very low	<5	10-20	Undulating plain Redeposited old alluvial wash	Broken Pine Ridge to open savanna	High	OK: d OP: g OZ: d KP: d
KP	Old alluvium	Pn	Crooked Tree	Low	<5	5-20	Undulating plain Redeposited old alluvial wash	Pine savanna often with dense cover of tall pines and large oaks	High	QP: d HZ: c OP: d FP: d ZY: a
QP	Old alluvium over limestone	K	Tok	Very low	<5	<15	Flat plain	Open savanna with few pines and oaks	High	KP: d BJ: c OP: d BF: c
TP	Old alluvium	Pn	Savanna Bladen	Very low	<5	<5	Flat plain Saline plain	Open savanna	Very High	BP: d TY: g BX: g QP: g
BP	Old alluvium	Pn	Boom Bocotora	Very low	<5	<57	Pitted plain Low plain	Open savanna	Variable	BF: c TP: d BX: g KP: g
MP	Granite> metasediments	Pn + V	Pinol Cooma Baldy	High	60	400-1020	Granitic plateau Metasedimentary plateau	Pine forest. Grassland above about 900 m altitude	Moderate	CX: a CR: g TR: c

also included in this land system. The land system contains the most agriculturally suitable soils in the project area. The Stann Creek Coastal Floodplains land system itself (SF) is only found in the project area in the extreme southern part of the Central Coastal Plain land region, where its only subunit is low floodplain bench.

Scattered occurrences of the Maya Mountains Floodplains land system (MF) ('M' stands for Maya Mountains local variant) are found in the Maya Mountains and Western Uplands land regions, particularly along the Macal River. Its terrace tends to be dissected and the alluvium is thought to be coarser – probably containing boulders – than in the Cayo Floodplains land system.

Two other small Floodplains Suite land systems are found within the project area. The Chiquibul Terraces land system (VF) contains scattered patches of siliceous alluvium on a dissected terrace about 50 m above the Chiquibul Branch in the extreme south of the Western Uplands land region. There are also probably Quamina Subsuite soils in the floodplain. The siliceous alluvium appears to be derived from tributaries from the Richardson Peak Mountains land system to the south, rather than from the main Chiquibul Branch.

Airphoto interpretation indicates levées along the banks of the drowned Spanish Creek, where it enters the project area in the extreme south of Northern Belize. They have been assigned to a Spanish Creek Floodplains land system (HF).

The Belize Valley is drained by the Belize and Sibun rivers. Downstream of Young Girl Run, about 10 km upstream of Belmopan, the floodplains are considered part of the Lower Belize Floodplains land system (BF) – the "lower valleys of the Belize and Sibun rivers" landform complex of Jenkin *et al.* (1976). Upstream, they are considered part of the Upper Belize Floodplains land system (IF) – the "upper valleys of the Belize and Sibun rivers" landform complex of Jenkin *et al.*, except that the upper valley of the Sibun River is ascribed to the Cayo Floodplains land system in the current survey. Both land systems appear to have the same sequence of low floodplain bench, high floodplain bench and terrace.

There appear to be large areas of backland – the flat, often swampy land between the channel and floodplain edge – in the Lower Belize Floodplains land system. Both the low and high floodplain benches have significant backlands, but the low floodplain bench backland is the more extensive. Jenkin *et al.* also mapped gypsic phases which have been allocated subunit status. Alluvial wash, formed by a floodplain splay over older alluvium to form a Sennis Subsuite soil, and a low terrace occurs along the Sibun River. There appears to be a stony terrace above the Belize River near Belmopan.

The Upper Belize Floodplains land system contains more uniform floodplain benches, but a variety of terraces. The outliers of Puletan Suite soils demarcated as the old terrace and gravelly old terrace subunits, provide additional evidence that the Pine land system type in Northern Belize is probably derived from ancient drainage from the Maya Mountains (see Geology section). The edges of the old terrace, overlying Willows Bank and Duck Run series soils have been ascribed to the terrace subunit. Dissected terraces, and associated hillock and undulating plain subunits, are found in the Eastern Branch Valley and in the abandoned Pilgrimage Valley.

WATERLOGGED TYPE (W)

All the land system in the Waterlogged Type (W) are waterlogged in the wet season, and some are permanently waterlogged. Soils belong to the Tintal Suite. Since the Stann Creek Swamps land system (SW) of the Stann Creek District survey (King *et al.*, 1989) is now considered to extend throughout the country, it is given the more general name 'Sibal Swamps' after its main soil type. It has three subunits: herbaceous swamp, which is permanently flooded or waterlogged (Figure 29); marsh forest plain (Figure 30), equivalent to King *et al.*'s (1989)

Table 14

Floodplains land system types

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
CF	Alluvium	Ad	Melinda BV: Hattieville	Very low	<20	30-200	Calcareous high floodplain bench High floodplain bench	High broadleaf forest	High	TX: a BX: a BF: g BK: d
SF	Alluvium	Ad	Melinda	Very low	<5	10	Low floodplain bench Alluvium wash	High broadleaf forest	Very high	BP: c
MF	Alluvium	Ad	Coarse Melinda	High	<30	400-600	Dissected terrace Floodplain	High broadleaf forest	High	CF: g TR: c CR: c SO: c
VF	Alluvium Hard limestone	V + Ad	Melinda Chacalte	Very low	5-50	500-600	Dissected terrace Alluvial wash	High semi-deciduous forest	Variable	TX: g BX: g MF: g
HF	Alluvium	Ad	Melinda	Very low	<5	20	Levée	High broadleaf forest	Very high	SW: c HZ: c
BF	Alluvium	Ad	Melinda	Very low	<5	<30	High floodplain bench Low floodplain bench backland	High broadleaf forest	Very high	P: c BK: g LK: c HZ: c
IF	Alluvium	Ad	Melinda	Very low	<5	30-80	High floodplain bench Low floodplain bench	High broadleaf forest	Variable	LK: c IK: a CK: c TX: a

Figure 29

Herbaceous swamp subunit of the Sibal Swamps land system, surrounded by the Tok Plain land system

Figure 30

Marsh forest plain subunit of the Sibal Swamps land system

swamp forest plain, which is considered mostly only seasonally waterlogged; and savanna plain, which is an intergrade between the herbaceous swamp and the marsh forest plain.

The swampy area along the Hondo River and its main unnamed tributary south-east of Albion Island is called the Hondo Swamps land system (OW). It is distinguished from the Sibal Swamps land system because the satellite imagery

Figure 31

Pasture on the open savanna plain subunit of the Neustadt Swamps land system

indicates scattered patches of mangrove mapped as the 'swamp with mangrove' subunit; and the soil survey recognized the presence of both Pucte and Sibal subsuites.

The Corozal Swamps land system (ZW) covers the herbaceous – broadleaf forest mosaic between Chunox and Little Belize. The Neustadt Swamps land system (NW) represents the large closed depressions south of Neustadt in the Bravo Hills land region (Figure 31), containing soils of the Chucum Subsuite. The depressions are probably collapse dolines produced by dissolution of limestone beneath the Barton Creek chert band.

The open savanna plain (Figure 31) is the most extensive subunit. It is found at the lowest topographic level. Most of it is probably waterlogged for most of the year, where it has not been drained by the Mennonite community. The next highest topographic level is covered with a low marsh forest plain, presumably waterlogged for less of the year. The seasonally waterlogged marsh forest plain occurs at the next highest level. Because of the similarity of the soils, the occurrences of the Akalche Series in the lower Belize Valley have also been ascribed to this land system as the undulating plain subunit.

Swampy areas within the Central Coastal Plain that appear to lie in a mixed zone of fresh and saline water have been ascribed to the Belize Swamps land system (BW). Parts of the herbaceous swamp land units are probably partially saline, but the marsh forest subunit is probably free of salinity. The glady marsh forest subunit is an intergrade between the herbaceous swamp and marsh forest subunits. Isolated areas of mangrove are demarcated as a separate subunit.

The poorly drained seasonally waterlogged "flat vale areas at foot of dip-slope" unit landform (IIb3) of Jenkin *et al.*'s (1976) Escarpments and Plains landform system have been ascribed to the Cadena Creek Plain land system (LW). The characteristic soil is the Akalche Series.

STRAND PLAIN TYPE (B)

The longshore current transports beach sediments southwards past the bay-head to produce long linear 'bars'. The eastern coast of Northern Belize and Ambergris Cay displays these beaches and bars blocking off lagoons from the sea. The term

Table 15

Waterlogged land system types

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
SW	Alluvium	Ad	Sibal	Zero	Zero	<100	Herbaceous swamp Savanna plain	Herbaceous: mostly rushes and sedges; and marsh forest	Very high	Usually clear. ZY: d
OW	Alluvium	Ad	Sibal Pucte	Very low	Zero	<5	Marsh forest plain Swamp with mangrove	Herbaceous to marsh forest and mangrove	Very high	ZZ: a OZ: d OA: a OK: d
ZW	Limestone	Pn	Puluacax Xaibe	Zero	<5	<5	Flat plain	Herbaceous-low broadleaf semi-deciduous forest mosaic	High	ZI: g GW: c
NW	Alluvium	Ad	Chucum	Very low	<5	20-100	Open savanna plain Low marsh forest plain	Variable	High	OX: a NK: a BK: d BP: c
BW	Alluvium	Ad	Sibal	Very low	Zero	<5	Herbaceous swamp Glady marsh forest	Variable	Very high	TY: d BF: d BP: c
LW	Limestone	Pn	BV: Akalche BV: Beaver Dam	Very low	<5	30-120	Undulating plain Flat plain	Low akalche bush	High	CZ: g OX: a LK: g BK: g

strand plain is used to describe any series (both modern and old) of bars and intervening swales, including the seaward beach.

There is, however, very little supply of beach material in the Northern Coastal Plain because of the lack of runoff on limestones. The strand plains represented by the Ambergris Strand Plain (AB) land system are consequently narrow. Ambergris Cay itself has the best developed strand plain because of the large area of fetch from the Yucatan Peninsula, but the beach at San Pedro has retreated in the last twenty years, either due to marine erosion or "by human activity such as vegetation clearance both above and below the water line, sand dredging offshore, increased storm water run-off from the town and general interference with the beach line" (Cox, 1989).

In the Central Coastal Plain, there are scattered occurrences of the Toledo and Stann Creek Strand Plain land systems. The Stann Creek Strand Plain land system (SB) "consists of very gently undulating bars with a few poorly drained swales in between" (King *et al.*, 1989). It is usually wider and deeper than the bars along the east coast of Northern Belize because of the greater availability of sediment. The Toledo Strand Plain land system (TB) contains a greater area of poorly drained swale than bar. The Matamore Strand Plain land system (SM) "is an old strand plain, consisting of sandy bars along a former coastline" (King *et al.*, 1989), which is now 2 km inland from the present coastline in the project area.

SALINE SWAMPS TYPE (Y)

The Corozal Saline Swamps land system (ZY) occupies a 5-15 km wide belt along the eastern coast of Northern Belize. It is also found in scattered outliers further inland, mostly west of the New River drainage system, but it does include the swamps around Hill Bank (Figure 32) where mangrove is found 50 km from the sea. The satellite imagery indicates mangrove in the Booth's River Swamp 70 km from the sea. Characteristic soils are from the Ycacos Suite. The most extensive subunit is savanna, which Gray *et al.* (1990) called "salt marsh with sparse mangrove" described in more detail in Appendix 6. The land system also contains large areas of mostly saline herbaceous swamp (Figure 32). Mangrove

Figure 32

Swamp subunit of Corozal Saline Swamps land system north of Hill Bank. It is fringed with mangrove

Figure 33

Mangrove subunit of Corozal Saline Swamps land system in Northern River near Bomba

patches tend to be small (Figure 33), and there are a few areas of tree savanna, which represent small outliers of broadleaf forest within the savanna on slightly raised ground.

Mangroves are more common and taller in the Belize Saline Swamps land system (TY) of the Central Coastal Plain. The low tidal flat subunit contains tall, medium and dwarf mangrove types on Ycacos Subsuite soils, whereas the small areas of high tidal flat support beach forest and a mixture of soils of Ycacos and Hopkins subsuites.

SOILS

Tables 8-16 list the main soil types of each land system and the table accompanying Map 1 and Appendix 1 lists the main soil types of each subunit. As some soils occur in several subunits, this section and Table 17 consolidates the abbreviated descriptions of the soil suites and subsuites. Fuller descriptions are given in Appendix 2. Descriptions and analyses of individual soil profiles are given in Appendix 3.

The soils were examined at about 1100 sites using a 1.2 m Edelman auger (with a 7 cm diameter head). The sites were mostly located along lines of vehicle access, but helicopter, boat and foot were used in some areas. At 89 sites selected as having representative soils, soil profile pits were dug, described and sampled. Most of the samples were analysed at the Tropical Soils Analysis Unit of NRI. The remaining samples will be analysed at the laboratory of Central Farm, Cayo.

The project area includes a range of soil parent materials and covers considerable climatic variation. Rainfall varies from probably 3000 mm p.a. in the higher parts of the Maya Mountains to less than 1500 mm in parts of Corozal District. The leaching and weathering regimes vary considerably over such a range.

The most widespread soils are the relatively shallow, dark, calcareous clays over limestone, which range from Southern Cayo to Northern Belize. Associated with them are less extensive areas of reddish calcareous clays. Reddish and

Table 16

Strand Plain and Saline Swamps land system types

Land system	Dominant rock type	Process	Main soil types	Drainage density	Local relief (m)	Altitude (m)	Dominant subunits	Characteristic vegetation	Water availability	Boundary clarity
AB	Alluvium	M + Md	Ambergris	None	<5	<5	Bar	Beach forest	Low	ZY: c
SB	Alluvium	M + Md	Hopkins	None	<5	<5	Bar	Beach forest	Low	TY: c TP: g
TB	Alluvium	M + Md	Hobkins Ycacos Sibal	None	<5	<5	Swale	Herbaceous swamp	Very high	TY: g
SM	Old alluvium	Pn	Matamore	None	<5	<5	Strand plain	Broadleaf semi-deciduous forest	Low	TY: c BW: c
ZY	Alluvium Limestone	M + Md	Shipstern Ycacos	Very low	Zero	<5	Savanna Swamp	Mangrove savanna Herbaceous swamp	Very high	Mostly abrupt
TY	Alluvium	A + M + Md	Ycacos	Very low	Zero	Zero	Low tidal flat	Mangrove	Very high	BW: d TP: g BP: a QP: a

Table 17

Soil classification summary

Suite	Parent material and main characteristics	Subsuite	Distinctive characteristics
Turneffe	Beach sand	Shipstern	Shallow calcareous sand over coral
		Ambergris	Deep calcareous sand
		Hopkins	Raw soils on deep siliceous sand of modern coast
		Matamore	Weakly developed sandy soils on relict inland strand plain
Melinda	River alluvium	Monkey River	Weakly developed soils in young siliceous alluvium
		Quamina	Weakly developed soils in mixed siliceous and calcareous alluvium
		Pasmore	Dark clays in calcareous alluvium
		Canquin	Moderately developed reddish soils in older siliceous river alluvium
		Sennis	Young river alluvium topsoil over old Pleistocene coastal alluvial subsoil
Puletan	Planosols over old coastal alluvium	Crooked Tree	Deep, freely drained sandy topsoil
		Boom	Shallow sandy topsoil
		Bocotora	Ironpan fragments in mottled subsoil
		Backlanding	Medium-textured topsoil
		Haciapina	Wet, deep sandy topsoil
		Buttonwood	Saline
Tintal	Wet alluvial and hillwash soils	Pucte	Seasonally wet marsh forest
		Chucum	Seasonally wet akalche bush
		Sibal	Permanently wet freshwater peats and gleys
		Ycacos	Permanently wet saline and brackish peats and gleys
Bahia	Recent coastal limestone	Consejo	Shallow peat or muck over gypsiferous limestone
		Remate	Very stony shallow mineral soils
Pembroke	Dark and coloured clay over Late Cenozoic limestone	Louisville	Black and dark grey
		Concepcion	Dark brown
		Xaibe	Red
		Puluacax	Yellowish and mottled
Yaxa	Dark and coloured clays over Cretaceous and Early Tertiary limestone	Yalbac	Dark
		Jolja	Dark and flinty
		Chacluum	Red
		Ramgoat	Red topsoil over very compact yellow subsoil
		Irish Creek	Deep, mottled grey subsoil
Chacalte	Dark clays over Cretaceous Limestone	Cabro	Shallow and stony
		Xpicilha	Moderate depth
		San Lucas	Deep hillwash
Vaca	Brown clays over Cretaceous limestone	Cuxu	Dark and reddish brown
Guinea Grass	Miocene limestone with moderate siliceous sandy impurities or drift	Lazaro	Medium-textured topsoil
		Pixoy	Coarse-textured topsoil
Revenge	Deep siliceous drift over Late Tertiary limestone	Felipe	Mottled, medium-textured subsoil
		Tok	White, plastic, calcareous fine textured subsoil
Altun Ha	Flinty and sandy Early Tertiary limestone	Jobo	Medium-textured topsoil
		Rockstone	Coarse-textured topsoil
Stopper	Granite	Powder Hill	Shallow and stony
		Mayflower	Deep and pale
		Canada Hill	Deep and red
		Pinol	Acid, mixed red and yellow soils of the Mountain Pine Plateau

Suite	Parent material and main characteristics	Subsuite	Distinctive characteristics
Ossory	Quartzites and argillites of Santa Rosa Group	Cabbage Haul	Shallow and stony
		Curassow	Deep and fine
		Pippen	Deep and coarse-textured soils at low altitudes
		Dancing Pool	Deep hillwash soils at low altitudes
		Granodoro	Red and yellow mixed residual soils of siliceous plains
		Machiquila	Pinkish yellow brown to red and yellow mottled soils on outwash from Grano de Oro Hills over limestone
		Cooma	Deep red and yellow soils of Mountain Pine Plateau
		Chiquibul	Shallow red and yellow soils at high altitudes
		Baldy	Yellow and grey prismatic clays of Bald Hills
Richardson	Bladen volcanics	Palmasito	Deep, red and yellow
		Doyle	Grey leached topsoil over deep red and yellow subsoils
		Ramos	Shallow red and yellow

yellowish acid soils on siliceous rocks in the Maya Mountains are another important and variable group. Young riverine alluvium derived from these rocks gives rise to brown and red soils in the Cayo Floodplains Land system. They are not extensive but have the highest actual and potential productivity of all soils in the project area. Considerable parts of the Northern and Central coastal plains carry lowland Pine Ridge vegetation, which usually grows on a distinctive set of acid and poorly drained soils with sandy tops, overlying brightly mottled compact sandy clay subsoil.

There are also extensive poorly drained and wet soils of the swamps, both freshwater and saline/brackish.

As in Toledo and Stann Creek districts (King *et al.*, 1986, 1989), the soils are classified in the Belizean three-tier system of suite-subsuite-series. As in the Stann Creek survey, no attempt is made to define series in this reconnaissance study. The suites are defined mainly on parent material, although climatic regions differentiate some suites on similar lithologies. The subsuites are defined on major morphological and chemical features of agronomic importance.

In the following brief descriptions of the suites and subsuites, the agricultural potential is mentioned in very generalized terms. A full range of assessments of the suitability of each soil for a wide selection of crops are listed in Table A2.3 and discussed in Appendix 2.

Turneffe Suite

The Turneffe Suite consists of well- and moderately drained soils formed on Pleistocene to Recent coastal deposits, sometimes underlain by shallow coral, and which can be predominantly siliceous or calcareous. Four subsuites are distinguished.

The Shipstern Subsuite includes soils with shallow coastal sediments overlying hard coral. They occur on coastal flats close to sea-level. Their natural vegetation is mangrove savanna. The profile consists of very shallow sand, silt or clay over hard sharp and rough coral, which sometimes crops out at the surface. The soils are predominantly pale-coloured. Some of them are saline. They have very limited agricultural use because of their shallowness and droughtiness.

The soils of the Ambergris Subsuite are formed in deeper calcarous sands. They are mainly found on or close to beaches. The profile consists of raw pale sand, mainly derived from comminuted coral or shells. They are very droughty soils and chemically fairly infertile. Their main agricultural potential is for cashew, pineapple and coconuts, but they will most probably be used for non-agricultural purposes, such as tourism.

Hopkins Subsuite covers a range of soils that occupy similar coastal positions and have similar poorly developed profile morphologies, but are formed in siliceous rather than calcareous sands. They are also droughty soils and even more infertile than those of the Ambergris Subsuite. They have limited agricultural potential, with cashew the most promising crop, but are a considerable touristic asset.

Matamore Subsuite soils are found on low ridges of old beach deposits that have been stranded inland by recent marine regression. They occupy very limited areas in the south-east of the project area. They are formed in siliceous sands, like the soils of Hopkins Subsuite, but have had longer to develop. As a result, they are slightly more brightly coloured due to the more advanced weathering, with yellows and yellowish reds predominant. They also have some horizonation with redder and slightly finer textured subsoils; but textures are still predominantly coarse, with only a few soils finer than sandy loam. These soils are fairly droughty and have low chemical fertility. They have moderate agricultural potential for crops that are chemically undemanding but need deep and freely draining root zones, such as coconuts, cassava and especially cashew.

Melinda Suite

Melinda Suite includes all well- and moderately drained soils formed in riverine alluvium. They are mostly found in the south of the project area where the Maya Mountains are an abundant source of alluvium. The limited river systems in the northern part of the country carry very little alluvium and form few alluvial deposits. Most of the soils are found in siliceous material. Five subsuites are distinguished in the project area.

The Monkey River Subsuite includes well- and moderately drained young soils found in recent siliceous alluvium. They are found on the low floodplain bench in the main streams draining the Maya Mountains. Colours are mainly grey and brown. Textures vary from cobble beds to clay. Depositional banding is more important than any post-depositional translocation of clay. The soils are subject to periodically high water tables and occasional floods. They are chemically fertile due to lack of weathering and leaching. Despite some drainage problems and flood hazards, they have moderate to high agricultural potential for tree crops and matahambre dry season food cropping.

The soils of the Quamina Subsuite are floodplain bench and terrace soils, formed in mixed siliceous and calcareous alluvium. Morphologically they are similar to the soils of the Monkey River Subsuite with greys and browns as the predominant colours, and variable textures layered by the vagaries of deposition. They are chemically slightly more fertile than the Monkey River soils. Like them they have some drainage limitations but are potentially productive agricultural soils.

The soils of Pasmore Subsuite cover very limited areas in Northern Belize. They are formed in young calcareous clay alluvium deposited by the few intermediate and major streams draining off the limestones. The soil is a deep, dark-coloured calcareous clay. Drainage in the subsoil is somewhat impeded, and mottles and gypsum crystals may occur. The soils have moderately severe drainage limitations but quite high chemical fertility. Their agricultural potential is moderate, but they are unimportant because of their small extent.

The soils of the Canquin Subsuite are formed on high floodplain benches and terraces along the main valleys draining out of the Maya Mountains (i.e., the Cayo Floodplains land system). The alluvium is siliceous. Because of its age since deposition it has been considerably weathered, so that colours are mainly red and yellow. The soils have also been well leached, so that they are moderately acid and somewhat deficient in some plant nutrients. There has also been time for some clay translocation, and the textural layering inherited from deposition is less apparent than in younger soils. Agriculturally these soils have good physical features of free drainage and adequate water supply, but their chemical deficiencies need to be remedied by liming and fertilisers. Nonetheless they are soils of high agricultural potential, especially for commercial citrus production.

The soils of the Sennis Subsuite have a limited extent in the project area. They are formed in compound alluvium, in which young alluvium of the Monkey River type has been deposited over the brightly mottled compact material characteristic of the old coastal alluvium normally underlying soils of the Puletan Suite (q.v). The agricultural potential depends mainly on the depth of the young alluvium. Where it is more than about 50-60 cm, these soils are similar to a poorly drained Monkey River soil, and potentially quite productive. Where the young alluvium is shallower, the compaction, poor drainage acidity and nutrient deficiencies of the underlying mottled material is more important, and the soils are devalued accordingly.

Puletan Suite

Puletan Suite soils form in deep old siliceous alluvium that has been deposited on the coastal plain, in mainly north-south alignment. The characteristic vegetation is lowland Pine Ridge, which varies from tree to grass savanna, with *Pinus caribaea* as the dominant or co-dominant tree species. All of the soils in the suite have some morphological features in common, such as a pale-coloured and coarse-textured topsoil sharply overlying a compact, brightly red and white mottled finer textured subsoil. The soils are all acid and very deficient in nutrients. The natural vegetation has a low biomass diversity and productivity, and the agricultural potential is also low, with limitations of poor drainage, droughtiness and multiple nutrient deficiencies. Six subsuites are differentiated within the project area.

The Crooked Tree Subsuite includes moderately to excessively well drained soils in which the pale-coloured, usually white, sandy topsoil is at least 50 cm deep and often much more, stretching to more than 2.5 m in some profiles. This depth permits free drainage and deep rooting. The vegetation can therefore partly offset the droughtiness and low nutrient contents of these soils. The natural vegetation is dense Pine Ridge tree savanna with well-grown oaks. The agricultural potential is also higher than in other Puletan soils, with potential for coconuts, pineapples, pasture and especially cashew.

The profile of the soils of the Boom Subsuite are rather similar to the Crooked Tree soils except that the pale-coloured, coarser-textured topsoils are shallower than 50 cm, thereby reducing the freedom of drainage and the depth of easy rooting. The natural vegetation has lower stature than that of Crooked Tree with few and smaller trees. The impeded drainage, droughtiness and nutrient deficiencies make these soils unsuitable for most crops.

The soils of the Boctora Subsuite include profiles with deep and shallow sandy topsoils, and thus encompass the depth ranges of both Crooked Tree and Boom subsuites. The distinguishing feature is the rock-like ferricrete in the mottled subsoil, formed by the deposited iron oxides and consequent cementation of the soil mass. This material occurs as gravel, separate boulder-like masses, or as a more or less continuous slab. The agricultural potential of these soils is variable but mostly poor. The ferricrete is a useful source of road material.

The soils of the Backlanding Subsuite are probably not extensive in the project area. They are morphologically similar to the soils of the Boom Subsuite, with a pale-coloured topsoil of less than 50 cm depth overlying a compact and brightly mottled subsoil. Backlanding Subsuite topsoils are medium- rather than coarse-textured. Fine sandy loam and silty loams are the most frequent texture classes. Their agricultural potential is similar to that of Boom Subsuite, i.e. low to very low. Minor benefits in available water capacity because of the finer textured topsoil are probably offset by slightly inferior drainage. The nutrient status is very low.

The soils of the Haciapina Subsuite form where eroded sandy topsoil material from Puletan soils upslope accumulate in poorly drained depressions. The Haciapina profile is characterized by a deep pale-coloured sandy topsoil, but unlike the topsoil of the Crooked Tree Subsuite, it is more or less permanently saturated. The soils carry a variety of Pine Ridge vegetation types, ranging from quite dense thickets with a high proportion of palmettoes to wet open areas of grasses and sedges. The soils have severe drainage constraints and multiple nutrient deficiencies. They have very low agricultural potential except possibly for irrigated rice.

The soils of the Buttonwood Subsuite are saline. Morphologically they are quite variable. The topsoil is often quite brownish and fluffy. The soils are not extensive and are found mainly as pockets on the seaward margins of the coastal plain, although small patches can occur inland where there are saline or brackish springs. The soils have a characteristic shrub savanna vegetation that is dominated by the silver buttonwood bush. Their agricultural suitability is very low; constrained by drainage, salinity and nutrient deficiencies.

Tintal Suite

Tintal Suite soils are permanently or seasonally waterlogged to within a few decimetres of the surface. There are a number of other soils that are seasonally waterlogged at greater depths, but they are classed as wet variants of other subsuites and are not included in the Tintal Suite. Although this suite is defined in terms of profile characteristics and not parent materials, the soils are all found in transported materials, either alluvial or deep slopewash.

The soils of the Pucte Subsuite are seasonally waterlogged clays on lower slopes and valley bottoms in limestone areas. They are widely scattered and probably total a considerable area, although individual bodies tend to be long, sinuous, and not very large. They carry a characteristic marsh forest (Figure 30) in which pucte trees are common – hence the name. They often have markedly mounded 'hogwallow' microrelief. The shallow topsoil is often brown and has a friable consistency and a very promising feeling of the crumb structure, but the subsoil is grey clay or silty clay with a massive or weak coarse blocky structure. This clay is wet throughout in the wet season, but the upper part dries out in the dry season. There are often brown and yellow mottles, and gypsum crystals are also often found in the lower subsoil. This soil is neutral or slightly alkaline and moderately well supplied with nutrients. Drainage is the main limitation. Given a sufficient outfall, some of these soils could be drained at a cost and be moderately productive for a range of crops, including sugar cane. In others, the engineering difficulties of water disposal will probably make them unsuitable.

The soils of the Chucum Subsuite are also seasonally waterlogged clays found in depressions in limestone areas. They carry a characteristic low scrubby bush, known locally as akalche, which has a high proportion of microphyllic and thorny species. The profile is mainly dark grey or grey clay, mottled yellow or brown. The structure is coarse blocky or prismatic, with shiny pressure faces and even striated slickensides in the lower subsoil. There is often plentiful and well-crystallised gypsum at depth. The soils are alkaline and have moderate contents of nutrients. Drainage is the main agricultural limitation in these soils. Because they are found in enclosed basins, they are difficult to drain, so their agricultural potential is low.

The Sibal Subsuite includes all permanently waterlogged soils in freshwater swamps. They carry a variety of specialized swamp vegetations, including herbaceous sedge and rush associations. The soil materials are heterogeneous, ranging from sand to heavy clay, and including some peats and mucks. The mineral soils are mostly grey and unmottled. Drainage is a very severe constraint, and these soils will require substantial engineering works to be made useful.

The Ycacos Subsuite includes all the deeper waterlogged soils of saline or brackish swamps. (Some very shallow soils over coral qualify for the Shipstern

Subsuite in the Turneffe Suite.) Ycacos soils carry various types of mangrove vegetation. The soil material is very heterogeneous, ranging from sand to clay, and including peat. The soils have multiple severe constraints for crop production, especially poor drainage and salinity. They are being increasingly cleared of mangroves for residential tourist and shrimp farming purposes. Some attention must be given to the role of mangrove forests in absorbing some of the impact of hurricanes, and the erosion of these soils by wave action following clearance.

Bahia Suite

The Bahia Suite includes the shallow soils over young coralline limestone around the shores of Chetumal Bay. Two subsuites are identified.

The soils of the Consejo Subsuite are shallow, organic and even peaty loams overlying gypsiferous limestones at depths usually less than 50 cm. The underlying limestone may be soft but is often capped by a layer of sharp and hard coral fragments. A feature of these soils is the occurrence of profuse gypsum crystals. The soils naturally carry a rather stunted deciduous broadleaf forest. The agricultural potential is limited mainly by shallowness and droughtiness, but also by nutrient deficiencies and imbalances.

The soils of the Remate Subsuite are very shallow and stony clays overlying hard coral – usually at a depth of 30-50 cm, which may be in the form of continuous sheets or layers of sharp fragments. The clay may be dark or reddish brown but black is the most common colour. The agricultural potential of the soils are severely limited by shallowness and droughtiness. The high stone contents would hinder arable farming.

Pembroke Suite

The Pembroke Suite contains dark and reddish calcareous clays overlying Orange Walk Group limestone. The soils are most extensive in Corozal District and the northern part of Orange Walk District. They are the main sugar cane soils. There are four subsuites.

The Louisville Subsuite includes most of the black clays over limestone in Corozal and northern Orange Walk districts., The soils form the core of the sugar cane area. The profile consists of black or very dark grey clays over limestone to a depth of 40 – 100+ cm. The deeper soils occur on the lower slopes, and their lower subsoils have scattered mottles, some gypsum crystals and appear to be intermittently saturated. However, most of these soils are well-drained, well-watered and contain moderate and well-balanced levels of the main nutrients. They are moderately suitable for a range of crops, especially sugar cane, cereals, cotton and pasture.

Concepcion is a relatively minor subsuite that contains brown clays that are intermediate between the black clays of Louisville and the red clays of Xaibe subsuites. The Concepcion soils are mainly found in the vicinity of the Libertad sugar mill. They are relatively shallow soils, in which the brown clays overlie limestone at depths of 30-60 cm. There is often a layer of hard limestone clasts between the soil and softer underlying limestone. The soils are limited by their shallow rooting depth and tendency to droughtiness. They tend to have a slightly lower potential for sugar-cane and annual crops than the Louisville black clays, but they are probably slightly better for most tree crops. The village of Concepcion was at one time well-known for the quality of the citrus fruit grown on these soils.

The Xaibe Subsuite includes the red clays that occur around Corozal town, and a larger area in the eastern part of the district. Beneath a darkened reddish brown topsoil, these soils have bright red clay subsoils overlying limestone at depths of 30-100+ cm. The shallower soils tend to predominate, especially in the northern area. The subsoil clays are very firm, almost compact in the dry season. There is often a layer of hard stones between the red clay and the soft underlying limestone. The soils are neutral to moderately alkaline, and have moderate nutrient contents, although phosphate and potassium may be rather low. The main agricultural limitations are the tendency to shallowness and droughtiness, and the deficiencies in some nutrients. They are rated rather less highly than the black clays for sugar cane and annual crops. They have a similar potential for tree crops although these are likely to suffer some moisture stress.

Puluacax is a minor subsuite, consisting of yellowish and brownish clays that occur on the margins of large areas of Xaibe clay in eastern Corozal District. The soil depth varies and the soils are often underlain by hard limestone at depths of less than 60 cm. The subsoil is usually mottled with greys and reddish browns and generally appears to have intermittently impeded drainage, corroborated by the low stunted bush, some of which is almost akalche. The soils are rather poorly drained for most crops, and have low potentials for everything except possibly rice, pasture and pineapples.

Yaxa Suite

The Yaxa Suite includes the dark and reddish clays formed on Cretaceous and Early Tertiary limestones, ranging northwards from the Belize River to Orange Walk town. They are the most extensive lowland soils in the project area. Large areas of the soils remain under semi-deciduous broadleaf forest, although disturbed by logging.

The most extensive soils are the dark clays of the Yalbac Subsuite, which occupy most of the Albion Island Plain with Hills, Shipyard Plain, Wamil Plain with Hills, Neuendorf Escarpment, Gallon Jug Plain with Hills and Yalbac Dissected Cuesta land systems. The topsoil is black or very dark grey clay, often with a marked fine blocky structure, which grades into a dark grey clay with a coarser blocky structure and generally firm consistence. Many of these sub-soils directly overlie limestone at depths of 40-80 cm, but there are some deeper hillwash soils on lower slopes, which have grey slightly mottled lower subsoils, occasionally with diagonal striated slickenslides and a few gypsum crystals. All of the soils are moderately alkaline and fully base-saturated. They are slightly undersupplied with potassium and phosphorus, but are still moderately fertile. The shallow soils tend to droughtiness and the deeper hillwash soils have slightly impeded drainage. The soils are moderately suitable for sugar cane and a range of annual crops. In areas of sufficient rainfall they are marginally suitable for coffee and cacao, but less so for citrus.

The soils of the Jolja Subsuite occur in the Blue Creek and Neustadt Plain land systems where the limestone sequence includes thick beds of flint. The soils are similar to those of the Yalbac Subsuite, in that their fine earth fractions consist of dark calcareous clays. Their distinctive feature is the presence of many flint stones, derived from beds and lenses of flints in the upper part of the Barton Creek Formation. In the soil, they may be concentrated as a surface pavement, subsoil stone layer, or fairly evenly distributed throughout the profile. The soils vary in depth from predominant shallow profiles found in most sites to less common deeper soils in areas of hillwash accumulation on lower slopes. The soils are slightly less calcareous than those of the Yalbac Subsuite because of the acidic influence of the flints. They are also slightly less fertile. Their agricultural potential is also limited in some profiles by the thickness and impenetrability of the flint stone line.

The Chacluum Subsuite consists of the shallower red clays found over Cretaceous and Early Tertiary limestones in the Hill Bank Plain and parts of the Gallon Jug Plain with Hills land systems. The profile consists of dark reddish brown clay topsoil over reddish clay subsoil, overlying limestone at depths of 30-80 cm – usually towards the shallower end of the range. The soils are neutral or slightly alkaline and moderately fertile, although there may be some phosphate and potassium deficiencies. These and the tendency to droughtiness in the shallower soils limit the agricultural potential slightly. They are currently being developed for citrus to the south-west of Hill Bank.

The soils of the Ramgoat Subsuite also have reddish clay topsoils, but are distinguished by yellowish clay subsoils, often with scattered black iron concretions. The subsoil is very hard, almost indurated in the dry season but appears to be reasonably permeable to water and penetrable by tree roots. These soils are deeper than those of the Chacluum Subsuite, and the underlying limestone is usually found at depths greater than 80 cm. The soils are deep, with apparently reasonable capacity of available moisture, and are moderately fertile; but their agricultural potential is probably limited by impeded drainage and the effects of the subsoil induration, even if only seasonal, on crop roots.

The soils of the Irish Creek Subsuite are deep and rather poorly drained. They occur on lower slopes and along swamp margins, generally downhill of areas of Chacluum and Ramgoat soils. The profiles consist of grey and red mottled clays, of 1-2 m depth overlying limestone. The subsoil often contains manganese concretions and occasionally some gypsumm crystals. The soils are calcareous and moderately alkaline. They are well supplied with moisture and are moderately fertile, but their agricultural potential is limited by impeded drainage except for rice.

Chacalte Suite

Chacalte Suite clays form on the Cretaceous limestones to the south of the Belize Valley. They occur in the rugged Central Foothills and Western Uplands. Large areas remain under semi-deciduous broadleaf forest, although they have been logged, especially for mahogany. The three subsuites are distinguished mainly on depth of soil.

The soils of the Cabro Subsuite are shallow and stony. They occur on the steeper slopes of the predominant karst topography. They are mostly black or dark grey clays, but dark brown and reddish brown colours also occur. Hard limestone is found at a depth of less than 40 cm, and the overlying soil contains limestone fragments. The soils are moderately alkaline and calcareous. They are moderately fertile but their agricultural potential is severely limited by their marked droughtiness.

The Xpicilha Subsuite contains moderately deep clays on gentler slopes. They are mainly dark grey or black, 30-100 cm deep, but reddish clays also occur. The profile consists of a fine blocky very dark topsoil, over a dark coarse blocky, occasionally prismatic subsoil. There may be an olive coloured massive clay, with black manganiferous concretions, just above the limestone. The soils are calcareous and moderately alkaline and fertile. Steep slopes are often a constraint to arable agriculture, but many of these soils are moderately suitable for cacao. Their chemistry makes them less suitable for citrus.

The San Lucas Subsuite consists of deep and imperfectly drained calcareous clays on gentle lower slopes and in interkarst basins. The upper part of the profile consists of black or dark grey blocky clay, but the lower subsoil is usually grey clay with yellowish and brownish mottles. It has a weak coarse blocky, prismatic or slightly wedged structure, often with marked shiny clay coatings. It often contains black manganiferous concretions. The soils are calcareous and alkaline and have adequate contents of most nutrients, although phosphorus and potassium may be slightly deficient. These are well, sometimes excessively, watered soils, and intermittently impeded drainage is their main agricultural limitation.

Vaca Suite

Vaca Suite soils are brown clays on Cretaceous limestone in the Vaca Hills and parts of the Xpicila Hills with Plains land systems. The topography is rugged and karstic and most of the soils remain under semi-deciduous broadleaf forest, albeit logged for mahogany. Some areas in the north have been cleared for pasture and milpa cultivation (see section on Farming Systems).

Cuxu Subsuite is the only subsuite that has been distinguished. It consists mostly of shallow, stony, dark brown clays. The clays are mostly less than 30 cm deep over hard fractured limestone, but there may be pockets in the weathering front with clays up to 80 cm deep. The soils are calcareous, moderately alkaline and fertile. Their agricultural potential is limited by their droughtiness, generally steep slopes and erosion hazard. The high stone contents in the shallower soils hinder cultivation.

Guinea Grass Suite

The soils of the Guinea Grass Suite developed either from sandy limestone or in shallow sandy siliceous alluvium overlying limestone. They occur in the northern parts of Orange Walk District and are used widely for sugar cane and winter vegetables. Very little of their natural vegetation is extant, but appears to have been semi-deciduous broadleaf forest. The generalized profile is a dark coarse- or medium-textured topsoil over a dark-coloured medium or fine-textured calcareous subsoil. Two subsuites are distinguished according to the depth of sandy topsoil.

In the Lazaro Subsuite the topsoils are fairly shallow with a medium texture. The black or dark grey sandy loam or sandy clay loam is moderately structured. It grades fairly sharply into dark grey sandy clay with a moderate blocky structure at a depth of 20-50 cm, overlying limestone at a depth of 50-150 cm. The deeper soils occur on lower slopes as slopewash. Their lower subsoils may be moderately mottled. The soils are neutral or slightly acid in the upper horizons, but the finer textured subsoils are calcareous and moderately alkaline. There are moderate supplies of plant nutrients. These are fairly well watered, drained and fertile soils and are suitable for a wide range of crops. At present, they are mainly used for sugar cane and feed sorghum.

In the Pixoy Subsuite the upper part of the profile consists of loamy sand or sandy loam. It is dark at the surface, but grey at depth. The topsoil may reach a depth of 80 cm or more. It is underlain by dark calcareous sandy clay or sandy clay loam, with a coarse blocky structure and is very hard and compact when dry. The subsoil overlies limestone at a depth of 50-150 cm. The sandy topsoil is distinctly acid and deficient in phosphorus and other plant nutrients, partly offset by the more fertile calcareous subsoil. The soils are less watered and fertile than those of the Lazaro Subsuite, but are still moderately or marginally suitable for a wide range of crops.

Revenge Suite

Revenge Suite soils are also developed in mixed siliceous and calcareous parent materials. The thickness of siliceous alluvium overlying the calcareous material is usually greater than in the soils of Guinea Grass Suite, but limestone or calcareous soil is usually found within rooting depth, which distinguishes these soils from those of the Puletan Suite, which are found in much deeper siliceous deposits. The soils of the Revenge Suite are unable to support broadleaf forest, and their natural vegetation is mostly Pine Ridge savanna, with some patches of Broken Pine Ridge or even Broken Ridge forests. Two subsuites have been identified in this survey.

The soils of the Felipe Subsuite are intermediate between the dark soils of the Guinea Grass Suite and the pale-coloured, texturally differentiated soils of the Puletan Suite. Beneath a dark-coloured sandy-sandy loam topsoil, there is a deep light grey or pale brown coarse textured soil, overlying a compact medium-textured soil, which is distinctly mottled but lacks the intense variegation of the subsoils of the Puletan Suite. The main colours are light grey, brown and reddish yellow. This horizon overlies limestone at well over a metre depth. The upper siliceous layers of these soils are acid and deficient in most plant nutrients. They also tend to be droughty and have limited agricultural potential.

The soils of the Tok Subsuite carry a poor Pine Ridge savanna as their natural vegetation, and are interspersed with the deep acid planosols of the Puletan Suite. They have light-coloured – often yellowish sandy upper layers beneath the thin darkened sandy topsoil. The subsoil is a grey, slightly mottled sandy clay, which is calcareous and often includes gypsum crystals. Its most distinctive feature is its extraordinarily plastic and sticky consistence, which persists well into the dry season. The subsoil overlies limestone at depths of 60-200+ cm. The siliceous topsoils are moderately acid and may contain very low levels of some plant nutrients such as phosphorus. However, the main and very severe agricultural constraint is the physical nature of the subsoil which limits rooting and drainage.

Altun Ha Suite

The stony calcareous soils of the Altun Ha Suite are formed on the Doubloon Bank Group limestones with flints that outcrop either side of the Old Northern Highway from Dumb Cane Pine Ridge southwards to Sandhills. The natural vegetation is semi-deciduous broadleaf forest, but it has been extensively cleared for cultivation and pasture. Two subsuites have been distinguished.

The Jobo Subsuite consists of fine- and medium-textured stony soils over limestone. Colours are generally dark, but include dark brown and dark reddish browns as well as blacks and greys. Textures may be as coarse as sandy clay loam in the surface horizons, but become finer with depth. Flints are scattered throughout the profile or concentrated as a stone layer between the soil and the underlying hard microcrystalline limestone, which tends to fracture into sharp angular fragments. The soils are neutral or slightly alkaline, and are moderately fertile. Their agricultural potential tends to be limited by their shallowness and tendency to droughtiness, except where deeper soils occur as slopewash on lower slopes. The stoniness is also a constraint to root penetration and may hamper cultivation.

The soils of the Rockstone Subsuite are rather similar in colour and stoniness, but have coarser-textured upper horizons. The topsoils are stony sands-stony sandy loams, but the subsoils may be as fine as sandy clay. The soils are also underlain by limestone but the topsoils are more acid, nutrient-deficient and droughty than the Jobo soils; so the soils of the Rockstone Subsuite have more limited agricultural potential.

Stopper Suite

The Stopper Suite includes all soils derived from granitic parent materials. They are confined to Southern Cayo. They cover a wide range of altitudes and topographic positions. On the steeper mountains they mostly carry broadleaf semi-deciduous forest, but the Mountain Pine Plateau carries pine woodland and savanna as its name implies. Four subsuites are thought to occur in the project area.

The Powder Hill Subsuite includes the shallow stony soils on most of the steep slopes of the granitic outcrops in the Richardson Peak Mountains land system. Beneath a slightly darkened medium-textured topsoil, the profile consists of brownish, greyish or reddish sandy loam – sandy clay, with frequent quartz or granite stones, which grades into weathering granite within 50 cm of the surface. The soils are acid and deficient in several nutrients. Their agricultural potential is limited by their infertility and droughtiness, but vulnerability to severe erosion, including development of gullies if cleared of the natural broadleaf forest cover, is the main constraint on their agricultural use. They should be excluded from all development plans and left under unlogged protective forest.

Mayflower Subsuite comprises deeper soils than Powder Hill. Beneath a moderately darkened topsoil they are pale-coloured with greys and yellows predominant. They are mostly coarse- or medium-textured, with much angular quartz grit and coarse sand. They are acid- and base-deficient, and also have low contents of phosphate. They are rather droughty and infertile soils, but are moderately or marginally suitable for tree crops provided they are limed and fertilized, but they are very erodible and should be left under protective forest on slopes steeper than about 12°.

The soils of the Canada Hill Subsuite are also deeper with weathering granite at a depth of more than 50 cm, and often deeper than one metre. They differ from Mayflower in having bright red subsoils due to the high contents of iron oxide minerals. They are also medium- rather than coarse-textured, although their sand fractions are still coarse and angular. They are acid and base-deficient, and need heavy liming and fertilization. Like the other granitic soils they are erodible and should be left under protective forest on even moderate slopes. On gentle slopes these soils are suitable for citrus and other tree crops.

The Pinol Subsuite includes all of the granitic soils of the Mountain Pine Plateau and Copetilla Mountains land systems. They range in colour and texture from pale yellow loamy grits and coarse sands to bright red sandy clays. They all tend to become redder and finer-textured with depth. They are acid and very base-deficient. Even with liming and fertilization they seem to be of very low agricultural potential. Their present use for productive pine forestry is probably the most suitable.

Ossory Suite

The varied and extensive Ossory Suite includes all the soils derived from the metasediments of the Santa Rosa Group, the main outcrops of the Maya Mountains which range from almost pure quartzites to dark schistose argillites. It also includes soils derived from the Margaret Creek Formation (see Geology section). In the Mountain Pine Plateau, Ossory soils carry pine savanna and woodland. Over most of the Richardson Peak Mountains land system, they are under semi-deciduous broadleaf forest, but areas subject to intense or recurrent fires are covered with fire climax soils dominated by the tiger bush fern. There are thought to be nine subsuites represented in the project area, but not all of them were seen in the course of fieldwork.

Four of the subsuites comprise soils found mainly at lower altitudes. More details are given in the Stann Creek report (King *et al.*, 1989). These subsuites are the shallow grey sandy soils over quartzite (Cabbage Haul), the deeper and redder fine-textured soils (Curassow), similar deep and red but coarse-textured soils (Pippen) and the deep reddish mixed soils in hillwash on lower slopes (Dancing Pool). These soils are all acid and have low nutrient contents. Cabbage Haul soils are also very droughty, but the others can be used for tree crops with liming and fertilization, but care must be taken with soil conservation; and steep slopes (more than about 15°) should be left under protective forest.

The soils of the Granodoro Subsuite are restricted to the Capayal Plateau land system and the siliceous plains (subunits SU, SLK, SR and SMK) of the Xpicilha Hills with Plains and Vaca Hills land systems. They are moderately shallow red and red grey soils derived mainly from argillites. They are acid and have low nutrient contents. They are rather droughty and infertile and have limited agricultural potential. Some of the slopes are quite steep and are best left under protective forest.

The soils of the Machiquila Subsuite occur on the flanks of the Grano de Oro Hills (alluvial wash subunit). They are formed in complex parent material in which alluvial wash probably from the Santa Rosa metasediments, but possibly from the siliceous rocks of the Margaret Creek Formation, overlie the basal limestone of that formation or buried downtilted Cretaceous limestone. The soils are reddish-coloured and medium-textured, grading into olive-coloured clays, often with black manganiferous concretions over the limestone. They are deep and well-watered soils, but the subsoil drainage is seasonally impeded and they suffer from some nutrient deficiencies. Most of them are marginally suitable for a range of arable and tree crops.

The Cooma Subsuite includes most of the deeper soils from metasedimentary parent materials on the Mountain Pine Plateau. They range from yellowish sandy soils over quartzite to reddish sandy clays over argillites. They all tend to become redder and finer-textured with depth. They often have plentiful black manganiferous concretions. On the metasedimentary plateau subunit, there is often a shallow buried pavement of argillite fragments. The soils are acid and deficient in bases and other nutrients. Experimentation has demonstrated low agricultural potential and they are best used, as at present, for long-rotation extensive pine forestry.

The soils of the Chiquibul Subsuite are the shallow equivalents of the Cooma soils and occur mostly on dissected metasedimentary plateaux. They tend to be less than 40 cm deep and overlie fairly hard but fractured metasediments. They vary from pale coarse-textured to more reddish fine-textured fine earths. They are acid and base-deficient. In addition to infertility, their agricultural potential is limited by their tendency to droughtiness, and vulnerability to erosion on the steeply sloping sites. They are best left under natural vegetation, protected from fire and logging on the steeper slopes.

The Baldy Subsuite includes the soils of the grasslands of the high plateau and valleys subunits of the Mountain Pine Plateau. The soils have a characteristic combination of pale yellow and grey colours with fairly fine textures. They also have a thick surface pavement of quartzitic stones, through which the tussocky Mountain Pine Ridge grasses grow. Their upper subsoils have pronounced and distinctive prismatic structures. The soils are extremely acid and leached and very deficient in most nutrients. Their agricultural potential is very limited, and the limited area in which they occur is probably best developed for tourism and recreation, once it is relinquished by military interests.

Richardson Suite

The Richardson Suite occurs over an outcrop of the Bladen metavolcanics on the main divide of the Maya Mountains. Access to the area is difficult and these were seen as part of the Doyles' Delight scientific expedition of 1989. The soils are covered with natural semi-deciduous and evergreen broadleaf forest, in which the palm *Colpothrinax cooki* is a prominent component, especially on ridge crests. Some of these forests grow to considerable height and biomass. Three subsuites are distinguished, although one of these (Ramos) was not seen in the course of fieldwork.

The soils of the Palmasito Subsuite occur on the flank slopes and lower crests of the main divide ridge. They are deep soils, with weathering metaandesite found at depths usually greater than one metre, even on very steep slopes. There is often a substantial litter layer over reddish brown clay loam which grades into a friable, porous reddish clay or silty clay. The subsoils have marked fine blocky or crumb structures. They are acid and base-deficient. If developed for agriculture they are likely to need heavy liming and fertilization. They are well drained and watered, and appear to have low erodibility under natural forest, but heavy and intense rainfall on very steep slopes are likely to cause very severe erosion if the forest is removed. They should remain under protective natural forest.

The soils of the Doyle Subsuite occur only on the highest ridge crests of the main divide. They have a complex morphology in which a shallow podzol overlies a deep reddish andesitic soil. The sequence of horizons is deep fibrous litter; a thin dark mixed organic and mineral topsoil; a thin pinkish grey leached horizon; a thin very dark horizon of organic matter accumulation; a moderately thin and rather diffuse reddish brown horizon of iron oxide accumulation; a deep reddish fine-textured horizon derived from *in situ* weathering of andesite; and finally weathering andesite. The soils are very acid and base-deficient, but have moderate phosphate levels. There may be a potentially severe erosion hazard. They cover very limited areas and it is strongly recommended they should be left under protective natural forest.

The Ramos Subsuite consists of shallow soils derived from the Bladen metavolcanics. They were not seen in the course of fieldwork but there are very likely to be some on recently eroded steep slopes. The profile is likely to consist of reddish brown medium-textured topsoil over a reddish stony and fine-textured subsoil overlying weathering metaandesite within depths of 50cm. The soils are probably moderately acid and base-deficient. Their agricultural potential is limited by shallowness and droughtiness, but the high erosion hazard is the most severe constraint. As most of these slopes are on slopes steeper than 15°, often much more, they should all be left under protective natural forest.

HYDROLOGY

Northern Belize

RIVERS

There are four river systems draining Northern Belize. The greater part of the sinuous courses of all four is through swamp and lagoon, and flow is slow and sluggish. It is impossible to delineate catchment boundaries with any accuracy, because of the karstic nature of part of the landscape and the low relief of the rest.

The New River has the largest catchment area with about 1400 km^2. The river rises in the Yalbac Hills and flows via swamp and creek (Irish and Ramgoat) to the New River Lagoon, which extends over 30 km from Hill Bank to Shipyard. The lagoon and river course downstream maintain a general NNE direction, probably controlled by tectonics. North of the lagoon the river maintains a defined, though sinuous and often braided channel until it reaches Chetumal Bay. The river is used to transport sugar barges from Tower Hill factory to the sea (and thence to the port of Belize City).

Four gaugings of the New River were made in 1990 from the bridge at Tower Hill. The measured flow was 10 m^3/s on 2 April, and 4, 3.6 and 3.5 m^3/s on 1, 7 and 14 May. In severe floods, every five years or so, the Orange Walk pontoon bridge has to be closed when the river rises by up to 3 m. The flood may last for two months. Similar flooding can affect the San Estevan ferry, and the San Antonio pontoon bridge on a minor tributary of the Rio Hondo.

In the south, the catchment immediately to the east of the New River is tributary to the Belize River. It consists of the Northern, Western and Southern Lagoons (not to be confused with those further south on the coast between Belize City and Gales Point) with their associated creeks (Black and Spanish). It covers 370 km^2 of the project area. Crooked Tree lies within this catchment. The causeway from the Northern Highway to Crooked Tree has reverted water circulation in the lagoon, thereby destroying swamp forest along the north-eastern shore, and disturbing fish in the Southern part.

The Rio Hondo catchment lies in the west of Orange Walk and Corozal districts. Its main tributary within Belize is the Rio Bravo whose sub-catchment covers about 1100 km^2. The Mennonites have built a low dam across the Rio Bravo just above its junction with the Rio Hondo, impounding a 5 km-long reservoir, and generating 35 kW of electricity. One flow measurement in February 1984 gave 26.2 m^3/s, but at the end of the dry season the generator has to be taken out of service because there is not sufficient flow in the river. Downstream of this junction, the Rio Hondo drains approximately 800 km^2 of land. By far the greater part of the Rio Hondo catchment, however, is in Mexico and Guatemala.

Between the Belize River mouth and Sarteneja in the extreme north-east, drainage is presumed to be mostly via ill-defined flow to the sea, except for the Northern River which with its Quashie Banner Creek tributary drains a probable area (this catchment is especially hard to define) of about 500 km^2, and the Santana Creek to the south.

Most of the high flow of rivers during the wet season will originate from overland flow, while the lower flow in the dry season will come almost entirely from groundwater storage. Calculation of the contribution of each of these elements could be obtained from a continuous record of river flow. For proper basin management for fisheries, land development and determination of irrigation potential, a hydrometric station should be established on the New River as soon as possible.

GROUNDWATER

Limestone is the only aquifer in Northern Belize. The clays and sands of the Rio Hondo and New River valleys are not water-bearing. Variability in the limestone formation is likely to produce variable water-bearing properties. Unfortunately, few wells have been tested; where they have been, there is surprisingly little quantitative information about yield. While a well is being pumped, the water level in it must fall and any worthwhile yield test must relate the pumping rate to this drawdown. If the lowering is small, it is reasonable to suppose that the well can be pumped at a higher rate. The two existing Belize Sugar Industries (BSI) wells at Chan Pine Ridge (Tower Hill 1 and 2) were tested in December 1965 (Wright, 1970). In one a yield of 273 USgall/min (1240 l/min) produced a drawdown of 27 ft (8 m), while in the other a rate of 320 USgall/min (1450 l/min) gave a drawdown of 29 ft (9 m). The present yield from one of them (they are used alternatively, never together) is 400 USgall/min (1820 l/min). Tower Hill 3, some distance away, yielded 500 USgall/min (2270 l/min) for a drawdown of 56 ft (17 m) and 700 USgall/min (3180 l/min) for 104 ft (32 m). Tower Hill 4 close to San Lazaro was pumped at 650 USgall/min giving a drawdown of water level of 75 ft (23 m). In all the wells the water level recovered within a couple of minutes of the pump being turned off. The well at Pembroke Hall (Libertad) was pumped at 500 USgall/min (2270 l/min) with a drawdown of 3 ft (1 m) and 1000 USgall/min (4550 l/min) with 18 ft(5.5 m).

Exploratory wells drilled around Corozal and Orange Walk towns (Versey, 1972) were all tested at 120 USgall/min (546 l/min). In two wells at Calcutta and one at Tacistal the water level fell by less than 6 in (15 cm). The first production well at Calcutta subsequently drilled by the Water and Sewerage Authority was pumped at 165 USgall/min (750 l/min) with a drawdown of 3 ft (1 m) and a second, drilled recently, yielded 225 USgall/min (1020 l/min) with the same drawdown. Five test wells round Orange Walk gave drawdowns of 1.5, 2, 4, 7 and 7.5 ft (0.5, 0.6, 1.2, 2.1 and 2.3 m) for the same 120 USgall/min (546 l/min).

Any one of these wells with drawdowns of 4 ft (1.2 m) or less would produce more than the 120 USgall/min (546 l/min). They would certainly be good for 500 USgall/min (2270 l/min) (if the pump is set deep enough) and, with a bigger and deeper bore, even more than that. From this survey we get a good indication that high yield wells can be drilled into limestones.

There will, however, be failures: two of the test wells near Orange Walk had excessive drawdowns and pulled sand into the well. Some of the wells drilled for the rural water supply programme are not used because according to their drilling characteristics, they are not expected to support even a handpump. In any major groundwater development programme, small diameter (6-8 in, 15-20 cm) test holes should be drilled first; after which the successful ones could be deepened and reamed for use as production wells. Such a system would minimize cost.

The limestone appears to be recharged vertically through the soil where it is not too thick and clayey, and laterally by runoff from local flooded areas. It discharges by seepage to the rivers (slow because of the very low gradient), evaporation from low-lying areas, and withdrawal by wells. The water levels in wells fluctuate from dry to wet season accordingly.

The Shipyard and Little Belize communities, and a number of cattle farms, rely upon wind power for pumping groundwater to surface storage reservoirs.

Windmills have the advantage of not being so easy to steal as moveable petrol- or diesel-fuelled pump units.

WATER QUALITY

The only complete inorganic analyses of water were done by BSI quoted by Wright (1970) and are included here as Table 18. Twenty partial analyses by BSI were quoted by Versey (1972) and are included here as Tables 19 and 20. Forty partial field analyses done in the course of the present survey are given in Table 21.

Table 18

Chemical analyses of well waters from Orange Walk and Corozal districts (milligrams per litre)

	1	2	3	4	5	6
pH	7.7	7.3	7.8	7.0	7.3	7.7
Alkalinity	104	316	344	245	312	186
Total hardness	260	800	560	2000	1100	1860
Permanent hardness	156	484	216	1785	788	1674
Calcium	74	116	179	528	324	516
Magnesium	18	124	27	165	70	139
Sodium	26	197	62	–	73	67
Iron	–	0.08	0.2	0.05	27	0.06
Manganese	–	–	–	–	2	–
Chloride	76	191	24	133	137	112
Sulphate	200	580	300	1325	1020	2220
Bicarbonate	127	385	420	399	380	227
Silica	31	30	59	21	32	17
Total dissolved solids at 103°C	524	1696	830	2471	2055	2996

1. Sample from Tower Hill 1 collected during pumping test.
2. Sample from Tower Hill 3 collected on 14.2.1966.
3. Sample from Tower Hill 4 collected on 28.4.1966.
4. Sample from Pembroke Hall Factory well.
5. Sample from test well to west of Pembroke Hall Factory.
6. Sample from adjacent well to 5 above.

Source: Wright, 1970

Table 19

Well water analyses – May, June 1972 (mg/l)

Source	Temporary hardness	Total hardness	Chloride	Total dissolved solids
Orange Walk/Yo Creek 1 (after 1 h)	106	380	150	421
Orange Walk/Yo Creek 1 (after 8 h)	123	460	140	665
Orange Walk/Yo Creek 2 (after 2 h)	182	540	140	833
Orange Walk/Yo Creek 2 (after 7 h)	179	550	80	797
Orange Walk/Yo Creek 5 (after 2.5 h)	160	540	180	1152
Orange Walk/Yo Creek 5 (after 5.5 h)	182	560	170	975
Yo Creek water system	258	460	500	1299
San Jose Palmar water system	154	600	120	753
Tower Hill/Chan Pine Ridge (BSI)	196	370	180	585
Chan Pine Ridge 1 (after 1 h)	280	750	90	1063
Chan Pine Ridge 1 (after 5 h)	224	700	100	1019
Otro Benque hospital site (after 5 h)	168	500	200	1106
Otro Benque (BSI housing)	207	550	n.d.	1240
Orange Walk/Yo Creek 2 (deepened)	112	600	120	886

Source: Versey, 1972

The main characteristic of the waters of Northern Belize is their hardness, which is high enough to be detrimental for drinking and even more for industrial use. The hardness is mostly permanent so that deposition of lime in boilers, irrigation lines and well screens is not a serious problem. The average total hardness from twenty analyses of the water from exploratory wells around Orange Walk town was 540 mg/l (parts per million) (Versey, 1972). The average temporary hardness of the same samples was 180 mg/l. In the wet season, the values, particularly of the temporary hardness, are lower.

The average total dissolved solids (TDS) can be reliably calculated for neutral waters such as these by multiplying the conductivity values by 0.64, which gives average TDS values of 1200 mg/l for Corozal and Belize districts and 900 mg/l for Orange Walk District. Actual measurements of TDS were comparable. Especially high values are usually due to a high concentration of the sulphate ion except in some coastal areas where chloride can be dominant. The highest sulphate values recorded from wells were 2200 mg/l from one of the Pembroke Hall wells (Table 18) and 1700 mg/l from one near Paraiso. The dry season flow of the Rio Bravo has 1500 mg/l and the Rio Hondo 860 mg/l. The New River showed a small increase from 720 to 850 mg/l between mid-March and mid-May while its flow fell from 10 to 3.5 cumecs.

Chloride is not excessive; the only high values measured were in a brackish pond near Sarteneja (2500 mg/l) and in a handpump well at Santana (1600 mg/l). The average for each of the districts is: Belize, 485 mg/l; Corozal, 335 mg/l; and Orange Walk, 127 mg/l. From the graph in Figure 34 we see the relationship of conductivity to chloride and sulphate concentrations. The diagonal line separates the fields where each ion is dominant. All samples from east of the New River (with the exception of Chunox) fall in the chloride field. Those from west of the New River (with the exception of boreholes at San Juan, Yo Creek, and August Pine Ridge) fall in the sulphate field.

At the end of each wet season percolating rainwater forms a layer above and distinct from the body of groundwater below. This layer will have a much lower concentration of all ions than the groundwater. During the dry season it will slowly be depleted by human and plant use, and slow percolation to the rivers. There will also be mixing between the two water layers. In Orange Walk District, the deeper water is relatively high in sulphate; in Belize District (along the old Northern Highway at least) it is high in chloride; in Corozal District it is high in sulphate and moderately high in chloride. In coastal areas this deep water will be brackish and the only water of good quality will be in the layer of fresher water above.

Samples were analysed for nitrate by the Water and Sewerage Authority laboratory. The background value averaged 4.3 mg/l with anomalies of 16.8 and 28.4 mg/l due to domestic pollution.

Table 20

Well water analyses – October 1972 (mg/l)

Source	Temporary hardness	Total hardness	Chloride	Total dissolved solids
Orange Walk production well	25	308	64	470
Calcutta	42	542	204	960
San Joaquin	38	532	178	890
San Andres	36	320	82	580
Tacistal	36	496	172	700
San Lorenzo road	31	524	144	–

Source: Versey, 1972

Table 21

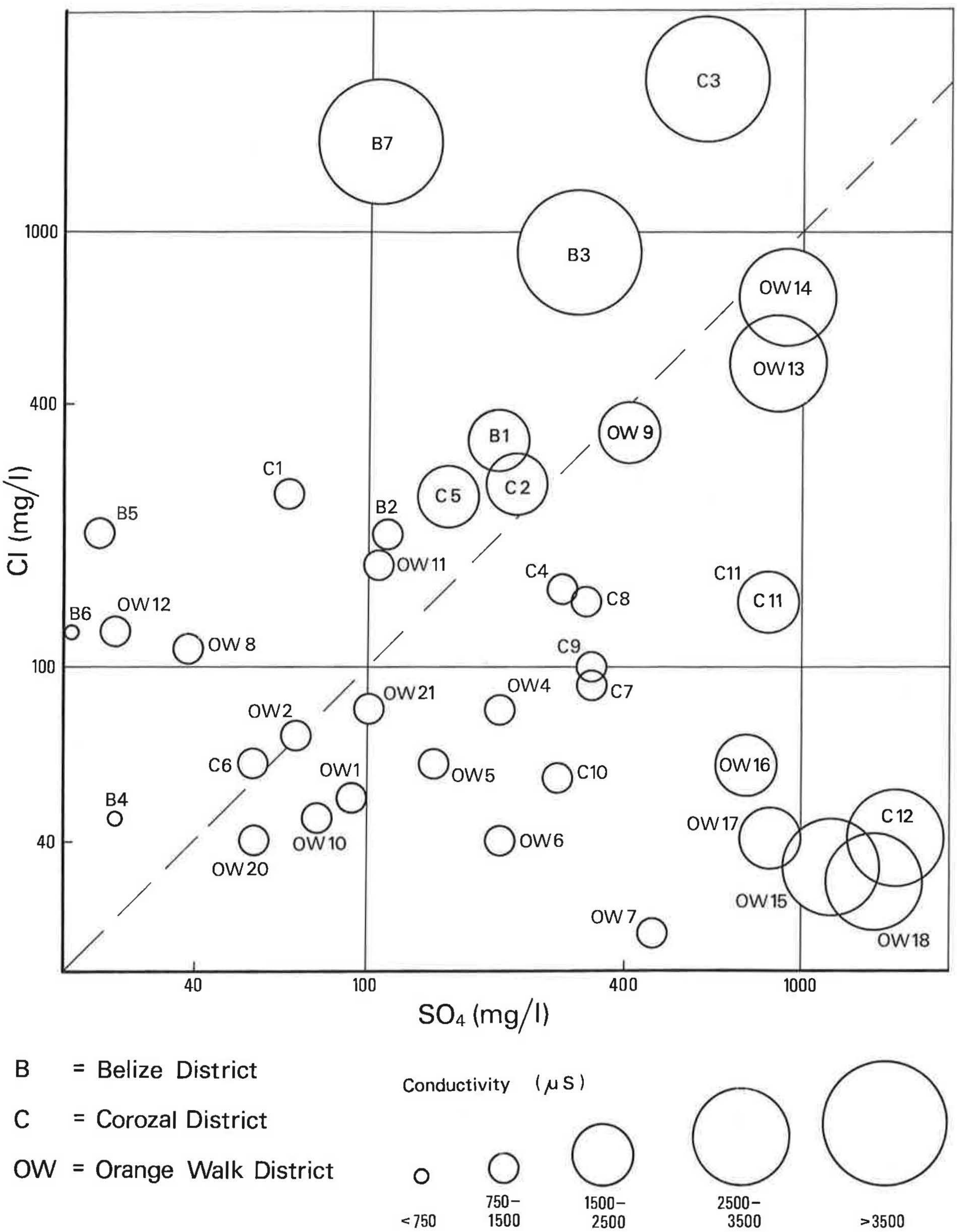
Water quality: field analysis

Locality	Type of source	Chloride mg/l	Sulphate mg/l	Conductivity ≤s
Corozal District				
1. Sarteneja village	Dug well	250	65	990
2. Sarteneja nature reserve HQ	Dug well	260	320	1700
3. Sarteneja nature reserve HQ	Pond	2500	600	6800
4. Chunox	Dug well	150	280	1300
5. Progresso, Hill Bank	Dug well	240	155	1500
6. Concepcion	Borehole	60	56	860
7. San Joaquin	Dug well	90	330	1300
8. Carolina	Dug well	140	320	1200
9. Ranchito	Tube well	100	330	1300
10. Chan Chen	Dug well	55	275	1000
11. Chan Chen	Borehole	140	850	2050
12. Paraiso	Dug well	40	1700	2850
Orange Walk District				
1. Carmelita	Dug well	50	90	800
2. Carmelita	Dug well	70	70	760
3. Little London	Borehole	40	5	580
4. San Lazaro (G. Hernandez)	Borehole	80	200	1200
5. Blackwater Creek	Borehole	60	140	950
6. New R., San Estevan (29.3.90)	River	40	200	720
7. New R., Orange Walk (12.5.90)	River	25	460	850
8. Yo Creek water supply	Borehole	110	<50	1100
9. Yo Creek	Stream	340	400	2100
10. Chan Pine Ridge (BSI wells)	Borehole	45	76	920
11. August Pine Ridge	Borehole	170	105	900
12. San Juan (Douglas)	Borehole	120	<<50	1000
13. Trial Farm, Orange Walk	Borehole	500	900	2500
14. San Luis	Borehole	700	950	3000
15. San Roman	Dug well	35	1200	2500
16. San Roman	River	60	750	1700
17. Rio Hondo at Douglas	River	40	860	1700
18. Rio Bravo at Blue Creek	River	32	1500	2700
19. New River lagoon	Lagoon	40	200	980
20. San Carlos	Dug well	40	55	1100
21. San Lazaro	Dug well	80	100	1200
Belize District				
1. Santa Marta	Borehole	330	200	1800
2. Maskall	Borehole	200	110	1350
3. Northern River, Maskall	River	900	300	3600
4. Crooked Tree	Dug well	45	<<50	505
5. Sandhill	Borehole	200	<<50	800
6. Lucky Strike	Borehole	120	Trace	480
7. Santana	Borehole	1600	140	4500

Southern Cayo

The largest drainage basin of Southern Cayo is that of the Eastern Branch of the Belize River with an area of about 1400 km^2. It drains the western part of the Mountain Pine Plateau land system by means of the Rio On, Rio Frio, Privassion Creek and other tributaries; and the central part of the Maya Mountains land region by means of the Macal River and its tributaries. The headwaters of the Macal are entirely within the Santa Rosa metasediments, but the lower reaches have cut through Cretaceous limestones into the underlying granite. A river gauging station has operated since 1981 at Cristo Rey. The mean daily flow drops below 4.5 m^3/s (lowest recorded: 4.36 m^3/s) in the dry season. The highest mean daily flow was 721 m^3/day with a peak rate of 1523 m^3/s on 17 September 1986. The river is being considered as a power source.

Figure 34



Cl (mg/l)
SO4 (mg/l)
1000
400
100
40
40
100
400
1000
B7
C3
B3
OW14
OW13
B1
OW 9
C1
C 5
C 2
B5
B2
OW11
C4
C8
C11
C 11
B6
OW12
OW 8
C9
C7
OW21
OW4
OW2
C6
OW1
OW5
C10
OW16
B4
OW10
OW6
OW17
C 12
OW20
OW15
OW 7
OW18
B = Belize District
C = Corozal District
OW = Orange Walk District
Conductivity (μS)
<750
750–1500
1500–2500
2500–3500
>3500

The other northward-flowing rivers have much smaller mountain catchments: Barton Creek, 70 km^2; Roaring Creek, 80 km^2; Caves Branch, 70 km^2; and Sibun River (with the Dry River and Margaret's Creek tributaries), 220 km^2. They have formed deep valley cuts into the limestones of the Central Foothills land region, wherein the dry season stream flow disappears underground into solution channels and caves, while the wet season flow is augmented by ephemeral springs which discharge the overflow from these same channels.

Day *et al.* (1987a) have surveyed the hydrological problems along the Hummingbird Highway. They quote historical evidence to demonstrate shortages of water supply for both domestic and agricultural purposes towards the end of the dry season in April or May. "In Dry Creek,... dry season flow may be negligible, and water supply may be a problem for farmers", but domestic water can usually be obtained from springs and caves along the edge of the valley.

Dry season flow in Caves Branch may fall below 1 m^3/s (Miller, 1981, 1983) "and cattle watering can become a potentially serious short-term problem" (Day *et al.*, 1987a), but milpa farmers (see Farming Systems section) use the springs and caves along the edge of the valley. "The Sibun River usually maintains flow throughout the dry season" (Day *et al.*, 1987a). St Margaret's village has several wells and there are wells at Over-the-Top and miles 32.5 and 33. "Several small springs north of the highway are... used for domestic and lime kiln supply". Except for the Blue Hole, there are few perennial water supplies between the Caves Branch and Sibun River.

Table 22 shows estimated river discharges. Floods often change river courses, damaging agricultural land. "In Dry Creek,... floodwaters during the 1984 wet season caused the loss of some 2 ha (5 acre) of land" (Day *et al.*, 1987a).

The Western Uplands land region is drained by the Chiquibul Branch in the south and a number of other mainly westward-flowing streams, all of which sink underground in the dry season. There is a shortage of water in the whole land region, except possibly in the valley bottom subunit of the Vaca Hills land system.

Table 22

Estimated river discharges in the Hummingbird area (m^3/s)

Period	Caves Branch	Sibun	Dry Creek	St. Margaret's Creek
Dry season	<1	<5	<1	<1
Wet season (annual)	50	100	50	20
Wet season	150	250	150	50

Source: Day *et al.*, 1987a

Central Coastal Plain

The drainage of the Central Coastal Plain is dominated by the Belize and Sibun rivers and the Northern, Southern and Western lagoon catchments. The whole region has a high water table, much of which is saline. The thickness of the freshwater lens floating on the saline water along the coast, however, is less than a metre and "most permanent residents rely on hand-dug wells or collection of rain water except in dry years when they must find alternate sources of freshwater" (Hartshorn *et al.*, 1984).

VEGETATION

The study area falls almost entirely within the Subtropical Moist Forest Life Zone as defined by Holridge (1967) and mapped for Belize by Hartshorn *et al.* (1984). The vegetation has distinct edaphic associations. Wright *et al.* (1959) recognized 18 main classes and some 75 subclasses. The vegetation can however be more broadly grouped into the following classes:

(i) Broadleaf Forest

(ii) Pine Forest and Orchard Savanna (known as 'Pine Ridge')

(iii) Freshwater Marsh Forest and Swamp

(iv) Cohune Palm Forest

(v) Mangrove and Littoral Swamp.

Broadleaf forest

Broadleaf forest is the dominant climax vegetation of the project area and is well represented despite agricultural clearance. Wright *et al.* (1959) classified it as rich in lime-loving species and mostly deciduous seasonal forest with smaller areas of deciduous, semi-evergreen forest associated with alluvial soils. Canopy height varies from 15-30 m and in composition and structure depending on the soil, drainage and degree of disturbance.

Common species forming the forest canopy include sapodilla (*Manilkara zapota* (L.) van Royen); mamey ciruela (*Pouteria campechiana* (HBK.) Baehni); breadnut (*Brosium alicastrum* Swartz); mapola (*Pseudo bombax ellipticum*); hogplum (*Spondias mombin* L.); and the prime timber species mahogany (*Swietenia macrophylla* King) and cedar (*Cedrela mexicana* Roem.). In addition to mahogany and cedar the other important timber species include santa maria (*Calophyllum brasiliense* Camb.); nargusta (*Terminalia amazonia* (R. and P.) Steud.); mylady (*Aspidosperma Cruenta*); billy webb (*Sweetia panamensis* Benth.) and ironwood (*Dialium guianese* (Aubl.) Steud.).

On limestone such species as black poisonwood (chechem) (*Metopium brownei* (Jacq.) Urban) and glassywood (*Guettarda combsii* Urban) are found, whereas in those areas with more acid soils, santa maria and nargusta are particularly evident. Riparian forest forms a specific subclass, characterized by very tall individuals of such species as the cotton tree (*Ceiba pentandra* (L.) Gaertn.); booknut (*Cassia grandis* L.), fringed by the cohune palm (*Orbignya cohune* (Mart.) Dahlgren) and bamboo thicket (*Guadua spinosa* (Swallen) McClure).

Transitional broadleaf forest was originally mapped by Wright *et al.* (1959) to distinguish between those areas supporting stable plant communities from this broadleaf forest, characterized by an unstable structure with greater segregation of species, fewer conspicuous emergents and lower canopy height (10-20 m). In the project area it is principally located within the Sibun Forest Reserve and the north-eastern end of the Chiquibul Reserve on steep metasedimentary hills. Nargusta and *Virola brachycarpa* Standl. dominate this forest with the mountain cabbage palm (*Euterpe oleracea* Mart.). Where the forest has an open and uneven canopy (termed 'Broken Ridge'), and has been invaded by pine trees, the term 'Broken Pine Ridge' is commonly used.

Past clearing, hurricane damage and logging of the forest cover is reflected in the composition of the forest. Species indicative of secondary forest include narrow leaf moho (*Belotia campbellii* Sprague); broadleaf moho (*Helicarpus donnell-smithii* Rose); quamwood (*Schizolobium parahybum* (Vell.) Blake, salmwood (*Cordia allidora* (Ruiz & Paron.) Cham.); *Trema* spp.; *Inga* spp. and the cotton tree. The breadnut is particularly frequent around archaelogical sites and the cedar, although associated with primary forest has a greater frequency in secondary formations (Standley and Record, 1936).

Pine forest and orchard savanna ('Pine Ridge')

The Caribbean pine (*Pinus caribaea* Morelet var *hondurensis* Barr & Golf), forms a series of associations with various broadleaf species – principally oak ('Oak Ridge') (*Quercus hondurensis* Trel.; *Q.oleoides* Schlech and Cham.; *Q. peduncularis* Nee var. *sublanosa* (Trel.) C. Muller), craboo (*Brysonima crassifolia* (L.) Hemsl.), and palmetto (*Schippia concolor* Burrett and *Acoelorraphe wrightii* (Griseb.) Wendl.) The natural range of *Pinus caribaea* is from sea level up to about 600 m. At higher altitudes it tends to be replaced by *Pinus patula* Schiede and Deppe spp. *tecummani* (Eguiluz & Perry) (Figure 26) – formerly known as *Pinus oocarpa;* but the distribution is also affected by soil factors. Both pines can form dense, mostly pure, stands if adequately protected from fire and regenerate prolifically following opening of the canopy. The best stands are to be found in the Mountain Pine Ridge Forest Reserve where the forest has long been managed as a commercial source of pine timber. In addition to this reserve, substantial areas of open pine savanna are found in the project area (Figures 21, 23 and 25) particularly along the New Northern Highway. There has been much discussion on the importance of fire in maintaining the structure of pine savannas. Since hardwood species do invade following long-term fire protection, there is a strong argument for the viewpoint that these areas are a (man-induced) fire disclimax (Johnson and Chaffey, 1973a).

Freshwater marsh forest and swamp

Marsh forest and herbaceous swamps develop on the waterlogged land system type (see Land Unit Description section). The marsh forest is generally open with emergents reaching 20 m (Figure 30). Species associated with these formations are the bullet tree of pucte (*Bucida buceras* L.); black poisonwood or chechem (*Metopium brownwei* (Jacq. Urban) and *Desmoncus schippi* Burnett. Logwood (*Haematoxylon campechianum* L.) is also a constituent of these marsh areas and forms a low marsh forest with *Pithecolobium albicans* (Kunth.) Benth. and palmetto (Wright *et al.*, 1959).

Freshwater lagoon areas such as those associated with Crooked Tree Reserve (Western and Northern Lagoons and Spanish Creek), and New River Lagoon, Booths River and Irish Creek in the west are permanently inundated and have a rush-sedge community. Patches of palmetto and knock-me-back (*Hyperbaena winzerlingii* Standl.) also occur.

Cohune palm

The cohune palm (*Orbignya cohune* (Mart.) Dahlgren) occurs extensively in broadleaf forest, and in some localities forms a dense cohune forest known as 'Cohune Ridge'. Other species associated with the cohune include mamey apple (*Mammea americana* L.), cojeton, (*Thevetia geumeri* Hemsl.) and wild rubber (*Castilla elastica* Cervantes).

Mangrove and beach forest and littoral swamp

Mangrove formations within the project area are indicated on Map 2. The true red mangrove (*Rhizophora mangle* L.) occurs close to the sea. On slightly higher ground the white mangrove (*Laguncularia racemosa* (L.) Gaertn.) and the black mangrove (*Avicennia germinans*) may also be present. Red mangrove is also found in areas only slightly saline and as far inland as Booth's River Lagoon. Buttonwood (*Conocarpus erecta* L.), is also associated with mangrove and sometimes forms dense groves; again it is more predominant in areas with lower levels of salinity (saline plain subunit).

Beach forest, with teabox (*Myrica cerifera*) L.) and cocoplum (*Chrysobalanus icaco* L.), is found on strand plain land systems and the high tidal flat of the Belize Saline Swamps land system.

Associated with the mangrove areas are open grassland with scattered mangrove (savanna subunit), which are areas of saline or littoral herbaceous marsh very widespread in the north-east of the project area. A more detailed description of the mangrove communities is given in Appendix 6.

FORESTRY

There are 16 forest reserves within the country totaling 6368 km^2 (2459 mi^2); of these four are located within the project area and cover 3046 km^2 (1176 mi^2) representing 26% of the project area. Table 23 summarizes their extent.

Table 23

Size of the forest reserves within the project area.

	Area	
Name	ha	ac
Freshwater Creek	30,050	74,260
Mountain Pine Ridge	51,480	127,210
Chiquibul	184,930	456,980
Sibun	38,187*	94,364
Total	304,640	752,800

* Total area of Sibun Forest Reserve is 42,975 ha, but part lies in Stann Creek District.

In addition to these national forest reserves there are substantial areas of forest on both private and other national land. The distribution of forest reserve boundaries is indicated on Map 2 and the location of the reserves is also indicated on Figure 35. A brief description of the four forest reserves is given below.

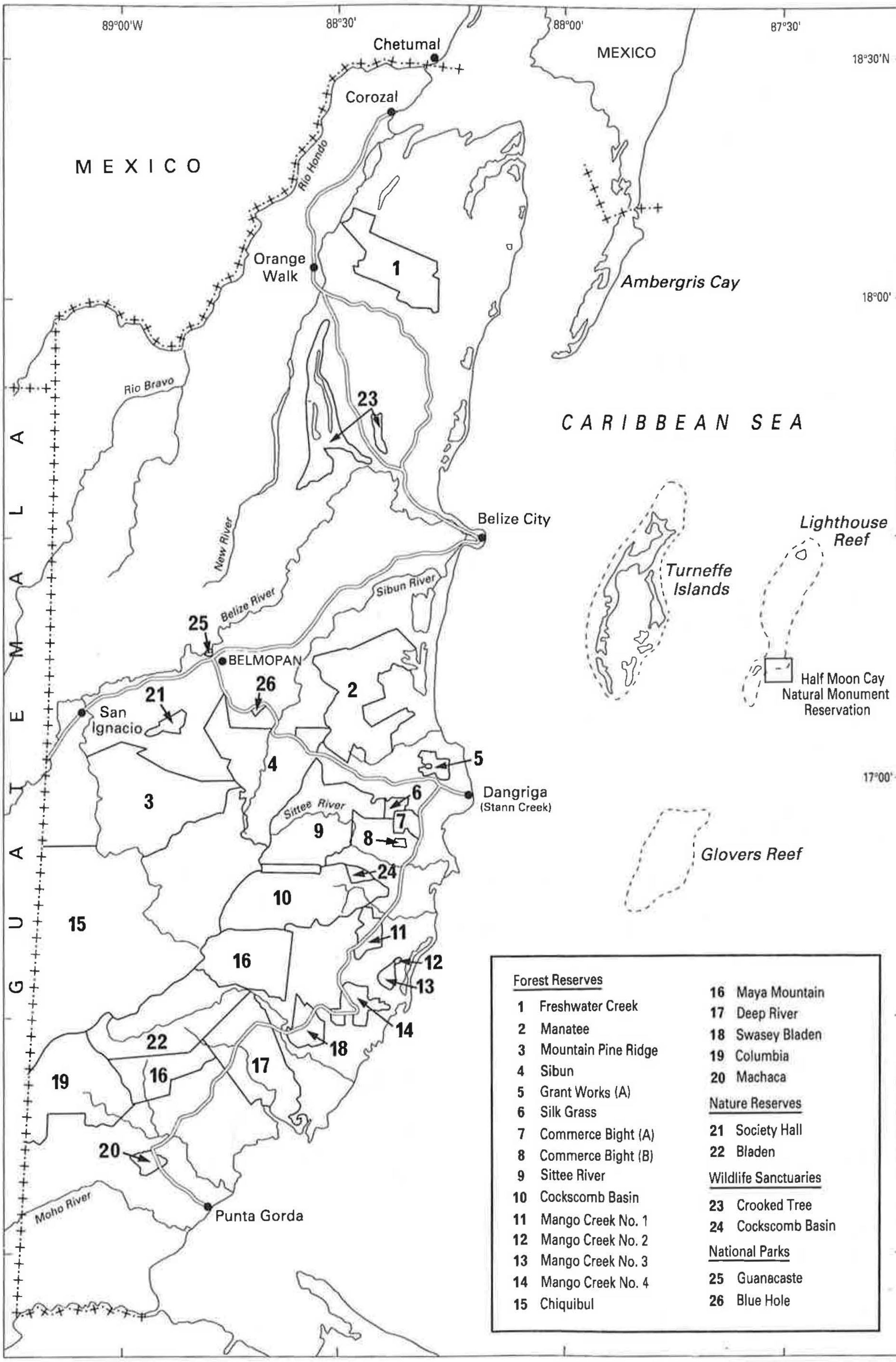
Nationally, the forest reserves are concentrated in the southern half of the country, since by the time the Forestry Trust was formed in 1923, much of the northern half had already been transferred to private ownership. The Forest Trust was superseded by the Forest Department in 1936. Fortunately the land under the responsibilty of the Forest Department includes the rugged Maya Mountains an area of fragile ecosystems, extreme beauty and serving a vital water catchment role. The Freshwater Creek Forest Reserve is the only remaining national forest reserve in the northern half of the country, the former Maskall Forest Reserve having been degazetted.

Freshwater Creek Forest Reserve

The Freshwater Creek Forest Reserve was a Crown Forest Reserve from 1930, but was gazetted as the Freshwater Creek Forest Reserve in 1960. Later the small Honey Jib Camp Reserve was absorbed. The reserve is located to the west of Orange Walk town and falls within both Orange Walk and Corozal districts.

The area is flat and poorly drained and mainly lies within the Xaibe Plain, Lazaro Plain, Jobo Plain and Corozal Saline Swamps land systems. Wright *et al.* (1959) described this area as a mixture of deciduous seasonal forest (rich in lime-loving species) together with high marsh forest. The forest has been logged for mahogany and a few selected hardwoods, and was formerly recognized as a good source of logwood, which is still plentiful. At present the whole forest is under a short-term forest licence and logging is concentrated in the eastern half; overall stocking of commercial-sized timber being poor in the western half. The reserve has never been inventoried and there is no management plan. There are no special conservation sites within the reserve, although it does enclose some interesting lagoon environments.

Figure 35


89°00'W
88°30'
88°00'
87°30'
18°30'N
18°00'
17°00'
Chetumal
Corozal
MEXICO
MEXICO
Rio Hondo
Orange Walk
Ambergris Cay
Rio Bravo
CARIBBEAN SEA
GUATEMALA
New River
Belize City
Lighthouse Reef
Turneffe Islands
Belize River
Sibun River
BELMOPAN
San Ignacio
Half Moon Cay Natural Monument Reservation
Dangriga (Stann Creek)
Sittee River
Glovers Reef
Moho River
Punta Gorda
Forest Reserves
1 Freshwater Creek
2 Manatee
3 Mountain Pine Ridge
4 Sibun
5 Grant Works (A)
6 Silk Grass
7 Commerce Bight (A)
8 Commerce Bight (B)
9 Sittee River
10 Cockscomb Basin
11 Mango Creek No. 1
12 Mango Creek No. 2
13 Mango Creek No. 3
14 Mango Creek No. 4
15 Chiquibul
16 Maya Mountain
17 Deep River
18 Swasey Bladen
19 Columbia
20 Machaca
Nature Reserves
21 Society Hall
22 Bladen
Wildlife Sanctuaries
23 Crooked Tree
24 Cockscomb Basin
National Parks
25 Guanacaste
26 Blue Hole

Mountain Pine Ridge Forest Reserve

The Mountain Pine Ridge Forest Reserve is situated between the village of San Antonio in the north and Chiquibul Forest Reserve to the south. The southern and eastern boundaries are marked by the Macal River and its Eastern Branch respectively. Private land separates the north-eastern boundary and Sibun Forest Reserve, except for 1.5 km (0.93 mi)close to the Macal River. The land between the Macal River (Eastern Branch) and the Belize-Guatemala boundary is still National land, but unreserved.

The area lies mainly within the Mountain Pine Plateau , Copetilla Mountains and Vaca Hills land systems. The leached, infertile soils of the Pinol and Cooma subsuites have given rise to a distinctive ecosystem dominated by *Pinus caribaea* var *hondurensis* and *P.patula* ssp. *tecunumanii*; the latter associated with the metasedimentary-derived Cooma soils to the south of the Brunton Trail (designated by subunit prefix 'c') and the former with the granite-based Pinol soils mostly to the north of the trail (designated by subunit prefix 'p'). Broadleaf forest is found in the more fertile pockets in valley bottoms and overlying limestone (e.g. Vaca Hills land system).

The Mountain Pine Ridge was declared a protection forest in 1944, but was reclassified as production forest in 1952. The first working plan was prepared in 1956 (Wolffsohn,1956) following an earlier enumeration, but plans were upset by the effects of Hurricane Hattie in 1961. The reserve has been inventoried three times in recent years: Johnson and Chaffey (1973a); Wilson (1981) and Sandom (in preparation). The 1989/90 ODA inventory has included the entire reserve; the earlier 1973 study omitted much of the steeper, *P.tecunumanii* land. The study by Wilson was a partial re-evaluation of the 1973 assessment. The 1973 inventory for the pine areas is presented in Table 24.

The partially analysed results of the most recent inventory suggest that the above data were collected at a time when the forest was still recovering from the effects of over-logging, huricane damage and unusually severe fires. Growth rates were estimated to be less than 2 m^3/ha/annum (30 ft^3/ac/annum). Recent stem studies indicate that *P. caribaea* is only achieving exploitable size within 45-90 years. However, the same studies reveal that the performance of *P. tecunumannii* is more productive by a factor of 2-3 fold (J. Sandom, 1990, personal communication).

Exploitation of the reserve commenced properly from 1959 with a total pine extraction of 134,680 m^3 (4,756,200 ft^3) over the 15 years of 1955-70 with production peaking in 1962/63 at 17-18,000 m^3 (600,000-635,000 ft^3). The sawmill at San Luis is now abandoned, but the reserve is still being logged by the Pine Lumber Company. 6,420.3 m^3 (226,730 ft^3) were removed in 1989 using a mill at Kinloch Camp. A small volume of logs including thinnings are also taken by the Forest Department for their own mill at Augustine: annual production is 700.8 m^3 (24,750 ft^3) of sawnwood; input of logs would be twice this figure. A third mill is located on private land close to the reserve boundary using pine from outside the reserve.

Fire is a constant threat to these forests, though a system of fire towers has kept losses to an acceptable level (Figure 36). The potential danger from fire will be increased if the recent excisions from the northern zone of the reserve are extended. A block of 260 ha (650 ac) between the Privassion Creek and Main Gate is expected to be made available for citrus farming and further requests for excisions must be expected as the pressure for land builds up from San Antonio and San Ignacio. There is no working plan in operation, but one will come with the latest inventory. The reserve still needs to be zoned into protection and production areas. Pinol soils are particularly susceptible to erosion, and logging on slopes in excess of 25-30% should be avoided unless the concessionaires can demonstrate expertise in high-lead logging. Such areas should therefore be demarcated as limited production or complete protection forest. An indication of those areas to be managed chiefly for protection are indicated on Map 2d.

Table 24

Mountain Pine Ridge: summary of 1973 inventory for pure pine strata

	Area		dbh**		Mean vol	
Type*	ha	ac	cm	in	m³/ha	ft³/ac
1.	5134	12,686	>7.6	3.0	19.5	279
			>15.2	6.0	13.9	198
			>25.4	10.0	6.0	86
2.	7342	18,143	>7.6	3.0	13.7	196
			>15.2	6.0	9.7	139
			>25.4	10.0	4.8	69
3.	6480	16,013	>7.6	3.0	5.7	81
			>15.2	6.0	3.7	53
			>25.4	10.0	1.8	26

Source: Johnson and Chaffey, 1973a.

Notes: * 1. Pine forest, 70% canopy closure or above
2. Pine with canopy closure 40-70%
3. Pine with canopy closure less than 40%
** Diameter breast height.

The Mountain Pine Ridge Reserve and Chiquibul Reserve to the south have good potential for recreation and tourism. Mountain Pine itself has within its boundaries the Rio Frio Caves and the Rio On waterfalls, both of which have not been given any special protection category. Close to the boundary but under private ownership are the Thousand Foot Falls and Double Waterfall. Also just outside the present boundary is the attractive grassland landscape of Baldy

Figure 36

Smoke from fire on army firing range blowing towards Mountain Pine Ridge Forest Reserve

Beacon (Figures 7, 27 and 37) at an altitude of 1020 m. Its attraction is reduced by its use as a firing range by the army (Figure 36). A proposal has been made to include both this area and the Falls within the reserve (Hartshorn *et al.*, 1984). The reserve has a good road network, well maintained by the Forest Department.

Chiquibul Forest Reserve

Chiquibul Forest Reserve is the largest forest reserve in the country. Its northern boundary is contiguous with the Mountain Pine Ridge at the Macal River and it is bordered to the south and east by the Maya Mountains Main Divide, and the reserves south and east of the divide. There is, however, an area of unreserved National land (in the Vaca Hills) which abuts the north-west corner of Chiquibul.

The reserve falls mostly within the Xpicilha Hills and Plains in the east and the steeply dissected Richardson Peak Mountains land systems, in the west and south.

The forest was classified by Wright *et al.* (1959) as broadleaf forest (rich in lime-loving species), composed of both deciduous semi-evergreen seasonal forest and deciduous seasonal forest. The forest forms a major contrast to the pine forest to the north although there are isolated pockets of pine shrubland (San Pastor Pine Ridge) – demarcated on Map 1d as a southern outlier of the Mountain Pine Plateau land system – which account for less than 5% of the total area.

The Chiquibul Reserve was gazetted in 1956, but had been exploited for its mahogany and cedar from the mid 1920s. A partial inventory was carried out in 1955/56 and a working plan prepared in 1957, but the reserve was badly damaged by Hurricane Hattie in 1961 and a salvage operation was required. An inventory was carried out during 1969-71 (Johnson and Chaffey, 1973b), excluding the very mountainous area in the Richardson Peak Mountains land system south of the Rio Ceibo Grande. The area was divided into two working circles: Main Felling Series, mainly comprising the Xpicilha Hills and Plains land system; and the Mountain Felling Series, comprising the central third of the reserve covering the Richardson Peak Mountains land system and the scattered

Figure 37

Altiplanation terraces on the Baldy Beacon grassland (high plateau subunit of the Mountain Pine Plateau land system)

Table 25

Standing volumes from the inventory of Chiquibul Forest Reserve 1969-71.

Species	Mean volume m³/100 ha	Mean volume ft³/100 ac
Main Felling Series		
Mahogany	19.2	274
Cedar	32.2	460
Secondary timbers*	1847.9	26,406
Others	207.9	2,971
Total	2107.0	30,111
Mountain Felling Series		
Mahogany	54.8	783
Cedar	79.8	1,140
Secondary species*	2153.7	30,775
Other	388.8	5,556
Total	2677.1	38,254

Source: Johnson and Chaffey, 1973b.

Note: All volumes to 50 cm dbh or greater (5 ft girth at breast height)
* Composed of 47 species.

Table 26

Stocking and volume data from the 1975 BEC inventory

Timber group	Stocking /ha	Stocking /ac	Volume m^3/ha	Volume ft^3/ac
60-150 cm dbh				
Cedar and mahogany	1.0	0.4	1.5	21.5
Soft light	0.5	0.2	0.9	12.8
Medium soft light	0.5	0.2	0.5	7.1
Moderate hard	0.0	0.0	0.4	5.7
Hard light	1.5	0.6	1.7	24.3
Hard dark	1.0	0.4	1.4	20.0
Very hard dark	4.0	1.6	4.5	64.3
Others	0.7	0.3	0.9	12.9
Total for dbh 60-150 cm	9.1	3.7	11.8	168.6
>10 cm dbh				
Cedar and mahogany	10.1	4.1	2.9	41.4
Soft light	3.0	1.2	1.6	22.9
Medium soft light	4.2	1.7	2.1	30.0
Moderate hard	3.5	1.4	1.7	24.3
Hard light	11.1	4.5	6.9	98.6
Hard dark	12.1	4.9	4.9	70.0
Very hard dark	32.1	13.0	11.8	168.6
Others	11.6	4.7	4.1	58.6
Total for dbh >10cm	87.7	35.5	36.0	514.4

Source: Tropical Forestry Action Plan, (ODA, 1989).

occurrences of the Xpicilha Hills and Plains and Chapayal Plateau land systems east of the Raspaculo and Monkey Tail and Plains branches only suitable for careful selection felling or complete protection.

Table 25 shows the poor stocking for the two primary timbers, with respect to the Main Felling Series due to both early logging activities and the substantial damage from the hurricane (compare with Table 26), but the standing volumes in the Mountain Felling Series were adequate. Estimates were also made of the amount of regeneration of mahogany and cedar. As expected, results were very variable, but overall the number of mahogany and cedar seedlings in the Main Felling Series was only 2138/100 ha (865/100 ac) of which 660/100 ha (267/100 ac) were well established and fully able to compete. Today, the forest is still understocked but in places there is a dense pole crop. Some logging has, however, been allowed in the extreme north-west corner of the reserve and in the unreserved land in the Vaca Hills. Logging should now be curtailed until the forest has time to recover fully. Future logging should be limited to the Main Felling Series with the remaining forest maintained for protection.

The Caracol Archaeological Reserve, Belize's largest Mayan ceremonial centre, lies within the Chiquibul Forest Reserve. It has the status of a National Monument and an area of 5 km^2 (2 mi^2). The Archaeology Department intends enlarging the area under National Monument to the area bounded by the Cohune Ridge in the north and Sapote Camp in the south; the protected area would then be about 140 km^2 (54 mi^2). Access is through the Mountain Pine Ridge and has been recently improved. In addition, the reserve encloses a vast labyrinth of caves; one of the largest systems in the world, but still largely unexplored. The mouth to these caves and the Puente Natural (a natural formation of a stone bridge spanning a section of the Chiquibul Branch of the Macal River) deserve special protection.

Sibun Forest Reserve

The Sibun Forest Reserve is mostly within Cayo District, but a small part falls inside Stann Creek District. It adjoins Sittee, Chiquibul and a short section of the Mountain Pine Ridge reserves. The landscape is deeply dissected and the Sibun Gorge cuts through the centre of the reserve. The reserve was gazetted in 1959, although it was a Crown Forest Reserve from 1930. An area of 8550 ha (21,100 ac) was set aside in 1977 to bring it to its present size.

The reserve mostly lies within the Richardson Peak Mountains land system, but it also covers parts of the Mountain Pine, Copetilla Mountains and Xpicilha Hills and Plains land system. The forest has been classified by Wright *et al.* (1959) as predominantly Transitional Broadleaf Forest and Shrubland (poor in lime-loving species), dominated by *Terminalia amazonia* and *Calophyllum brasiliense* together with *Virola koschnyi* and *Xylopia frutescens*. On the flatter land the forest is dominated by the cohune palm. The reserve has not been inventoried and was known to have been severely damaged by Hurricane Hattie.

Steep slopes prevent production forestry for most of the reserve. Logging would be possible only in a few selected areas along the northern edge of the reserve and indeed most of this northern zone gives the impression of being heavily logged. Encroachment from the Hummingbird Highway has been tolerated. The 1988 aerial photography indicates forest clearance has extended into the reserve in the section between Sibun Camp and the eastern boundary near Middlesex. A request for excision of a strip of land along the Hummingbird Highway is expected, which would effectively isolate the north-east corner of the reserve. A short-term forest licence has been given for some of the accessible land close to the road; otherwise the reserve is regarded as protection forest.

There are no special protection areas within the reserve, but the Blue Hole National Park is just north of the reserve on the Hummingbird Highway (on national land) and covers an area of 233 ha (575 ac).

Other important forest areas

Appreciable areas of forest are located outside the four reserves. The western half of Orange Walk District is heavily forested. The Belize Estate Company (BEC) formerly owned a huge tract of land from Labouring Creek to the Rio Bravo and from the Guatemala border and to the east of New River Lagoon, covering more than 405,000 ha (1 million ac). In 1983, the main block of 280,000 ha

(700,000 ac) was sold, but largely retained under forest; the main exception being the land to the immediate west of New River Lagoon which is being cleared for agriculture. The forest is rich in mahogany and was exploited by BEC over a period of 100 years. It is still regarded as the richest commercial forest in the country. In the 1930/40s trees of 290 cm dbh (30 ft girth) were commonly reported and one giant of 327 cm dbh (33 ft 8 in girth) was measured (Miller, 1941). In 1975, an area of 203,000 ha (500,000 ac) was inventoried by BEC. The main results are summarized in Table 26.

The Belize Estate Company was interested only in mahogany,cedar and occasionally, santa maria. The company managed the forest in a responsible manner, keeping to the prescribed diameter limits and aiming for a sustainable production. Nevertheless there were indications that the larger-sized timber was becoming more difficult to locate. Records from the Hill Bank area (Table 27) indicate a decrease in the number of mahogany and cedar. The apparent improvement in the last year is due to the reduction of the minimal diameter limits from 63 cm to 58 cm (78 to 72 in girth).

The southern block of this land is now being logged by the Belize Timber Company. Current logging provides an average log off-take of slightly less than 8 m^3/ha (110 ft^3/ac) but utilizes a wide range of species, (Canton, 1990, personal communication).

The northern block of the former BEC land, comprising a total of 152,000 ha (375,000 ac), is managed by the Programme for Belize Trust for the multiple objectives of conservation, research and limited production.

Forest management

The project area falls under the control of the District Forest Officer (West) with respect to Mountain Pine Ridge and Chiquibul Forest reserves; and the District Forest Officer (South) for Sibun Forest Reserve. Freshwater Creek in Orange Walk District is directly administered by the Principal Forest Officer at Belmopan. Range offices relevant to the project area are located at Augustine and San Ignacio (Western Region); Melinda (Southern Region); and Orange Walk, Belmopan and Belize City.

The forests have traditionally been managed under the selection system, by enforcement of a minimum diameter limit for logging for mahogany and cedar, which is currently 58 cm dbh (6 ft girth), and 36 cm dbh (44 in girth) for pine.

The Tropical Forestry Action Plan (TFAP) prepared with the assistance of the Overseas Development Administration (ODA, 1989), raised concern at the present method of silviculture. Pines are light-demanding species, and the TFAP

Table 27

Loggable trees identified in the Hill Bank Coupe, (mahogany and cedar)

Year logged	Number of trees	Area		Trees/unit area	
		km^2	mi^2	per km^2	per mi^2
1973	6152	172	66.5	35.7	92.5
1974	4327	133	51.5	32.4	84.0
1975	4035	171	66.2	23.5	61.0
1976	5412	265	102.5	20.3	52.8
1977	5388	234	90.5	22.9	59.5
1978	4518	238	92.0	18.9	49.0
1979	4417	249	96.0	17.7	46.0
1980	3945	228	88.0	17.3	45.0
1981	5439	179	69.0	20.8	54.0
1982	7958	205	79.0	33.9	88.0

Source: BEC records, also quoted in Munro (1989) document has recommended a clear-felling system should be used to promote maximum regeneration from selected seed trees.

Both mahogany and cedar are also moderately light-demanding species, and regeneration is encouraged by an opening of the upper canopy. The present policy is to manage the pine forest on a polycyclic system, whereby trees exceeding the current diameter limit can be felled. However, unless this results in an appreciable opening of the canopy, regeneration is sparse. The TFAP has recommended more flexibility in future management of the mahogany-rich forests, with more intensive and geographically restricted logging.

The present system of issuing licences or permits for one or two years and very occasionally for longer (but never for more than 10 years), means timber concessionaires on government land have no incentive to invest in roads or long-term planning.

There are no forest plantations in the project area and there have been no recent attempts at silvicultural improvement of the forest by climber cutting or enrichment planting. Some early silvicultural work in Chiquibul Forest Reserve reported by Johnson and Chaffey (1973b), was destroyed by hurricanes. There are series of growth and yield plots within the Mountain Pine Ridge Forest Reserve, which have assisted the 1989/90 inventory, but there are no yield plots in broadleaf forest, either within or outside the project area.

Forest utilization

Timber production peaked in 1952, since when its economic importance has declined. Between 1980 and 1986 forestry accounted for only 1.7-2.7% of the Gross Domestic Product. There are 46 sawmills in the country, 20 of which are located within the project area. The mills tend to be in groups close to the source of logs, with 10 in the Shipyard – Blue Creek area, 3 in Orange Walk Town, 3 in the Mountain Pine area and single mills at Corozal Town, Little Belize, Maskall and Carmelita. The largest mill strictly within the project area produces about 1 million board feet (2400 m^3) but most mills produce only one-tenth of this. Some sawmillers do their own logging and others buy logs from contractors on the open market. The TFAP (ODA, 1989) estimated that 18% of the national log production in 1987 was produced by non-sawmillers.

The Forest Department issues forest licences and permits. In 1989 there were two long-term licencees (maximum 10 years), 27 short-term licence holders, 57 forest permit holders and 18 private forest permit holders within the project area. However, these numbers are constantly changing. In addition many logs are moved from one area of the country to another and many timber operators in the Belize Valley will receive timber from the project area. In Table 28 the 1989 production from both the project area and Belize Valley is detailed.

Table 28 indicates that, for those concessionaires within the project area, production from government and private land is about equal with respect to hardwoods. Nearly all the pine comes from the Mountain Pine Ridge. However, if licence and permit holders for Belize Valley are included (many of whom are extracting logs from the project area), hardwood production from private lands represents 70% of the total. It is a major concern that there is no accurate data base indicating the state of the forest on private land.

There are no veneer mills or pole treatment plants within the project area, but there are numerous small woodworking and furniture workshops in the major centres, particularly the Mennonite community at Shipyard.

Nationally, a little over 25% of the sawn timber is exported, of which mahogany and cedar represent 90% of its value. The main use of timber within the country is for house construction although the market is being reduced as more use is made of concrete. The TFAP indicated that greater use should be made of secondary species on the home market, in order to release greater amounts of mahogany and cedar for the export market. Many of the larger

Table 28

Log production within the project area and Belize Valley for 1989 by licence groups (m^3)

Licence Group	Mahogany	Hardwood	Cedar	Pine	Others
Project Area:					
Long-term	1,496	1,292	3	5,289	16
Short-term	2,410	2,990	5	1,926	30
Forest permit	1,995	1,784	6	1,194	71
Subtotal, government land	5,901	6,066	14	8,409	117
Private forest permits	4,973	5,123	135	831	6
Total	10,874	11,189	149	9,240	123
Belize Valley*:					
Long-term	0	0	0	0	0
Short-term	458	1,033	0	249	0
Forest permit	159	190	12	0	0
Subtotal, government land	617	1,223	12	249	0
Private forest permits	2,684	25,649	182	2	0
Total	3,301	26,872	194	251	0
Total for project area and Belize Valley	14,175	38,061	343	9,491	123
National total	14,351	38,361	346	14,747	165

Source: Forest Department records.

Note: * Conforms to the area covered by Jenkin *et al.*, 1976

sawmillers now appreciate this and are increasing the range of commercial timbers both for the home market and for export.

Conservation

The Ministry of Agriculture and Fisheries is responsible for the administration of the 1981 National Parks Systems Act and the Wildlife Protection Act, which extend the powers of the Fisheries and the Forestry ordinances of 1958 and provide for the preservation and protection of important natural and cultural features. The National Parks Act provides for the establishment and regulation of National Parks, Nature Reserves, National Monuments and Wildlife Sanctuaries. Ancient monuments are separately protected under the Ancient Monuments and Antiquities Ordinance (1971) controlled by the Archaeology Department. The Forestry Department has temporarily delegated the role of management of the protected areas outside forest reserves to the Belize Audubon Society, but with the proposed formation of a Conservation Division within the Forestry Department (ODA, 1989) the Forestry Department will gradually be able to resume its conservation role.

The location of the legally recognized protected areas and the other areas of interest have been documented by Zisman (1989), Hartshorn *et al.* (1984) and the TFAP (ODA, 1989). The legally protected areas within the project area are listed in Table 29 and are illustrated on Figure 35 and Map 2.

In addition to those sites that have a legally declared conservation status, the maps indicate the positions of two sites in the project area that benefit from protection from their private owners: the potentially very important Rio Bravo Conservation and Management Area and secondly the Shipstern Reserve.

Table 29

Legally protected areas within the project area

Name/Area	Location	Description	Comments
Crooked Tree Wildlife Sanctuary (1810 ha, 4470 ac)	Belize District on land surrounding Crooked Tree Village (lat 17° 47' , long 88° 32'W) Two separate blocks enclosing: (i) Crooked Tree Lagoon, Southern and Western Lagoons, Spanish Creek and Revenge Lagoon (ii) Mexico and Jones lagoons to the east of Biscayne	Logwood forest adjacent to the lagoons with pine and low broadleaf forest and shrubland also enclosed. Major value stems from the variety of birdlife and as a breeding area for egrets, herons, ibis and especially Jabiru stork (*Jabiru mycteria*)	Established 1984, managed by the Belize Audubon Society (BAS)
Blue Hole National Park (233 ha, 576 ac)	Cayo District at mile 45 on the Hummingbird Highway. Lat 17° 9'N, long 88° 40'W, about 19 km south of Belmopan	Area of broadleaf, deciduous, seasonal forest within a karst landscape. A collapsed cave formed by a tributary of the Caves Branch has developed into an attractive deep pool	Declared a National Park 1986. Managed by BAS. Well-visited due to location
Society Hall Nature Reserve (2729 ha, 6743 ac)	Cayo District, 10 km SE of Georgeville. Lat 17° 6'N, long 88° 53'W	Area of rugged karst covered by broadleaf deciduous seasonal forest	Donated to the Government in 1975 and leased back to its original owners. BAS to take on management. Boundary of project area bisects the reserve
Caracol National Monument (500 ha, 1200 ac)	Within the Chiquibal Forest Reserve at lat 16° 46'N, long 89° 7'W	Important Mayan Centre with 21 stelae inscribed with important historical information	The monument is under reservation. Proposal to expand present area protection to 140 km^2 (54 mi^2)
Hol Chan Marine Reserve (411 ha, 1016 ac)	Southern tip of Ambergris Cay lying to the SE of the cay. Lat 17° 52' , long 88° 00'W. Includes area 1 m (3 ft) above to 5.5 m (18 ft) below sea level	Covers a succession of environments, including mangrove and also seagrass beds. The lagoon area has manatee, queen conch and spiny lobster. It was declared a protected area to prevent overfishing	Declared a marine nature reserve in 1986, managed by the Fisheries Unit
Bird Cay Bird Sanctuary (0.5 ha, 1 ac)	Belize District within Northern Lagoon. Lat 17° 22'N, long 88° 19'W	Mangrove area with coconut palms. Breeding colonies of egrets, boat-billed herons, anhingas, cormorants and white ibis	Gazetted under Crown Land ordinance in 1977, administered by BAS
Dobloon Bank Cay Bird Sanctuary (0.8 ha, 2 ac)	Small cay situated with Dobloon Bank Lagoon adjacent to Freshwater Creek Forest Reserve. Lat 18° 05'N, long 88° 8'W	Small red mangrove cay. Nesting place for wood stork, great egret and boat-billed heron	Gazetted in 1977, managed by BAS
Little Guana Cay (1.5 ha, 3.7 ac)	To the west of Ambergris Cay, 5 km SW of Santa Cruz. Lat 18° 2'N, long 87° 58'W	Mangrove swamp. Nesting area of the reddish egret and tri-coloured heron	Gazetted in 1977, managed by BAS
Un-named mangrove cay bird sanctuary (0.4 ha, 1 ac)	Lat 17° 19'N, long 88° 20'W within Northern Lagoon	Area of mangrove and herbaceous marsh. Breeding area for egrets, boat-billed herons, anhingas, cormorants and white ibis	Gazetted in 1977, managed by BAS

The Rio Bravo is an area of 61,500 ha (152,000 ac) on part of the holding formerly under the Belize Estate Company. Ownership and management will be under the Programme for Belize in perpetuity. The Programme for Belize will manage the forest for conservation, research, environmental education as well as production (Programme for Belize, 1990). The forest is predominantly broadleaf forest, particularly rich in mahogany, but there are also appreciable areas of low marsh forest and herbaceous marsh (Sibal and Corozal Saline swamps land systems and lower slope subunit in the Gallon Jug Plain with Hills land system).

The Shipstern Wildlife Reserve was established as a private nature reserve in 1987 and is located in the north-eastern tip of Corozal District. The reserve encloses part of the Shipstern Lagoon, surrounding land and the small (1.0 ha, 2.5 ac)) Shipstern Cay – total area of 9016 ha (22,280 ac). In addition, the lagoon area to the east of the reserve has been declared a no-hunting zone. The reserve has a wide range of environments including secondary broadleaf forest (recovering from hurricane damage), littoral swamp and mangrove. The reserve has a population of white-winged doves (*Zenaida asiatica*), reddish egrets (*Egretta rufescens*) and white ibis (*Eudocimus albus*). A range of mammals is found in the forest including the jaguar (*Panthera onca*).

Proposals have been made to give the reserve a more formal protection status, and the owners would like to expand to the south, although this would involve negotiating with the present land owners.

Other proposed conservation areas

Concerned individuals and organisations have in past years recommended expansion of the area under protection. These recommendations have most recently been summarized by Zisman (1989) and the TFAP (ODA, 1989). The Belize Center for Environmental Studies (BCES) is also summarizing the available data on possible sites (BCES, 1990, personal communication). The sites within the study area are summarized in Table 30.

A major proposal encompasses the Northern and Southern lagoons to the south-west of Belize City. The lagoons support a high population of Caribbean Manatee (*Trichechus manatus*) and are a breeding area for waterfowl. To the east of the Northern Lagoon, there are appreciable areas of mangrove which should be considered for inclusion within the area of protection.

Other proposals include the area where the Sibun River cuts through the karst of the Hummingbird Plain with Hills land system at Cedar Bank ; and the Baldy Beacon, Bald Hills and Hidden Valley for inclusion into the Mountain Pine Ridge Forest Reserve. These areas are on private land and transfer of title would involve compensation.

There are numerous areas of archaeological interest, in addition to Caracol. Some of the more important are indicated on Figure 35. Two of particular importance are the various ruins at Indian Church (Lamanai) covering 3000 years of various cultures including Mayan artifacts, a 17th century Spanish church and a 19th century sugar mill; and Colha located within Cobweb Swamp and about 3.5 km (2 mi) south of Freshwater Creek Forest Reserve. The site was formerly a manufacturing centre for Mayan stone tools. Both areas only receive minimum protection and proposals have been made for the zone of protection to be expanded. A detailed check list of archaeological sites within the country is given in Hartshorn *et al.* (1984).

There have been proposals for special conservation status within the boundaries of the existing forest reserves. In Chiquibul Forest the Raspaculo Branch of the Macal River has been suggested for part of a Nature Reserve which would also encompass the Upper Macal and part of the Pine Ridge between the river and the Brunton Trail (Hartshorn *et al.*, 1984). The area is particularly rich in bird life including the king vulture (*Sarcoramphus papa*) and the solitary eagle (*Harpyhaliaetus solitarius*). An earlier report (FAO, 1978) although recognizing the value of the area, could see no need for special classification. Currently, the

Table 30

Areas already proposed for protection

Name	Location	Description	Comments
Northern and Southern Lagoons	About 17 km (11 mi) SW of Belize City up to the northern limit of Northern Lagoon. Areas streteches 20 km (12 mi) to the Southern Lagoon. Total area up to 20,000 ha (50,000 ac)	Brackish lagoonal complex. Northern Lagoon already contains two small bird sanctuaries (Bird Cay and Unnamed mangrove cay). Area known for high population of the Caribbean Manatee – especially within Southern Lagoon. Morelets and American crocodiles also occur. Important breeding area for waterfowl. Dominant land systems: Belize Swamps, Toledo Saline Swamps and Puletan Plain	All or parts of these two lagoons have been recommended for protection by FAO, BAS (Munro, 1983), Hartshorn *et al.* (1984) and Zisman (1989). There is an extensive area of mangrove to the east of Northern Lagoon which should also be included
Sibun River karst	Lat 17° 22'N, long 88° 25'W to the south of the Sibun River. Between Gracey Rock and mile 33 on the Western Highway. Proposed area 4790 ha (11,840 ac).	Located on the edge of the project area in karst topography. Mostly secondary forest and low scrub but flat-bottomed basins within the low karst support better quality forest. Land system: Hummingbird Plain with Hills	Proposed for protection by Hartshorn *et al.* (1984). Area affected by limestone quarrying
Baldy Beacon	Within 1 km (0.6 mi) of the northern boundary of Mt. Pine Ridge. Lat 17° 00'N, long 88° 47'W. Proposed area 9700 ha (24,000 ac)	Area underlain by granite supporting a distinctive ecosystem of tough grasses. Unusual orchids believed to be in the area. Land system: Mountain Pine Plateau	Hartshorn *et al.* (1984) proposed inclusion within the Mt. Pine Ridge FR. Land presently privately owned but used as a firing range by the army – resulting in frequent fires (Figure 36).
Thousand Foot Falls (Hidden Valley Falls)	5 km (3 mi) to the north of present Mt Pine Ridge FR. Lat 17° 03' long 88° 50'W. Area required: about 4 ha (10 ac)	Falls are located at an altitude of 600 m in position of a geological fault. Longest falls in the country	Important tourist attractions on private land but access is allowed. If land became available, the boundary of the Mt. Pine Ridge could be extended to include Baldy Beacon and these falls. Recommended by FAO (1978) and Hartshorn *et al.* (1984)
Double Waterfall	Located close to Thousand Foot Falls. Area required about 8 ha (20 ac)	A separate double waterfall	

site is not under any special threat, but we recommend that the steeper land on both sides of the Macal River and the Raspaculo Branch should be regarded as protection forest.

In 1986 proposals were made for the setting aside of a large proportion of Chiquibul Forest Reserve as a biosphere reserve, linked to a similar reserve in Guatemala. There is a good case for expanding the Caracol site and providing special protection to the cave area, and delineating all land to the south of the Rio Ceibo and east of the Mountain Felling Blocks (longitude 88° 47'W approx) as full protection forest, which would include the upper Raspaculo Branch.

The Sibun Gorge in the Sibun Forest Reserve has been recognized to be of special interest, although it is still protected by difficult access. The Caves Branch of the Sibun River has numerous interesting cave formations. The upper part lies within the reserve, but gradual incursions into the reserve have put the area under threat, and recommendations have already been made for it to be included in an extension of the Blue Hole National Park (ODA, 1989).

Other proposals

Some 6660 km^2 (2570 mi^2) or 30% of the country lie already within reserves or conservation areas, the management of which is already stretching the capacity of the Forest Department. Further expansion of the area under protection must therefore be well considered. A gap analysis was carried out for the TFAP to determine which major vegetation types (using the classification of Wright *et al.* (1959)) were not represented within the reserves. The list would appear to be slightly inaccurate by listing too many types outside the reserves. Re-examining the list the main gaps appear to be :

(i) Broadleaf forest with occasional lime-loving species; evergreen seasonal forest;

(ii) Broadleaf forest with few lime-loving species; evergreen seasonal forest;

(iii) Transitional broadleaf forest rich in lime-loving species;

(iv) Transitional low broadleaf forest and shrubland rich in lime-loving species;

(v) Pine forest and orchard savanna with lime-loving species;

(vi) High swamp forest;

(vii) Palm forest;

(viii) Mangrove swamp;

(ix) Cohune palm.

Of these types, (iii), (iv), (v), (viii) and (ix) are in the project area. The first occurs in the area immediately north of Maskall between the old Northern Highway and Quashie Banner Creek and also to the west of Maskall. Type (iv) also occurs in the Maskall area to the south of the settlement and in the former Maskall Forest Reserve. Type (v): pine forest and orchard savanna also occurs in the Maskall area as well as on government land south of Freshwater Creek Forest Reserve near Honey Camp. A small reserve to the west of Maskall straddling the Northern River would conveniently cover all three forest types. There is still government land in this area and a suggested site is indicated on Map 2c.

In 1989, Regulation 52 under the existing Forestry Ordinance was passed to extend the powers of the Ministry with respect to the cutting of mangrove, which is now prohibited unless prior approval is obtained from the Forestry Department. Mangrove is not well represented in existing reserves, although there is a small area within the Shipstern Reserve. Proposals have been made by the Belize Center for Environmental Studies for a mangrove reserve in the Temash River in Toledo District. The area to the east and north-east of Northern Lagoon has an appreciable area of mangrove as well as herbaceous swamp. The proposed reservation of this lagoon should include the mangrove.

Cohune Palm is not represented in any of the Government forest reserves but it does occur within the proposed Rio Bravo Reserve.

Land use planning for forestry

The TFAP raised concern about the lack of land use planning and the excisions being made from the forest estate without appraisal of the consequences. The recent proposals for excisions from the north of Mountain Pine Ridge and the north-west corner of Sibun Forest reserves are relevant. Further zonation of the forest estate is needed so that rational decisions can be made on the long-term use of individual reserves. The boundaries of the forest reserves have been included on Map 2 and an approximate protection zone marked, to indicate those areas which, because of slope, water catchment role or special conservation value, should not be managed for production.

HUMAN RESOURCES

Population

The national population at March, 1990 was identified by the Central Statistical Office (CSO) as about 183,000, including for the first time, an estimate for unregistered migrants. This is an increase of 25.9% on the 1980 census total (which excluded unregistered persons) of 145,353.

Table 31 shows the distribution of the identified 1990 population as between districts, and between urban and rural areas. Aggregation of district statistics precludes assessing population in those parts of the Belize and Cayo districts which lie within the project area. However, an indication of village populations is given from Foster (1989) at Appendix 7.

The only parts of the project area which had experienced a net loss of population in the last 20 years were Blue Creek, which had sustained a net loss of some 400 emigrants to South America in the 1970s; and the farmlands fronting the Old Northern Highway which have reverted to wamil (see Current Land Use section) and for which the population decline during the 1980s has not yet been quantified. Over the last five years Silvester's Camp and Gallon Jug village in Orange Walk District, dismantled in 1965, have been re-established and now have an aggregate population of some 300 (C. Trehan, 1990, personal communication).

The joint population of Corozal and Orange Walk districts is 57,620, i.e. 31.5% of the national population. Their total rural population is 39,971 or 41.7% of the total rural population. Many of the urban residents in Corozal and Orange Walk towns (aggregate population 17,649) derive their income from farming, particularly from sugar cane.

Employment

In its 1989 Annual Report the Social Security Board reported the total number of registered insured persons as 68,324, of which 37,267 were presumed to be economically active. A total of 19,677 persons (52.8%) were reported as receiving earnings of less than BZ$110 per week. For Corozal and Orange Walk districts the aggregate number of insured persons was reported (Link, 1990) as 18,613, i.e. 27.2% of the national total, with the sugar industry accounting for 11,466 (i.e. 16.8% of the national total). The latest labour force survey (as supplied by the Central Statistical Office, 1984) identified levels of unemployment as indicated in Table 32. The nature of the many farming activities favours the recruitment of men.

The above statistics indicate a serious burden of female unemployment both for the project area and nationally, and the need to achieve considerable improvements in the utilization of this human resource, especially in Corozal rural areas. Probably the only means by which substantial changes to this pattern might be changed in agriculture would be through the creation of downstream

Table 31

Provisional 1990 population census

	Total
Country Total	183,076
Urban	87,285
Rural	95,791
Corozal	28,227
Corozal town	7,260
Rural	20,967
Orange Walk	29,393
Orange Walk town	10,389
Rural	19,004
Belize	55,907
Belize City	43,715
San Pedro	1,597
Rural	10,595
Cayo	35,194
Belmopan	3,355
San Ignacio/Santa Elena	7,989
Benque Viejo	3,558
Rural	20,292
Stann Creek	17,868
Dangriga	6,837
Rural	11,031
Toledo	16,487
Punta Gorda	2,585
Rural	13,902

Source: Central Statistical Office

Table 32

Unemployment in Corozal and Orange Walk districts, shown as percentage of total work force

	Male	Female
Corozal District		
Urban	2.4	11.1
Rural	3.5	37.2
Orange Walk District		
Urban	12.3	22.7
Rural	4.1	23.3
National		
Urban	10.2	22.8
Rural	3.0	26.9

processing and manufacturing, which by their nature can be less physically demanding than farming activities. We could not attribute female unemployment to any particular factor, but would recommend the commissioning of a study of its causes, especially in the rural areas of Corozal District.

The influx of a large number of both temporary and permanent migrant, Spanish-speaking persons into Belize during the 1970s and 1980s (Cutler Stone, 1989) has begun to have a detectable impact upon the national economy, and warrants special mention in relation to agricultural development within the project area. Bilingual Belizean children born to migrants since the 1970s are now entering the labour pool and are the medium for full assimilation of migrant families into Belizean society. Indeed most of the heritage of such children, especially where they have been through the national education system, is Belizean.

Within the project area, and most noteably within the sugar industry, many Belizean employers depend upon the authorized employment of migrant workers, not only for seasonal farm activities but also to some extent for routine farm operations. The work force of some Belizean farmers, especially in remote rural locations, entirely comprises migrant employees.

Approximately half of all sugar cane-harvesting workers are seasonal migrants (E. Zetina, 1990, personal communication). With an average cutting rate of 4 tons per man day, a harvesting work force of about 1800 men is needed over the six-month season, of whom 900 may be migrant workers. Quan (1989) identified August to October as a notably slack period in the sugar cane production cycle, with insignificant field labour (and haulage) requirements at this time, although nearly all of BSI's work force is permanently employed on a year-round basis (J. Montalvo, 1990, personal communication).

The current scope for employment of migrant women in agriculture in Northern Belize is limited, and any influx of female migrants into the Corozal District, in particular, is likely to exacerbate the high level of rural female unemployment indicated by the 1984 survey.

For 1987, the Labour Department granted 2753 temporary employment permits nationwide, including 2001 (72.7%) for agriculture. Corozal and Orange Walk districts received 905 (32.9%) permits, of which 809 were for agriculture. Nationally, the ratio of nationalities entering authorized temporary employment were: Guatemalan 45%; Salvadorean 17%; Honduran 13%; Mexican 10%; USA 8%; other 7%.

Migration

The employment of migrant workers has produced a two-tier wage structure within the rural economy. Newly arrived work seekers from neighbouring republics with agricultural wage inflation at lower levels than Belize, are willing to settle for emoluments unacceptable to Belizeans. To some extent, migrant worker acceptance of these terms is governed by the perception of the Belize dollar as being a hard currency.

In December 1989 a total of 4774 persons from El Salvador (71.3%), Guatemala (27.3%) and other origins (1.4%) had been registered in Belize as refugees (Pitts, 1990, personal communication); but these figures are estimated to constitute only one fifth of the total persons who have entered and remained in the country without submitting themselves to normal immigration formalities. The above ratios may not necessarily be indicative of the ratio of nationalities of unregistered migrants.

Some 75% of registered refugees in 1988 were recorded by Foster (1989) as resident in Cayo District with some 17% in the Corozal and Orange Walk districts, leaving just 8% located in other districts.

Within Orange Walk District, Foster identified concentrations of these communities in *inter alia* Yo Creek, Guinea Grass, August Pine Ridge, San Felipe, Indian Church, Trial Farm, Santa Marta, Fireburn, Honey Camp and Orange Walk town; in Belize District a mainly Salvadorean community has settled at Bomba. Data for the Corozal District were not available.

The land along the Hummingbird Highway in Cayo District is a notable focus of dispersed settlement, but the settlers are being encouraged, with assistance from the United Nations High Commission for Refugees, to relocate in the village of Las Flores and in a proposed 1000 acre (400 ha) settlement project known as Armenia (both sites are outside the project area). Both areas are being provided with a range of services, including a fresh water supply.

In a presentation to an international conference in 1989, the Government of Belize reported *inter alia*: "The predominantly rural location of refugees is appropriate for a national policy which emphasizes agricultural development in a country which is largely developmentally dependent on agriculture".

Availability of competitive migrant labour has been an indispensible component of several major agricultural expansion programmes throughout the country over the last decade. The maintenance of the pace of such development is likely to be assured, only if the policy to authorize employment of migrant persons is allowed to continue on the existing controlled basis.

Appendix 8 illustrates wage and salary levels encountered by the team in May, 1990.

Settlement

The economic and social impact of Mennonite settlement within the project area has been considerable. The Mennonite population within the project area amounts to some 3200, comprising the communities of Blue Creek (398; established 1959) (D. Dyck, 1990, personal communication), Shipyard (some 2000; established 1958) (G. Friesen, 1990, personal communication) and Little Belize (some 800; established 1979) (J. Elias, 1990, personal communication). These communities have established a sound record for relatively intensive utilization of the land resources that have been made available to them. Conversely, there are several large land holdings belonging to non-resident interests that have barely been developed in recent years, and in some instances were found to employ a skeleton staff only sufficient to maintain the integrity of the estate.

Most of the natural increase of the Mennonite population is now being accommodated by the rapid development of lands acquired by these communities since 1988, particularly in the vicinity of Indian Church and San Felipe (some 37,200 acres (15,100 ha)). The Shipyard community is developing 16,500 acres (6680 ha) and the Blue Creek community will develop up to 20,000 acres (8000 ha): the community of Little Belize continues to develop bush lands within its 28,000 acres (11,000 ha) property at the rate of some 1000 acres (400 ha) annually. The development of the new lands will therefore maintain the pace of farm development already observed.

The Mennonite farms are the nation's principal bread-basket, and their production system is orientated largely to the local market. The Belize Marketing Board should monitor these communities' plans for agricultural production, in order to ensure output intended for the local market does not surpass national self-sufficiency. The possibilities for actively encouraging these communities to produce for export markets should be investigated.

We anticipate that expansion of Mennonite agricultural production over the next decade will lead to a marked increase in wealth among these communities. Given their preference for cultural isolation, there is a risk that some of the Mennonites become regarded as a selfish elite. Efforts should therefore be made to incorporate them more into the nation's social, political and administrative framework.

Distribution of land holdings

Table 33 shows that while the majority of farmers in Corozal and Orange Walk districts had holdings of between 5 and 50 acres (2-20 ha), the largest area of land was held by those with more than 50 acres (20 ha). In Corozal, 63% of the farmers held 40% of the land in holdings of 5-50 acres (2-20 ha), 16% with holdings over 50 acres (20 ha) had 59% of the land. In Orange Walk, 59% of the holdings were in the 5-50 acres (2-20 ha) category, occupying 23% of the total land area; whereas 20% of the holdings were over 50 acre (20 ha) and accounted for 77% of the listed area. No data are available on any relationship between size of holdings and herd quality. Fragmentation of land holdings is not a serious factor in farm management. Nevertheless in Corozal, 7% of holdings have four or more parcels of land; 54% have two or three. In Orange Walk, the census recorded 46% of holdings with two or three parcels and 1.8% with four or

Table 33

Number and size of holdings in Corozal and Orange Walk districts

		Holdings with Land			
District	Characteristics	<5 ac	5-50 ac	>50 ac	Total
Corozal	Number	425	1,245	311	1,981
	% of total	21	63	16	
	Area (acre)	574	23,924	35,736	60,234
	Area (ha)	232	9,682	14,462	24,376
	% of total	1	40	59	
Orange Walk	Number	465	1,363	466	2,294
	% of total	20	59	20	
	Area (acre)	933	29,329	98,912	129,174
	Area (ha)	378	11,869	40,029	52,275
	% of total	1	23	77	

Source: Ministry of Agriculture, 1987

Note: It is not possible to disaggregate the figures for Cayo and Belize districts to obtain the data for those parts in the project area

more. Since many farmers live in villages and not on their main farming land, the control of praedial larceny and cattle rustling is difficult.

NATIONAL LANDS

Extensive tracts of land within the project area remain unalienated national lands, notably in the vicinity of the New River Lagoon in Orange Walk District and along the New Northern Highway in Belize District. The government has recently acquired and reserved 7200 ac (2900 ha) southeast of San Felipe which is intended for eventual incorporation into a settlement scheme, possibly administered by the Belize Land Development Authority. There is a further 6000 ac (2000 ha) of national land along its north-western boundary, making for an aggregate parcel of some 13,000 ac (5000 ha) available for future agricultural development or other dedicated uses.

Unlike other Central American countries, Belize does not have a large landless poor population; but as indicated in the Migration section above, a large number of refugees need to be settled. Selected national lands identified as being suitable for agriculture could be developed for this purpose. In this context, we have considered 13,000 acres (5000 ha) at San Felipe, described above. However, from our evaluation of the land systems within this block, as set out at Appendix 9, although 11,000 ac (4000 ha) of these lands have a grade 1 agricultural value (see Appendix 1), most of the land that is not yet cultivated is only grade 2.

LARGE PRIVATE ESTATES

Recent changes of ownership of some 400,000 ac (150,000 ha) of broadleaf forest in western Orange Walk District has attracted national and international attention, particularly from environmental conservation lobby groups.

Given the relative lack of population pressure in this sector, the large estate owners need not be hasty in devising a strategy for optimising the utilization of their properties. They have plenty of opportunity to co-ordinate their actions and, if appropriate, to agree upon a common course of action which might embrace the shared use of resources, e.g. capital-intensive facilities that are only justified when employed virtually continuously.

Owners of large estates located within more populous areas may be encouraged to make use of available human resources through development of suitable agricultural enterprises that are appropriate for the respective land systems. Where the agricultural value is identified as marginal or less, alternative commercial exploitation might be considered, e.g. tourism, where environmental features such as landscape, fauna and flora, favour this activity.

A number of land holdings of non-resident interests are being logged mostly by Belizeans under royalty agreements, which in one case incorporates undertakings to assist natural forest regeneration by planting mahogany seedlings under breaks in the canopy. This provides for the commercial exploitation of the forest on a sustainable basis.

LAND TAXATION

The existing system of land tax collection requires refinement to ensure that all potential tax payers are assessed. Tax payments on agricultural land, usually rated at 1% of the unimproved value and amounting to BZ$ 0.10-3.00/ac (BZ$ 0.25-7.5/ha) per year (depending upon land use potential and location), depend in many cases upon declaration by the holder of the holding size and its character to the Land Revenue Administrator. Land tax could probably be collected more efficiently by *inter alia* re-activating a 1972 plan (L. Belisle, 1990, personal communication) for the creation of a Land Adjudication Ordinance which would facilitate identification of land ownership.

Land tax ledgers are held at Belmopan for each district. Ledger records are currently maintained in a different manner from title records. Most title records are held at the General Registry, Belize City; new title registrations are now handled by the Lands Department in Belmopan, which is adopting a national grid recording system based upon the Universal Transverse Mercator projection.

Land taxation should be used to stimulate rational development of idle lands with a high agricultural value (see table accompanying Map 1). The existing taxation structure might conceivably be kept in its present form, but be supplemented by a penalty system for potentially productive lands for which no sustained productive use is planned by the holder and, which for all practical purposes, are held for speculation. At the same time, land tax relief on lands which have been identified as having a high conservation value (see table accompanying Map 1c and Appendix 1), and which the owners are willing to conserve, should be introduced. The land should be left undisturbed (i.e. for protection forest). Such a policy would be most appropriate to parts of Southern Cayo District. The land tax penalty and relief systems which we advocate might be targetted at non-resident land owners in the first instance.

INFRASTRUCTURE, TRANSPORT AND COMMUNICATIONS

In 1984, Hartshorn *et al.* considered one of the major constraints to agricultural development was lack of infrastructure, but it has improved appreciably within the project area since then, most notably in respect of investment infrastructure, road and bridge construction and electricity.

Investment infrastructure

Unlike the currencies of other Central American states, the Belize Dollar continues to maintain its value against the US Dollar.

In 1988, the World Bank recommended "the government should accelerate plans to establish a free zone .... on the border near Chetumal to make use of low-cost Mexican electricity". In April 1990, the passing of the Export Processing Zone Act provided for the establishment and operation of one or more such zones. The first approved zone is at San Andres in Corozal District. Subject to the merits of each case, export processing zones can be established at other locations.

Also in April 1990, the framework of development and fiscal incentives available to new, approved export-orientated enterprises was simplified and consolidated in the Fiscal Incentives Act. The listed incentives give approved ventures the opportunity to operate under conditions which, with the exception of documentation requirements, broadly match those of an export processing zone. In respect of vehicles, the Fiscal Incentives framework for import duty exemption is wider in scope than the respective free zone regulations. Conditions have consequently been established in the project area to encourage export-orientated investment in both natural resources and associated industrialization.

With financial backing from the United States Agency for International Development (USAID), the Belize Chamber of Commerce and Industry, established a new division in 1986: the Belize Export and Investment Promotion Unit (BEIPU), which employs *inter alia* two executives who can assist investigation and preparations for new agricultural and industrial investment. They also undertake market research and have organized technical studies, including one in ginger cultivation (G. Graham, 1990, personal communication). BEIPU has also developed expertise in guiding new investors through the investment regulatory system.

Electricity

The reliability of the Belize Electricity Board (BEB) power supply has increased markedly since 1984, due *inter alia* to the recruitment of four professional engineers (M. Polonieo, 1990, personal communication). Improved efficiencies and the decline in fuel prices enabled BEB to reduce its universal tariff on consumption in excess of 150 kWh/month from BZ$ 0.43 to BZ$ 0.41/kWh in 1986. Table 34 identifies installed capacity and current peak demand for BEB power supply systems in the project area.

BEB has contracted with Mexico for the low-cost supply of up to 2700 kW through a 34.5 kV line which now serves Santa Elena, Corozal Town and intermediate villages. Negotiations have begun to increase the contract supply to 5000 kW, which could supply Orange Walk town as well. BEB's average cost of supplying power throughout the country could thereby decline during the 1990s.

The possibility now exists for the San Andres free zone to offer electricity to respective export processors on a tariff or contract supply terms below the existing national tariff. Accordingly, the possibilities for establishment of energy-intensive agricultural processing industries at San Andres should be investigated.

During the cane harvesting season BSI's Tower Hill complex is self-sufficient in electricity from bagasse-fired steam turbine generation.

Table 34

Power supply systems

Station	Installed capacity (kW)	No of generator sets	Firm capacity (kW)	Peak demand (kW)
Belize City	11,720	4	13,842	11,350
Belmopan	2,074	4	2,794	2,445
Corozal*	1,440 (standby)	2	n.a.	1,150
Ladyville	5,892	2	13,842	11,350
Orange Walk	2,160	3	720	1,260
San Pedro	1,678	5	858	850
Sarteneja	165	2	75	38

Source: BEB

Note: * Supplied from Mexico

The Blue Creek Mennonite community operates a low-head hydroelectric plant on the Rio Bravo, developing 35 kW. Possibly the design of this facility could be copied for use elsewhere within the project area.

Fuels

Unlike neighbouring states, Belize has no shortage of firewood stocks. Within the project area firewood and lumber scrap are utilized both for cooking and in hot water/steam generation. Butane gas imported from Mexico and retailing at BZ$1/kg is also extensively used. The duty applied to the landed costs of fuels is indicated in Table 35.

Table 35

Duty applied to the landed cost of fuels

	Import duty BZ$/US gall	Stamp duty CIF	Revenue replacement duty/Imp gall
Diesel	0.2665	12%	0.60
Petrol (all grades)	0.4496	12%	1.29
Kerosene	Nil	Nil	0.05

Note: CIF = cost, insurance and freight

A schedule illustrating prevailing bulk and retail prices of petroleum products within the project area is presented at Table 36. A large number of farmers within the project area confirmed they normally purchase motor fuels from Chetumal in Mexico, paying the respective duty as they re-enter Belize. The sugar cane transportation cost structure seems to be based upon a general assumption that this practice can be perpetuated.

Table 36

Prices of petroleum products in BZ$, May 1990

Place	Kerosene	Diesel	Premium petrol (92 octane)	Regular petrol (87 octane)
Belize City	2.02	2.88	3.90	3.78
Orange Walk	1.9	2.97	3.99	3.87
Corozal		2.98	4.00	3.88
Blue Creek		2.99	4.01	3.89
Bulk* delivered				
Belize City	1.74-1.77	2.70	3.58-3.64	3.51-3.56
Orange Walk	1.80-1.84	2.76-2.77	3.68-3.73	3.60-3.63

Notes: Corozal delivery charge = 1-3 c/gal on top of Orange Walk prices
Service includes free provision of storage and pump at consumer's site

Telecommunications

The telephone network in Northern Belize extends beyond the towns to outlying communities, including Blue Creek, San Felipe, and Maskall which are provided with a community telephone. Facilities also exist for patching radio communications networks into the telephone system where it is manned by an operator. Radio telephones are installed in remote areas at an installation cost of BZ$ 24,000 (C. Slusher, 1990, personal communication). During the 1980s radio has become an important medium for communication in Belize. Some of the larger estates, as well as the Blue Creek community, use VHF radio.

The Offices of Telecommunications is responsible for radio licencing and channel assignment. It levies an annual licence fee, which is currently being reviewed, of BZ$ 75 for each base station and BZ$ 35 for each mobile unit. Radio can be used to co-ordinate dispersed agricultural operations, and could facilitate scheduling sugar-cane deliveries to the BSI factory.

Road system and road transportation

Further development of the public road system is determined largely by policy decisions related to agricultural expansion and diversification (P. Carillo, 1990, personal communication).

The Hummingbird Highway falls partly within the project area. When conceived in the 1950s, the road was not designed for the present volume of traffic; especially since the completion of the highway in the 1960s, cargoes formerly transported by coastal freighter could be hauled to and from Belize City by road. As a single-track road, sealed only with a thin tar cap, much of the highway quickly deteriorated under pressure from articulated bulk citrus transporters, for which it was not designed.

Two sections of the highway including several bridges, are being reconstructed with financial assistance from international agencies; but the rehabilitation of only some 30% of the entire highway is currently contemplated. Lack of good access to the Stann Creek citrus processors prevents further development of the citrus industry in areas north of Belmopan.

During the 1980s the government, with financial assistance from USAID, has given priority to the extension of public roads within the northern districts, including constructing an extensive network of feeder roads from the Rio Hondo Valley to the Northern Highway, and building all-weather two-lane roads connecting *inter alia* Sarteneja with Orange Walk through Chunox; and San Felipe with Cacabiche and Indian Church. The commissioning in 1989 of the construction of a bridge to replace the New River ferry at San Esteven, will improve road access from Little Belize, Chunox and Sarteneja to Corozal and Mexico.

In addition to the re-alignment of the Northern Highway between Sandhill and Carmelita in 1982, two other major all-weather roads have been built recently; one paid for by private interests from the Rio Bravo conservation area to Gallon Jug; the other built by Coca Cola's subsidiary, Refreshment Product Services Inc, linking the new San Felipe-Cacabiche public road with Hill Bank. The latter road provides access to large tracts of private and public lands to the west of New River Lagoon which had previously been practically inaccessible except by river navigation. The construction by the government of bridges to Rancho Dolores and Bermudan Landing have also provided an all-weather route to Belize City. Old logging roads on private estates between Hill Bank and Gallon Jug have also been re-instated.

Maps 1 and 2 show the main new roads for the project area (i.e. excluding the Belize Valley), as determined from the 1987 satellite imagery, 1988 aerial photography, and 1989/90 fieldwork. The maps show the most important roads for that part of the project area. Every new road in the dense road network of the main sugar-growing area has not been demarcated.

The rapid rate of land development near Indian Church, north of Hill Bank, and the on-going development of new citrus plantations in lands located some 10 mi (16 km) south-south-east of Hill Bank now provide a case for establishing a direct all-weather road link between Hillbank, and the Belmopan area, which would *inter alia* facilitate access to the citrus processors in Stann Creek District. The northern districts would thereby become far more accessible.

Road construction and maintenance costs are set out in Appendix 10. Road transportation of freight and equipment can be readily organized in Northern Belize with truckers. Illustrations of haulage costs for a range of cargoes are reproduced in Appendix 10. Trucks dedicated to sugar-cane haulage are apparently under-utilized from July until November. BABCO's programme for the commercialization of new crops could be designed for cropping patterns that make use of them.

Public transport fares (buses and taxis) are subject to price control and respective fares are reported in Appendix 10.

River navigation, port facilities and marine transportation

With the expansion of the road network, reliance upon water navigation for gaining access to remote villages is declining. In some areas, however, navigation is still the preferred mode of transportation, especially between communities living on the banks of the New River and New River Lagoon. Lumber is also taken by raft from New River Lagoon to a sawmill in Orange Walk. Sugar continues to be barged from Tower Hill to Belize City for bulk storage and cane syrup is barged from Libertad to ocean-going tankers.

Port charges (see Appendix 11) discriminate in favour of exports and imports. Illustrations of marine freight costs for shipment to listed destinations are also indicated in Appendix 11.

One of the shipping companies operates its own fleet of 50 reefer trailers within Belize and has installed ten plug-in electricity points for reefers in a purpose-built compound adjacent to the port.

When the direct road link between the Southern Highway and Belize City is completed, allowing easier access to Big Creek, it may be possible to contemplate the export of chilled or frozen product from the project area to Europe on banana vessels, which are due to commence sailings from Big Creek in 1990 (M. Mena, 1990, personal communication). The feasibility of such shipment has been confirmed by the shippers, and the journey time to Portsmouth, UK is estimated as 12 days (T. Stickney, 1990, personal communication), which will be about 9 days quicker than the current service from Belize City to the UK.

Air transportation

Some mechanized farming operations are most practicably carried out by air, notably rice seeding, fertilizing and spraying (J. Dyck, 1990, personal communication). Two aircraft in the project area provide this service.

Good road access along the Northern Highway to the International Airport at Ladyville allows air freighting of perishable produce from Corozal and Orange Walk abroad. Some experience of flying out perishable produce cultivated in other parts of the country has been gained, though (with the exception of cut flowers) not on a sustained basis. As yet there is no plan to establish chilled storage facilities at the International Airport, but should the need arise there may be scope for utilizing the facilities of Belize Meats Ltd which are nearby. Details of international carriers and air routes out of the International Airport, and illustrations of air freight rates, are listed in Appendix 12.

CURRENT LAND USE

Map 2 indicates the amount of land under cultivation. It is mainly based on 1987 Landsat TM imagery and 1988 aerial photography. The data will be put into the Belize Geographical Information System (GIS) compiled by the University of Edinburgh so that it can be compared *inter alia* with Map 1, to demonstrate the amount of land with development and conservation potential that is not already under cultivation. The GIS land use database can be continually updated from new satellite imagery.

Since the Ministry of Industry and Natural Resources is using SPOT imagery and the 1988 aerial photography to provide detailed land use mapping of the whole country, it was decided there was no point in duplicating this activity. However, since the ministry's mapping programme will inevitably take some time, there did seem to be some merit in producing maps now, indicating the current extent of cultivation, compared with the extent in 1969-72 as indicated by the aerial photography of that date, even if the maps will not be as accurate as those which will eventually be obtained from the ministry.

At the time of the assessment, the latest satellite image of Northern Belize was a 1987 Landsat TM image. A supervized classification, whereby a range of image reflectance values from known areas of cultivation were used to define the extent of cultivation over the whole image, was performed on the GEMS image processor at the University of Edinburgh. The classification output was then edited by comparison with the 1988 aerial photography, visual interpretation of the Landsat imagery and fieldwork during the 1990 season. It is estimated that the resultant classification accuracy is 90%. The area covered by Map 2d is not covered by the Landsat image. The land use information for this sheet was derived from the 1988 aerial photography and 1989 SPOT imagery for the area south of latitude 16°50 N.

The following land use categories were defined: abandoned, banana, beans, cacao, cashew, citrus, newly cleared land, coconut, coffee, cotton, maize, (maize or sorghum), mango, milpa, mixed farming, pasture, pineapple, plants, shrimp mariculture, sorghum, sugar-cane, urban. The plants category is for a couple of places along the Old Northern Highway which sell a variety of different plants. The urban category includes land not actually in cultivation, though it may be associated with agriculture, e.g. the offices of Hershey Estates. Areas demarcated as mixed farming include areas of mainly permanent agriculture which grow too great a variety of crops to distinguish separately. It also includes some areas where it was not clear from the remote sensing imagery which crops are grown.

A large part of Northern Belize which is mapped as being under sugar cane, really represents land mainly devoted to sugar-cane farming. It therefore includes maize fields and other crops grown mainly for local consumption. The boundary between land indicated as being under sugar cane and land under milpa subsistence cultivation (see Farming Systems section) is inevitably diffuse and varies from year to year. It was not clear from the remote sensing imagery whether some of the land with peripheral access to the processing factories, was growing sugar cane. Evidence was gathered mostly from field observation and local information.

Areas without any specific land use demarcation represent either 'natural vegetation', which albeit will almost certainly have been disturbed by man some time in the past, and could well be the product of ancient Mayan silviculture (Gomez-Pompa and Kaus, 1987), or wamil-forest regrowth after cultivation.

Coconuts used to be grown extensively along the Old Northern Highway. Most of them have now been smothered by wamil (Figure 38), which makes the demarcation of the extent of coconut cultivation on Map 2c difficult.

The area demarcated as 'maize and beans' on Map 2a is the Little Belize Mennonite community. Most of the areas demarcated as pasture on Map 2b represent Mennonite settlement, except for the ranch north of San Felipe. (Only the major land use is indicated on Map 2). Since the 1988 aerial photography, there has been considerable expansion of the area occupied by the Mennonite communities, and as indicated in the section on 'Settlement', new land is being acquired in the vicinity of Indian Church and San Felipe, which is not indicated on Map 2b.

There is also some post-1988 expansion of the land under sugar cane, particularly in western Corozal District; and expansion of citrus lands along the

Figure 38

Wamil smothering a coconut plantation along the Old Northern Highway

Hummingbird Highway. The poor soils along the New Northern Highway south of Orange Walk discourage settlement.

As indicated above, the land use extent of 1969-72 is taken from aerial photography of that date. North of latitude 17°40′ N, the aerial photography was flown in 1972. South of that latitude to latitude 16°45′ N, the aerial photography was flown in 1969, and south of 16°45′ N, it was flown in 1970.

Table 37 lists areas under cultivation in 1969-1972 and 1987-1988. The total area of land within the agricultural cycle is about 9% of the project area compared with about 6% in 1969-1972. If steep slopes are excluded, the percentage of land within the agricultural cycle in 1969-1972 and 1987-1988 becomes 8 and 12 respectively. If, in addition, all 'Pine Ridge' and swampy soils are excluded, the percentage of land within the agricultural cycle in 1969-1972 and 1987-1988 becomes 14 and 21 respectively. The areas with the densest cultivation are the sugar lands of the north, notably land systems ZZ, ZI, JI, OZ and OK, and the Cayo Floodplains land system. These include areas with the most agricultural potential. There has been significant expansion since 1988, but there is still some land with moderate to good agricultural value on the southern and eastern fringes of the sugar lands, particularly in the Xaibe Plain, and the upstream floodplains of the Caves Branch and Sibun River valley systems.

The most important crop is clearly sugar cane with 473 km^2 of land, (half the total area under cultivation) currently devoted mainly to sugar cane farming, compared with 380 km^2 in 1969-1972, representing an increase of 24% in fifteen years. The increase is probably greater because the 1969-1972 data area based on the extent of sugar cane cultivation as indicated by the 1:50,000 scale maps, which seem to have assimilated the odd forest grove within the mapped sugar cane land. Fieldwork indicated a continued expansion of land under sugar cane.

There are 191 km^2 of pasture – a fifth of the total land under cultivation. By adding in the farming systems which include pasture, maize and sorghum, the area becomes 306 km^2 – a third of the total land under cultivation, representing a five-fold increase over the 1969-1972 period, almost entirely due to expansion of land under Mennonite control, particularly in the north-west of Orange Walk District.

Table 37

Area of cultivation in 1969-1972 and 1987-1988

	Area (km^2)	
Land use	1969-72	1987-88
Sugar cane	380.4	473.2
Pasture	12.0	191.1
Pasture and sorghum	46.4	66.2
Pasture, maize and sorghum	–	49.0
Milpa	29.8	66.1
Coconut	126.3	37.9
Coconut and pineapple	–	9.8
Mixed farming	44.9	10.8
Maize and beans	–	19.7
Maize and sorghum	6.4	3.4
Citrus	0.7	7.4
Cashew	4.4	4.3
Cacao	4.5	5.2
Mango	0.4	0.5
Mango and coconuts	3.0	0.1
Cotton	–	2.8
Rice	–	1.9
Sugar cane and bananas	–	1.2
Others	–	2.3
Shrimp mariculture	–	1.3
Cleared land	8.3	1.4
TOTAL	667.5	955.6
Urban	7.3	11.6

Despite the adoption of sugar cane growing by milpeiros, milpa land which seems to be still outside the sugar cane-growing area, has grown from 46 km^2 in 1969-1972 to 66 km^2 in 1987-1988. This includes milpa cultivation within the Rio Bravo Conservation and Management Area, and milpeiro incursion from Guatemala in Southern Cayo (Maps 1b and 1d respectively).

Land under coconut has declined markedly both along the coast and the Old Northern Highway where the forest has been allowed to smother the coconut trees (Figure 38). The apparent decline in mixed farming is mostly due to the inability to distinguish specific crops on the 1969-1972 aerial photography. The maize and beans category represents the area under Mennonite cultivation at Little Belize. The area under cashew has remained about the same.

Of the other crops, citrus, cotton, rice and shrimps all indicate promising new crops, while the increase in urban land is largely due to the expansion of Belize City, with the concomitant loss of mangrove. Cacao production has only increased slightly, while much of the land on the Hummingbird Hershey Estate has been put under citrus.

FARMING SYSTEMS

Historical overview – commercial agriculture

SUGAR CANE

Until the mid-19th century, agriculture was an insignificant activity in Belize. At that time the population of the colony (approximately 15,000) was boosted by the arrival of some 10,000 refugees fleeing the Caste War in Yucatan, Mexico. The refugees were encouraged to settle in the north, where they practised slash-and-burn shifting cultivation, known in Belize as 'milpa' farming. They also established a new crop: sugar cane (Hartshorn *et al.*, 1984).

After peaking at some 2800 tons in 1880, sugar production declined, due to the opening up of the UK market to tariff-free sugar imports from the rest of

Europe. In 1935, six sugar mills remained, all in Corozal District, with a total output of 416 tons (423 tonnes) (BSI, data collected in 1989).

The construction of Belize's first central sugar-processing plant, in Corozal District was completed in 1937 at a cost of BZ$ 133,000, financed by private investors and a BZ$ 58,000 loan from the government. Until the 1950s this mill was handling cane from some 2000 ac (800 ha).

The devastation of Hurricane Janet in Corozal District in 1955 prompted legislation to assist in the organization of the cane farmers and the procurement of new capital from overseas for renovating the factory. In 1963 production reached nearly 28,000 tons. At the end of that year the shareholders in the company factory sold their interest to Tate and Lyle Ltd of the UK, which renamed the company Belize Sugar Industries Ltd (BSI).

In anticipation of being eligible for a 30,000 tons USA sugar quota, the company expanded the factory to an annual capacity of 45,000 tons and embarked on the construction of a second factory at Tower Hill, Orange Walk, completed in 1967. In that year world sugar prices slumped, and the USA quota was set at just 10,000 tons, leaving the UK 20,500 tons quota as the only other profitable sugar market. The industry agreed to limit annual production to 60,000 tons.

Over the next three years BSI's financial position deteriorated seriously and in 1972 the company sold most of its cane lands to some 220 cane farmers and redundant field employees, giving them 8 years to pay. World sugar prices then increased rapidly and BSI had record returns in 1974 and 1975. The European Community (EC) quota climbed to 40,000 tons and the USA suspended its quota system. Tables 38, 39 and 40 give the breakdown of quotas and sales by destination for the last 17-20 years.

The buoyant sugar market, underpinned by the USA and EC, led to a two-stage expansion of the Tower Hill factory to a capacity of 75,000 tons in 1980. The cycle of the 1960s and 1970s was then repeated: by 1985 when BSI's installed capacity had risen to 120,000 tons, the world price fell to 3 US cents/lb (6.6 cents/kg), and although the EC quota was maintained, Belize's effective USA market was slashed to 18,000 tons. BSI opted to close the Corozal factory, and

Table 38

Sugar exports 1973-1990

	Negotiated price quota		Free quota (Canada)		USA quota		EEC		World	
	t	US$ 000	t	US$ 000	t	US$ 000	t	US$ 000	t	US$ 000
1973	20,829	2,282	12,193	1,692	42,317	6,340	–	–	–	–
1974	20,829	4,860	12,802	11,094	51,500	17,820	–	–	–	–
1975	–	–	–	–	40,926	19,354	38,020	18,859	–	–
1976	–	–	–	–	12,736	4,181	43,863	13,441	–	–
1977	–	–	–	–	39,345	9,078	47,069	16,827	–	–
1978	–	–	–	–	67,432	15,667	41,891	17,328	–	–
1979	–	–	–	–	51,248	13,046	41,620	17,961	–	–
1980	–	–	–	–	62,860	33,230	35,814	16,023	–	–
1981	–	–	–	–	49,683	27,778	42,192	15,558	–	–
1982	–	–	–	–	38,807	14,427	41,660	15,728	19,254	3,214
1983	–	–	–	–	27,412	12,584	43,100	15,567	40,350	7,389
1984	–	–	–	–	28,653	13,332	43,685	14,480	24,772	4,728
1985	–	–	–	–	12,243	5,317	42,813	13,668	41,810	4,514
1986	–	–	–	–	16,460	6,432	41,880	18,882	35,783	4,956
1987	–	–	–	–	8,738	3,827	41,805	23,301	30,220	4,629
1988	–	–	–	–	9,500	2,692	42,992	24,287	23,496	4,853
1989	–	–	–	–	16,167	7,283	44,048	22,902	24,802	6,890
1990	–	–	–	–	16,399	7,514	42,598	22,905	35,194	10,694

Source: BSI

Table 39

Domestic sugar consumption

	Plantation			Industrial use
	White	Brown	Total	
1970	3434	821	4255	n.a.
1971	2013	977	2990	n.a.
1972	2488	968	3456	n.a.
1973	2991	946	3937	n.a.
1974	2891	1265	4156	n.a.
1975	4004	1014	5018	244
1976	3392	1456	4848	703
1977	4406	1043	5449	890
1978	5029	912	5941	1000
1979	5627	861	6488	931
1980	5864	834	6698	614
1981	6083	1289	7372	1093
1982	4620	1242	5862	478
1983	5071	922	5993	868
1984	5245	875	6120	437
1985	5184	882	6066	412
1986	4874	913	5787	303
1987	5530	914	6444	Not known*
1988	5925	1045	6970	Not known*
1989	5983	1111	7094	Not known*
1990	6308	1252	7560	Not known*

Source: BSI

Note: * No longer a two-price system for domestic and industrial

Table 40

Belize Sugar Industries cane prices (BZ$) as of 14 May 1990 by district

Year	Corozal (per ton)	Orange Walk (per ton)
1972	18.13	17.12
1973	18.73	17.43
1974	47.03	45.08
1975	65.03	59.39
1976	40.12	38.84
1977	38.07	32.21
1978	40.80	34.76
1979	44.02	38.77
1980	63.25	62.46
1981	57.79	54.27
1982	37.67	37.10
1983	38.65	37.81
1984	40.85	39.14
1985	32.30	31.55
1986	41.55	39.11
1987	51.14	47.95
1988	55.62	51.25
1989	55.54	51.40
1990	55.66	54.43

Source: BSI

under a financial restructuring programme, Tate and Lyle agreed to dispose of 90% of its interest in BSI, i.e. 81% to BSI employees, 6% to Government and 3% to DFC. Since 1986 BSI has operated profitably employing 530 permanent staff and some 100 seasonal workers. The USA sugar quota over the period from 1st January 1989 to 30th September 1990 was 27,010 tons.

In 1987 as part of its programme to develop the production of ethanol from sugar-cane for the USA market, the National Oil Company of Jamaica, Petronol Ltd, agreed to purchase BSI's Corozal factory and 4000 ac (1600 ha) San Pablo lands for US$ 3.7m. Petrojam (Belize), a subsidiary of Petronol, has since acquired a further 900 ac (360 ha) of land from farmers. In 1989, following the conversion of the factory for production of high test sugar syrup (for export to Jamaica), Petrojam processed 57,000 tons of cane. In 1990, they processed 112,000 tons of farmers' sugar cane.

For 1989/90 a throughput of 120,000 tons was targeted and the long-term plan is to achieve a steady throughput of 450,000 tons, of which some 270,000 is expected to be bought in from farmers, leaving the balance to be supplied from the cane lands now being developed by Petrojam at San Pablo and elsewhere, and which are planned to extend to 6000 ac (2400 ha) (F. Marshall, 1990, personal communication). To satisfy Petrojam's requirements some 4000 ac (1600 ha) of farmers' cane lands need to be rehabilitated to make them more productive. The sugar-cane industry will remain the backbone of the economy in the northern districts for at least the next ten years.

COCONUTS

Goodban (1952) referred to the coconut industry as the longest established agricultural export industry in the country. In Northern Belize, it was established on the cays and in the coastal areas. The export trade was mainly concerned with whole nuts for the American confectionary market and at its peak averaged 6 m nuts per year. Hurricanes in 1942 and, particularly, in 1961 caused serious damage and the industry went into decline: the present situation is considered later in the section on Crops.

PINEAPPLES

Wright *et al.* (1959) described the emergence of a successful, small-scale pineapple enterprise for canning in Corozal District, which continued for three years until the cannery operations in Stann Creek District were suspended.

TEMPERATE VEGETABLES

During the 1980s, a number of mainly foreign-owned, irrigated, winter vegetable farms were established within the project area at *inter alia* Sand Hill, Revenge and Orange Walk but, by 1989, the industry had collapsed. Research into a number of possible crops has been undertaken in recent years: the results are summarized below under Diversification.

BEEF CATTLE

Periodic consideration has been given through much of this century to the potential for the establishment of a beef cattle industry in Belize, specifically for Cayo and Orange Walk districts. From the early years of the century, there have been introductions of many breeds with the aim of improving the local Criollo (Creole) type cattle: the benefit from the introduction of bigger-boned Zebu animals is widely seen in Northern Belize. Nevertheless, the national herd remains small and seasonal fodder shortages, poor husbandry, low calving rates and the slaughter of undersized animals are common. The current position and possible ways to improve it are discussed in the Cattle subsection of the Livestock section.

BEES

Northern Belize is ideally suited to beekeeping and had been the major centre of the national industry until its recent devastation by the arrival of the Africanized bee. Possible approaches to the rehabilitation of the industry are discussed in the Bees subsection of the Livestock section.

SHRIMPS

Pond culture of shrimps has been introduced over the last decade and production techniques suitable for local conditions developed.

Current farming systems

The term farming system is used to refer to the whole farm business operation of a family or company: it covers all their crop and animal husbandry enterprises and their linkages, together with the inputs they employ, whether formal (credit, fertilizer, chemicals) or informal/traditional (the use of forest products or felling of primary or secondary forests for crop cultivation). There is a great diversity of enterprises and ranges of scale in the project area, but most lie within the following framework:

(i) Estates (>1000 ac,>400 ha)
- cattle, sugar, cacao, citrus

(ii) Family farm (<50 ac, <20 ha)
- sugar cane plus subsistence crops
- sugar cane plus subsistence crops and cattle
- cacao plus subsistence crops
- citrus plus subsistence crops

(iii) Mechanized family farm
- arable
- mixed farming (crops/livestock)

(iv) Milpa – traditional (subsistence farming)
- subsistence crops plus sugar cane
- subsistence crops plus part-time urban employment
- subsistence crops plus fishing.

(v) Shrimp farming

ESTATES

The principal activities of the estates are the production of the crops listed either solely or together with other enterprises. The individual enterprises are discussed in the Crops section; with few exceptions, estate land within the project area is underutilised.

MILPA

The historic milpa system consists of felling and burning high forest, and growing basic food crops for subsistence for one or two years before the land is left to recover under tumbledown fallow. It is only practised now in the remote parts of the project area (see Map 2) but many farmers resort to short periods (2-4 years) of tumbledown fallow. The increasingly limited area of land available for this aspect of the farming system is frequently commented on by the growers. In Orange Walk and Corozal districts, the principal component of most farming systems is the production of sugar-cane. A particular part of the holding is usually permanently set aside for this. It is not included in rotation with the other (mainly food) crops, which are produced on the balance of the land. The maintenance of soil fertility on these areas through the use of natural fallow is becoming increasingly inadequate and there is an urgent need to find alternatives. The work being undertaken in Corozal District on the use of such crops as velvet bean, jack bean, leucaena and other legumes (Post and Hamstra, 1989) has identified possible means of improving fertility and this work deserves expansion.

'Milpa' techniques are used for the production of the staple foods – maize on the better-drained areas, and rice on the low-lying land. Accurate data on the area cultivated and yields obtained are difficult to gather, but for 1989 the Department of Agriculture estimated the area cultivated to maize in Orange

Walk District was 2475 ac (1000 ha) and in Corozal, 1300 ac (525 ha). The area of rice was 225 ac (91 ha) and 20 ac (8 ha) respectively. The average yields were estimated to be 1200 lb/ac (1340 kg/ha) for maize and 1000 lb/ac (1120 kg/ha) for rice. A range of beans particularly red kidney, black and soya, may be planted in or following the maize.

Ground provisions are important subsistence crops, particularly for the small farmer with less than 50 ac (20 ha) . The major ones are yams (*Dioscorea* spp.), cocoyam (*Xanthasoma sagittifolium*) and sweet potato. They may be grown in the 'milpa' area or elsewhere. Plantains are similarly a widely grown food crop in spite of the incidence of black sigatoka disease and the spread of Moko disease. Bananas are also grown, but are less important than plantains: the 1984/85 Agricultural Census (Ministry of Agriculture, 1987) recorded 267 ac (108 ha) of plantains and 132 ac (53 ha) of bananas in Orange Walk; the respective figures for Corozal were 479 ac (194 ha) and 132 ac (53 ha).

FRUIT TREES

A wide range of fruit trees are grown throughout the project area, principally for home consumption: these include mango, citrus, craboo (crabboe), sapodilla, mammey apple, plums, guava, avocado and custard apple.

MENNONITES

Over the last thirty years, three Mennonite communities have been established – at Blue Creek and Shipyard in Orange Walk District and Little Belize in Corozal District. Farming is on a family basis, but inputs, infrastructure (roads) and marketing, are provided by the community. Crop production is more highly mechanized than elsewhere in Northern Belize. Each of the three communities has its own farming system. No commercial sugar cane is grown.

The Blue Creek community has 25,000 ac (10,000 ha) of which about half has been cleared and is farmed by 84 families. The cleared land is broadly divided into low-lying areas used for rice (431 ac (174 ha) producing 1800 lb/ac (2020 kg/ha); better-drained areas for sorghum with yields of 2000 lb/ac (2200 kg/ha); well-drained land for maize (1665 ac (674 ha) at 1470 lb/ac (1650 kg/ha)); and rolling or stony areas under permanent pasture.

There appears to be little land under permanent arable cultivation. Newly cleared 'bush' may be sown to two successive annual crops of maize or, in a few cases, maize followed by beans. In 1989 there were 135 ac (55 ha) giving an average yield of 456 lb/ac (511 kg/ha). There is then an invasion of grasses which cannot be controlled economically; the land is therefore put under pasture for three years. (The community have about 5000 head of cattle). Sorghum is extensively grown: after combining, the stover is grazed by cattle. Sorghum is fed to broilers: 0.5 m were raised in 1989. Pigs are also raised but mainly for home consumption (498 in 1989).

The community at Shipyard is larger than that at Blue Creek – 250 families. Some land has never been cultivated; other parts are only occasionally used. It is basically a subsistence community. For doctrinal reasons, the community use only steel-wheeled agricultural machinery; horses and buggies are used for transport. Sorghum is the main cereal grown. Earlier attempts to grow maize produced only poor crops over much of the area. Today, less than 400 ac (160 ha), sometimes followed by beans, are grown each year. Rice is grown in the poorly drained areas but yields are low (600 lb/ha (670 kg/ha)). Sorghum is sown in late November/December for harvest in March/April. The crop is usually fertilized with a compound (17:17:17; 18:46:0; 14:28:0) at 100 lb/ac (112 kg/ha). Pioneer varieties are used. There is little problem with pests and diseases. The current area of production is approximately 4000 ac (1600 ha) yielding up to 3000 lb/ac (3350 kg/ha). After harvest, the stover may be grazed. The land may be used again the following year or left fallow for 18 months. Much of the area with shallow soil lies under permanent pasture, all of which is naturally established. Most households have some cattle: the largest herd is about 600 head. Several families rear broilers but the scale is much smaller than at Blue Creek.

Other forms of income generation include one substantial saw mill and three smaller ones. There are also a number of furniture makers. To fulfil the demand for more land, 16,500 ac (6700 ha) have been bought north of Irish Creek.

At Little Belize, 200 Mennonite families farm 28,000 ac (11,300 ha) covering a range of soils and swamp lands: Pembroke, Bahia and Tintal soil suites. The main cropping system is maize followed by red kidney beans. About 4000 ac (1600 ha) were planted in 1989 and the intention is to increase this to 5000 ac (2000 ha) in 1990. The Little Belize farmers, like those at Shipyard, use only metal-wheeled implements. The seed of the maize variety grown, Pioneer 5800, was obtained in Guatemala and yields in the region of 2500-3000 lbs/ac (2800-3350 kg/ha). Army worm and grain weevil are the only notable pests. Following the maize harvest, the stover may be grazed or worked in by disc plough. Red kidney beans are sown in November/December (see Beans subsection of the Crops section). The maize-bean cropping pattern is usually fallowed annually. Fallowing is said to lead to lower yields, though the reason for this is not known. Previously, vegetables – tomato, cucumber, cabbage, radish, sweet peppers, okra, water melon, squash – were grown for the Orange Walk market (20 miles (32 km) away) but it quickly became oversupplied. Current production is therefore much reduced. One farmer sells 2000 broilers per week in Orange Walk and Corozal; otherwise livestock are largely limited to cattle and pigs for home use.

DIVERSIFICATION

In the mid 1980s, there was widespread concern over the future of the sugar industry (see earlier Historical Overview section): it appeared likely that international quotas would be reduced and prices would fall. A number of initiatives were therefore taken to identify alternative crops, either to diversify out of sugar or to complement its production and thus reduce dependency on it. While several possibilities existed for import substitution – oilseeds, onions, Irish potatoes, pig products – emphasis was given to crops suitable for export. For this, vertical integration from grower to packer/processor to eventual overseas market would be essential. In the event, the sugar quotas have not been reduced and in 1990 the price to growers has held at the attractive levels of the last three years (see Sugar subsection of the Crops Section). The interest of cane farmers in diversification has therefore dwindled. Nevertheless, the need to introduce alternatives to sugar cane remains, both in case the sugar market were to weaken permanently and to make use of land that became available as a result of intensification of sugar cane production methods leading to higher yields of sugar per unit area (see Sugar subsection of the Crops section).

Earlier attempts, starting in the 1960s, to diversify through the growing of winter vegetables for the USA market failed. While the USA vegetable market depends extensively upon imports, especially from Mexico, during the period mid-December to mid-April, the market windows for exports from Belize tend to be short and highly competitive. The situation was exacerbated by difficulties in the clash of labour needs with sugar-cane harvesting and from the poor marketing arrangements. In the mid-1980s, farmers were encouraged to plant annatto for the export trade. Several stands were fruiting well in 1990 but none was harvested because of the lack of a market. During 1989/90, BABCO prepared detailed input-output models for a number of the crops on which they had been working since 1985: a summary of the financial performance of these crops is presented in Table 41. In comparing their performance with sugar cane, the farmer would note that although most of these crops are more profitable on a per acre basis, they are higher risk, capital-intensive and have no ratoon value.

BABCO has identified and developed technological packages for a number of crops, some of which are considered potentially profitable: they are mango,

Table 41

Financial performance of various crops during 1985-90

Crop	Yield/cycle lb/ac	Yield/cycle kg/ha	Price (BZ$) /lb	Price (BZ$) /kg	Gross sales (BZ$) /ac	Gross sales (BZ$) /ha	Production+shipment cost (BZ$) /ac	Production+shipment cost (BZ$) /ha	Gross margin (% of costs)
Onion	10,000	11,000	0.50	1.10	5,000(BZ)*	12,000	2,740.28	6,771.51	82
Hot pepper	6,000	7,000	1.65	3.64	9,900(US)*	24,000	6,550.29	16,186.40	51
Papaya	40,000	45,000	1.50	3.31	60,000(US)*	148,000	43,295.03	106,986.34	39
Bell pepper	20,000	22,000	1.12	2.47	22,400(US)*	55,400	13,900	34,300	61
Soya bean	1,700	1,900	0.33	0.73	561(BZ)*	1,390	409.35	1,011.50	37
Sesame	700	800	0.55	1.21	385(BZ)*	951	326.58	807.01	18
Sweetcorn	UNECONOMIC								
Zucchini	30,000	34,000	0.90	1.98	27,000(US)*	67,000	18,298.70	45,217.70	48
Snap beans	9,990	11,200	0.94	2.07	9,390.6(US)*	23,205	7,288.46	18,010.40	29
Cucumber	33,000	37,000	0.55	1.21	18,000(US)*	44,000	15,205.64	37,574.66	18

Source: BABCO **Note**: * Market indicated

pineapple, passion fruit, carambola, papaya, onion and soyabean. They have started producing papaya commercially for export. There has also been an increase in the production of red kidney beans for export. The 1990 position of each of these is considered in the section on Crops, but a number of cautionary points on diversification need to be made:

(i) At the present time sugar cane remains the basic crop for most farmers in Northern Belize, except the Mennonites: it is well-suited to local conditions and farmers are very familiar with it.

(ii) Organizing strict harvest regimes and quality standards of produce among groups of farmers presents formidable problems, as is shown by the continuing difficulties in scheduling deliveries of sugar cane to Tower Hill factory.

(iii) Tree crops (mango, carambola) have a period of several years of immaturity before the grower receives any return. Shorter-term crops – papaya, onions – usually require high inputs and irrigation. Many cane farmers are believed to be still in debt from earlier years and have difficulty obtaining finance. Before committing himself to further indebtedness, the farmer would want to assure himself of the realistic possibility of producing an economic yield for which there was an assured market.

(iv) The individual household would have to commit a sizeable proportion of the farm family labour to the new enterprise, if export standards are to be met and a significant addition to the family income gained. For soya beans, it is expected that participants will have to commit 30-50 ac (12-20 ha) to have a viable operation. For Northern Belize, this would probably have to be planted in the main season.

(v) It has been noted above that there is now little traditional milpa agriculture in the project area, and there is increasing concern over the problems encountered in producing the staple cereal crops. Although few farmers have tractors, they can be hired, but there is little experience of mechanized arable cropping outside the Mennonite communities. Use of machinery and labour needs to be better organized. Land cultivation on some of the fine-textured soils is very difficult and can be undertaken only when the moisture content of the soil is at a particular level. Such soils are suitable for sugar cane or pastures; if they are used for arable crops, the farmer must have a tractor available at short notice.

Fortunately, the current health of the sugar industry means these problems in diversification (and increased cereal production) can be addressed within a realistic time frame.

INSTITUTIONS IN AGRICULTURAL DEVELOPMENT

Regulation of production

VETERINARY AND PHYTOSANITARY STANDARDS

Under the direction of the Principal Veterinary Officer, the Ministry of Agriculture employs four field veterinarians, including one based in Orange Walk town, to serve the northern districts. There is also a private veterinarian in Corozal town. There is a Central Veterinary Laboratory in Belize City which undertakes clinical diagnostic analyses of blood and tissue samples, but it is not yet staffed to carry out residue testing in meat for export. Personnel are currently undergoing training abroad. Residue testing in the past has been carried out in laboratories in Costa Rica and Honduras at a cost of US$10 – US$55 for each of the seven analyses necessary for each herd batch.

Cattlemen seem generally satisfied with government veterinary services, but owing to shortages of transportation, veterinarians frequently had to be collected to provide services on farms. Procedures for the isolation of herds infected with notifiable diseases such as blackleg appear to be effective.

Importation of cattle, frozen embryos, and artificial semen requires a licence, and is strictly controlled to minimize risk of introduction of new diseases. On live cattle imports, a 30-day quarantine period is applied rigorously, but the ministry is flexible as to the siting of temporary quarantine stations provided no herds are on adjacent lands. There is a national screw-worm control programme.

While the veterinary service is organized regionally, phytosanitary support services are provided on a case-by-case basis by Ministry of Agriculture technicians from Central Farm, 130 miles (209 km) from Orange Walk. Part of the failure of the winter vegetable industry was attributed to the inability of farmers to diagnose and control pests and diseases rapidly enough. Ideally, they would have been supported by pest and diseases specialists resident in the area, or by Central Farm technicians who could be rapidly deployed.

Trapping of Mediterranean fruit flies (Medfly) in other parts of the country has on several occasions led to United States Department of Agriculture (USDA) embargoes on exports. For USDA purposes the project area is currently declared Medfly-free. Within the project area a trained ministry inspector supervizes all papaya packing to screen for insects.

The importation of seeds and plant materials is regulated by the Ministry of Agriculture, which has an established procedure for disinfection and phytosanitary inspection.

PRICE CONTROL

Table 42 shows the price controls imposed on staple items. Most red kidney beans are exported. In 1990 exporters in Belize City paid BZ$ 1.00-BZ$ 1.20/lb (BZ$ 2.20-BZ$ 2.60/kg), delivered Belize City. By May 1990 virtually all of Belize's 1989/90 red kidney bean crop had been exported (C. Soza, 1990, personal communication).

The Belize Marketing Board (BMB) is the exclusive importer of rice but from November 1990, it is due to give up this exclusivity and will instead monitor market prices (publishing a quarterly bulletin), and seek to ensure price and supply stabilization. Maize is marketed freely.

BMB is the sole distributor of condensed milk, which is imported on tender to BMB. The current retail price of BZ$ 0.98 per tin is subsidized by government to the extent of BZ$ 0.47 per tin, causing unofficial trade with Mexico. Notwithstanding the tradition of condensed milk consumption, we question the need to allow the subsidy to continue, especially as it reduces the competitiveness of domestically produced fresh milk.

Table 42

Price control on staple items

Product	Wholesale BZ$/lb	Wholesale BZ$/kg	Retail BZ$/lb	Retail BZ$/kg
Domestic red kidney beans	1.05	2.31	1.15	2.53
Imported red kidney beans	% based		1.20	2.64
Domestic milled rice – bulk	0.50?	1.10?	0.52	1.14
Domestic milled rice – labelled, packaged	0.75	1.65	0.85	1.87
Imported milled rice – bulk	0.60	1.32	0.64	1.41
Brown sugar			0.25	0.55
Plantation white sugar			0.33	0.73

The imposition of maximum retail prices for meat in 1970, paralleled by slaughter control measures, seriously depressed producer confidence.

IMPORTS CONTROL

The Ministry of Trade and Commerce is responsible for licencing the importation of *inter alia* commodities which supplement domestic production, e.g. red kidney beans, rice and meats (notably pork for curing) (J. McKesey, 1990, personal communication). The list of products subject to import licencing is presented at Appendix 14.

EXPORTS CONTROL

The following products are subject to export licencing:

Live animals (excluding pets)
Fish, crustaceans and molluscs (excluding aquaculture species)
Logs and lumber
Sugar
Citrus fruits
Beans

In 1988 all export licences for red kidney beans were granted to one individual, but as he could not fulfil his contracts, other exporters were eventually granted licences.

Research and Extension

OFFICIAL INSTITUTIONS

The Ministry of Agriculture undertakes crop trials at Central Farm and in the past it has carried out a number of regional experiments with assistance from external agencies, especially for pasture development. Central Farm is well regarded for its production of high grade bulls and pigs which are sold to breeders. Pigs are also produced for breeding purposes at the ministry's Yo Creek station in the project area.

The Belize College of Agriculture is integrated with Central Farm. It offers a two-year syllabus leading to a diploma. There are approximately 25 graduates each year, most of whom take employment in the ministry, non-governmental organizations or education (48%), and agriculture or agro-industry (26%) (R. Barrett, 1990, personal communication). A full breakdown of graduate placements is presented at Appendix 15.

Since 1984 the ministry has been more able to undertake research in livestock development and pasture improvement as a result of co-operative agreements with the United States Agency for International Development (USAID). The research is undertaken both at Central Farm and at selected satellite locations mainly in the project area. USAID has also been assisting the improvement of the ministry's institutional and technical capability.

The Caribbean Agricultural Research and Development Institute (CARDI) in Belmopan is the most important national centre for the trial of new crops. Recent trials have concentrated on new maize, peanut, red kidney bean, rice, soya, sorghum and sesame varieties.

Research in livestock and grain crops generally meets the requirements of the project area. The research and development of other farm enterprises (excluding sugar cane) is usually left to the initiative of either the farmers themselves or the Belize Agri-Business Company Ltd (BABCO).

Technical specialists, formerly employed in the ministry, have been recruited by a number of donor-funded projects, resulting in depletion of the ministry's technical resources. To some extent, these projects appear to have taken over ministerial responsibilities, which raises the question of whether the ministry will be able to fulfil some of these responsibilities when these projects have run their course.

A number of farmers interviewed during our fieldwork reported serious delays in receiving results of soil analyses from Central Farm; and remarked that the laboratory does not have a full trace-element testing facility. We therefore recommend that the current USAID-assisted programme to upgrade the facilities and personnel resources of the laboratory be given higher priority.

NON-GOVERNMENTAL ORGANIZATIONS

Belize has numerous non-governmental organizations (NGOs), many of which were initiated by external organizations. In particular, there is a great diversity of missionary organizations a large number of which provide training to small farmers, and offer subsidized medical care.

In the context of this report, the NGO of greatest significance is the Belize Agri-Business Company Ltd (BABCO) which commenced operations in 1985 and has concentrated on the research and development of a range of vegetable and fruit crops, with assistance from American technical and marketing experts. All BABCO's trials are taking place within the project area. Since 1986, BABCO has acquired experience in the cultivation of cucumbers, papaya, pineapples, onions, sweet peppers, soya, sesame, sweetcorn, zucchini squash, snap beans, dills, aubergines, passion fruit and cantaloupe melons and developed technological packages for cucumbers, papayas, onions, sweet peppers, zucchini squash and cantaloupe melons. It is also conducting trial plantings with carambola, lychees, avocado, rambutan, mangosteen , ginger and mangoes. Soya and sesame trials were conducted with the assistance of CARDI. A technological package was developed for soya.

Out of BABCO's initial budget of BZ$ 9.6m provided from USAID grant funds, BZ$2m remains available until June 1992. Further funding for research and development are being sought. (BABCO is contemplating extending its area of operation to Toledo District.) Its activities have been reviewed by Steele *et al.* (1988) and Hankins *et al.* (1990).

BABCO could continue to perform a valuable service in developing new crops, especially for the northern districts with its need to complement sugar-cane cultivation with other enterprises. Several years of research and development may be necessary for some crops, especially tree fruits, to determine their potential. BABCO should continue expanding the scale of its trial plots, so as to represent commercial cultivation conditions as nearly as possible.

There are potentially suitable areas for pineapple cultivation on the Xaibe and Lazaro plain land systems. BABCO should mount a semi-commercial trial for this crop in these locations, with the view to its possible industrialization.

BABCO's greatest potential lies in demonstration farming. In May 1990 BABCO was already investigating three possible orchard sites in Corozal District. BABCO should establish replicated long-term trials, budgeted for not less than 8 years.

Another NGO, the Belize Enterprise for Sustained Technology (BEST), financed by external donors, has given technical and marketing assistance to co-operatives in the project area during the 1980s. It is now concentrating its efforts in Toledo District.

Other NGOs active in the project area include Help for Progress, assisting development of a cattle co-operative venture at New River Lagoon, and the Belize Association for Rural Development. The Christian Reformed World Relief Committee is currently undertaking small-scale irrigated crop trials with farmers in Corozal District (T. Post, 1990, personal communication).

COMMERCIAL ORGANIZATIONS

BSI has been undertaking sugar-cane research and development for many years. New cane varieties have been introduced from the Barbados breeding station and further afield, for testing on *inter alia* BSI's Santa Cruz lands. In recent years there has been more emphasis on extension, in order to increase cane production and replace smut-susceptible varieties by resistant strains. BSI took soil samples from selected farms in 1990 for chemical analysis by Central Farm, so that BSI's field officers can provide farm-specific fertilizer recommendations. They will need to be able to recognize the soil types described in this report, aided by the land system boundaries which indicate which soil types are likely to occur in a particular area.

Financial Institutions

Belize's financial system is regulated by the Central Bank which set a minimum lending rate of 10% in August 1988. Prime Lending Rate has been 12% since January 1985. Previous to 1985 it was 14% (J. Rao, 1990, personal communication).

PARA-STATAL INSTITUTIONS

The Development Finance Corporation (DFC), established in 1972, is owned almost wholly by government. Its investment arm is the Development Finance Corporation Investment Company Limited. On 31 December 1989, DFC's total loan portfolio amounted to BZ$ 36.1m, of which agriculture and forestry constituted BZ$ 15.4m (42.7%) and agricultural processing a further BZ$ 0.7m.

Although DFC has been involved in a number of large-scale projects, it continues to be regarded as the only countrywide source of low-cost credit for the small farmer. As the official agency for rural credit, DFC has been obligated to take a more relaxed approach to loan security than commerical lenders; and has had to contend with project appraisal costs which are disproportionately high in relation to requested loan amounts. It has also had to work with slender margins of 3-4% on funds which it has lent out at fixed rates usually in the range of 10-12%.

During the 1980s DFC's record of principal recovery seriously declined. It is now being restructured and recapitalized, but continues to operate. The pace of loan approvals has declined from BZ$ 4.4m in 1988 to BZ$ 2.6m in 1989, of which agriculture accounted for BZ$ 0.8m (31%). In 1989, DFC approved loans for a total of 1118 beneficiaries, of whom 920 resided in the two northern districts and accounted for 30% of the amount approved. DFC therefore remains a very important source of credit within the project area. Its operations within the project area are handled by four field officers working from branches located in the towns of Corozal and Orange Walk.

There should be closer co-operation between the ministry's district offices and DFC to re-inforce the effectiveness of DFC's project monitoring, especially in respect of small farmers, who should receive some element of subsidy. Credit programmes should be designed not on the assumption of debt being partially forgiven, but on the basis of projects being properly implemented, which will necessitate a much greater level of supervision, so the respective subsidy element will need to be in the form of mobile staff resources both from the DFC and the ministry.

DFC is the main local intermediary for on-lending a primary allocation of World Bank credit funds (amounting to BZ$ 14.2m) to finance agricultural export crop production, this being the Bank's first venture into agriculture in Belize. DFC will start disbursing these funds in 1990. DFC terms to farmers may include a repayment period of up to 12 years with interest fixed at 12% (L. Belisle, 1990, personal communication).

DFC also has equity funding available for agro-industry provided by the European Investment Bank, and credit resources provided by several institutions including the Commonwealth Development Corporation, Canadian International Development Agency and USAID.

QUASI-COMMERCIAL INSTITUTIONS

The National Development Foundation of Belize Ltd (NDFB) is a non-profit, private volunteer organization based in Belize City which started advancing credit in April 1984 with the backing of a BZ$ 1.7m grant from USAID and loans and grants from other sources, including Belize's private sector. Its purpose is to undertake a co-ordinated programme of credit, business guidance and technical assistance to small and micro-enterprises, including the agriculture sector. The foundation employs seven field officers. As yet, its interest income is not sufficient to cover administration expenses.

Loans are made for terms of between one and five years and carry 12% interest, plus a 2% administration fee. There is heavy reliance upon character references in addition to project appraisal. Agriculture has accounted for 17% of the funds borrowed up to 30 April 1990 and a total of 383 borrowers (27% of the total of 1406). Total loans approved amounted to BZ$ 5.8m of which 20.6% were for borrowers in the Corozal and Orange Walk districts. Arrears of principal repayments were said to amount to 7% of the portfolio (M. Cuellar, 1990, personal communication). This record compares favourably with the performance of DFC, and indicates NDFB should be considered for appointment as an intermediary for the lending of a portion of the World Bank credit funds.

COMMERCIAL INSTITUTIONS

The banks currently accept only short-term deposits and, except for the on-lending of USAID funds, no loans are given on fixed interest rate terms. Interest rates on medium and long-term lending therefore fluctuate with market conditions.

Since 1987 the weighted average lending rate has held at about 14% and the weighted average interest rate spread (between deposits and loans) has widened from 6.5% to 8%. The average deposit yield is 6%, which is higher than the reported rate of consumer price inflation (Central Statistical Office, 1989). The cause of the widening of the interest rate spread should be identified.

On 31 December 1989 agriculture and forestry accounted for 14.6% (BZ$ 34.9m) of all bank lending (BZ$ 238.9m). In recent years lending for sugar and citrus enterprises has increased steadily to BZ$ 6.9m and BZ$ 7.6m respectively in February 1990; while lending for banana enterprises has risen dramatically from BZ$ 0.2m in 1986 to BZ$ 13.2m. During the 1980s the banks actively supported efforts within the project area to create a winter vegetable export industry.

Lending for cattle operations has declined by 60% to BZ$ 0.4m (February 1990) during the last four years, whereas agricultural lending as a whole has expanded by 179%. The decline in cattle lending is compatible with our other observations related to this farm enterprise (see Livestock section).

The banks seem willing to lend for agricultural production which has an established market, but they cannot be expected to finance experiments in diversification. Funding for these experiments must come from risk capital and grants.

CANE FARMERS' ASSOCIATION

The divisions of the Cane Farmers' Association in Corozal and Orange Walk have become important sources of credit to their members, and in recent years they have developed competitive bulk purchasing schemes for fertilizers, agro-chemicals and lubricants, financed by a loan from the Sugar Price Stabilization Fund (interest at 10%). The mark-up is 20% to cover administration (8%) and interest servicing (12%), with outstanding balances after October in each year incurring a further interest charge at 12%. Cash sales to members have a mark-up of only 8%. Annual turnover amounts to some BZ$ 1.1m (J. Villanueva, 1990, personal communication).

The two divisions are intermediaries for DFC in arranging cane planting and rehabilitation loans to small cane farmers. Since 1983 the Corozal Division has arranged a total of BZ$ 1.6m of such loans lent by DFC at 12% interest and on which the division is credited with a 1.5% commission, leaving DFC with net interest receipts of 10.5%. Loan servicing to DFC is direct through a deduction order from the farmer to BSI.

BELIZE SUGAR INDUSTRIES LTD

With the agreement of the Cane Farmers' Association, BSI has targeted the replanting of about 5000 acres (2000 ha), i.e. approximately one twelfth of all productive canelands, each year. At the beginning of each year it invites applications from farmers for assistance in replanting. BSI assistance takes the form of providing mechanical services on interest-free 2-6-month credit, encompassing land preparation activities and the supply of selected cane seed for up to 1200 acres (480 ha) of land in aggregate each year. The mechanical services may be from BSI direct, or through a BSI arrangement with third party contractors. The administration cost of this operation is borne by BSI.

CREDIT UNIONS

Of Belize's 25 active credit unions, with total assets of approximately BZ$ 40m, several are based in the project area. Loans advanced to members are usually for purchase of household goods, furnishing and for repairs. Interest is charged at 1% per month on the reducing balance. One credit union reported using bank overdraft facilities at 15-16% interest for 4-5 months after the cane harvest.

In the north of the project area a credit union reported agriculture constituting 3-4% of its portfolio in recent years, while another reported 13.5%, mainly for sugar cane, maize and beans cultivation. For small-scale producers the credit unions may be an important source of borrowing. The Mennonites also have their own credit union.

CONTRACT MECHANICAL AND EQUIVALENT LABOUR-INTENSIVE SERVICES

A number of mechanical services are available within the project area and illustrations of the range of costs of hiring these services (also equivalent labour-intensive services) are presented in Appendix 16. However, a number of farmers are requesting well-drilling equipment, indicating that the northern districts are not adequately serviced with this facility.

Part 3

Land suitability assessment

The choice of enterprise, cultivated crop or conservation consideration depends upon both physical and socio-economic factors. The underlying determinant and long-term viability is the physical feasibility. In the short-term, feasiblity depends more upon cost-benefit ratios.

PHYSICAL FEASIBILITY

In order to determine physical land suitabilities, land units with similar physical properties must be mapped. These land units have been described in the section on Land Unit Description. The project area has been evaluated in terms of suitability for a number of cropping systems and conservation potential for each land system subunit, as indicated in the table accompanying Map 1 and Appendix 1. The land suitability classification follows the system recommended by FAO (1976) which defines the suitability classes as:

Class S1 Highly suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
Class 2 Moderately suitable	Land having limitations which, in aggregate, are moderately severe for sustained application of a given use: the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land.
Class S3 Marginally suitable	Land having limitations which, in aggregate, are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
Class N1 Currently not suitable	Land having limitations which may be surmountable in time, but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
Class N2 Permanently not suitable	Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

The main limitation(s) (up to two) preventing the land unit from being more suitable is also indicated in the table accompanying Map 1c and Appendix 1. The limitation classification and code are taken from FAO (1983). Land suitabilities for individual soil substitutes are listed in Appendix 2.

SOCIO-ECONOMIC FEASIBILITY OF EXISTING AND ALTERNATIVE FARM ENTERPRISES

Enterprise selection criteria

A farmer will determine the feasibility of embarking on any enterprise by identifying the margin he will obtain from his direct outlay, including cash expenses and the incremental input of his own (and possibly his family's) time and effort. Where production is for subsistence (i.e. nothing is sold) the margin means absolute output; it is otherwise a purely financial measure.

When a possible alternative enterprise is contemplated, the margin should normally match or exceed that achieved from an existing enterprise without being accompanied by increased personal effort or increased risk. Substantial increase in risk and/or effort are only justified when margins are likely to be relatively high.

When a new enterprise is being considered for idle or forest land the prospective margin need not necessarily be as high as on existing enterprises of the farmer, but the prospective gains from this extra activity have to be reconciled with the incremental outlays of expenditure, time and effort beyond those already dedicated to existing farming operations.

Where land availability is limiting, and when the farmer can afford extra inputs of cash, time and effort beyond those already committed to the respective holding, he can contemplate not only the substitution of existing enterprises but also the more intensive use of land. To some extent, efforts to promote a winter vegetable industry in the 1980s were mistaken, since they assumed there would be a large number of farmers standing ready to apply the respective extra inputs of cash, time and effort.

Where an enterprise needs one or more mechanical operations, e.g. irrigation, the farmer needs to consider whether he can justify purchasing machinery for his own exclusive use, whether he can justify its purpose by hiring it also to his neighbours, or whether he should rely upon another source for providing the service to his farm. At the small-farmer level, divisibility of the use of an essential, but costly machine, often is not practicable. The cost of transferring a machine from one holding to another can heavily load its overall operating cost. As in the case of winter vegetable production, some intensive crops are technically feasible only when key mechanical operations such as irrigation and fungicide spraying are done at scheduled times. On a single large farm, this is a challenge; at the small-farmer level it is an exercise needing the greatest skills of co-ordination.

Land considerations

The farmer who has had the use of a parcel of cleared and stump-free land for many years may no longer consider the original cost of land development as an expense to be recovered out of production: for all practical purposes he will measure the viability of replacing one enterprise by another purely in terms of the direct cost and resultant direct benefits of the switch.

A farmer who is contemplating opening up new forest or wamil lands has also to consider obtaining a realistic return on his initial capital outlay, which may include the freehold cost and certainly will include land clearing expenses (net of any logging revenue), which can amount to BZ$ 150–BZ$ 600/ac (Appendix 16). When the feasibility of different farm enterprises is compared, the imputed cost of holding land depends upon the circumstances under which the land has been acquired and developed. Most farmers wish to consider the scope for substituting an existing enterprise, rather than developing an enterprise on unimproved land.

CROP AND LIVESTOCK ENTERPRISES

Crops

BEANS

Present position

Red kidney beans (*Phaseolus vulgaris*)

Several varieties of bean are commonly sown after the main season harvest of cereals: these include black and soya beans, but the red kidney bean is the most widespread, and preferred item of diet. It is grown on the milpa system with yields of 400-600 lb/ac (450-675 kg/ha). Crop failure is common because of the vagaries of weather and incidence of disease. Elsewhere it is semi-mechanized but faces similar problems.

The crop is gaining significance in Northern Belize. In 1989, the Department of Agriculture reported 1850 ac (750 ha) had been planted (in December 1988), of which 1440 ac (580 ha) were harvested for an average yield of 707 lb/ac (790 kg/ha). The 1989/90 area was estimated to be more than 1900 ac (770 ha). In Corozal District, some 400 ac (160 ha) of milpa-cultivated red kidney beans were harvested in 1989 at an estimated average yield of 600 lb/ac (670 kg/ha). At the Mennonite community of Little Belize, over 3000 ac (1200 ha) were harvested for a yield of 850 lb/ac (950 kg/ha). This community uses seed originally obtained from the USA and they have found from experience that the crop must be sown in November/December to avoid unacceptably low yields. Some 4000 ac (1600 ha) were sown in 1989 and it is planned to expand this to 5000 ac (2000 ha) for the 1990/91 season. The crop is fertilized with 75-150 lb/ac (85-170kg/ha) of NPK mixture 1:46:0. As elsewhere in Belize, wet weather during the growing season increases the incidence of disease, including web blight, early blight and a mosaic virus. Pests include leaf beetles and bugs. Sun-dried beans are sold for export: the current ex-farm price is BZ$ 1/lb (BZ$ 2.20/kg).

Soya bean (*Glycine max*)

The suitability of soya beans in farming systems has been tested by the Department of Agriculture and more recently by CARDI, but the current area grown in Northern Belize is still small (less than 100 ac (40 ha) in 1989/90). 40 ac (16 ha) were harvested in Corozal District in 1989 giving an average yield of 1200 lb/ac (1350 kg/ha). A non-governmental organization in Corozal is extending the growing of soya bean on a small-scale as a family nutrition crop, recommending sowing in either June or October-December: the variety PR.15-100.4.B.8. is presently recommended. The main objective of expanding the area cultivated from the national point of view, would be as an import substitute for stockfeed. The initial aim would be to produce some 1300 tons for feeding as full-fat dry roasted soya beans. To reach this quantity some 2000 ac (800 ha) producing 1500 lb/ac (1700 kg/ha) will be required. The crop has an assured market at a feed-mill at Spanish Lookout, Cayo District: the agreed buying price is BZ$ 0.33/lb (BZ$ 0.73/kg); some BZ$ 0.05/lb higher than the landed cost of equivalent imports (O. Reimer, 1990, personal communication).

In Orange Walk District, soya bean can be grown as an off-season crop but it is probably best grown both in Orange Walk and Corozal districts during the main season. Production would be mechanized and probably most suitable for medium and large farms. BABCO hopes to arrange for 600 ac (240 ha) to be planted in 1990, rising to 2000 ac (800 ha) by 1992. One of the keys to this will be the availability of a combine for the harvesting: several potential growers have declared they will not plant without an assurance of this facility. In June 1989, 5 ac (2 ha) of soya bean were sown in Little Belize and yielded 2000 lb/ac (2250 kg/ha). Further crops will probably not be grown in 1990 because the combine may not be available.

Development potential

The production of red kidney beans for export seems now to be established and expanding under the lead of the Little Belize community. For other individual farmers, without an established mechanized arable cropping system, the vagaries of rainfall and incidence of disease will continue to affect land cultivation more seriously. These problems may be eased if the current trials on the CIAT cross between the red kidney bean and the black bean are successful. The cost and return for mechanized red kidney bean production is indicated in Appendix 13.

Soya beans can be successfully grown in Northern Belize but production seems likely to be dominated by the larger mechanized farmers, for whom the present tentative marketing arrangements will require establishment to support substantial expansion.

CACAO (*Theobroma cacao*)

Present position

A commercial cacao estate was established on the Hummingbird Highway, Cayo District, in the 1950s: a number of 20-30-year-old cacao trees in the region are still bearing well. In recent years, the cacao industry of Belize has been centred on the Hummingbird Hershey estate in the same area. The estate expects to produce some 250,000 lbs (113,400 kg) of dried, fermented beans in 1990, which would be more than double the production in 1988.

The estate has planted a substantial range of imported F_1 hybrids although none has yet been identified as the most suitable for local conditions. A settlement scheme was established, under the shade of thinned forest, near the estate, in 1985. In the Hummingbird Highway area, pests and diseases are not a serious problem with well-maintained, disease-resistant hybrid cacao, although black pod *Phytophthora* sp. is present.

A small area of young, hybrid plants established under temporary shade, with irrigation, has been planted at Gallon Jug, which may be increased to a substantially larger area (900 ac (360 ha)). There is little cacao elsewhere in the project area: the 1989 annual reports of the Department of Agriculture in Orange Walk and Corozal record none.

Development potential

Ecologically and economically, cacao has limited potential in the project area. Successful cultivation of cacao requires a rainfall of 1500 – 2000 mm, preferably evenly distributed. Temperatures should be between 30 – 32°C mean maxima and 18 – 21°C mean minima (Wood, 1986). Under Belizian conditions, Corven *et al.* (1987) stated growth and flowering will be adversely affected if the temperature averages less than 16°C or, on the coldest days, the temperature falls below 10°C. Much of the project area is also in a higher latitude (16°30′ – 18°30′ N) than those where most of the world's production occurs (between 10°N and S: Purseglove (1968)).

The Hummingbird Hershey Estate guarantees to purchase all cacao beans of acceptable quality delivered to the estate: the price offered is linked to the world price and has therefore fallen over recent years. In 1990, the prices offered were BZ$ 0.48/lb (BZ$ 1.06/kg) for wet beans and BZ$ 1.25/lb (BZ$ 2.76/kg) for dried, fermented beans. (The ratio of wet to dried, fermented beans is approximately 4:1). This compares with BZ$ 1.70/lb (BZ$ 3.75/kg) for dried, fermented beans in 1987 (Corven *et al.*, 1987) and 1988 (King *et al.*, 1989). Thus, within the project area, new cacao growing is likely to be largely confined to the Hummingbird Highway area, where growers would have the option of using the low input system (Corven *et al.*, 1987) and of selling their wet beans to the Estate, if, at current prices, these methods seemed the most economic. If linked to a livestock enterprise, the pods could be fed to cattle (Juan *et al.*, 1983) or pigs (Montero and Juan, 1986) and thus gain a further return from the crop.

King *et al.*, (1989), noted that cacao under thinned forest would be more suitable on rolling land than citrus, because there would be less soil disturbance and potential erosion would be minimized.

CARAMBOLA (Averrhoa carambola)

Present position

Carambola (starfruit) was selected by BABCO as a potentially suitable crop for diversification. Several farmers' field trials have been laid down in Orange Walk and Corozal districts to test local acid fruit type seedlings top-grafted with sweet fruit type varieties – Cary from Hawaii and Atkins from Florida. Material from Thailand is under test at one site. Soil types for the trials range from the Puletan Suite to stony, red Xaibe. On the latter, lime-induced chlorosis was corrected with iron chelate. In general, early vegetative growth has been good. The Thai material bore after three years with some sweet and some acid fruit, reflecting the heterogeneity of the plants, and demonstrating the need to select carefully for the proposed product – fresh fruit or juice.

Development potential

It is too early yet to foresee the place of carambola in the diversification programme: several years' records of bearing and quality assessment will be required, but the crop does appear to grow on a range of soils in Northern Belize; and if potential markets for the fruit or juice are foreseen, the continuation of the trials will be fully justified.

CASHEW (*Anacardium occidentale*)

Present position

Throughout the project area, climatic and soil conditions well suited to cashew cultivation can be found and excellent specimens, often self-sown and receiving little attention, flower and fruit abundantly. Crooked Tree village in Belize District, is one of the main centres of cashew growing in the country. A number of families in the village are reported to earn in the region of BZ$ 6000/annum from the sale of roasted kernels in Belize City. In spite of such returns, much of the crop is left uncollected. Elsewhere in the project area, several attempts have been made to establish small plantations but none has yet been successful. One of 10 ac (4 ha) was planted ten years ago near August Pine Ridge (Orange Walk District) but growth has been stunted by periodic fires. A larger and more promising enterprise was started in 1988 near Backlanding (Figures 23 and 39).

In addition to the production of roasted kernels from the nuts, the cashew apple (swollen peduncle or hypocarp) is eaten raw or converted into wine, jam, jelly or juice; it is also eaten by stock. Yields of nuts vary greatly and data have never been systematically collected, but an earlier study estimated yields from a mature tree could be in the region of 30 – 60 lb (14 – 27 kg) per tree per year (Jenkin *et al.*, 1976). Coles (1986) considered a conservative estimate of annual yield of 22 lb (10 kg) per tree was reasonable. Thus yield and, from observations, kernel size appear to be satisfactory.

Development potential

Cashew has not been further developed in the past because of the economics of harvesting the nuts and the difficulty of processing them. With Belizean wage levels, it is doubtful whether estates would be economic: Jenkin *et al.* (1976) estimated labour requirements for harvesting was of the order of 100 – 150 man hours/ac/annum (250 – 370 /ha). The main harvest is in April/May, when many farmers are busy with other farming activities, and may continue until August/

Figure 39

Young cashew plantation near Backlanding

September. During wet weather, daily collections of the nuts from the ground will be necessary to produce high quality kernels. In 1990, raw cashew nuts-in-shell were produced by small-scale processors at around BZ$ 4.50/US gallon (BZ$ 1.20/litre), yielding 20% by volume of roasted nuts shelled.

Family enterprises such as those at Crooked Tree village should therefore be suppported. They would have good stands of well-bearing trees, thus reducing the nut collection time and all active members of the family could participate in the collection. Processing is difficult because the oil from the shell of the cashew nut is highly corrosive. NRI is currently testing a small-scale decorticating machine which can process 220 lb (100 kg) of cashew nuts per hour. Economic justification for using the machine would depend on the number of families involved and the potential annual harvest of trees available to them. If nuts are carefully dried, they can be stored without deterioration for months, so that processing can be over the year. Full working capacity of the machine could be ensured by buying additional nuts from elsewhere in Belize.

CITRUS

Citrus was discussed in detail in the land resource assessment of Stann Creek District (King *et al.*, 1989). The main citrus species grown is the orange, but grapefruit, limes and mandarin are also produced. In the last few years there has been a notable increase in the planting of citrus as a cash enterprise at various levels of activity, although there is very little grown in most of the project area, with the notable exception of the Cayo Floodplains. Most of the project area is at an uneconomic distance from the processing factories in Stann Creek District: the presumption must be that a new factory, possibly near San Ignacio, will be opened.

In the land resource assessment of Stann Creek District, King *et al.*, were concerned about the economics of growing citrus on Puletan soils, and the lack of fertilizer recommendations for specific soils. The same concern relates to Northern Belize. Other factors that might adversely affect yields are prolonged periods of drought and the incidence of temperatures below 13°C.

COCONUTS

Present position

Coconuts are found throughout the project area, growing either in small cocals or close to the house. The Agricultural Census 1984-85 (Ministry of Agriculture, 1987) recorded 49% of households in Corozal District and 36% in Orange Walk District had coconuts. There are no coconut estates. Production is solely for home use or for sale of nuts and oil on the local market. Most of the palms seem to be of the Tall variety, although some Tall x Dwarf hybrids have been planted. Palm weevils (*Rhyncophorus palmarum*) and the red ring nematode are serious pests. The District Agricultural Officer estimates 20% of the palms in Corozal District are affected by weevils. Scale insects may also cause yellowing of fronds on Ambergris Cay and the coconut mite has become a threat in recent years. Projecto International (1984) estimated yields at the national level at approximately 30 nuts/mature palm/annum. Coles (1986), referring to Corozal District, put the figure at 50 nuts/palm/annum. The selling price of nuts varies with the season but is usually BZ$ 20-25/100, with prices rising towards the end of the dry season. Coconut oil is produced along the Old Northern Highway for sale in Belize City: 60 (Tall) nuts are needed to produce one gallon (4.51) of oil, which sells for BZ$ 24 (H. Gordon, 1990, personal communication).

Development potential

Coconuts could reduce the country's dependence on imported vegetable oils and livestock feed, but past attempts have failed because it was not economically attractive to growers, a situation which remains. Similarly, export prices for fresh fruits to Europe or the USA are seemingly too low.

Lethal yellowing, which could appear in the next few years, is a potentially serious threat to coconuts in Northern Belize. It is already present in the Yucatan, Mexico. Central Farm is producing hybrids of Panama Tall x Malayan Dwarf, which are resistant to the disease and would be required in Northern Belize, if lethal yellowing were to reach there. Meanwhile, growers should be advised to use hybrid seedlings when replanting. They should also be planted among existing ornamental stands of coconut in tourist areas, particularly Ambergris Cay.

COFFEE (*Coffea* spp.)

Present position

Little coffee is grown in Northern Belize. The 1984-85 Agricultural Census (Ministry of Agriculture, 1987) records six holdings in Corozal District as having coffee but the area under the crop is noted as insignificant. For Orange Walk District, one holding of insignificant area was recorded. The Department of Agriculture Extension Officer (R. Gordon, 1990, personal communication) reported six acres (2.4 ha) of coffee had been planted in Maskall, Belize District at 8 feet by 10 feet (2.4×3.0m) on a brown sandy loam soil and "yielded 2000 – 3000 lb/a" (910 – 1360 kg/a). The enterprise was abandoned because no market was found for the product.

A robusta coffee (*C. canephora*) plantation has been started at Gallon Jug, using seed from Guatemala. An 18-month old stand growing under thinned forest looked healthy and stood 18-36 in (46-91 cm) tall (Figure 40). A very small area of arabica coffee (*C. arabica var. Bourbon*) is growing on a clearing of *Pinus caribaea* at an altitude of approximately 2000 ft (610 m) in the Mountain Pine Plateau and looks vigorous and healthy (Figure 41).

Development potential

Robusta coffee grows on a range of soils and is better able to tolerate adverse conditions and lower altitudes than arabica. Further small-scale trials are recommended as a possible import substitute. In trials, particular attention

Figure 40

18-month robusta coffee under thinned forest at Gallon Jug

Figure 41

Bourbon coffee (*C. arabica*) growing on the Mountain Pine Plateau

should be given to pruning, and care taken with processing. It would be interesting to record the productivity of the arabica coffee in the Mountain Pine Ridge.

COTTON (*Gossypium barbadense*)

Present position

In 1989, a company started growing Sea Island cotton (*Gossypium barbadense*), which can be sold at twice the price of other long-staple cotton (Averitts, 1990, personal communication), in Orange Walk District on the Memayal Indian Estate and Gonzales North, Yo Creek, (see Map 2a) (Figure 42). The former was cleared from eight-year old *wamil* (tumbledown fallow) and the latter was sited on former sugar-cane areas. The crop was sown between late October 1989 and mid-January 1990 over an area of 800 ac (320 ha). Standards of husbandry were high and, particularly on the Memayal area, there was an excellent stand on the 1989 sown areas. It would appear however that January is too late for sowing to achieve a good crop. The cotton was regularly sprayed with a biological insecticide and other insecticides have been applied when scouting has indicated the necessity; but there is evidence of boll weevil and some slight pest attack from leaf-eaters and stainers. Where considered appropriate, proprietary growth regulators, which can bring forward flowering by up to four weeks, were sprayed.

The target yield of 750 lb/ac (840 kg/ha) of lint should be achieved from most of the 1989 sowings. It is intended to gin the crop locally but no ginnery had been started by May 1990. The target area for sowing in 1990 was 2000 ac (810 ha), planted between August and December.

Development potential

Since the crop is at an early stage of development, there will be a degree of pest and disease escape. Environmentally, the conditions are suitable, standards of management are high, and provided there are no drainage problems during the wet season, most of the first crop showed promise of yielding well.

Figure 42

Sea Island cotton

GROUNDNUTS/PEANUTS (*Arachis hypogaea*)

Present position

In the early 1980s, CARDI screened some 300 – 400 cultivars of groundnuts with a view to selecting a suitable large nut form of confectionery groundnut. Trials at the BSI station recorded serious lime-induced chlorosis in calcareous soils, which was not corrected by twice weekly application of a solution of 1% ferrous sulphate at 150 l/ha (13.3 gal/ac). The trials were therefore abandoned.

CARDI estimated the domestic market for groundnuts was about 200 t/a and by 1983 the country as a whole had become self-sufficient. Nevertheless, the following problems were recorded (CARDI, 1989):

(i) A serious incidence of foliar diseases, exacerbated by high rainfall, use of unsuitable soils or repeated plantings on the same area;

(ii) Lime-induced chlorosis was common on calcereous soils;

(iii) There was a need to ensure that appropriate culvitars were selected for the intended use: roasted nuts, peanut butter or salted nuts;

(iv) High production costs.

Yields of 1650 lb/ac (1850 kg/ha) were achieved at Little Belize on an area of 3 ac (1.2 ha). In 1989, the total production for the whole country was 137 tons, of which 15 tons (11%) were provided by Orange Walk and Corozal districts.

Development potential

The domestic market for groundnut products is limited, and it seems likely that Belizean costs of production would be uncompetitive on the international market. Nevertheless, if a market were identified, production could be increased if care were taken in the selection of the cultivar and the site of production.

MAIZE (*Zea mays*)

Maize is grown principally as a main-season crop, but with a small crop during the off-season. The yields and the area planted appear to be fairly stable; about 6600 ac (2700 ha) were planted (over both seasons) in Orange Walk District in 1987-89. The production was 4500-4600 t (Garcia, 1989). In Corozal District, an estimated 3500 ac (1400 ha) of 'mechanized' maize was planted in 1989 and gave an average yield of 2500 lb/ac (2800 kg/ha) (Ramirez, 1990, personal communication). The cost and return of mechanized maize and sorghum production is shown in Appendix 13. The Department of Agriculture recommends the synthetic cultivars, Belgold 83 and VS550, with farmers bringing in new seed every three years: both are flint varieties with a large cob and seed, which yield and store better than local cultivars. Nevertheless, most farmers continue to use hybrid or local seed. Some white-seeded cultivars are grown for tortilla.

MANGO (*Mangifer indica*)

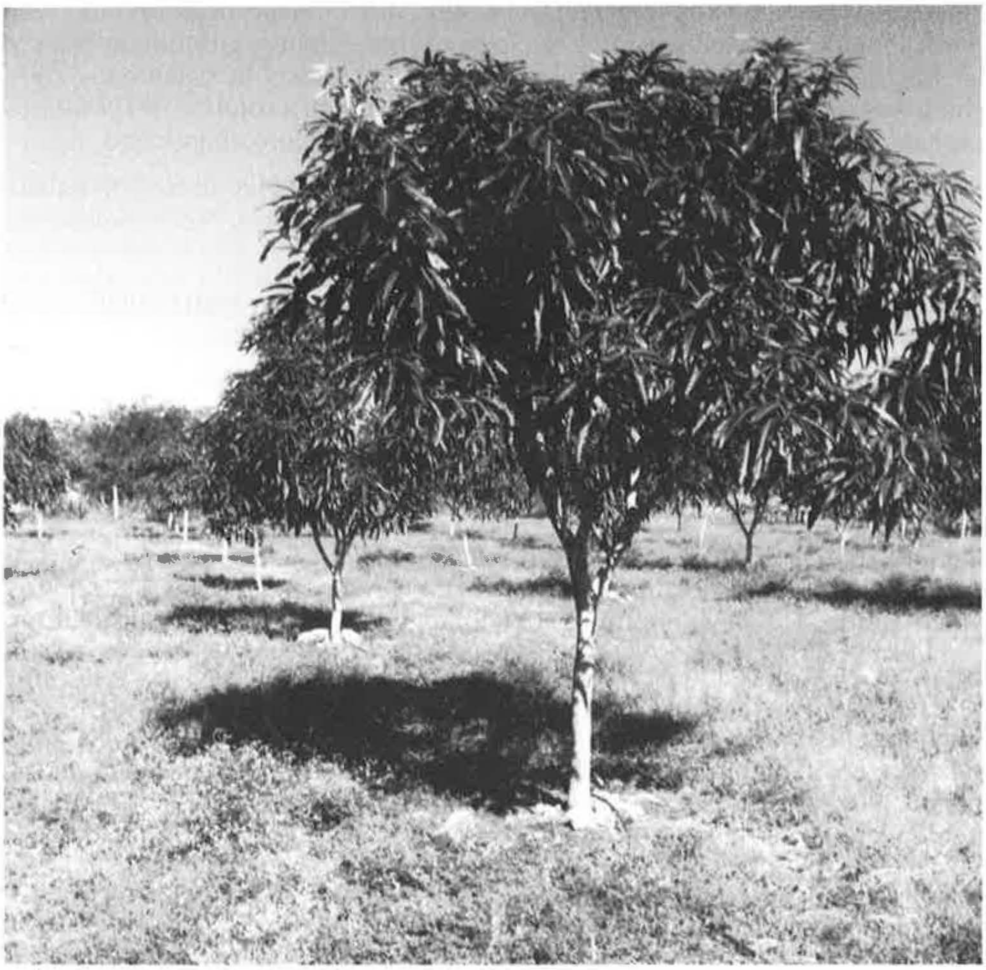
Present position

Well-grown specimens of mango trees can be seen throughout the project area. A range of cultivars is identified by growers: among those named are such well-known ones as Julie, Haden and Keith: also "Number 11", Hofius, Slipper, Mangoyanas, Cambodianas, Blue and Judge's Wig. The crop is so widely grown that there is very little local market for the fruit.

Mango is one of the crops identified for possible inclusion in a diversification programme. BABCO have put down a number of farmers' field trials, with the cultivars Keith, van Dyck and Tommy Atkins, with a view to assessing their suitability for fresh fruit export. A further five cultivars from Hawaii and Florida will also be tested. The interaction between cultivar and soil type should also be studied.

Figure 43

Grafted mango, Corozal



Seedling trees from Stann Creek District have been planted in one of the BABCO trials; but growth is noticeably uneven and it will be necessary to check that all trees have bred true. Elsewhere, grafted trees have grown well (Figure 43). It is intended to limit height to 10 – 12ft (3.0 – 3.7 m) by using pactobutrazol, and to induce flowering with potassium nitrate. Yields of 18 lgt/ac (45 t/ha) are anticipated.

Development potential

Mango grows well in Northern Belize; but it will be several years before the viability of the fresh fruit export market to the USA can be ascertained. The potential for mango puree for the European Community market should be considered. Some experience of frozen mango puree has already been gained by producers in Toledo District.

There may be a problem with controlling the Mexican and Mediterranean fruit flies within the limitations imposed by the quarantine regulations of the USA. The Ministry of Agriculture's eventual arrangements for a fruit export protocol with the USA will resolve this uncertainty.

ONIONS (*Allium cepa*)

Present position

It has been appreciated for a considerable time that the environmental conditions in Belize are suitable for the production of the national requirements of onions. Jenkin *et al.* (1976) recorded that it was official policy to continue investigational and extension programmes to this end. The importance of date of planting and the cultivar used, as well as the watering regime, has also been appreciated.

The Ministry of Agriculture recommends sowing in November for planting in beds in January, in order to minimize disease. In their trials in Orange Walk, small plots of Texstar, grown with trickle irrigation and harvested in May, gave yields equivalent to 10,000 – 17,000 lb/ac (11,000 – 19,000 kg/ha). In earlier trials in Corozal District, Yellow Bermuda yielded 9000 lb/ac (10,000 kg/ha) and New Mexico White Grano 9500 lb/ac (10,700 kg/ha). In Orange Walk District Red Tropicana yielded 10,000 lb/ac (11,000 kg/ha) (Bautista, 1987).

Under rainfed conditions, Red Creole, sown in September and planted in November, should yield about 6000 lb/ac (6700 kg/ha) in Northern Belize.

Over the last two years, BABCO has been experimenting with time of planting (November – March) and cultivars (25) on farmers' fields. The methods employed are intensive (BABCO, 1989) with trickle irrigation and regular applications of fungicide and insecticide. Field fertilization includes both major elements (N: 50 lb/ac (56 kg/ha); P_2O_5: 200 lb/ac (224 kg/ha); K_2O: 120 lb/ac (135 kg/ha)) and trace elements (Bo, Cu, Fe, Zn, Mn). As of April 1990 the most promising cultivars were Red Delight, Texstar and Special 38. Expected yields at farm level are 10,000 – 15,000 lb/ac (11,000 – 16,800 kg/ha). The most common disease in Northern Belize is purple blotch (*Alternaria* sp.): Texster can be particularly affected. In addition to the high standards of husbandry, particularly irrigation, that will be required, careful curing after harvest will be essential.

Development potential

It should be possible to make an increasing contribution to the demand for onions on the domestic market from locally grown produce.

PAPAYA (*Carica papaya*)

Present position

Individual trees or small stands of papaya, grown as a backyard crop, are common throughout the project area, and self-sown wild papaya is often seen on waste ground. In Chunox, Corozal District, there are several smallholdings (Figure 44) established to serve the local market. A number of cultivars are recognized on the basis of flesh colour and flavour and are referred to as Hawaiian, Solo, Mammey and White. Individual fruit size is often substantial: in excess of 10 lb (4.5 kg). Mites are reported to be the only serious pest; when identified they can be controlled by insecticidal sprays.

There have been several attempts over the years to produce papaya for export. In the 1960s, a Mennonite community in Orange Walk District produced substantial quantities, which were sold as dehydrated fruit to Canada; but the enterprise terminated in the early 1970s. In the 1980s, an estate on the Northern Highway bought in papaya (and pineapples) for export from 15 local farmers, until the company went into liquidation. Later, in Corozal District, three co-operatives were established to produce fresh papaya fruit for export, but the venture also failed, apparently due to both production and marketing deficiencies.

More recently, the hermaphrodite cultivar Solo has been produced for export to the USA. A vertically integrated operation has been started near Corozal, which had some 40 ac (16 ha) in bearing (variety: Sunrise) in April 1990, and planned to expand this to 100 ac (40 ha). The company has its own plant, where 8 – 12 individual fruits weighing 10 lbs (4.5 kg) in total, are packed into boxes (Figure 45).

The boxes are placed in a 40 ft (12 m) refrigerated container, which has a maximum load of 2700 boxes. Exports reached one container load per week and

Figure 44

Traditional papaya plantation

may have increased later in 1990. The container is trucked to Belize City for onward shipment to Florida. Earlier attempts at overland haulage through Mexico to MacAllen Texas, resulted in fruit damage, necessitating repacking (B. Hatfield, 1990, personal communication).

BABCO, who considers the export of Solo papaya as fresh fruit a promising enterprise for Northern Belize, have an area of 1 ac (0.4 ha) of their own, together with three farmers' field trials of 0.5 ac (0.2 ha) each. BABCO prepared the land on each site, installed a trickle irrigation system and supplied the seedlings. After planting, extension staff visit the growers regularly to advise on

Figure 45

Solo papaya packing plant near Corozal

Figure 46

Herbicidal spraying of Solo papaya near Corozal

fertilizer application, pest and disease control and other aspects of husbandry. The early vegetative growth of the trees has been good. One of the three co-operatives involved in the earlier failed venture has planted a new area of 3 ac (1.2 ha). The scheme is handicapped by shortage of funds for inputs and difficulties in undertaking the irrigation schedule.

Tentative recommendations can now be made on the various agronomic aspects of growing Solo papaya: variety, seedling selection, field spacing, weeding, fertilizing, pest and disease control and harvesting methods. The trees are coming into bearing at 9 – 10 months; at 24 months, the height of the trees makes spraying and harvesting difficult and it is intended to replant them at that time. Yields over this cropping cycle are estimated to be in the region of 40,000 lb/ac (45,000 kg/ha). Some aspects of production are still uncertain and cause for concern, including:

(i) Pests – mites, white flies and beetles attack the papaya but can be controlled. The export market is vulnerable to any incidence of Mediterranean fruit fly. In 1989, exports were suspended for 70 days when a specimen of the fly was found in Toledo District, in the south of the country.

(ii) Disease – anthracnose and leaf-spot fungus can be controlled, but the incidence of a mosaic virus disease is disconcerting: affected trees must be identified quickly and destroyed.

(iii) Environment – generally favourable, although cool weather (low 50s F; approximately 10°C) will adversely affect growth. Highly calcareous soils cause poor growth and chlorosis.

(iv) Irrigation – must be adequate: insufficient application leads to a lack of vigour and small fruit.

(v) Fertilizers – optimum levels (both major and trace) have not yet been confirmed.

Development potential

The prospects for successful estate production and export of fresh fruit of Solo papaya seem encouraging; but until the production factors referred to above are resolved, the prospects seem less certain for individual smallholders and co-operatives. Since standards at all stages of production from the selection of seedlings to the harvesting of fruit must be uniformly high, smallholders will probably need to regard papaya production as the major economic enterprise. Currently, two farm families, with areas of papaya of 1 ac (0.4 ha) and 1.5 ac (0.6 ha), appear capable of achieving an adequate level. Production may best be restricted to the red clays of Xaibe Subsuite, rather than the more calcareous darker clays.

PASSION FRUIT (*Passiflora* sp.)

Present position

The yellow passion fruit (*Passiflora edulis*) (from *flavicarpa*) is under trial by BABCO on three sites. It is also established at Gallon Jug. It is intended the fruit be used for juice. In all cases the seedlings have established well on their trellises and vegetative growth is vigorous and healthy (Figure 47). Flowering seems satisfactory but the extent of fruit set and yield has yet to be established. BABCO hopes for a yield of 7000 – 8000 lb/ac (7800 – 9000 kg/ha).

PINEAPPLES (*Ananas comosus*)

Present position

Small stands of pineapple are found in many parts of the project area. The main cultivar grown is referred to as Sugar Loaf but Apple, Horse Pine and some Cayenne (Figure 48) are also found. Some farmers have apparently abandoned Cayenne because it tended to produce small and fasciated fruit (H. Ramirez, 1990, personal communication).

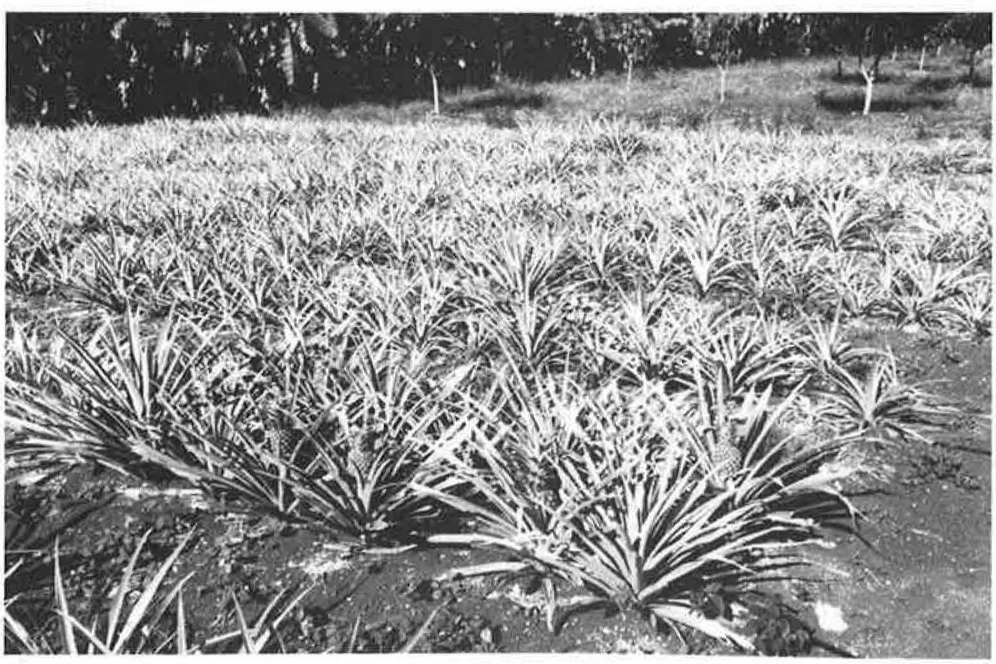
In 1989, District Department of Agriculture reports recorded 40 ac (16 ha) of pineapple producing an average of 5000 lb/ac (5600 kg/ha) in Orange Walk District and 26 ac (10.5 ha) producing 16,800 lb/ac (18,800 kg/ha) in Corozal District. Wright *et al.* (1959) mention pineapples in the vicinity of Corozal town

Figure 47

Passion fruit, Corozal

Figure 48

Cayenne pineapples, Corozal



in the early 1950s. They were planted on well-drained red Xaibe soils. Coles (1986) recorded the major pineapple-growing areas in Corozal District as Sartaneja, Chunox, Paraiso, Consejo and Chan Chen. A small processing unit in Corozal canned pineapple juice. Corozalita is the main pineapple-growing area in Belize District: some 10 families in the area grow the crop, both as a pure stand and under fruit trees. It is appreciated that shaded plants produce smaller and less sweet fruit. The main cultivar is Sugar Loaf. The plant crop seems to be widely planted (9 ft × 3 ft; 3 m × 1 m) and following the plant harvest, aerial suckers (shoots) are left to develop on the mother plant. In consequence, they tend to fall over and the fruit suffers from sun scorch. Harvested plants are not chopped for mulch. Plants are left to flower and fruit naturally, so that the main harvest is concentrated in June to July with a smaller crop in October. As ripe fruit becomes available in small numbers in May, the selling price may reach BZ$ 30 – 36/ dozen. During the main season, the price may fall to BZ$ 12/dozen, which suggests the market is then fully satisfied. Fruit may weigh 6-8 lb (2.7 – 3.6 kg). The crop appears to be free of disease, except for a small incidence of fruit rot, as fruit approaches ripeness. There is no sign of mealy bug wilt. Some fruit are lost to wild animals.

BABCO identified pineapples as a potentially profitable crop for export of fresh fruit and laid down farmers' field trials on three sites, using Cayenne material from Mexico. Soil types under test are Consejo, Remate and a 'Saragosa' clay. The general appearance of the plants is unthrifty and a number have come into fruit while the plant is too small to bear a satisfactory-sized fruit.

Development potential

The season for the local market could be extended easily by flower induction. The Sugar Loaf cultivar thrives in Northern Belize and is accepted on the local market. The production of juice and dried fruit could be expanded to increase returns to growers. BABCO is investigating whether the Cayenne cultivar is suited to the calcareous soils of Northern Belize; there is some evidence that it is not.

POTATOES, IRISH (*Solanum tuberosum*)

Present position

Belize imports considerable quantities of Irish potatoes, but although there has been a number of attempts to meet the demand locally, they have usually been small-scale and short-lived (Figure 49). The constraints have been poor tuberization, so that the weight ratio of crop to seed has been little more than 5 to 1. Shelf life has also been short. Seed potatoes have mainly been obtained from the USA and the cultivars may not have been suited to Belizean conditions. Nevertheless, two recorded instances suggest that, if the crop is planted in the cool season

Figure 49

Irish potatoes, Corozal District

(November) to ensure maximum tuberization, acceptable yields can be gained. At Little Belize, 3.2 lgt/ac (8.0 t/ha) were obtained from 2.5 ac (1.0 ha), using seed potatoes from Barton Creek (Cayo District). Crop to seed ratio was 9 to 1. At Blue Creek, 2000 lb (907 kg) were lifted from 150 lb (68 kg) of seed.

Development potential

Irish potatoes might be grown economically on deep, friable soils, and preferably on ridges with irrigation. The period of tuberization should be the coolest time of the year. Much work has been done on selecting cultivars suitable for the tropics and subtropics by the International Potato Centre in Peru, whose advice should be sought on any research programme.

RICE (*Oryza sativa*)

No irrigated rice is grown in the project area and indeed little at all in Corozal District (50 ac (20 ha) in 1989), apart from San Estevan and some 17 ac (7 ha) of direct-sown CICA8 at Little Belize. The total mechanized area recorded for Orange Walk in 1989 was 1281 ac (520 ha) giving an average yield of 2500 lb/ac (2800 kg/ha). The area was much less than usual because of a shortage of seed planted (Garcia, 1989). The greater part of the rice area lies in the two Mennonite communities of Blue Creek and Shipyard. Production is likely to increase in 1990 with the start of the development of an area of several thousand acres between San Felipe and Blue Creek. Growers are able to sell their rice in Shipyard at BZ$ 0.18-0.23/lb ($ 0.40-0.51/kg).

SUGAR (*Saccharum* cv.)

Present position

Sugar cane is the most important cash crop in Belize in terms of area planted, numbers of people employed and size of export earnings. It is the foundation of the economy of Orange Walk and Corozal districts. There is, nevertheless, uncertainty over the total area under cultivation. The Research Department of the Belize Sugar Industries (BSI), using Landsat TM imagery taken on 4 January 1987, estimated an area of approximately 66,000 ac (26,700 ha), divided as follows:

Healthy cane	– 24,000 ac (9700 ha)
Harvested fields	– 10,000 ac (4050 ha)
Poor and abandoned fields	– 32,000 ac (12,950 ha)

Zetina (1990) quoted a figure of 54,000 ac (21,850 ha) cultivated in 1987. Perhaps 5000 ac (2025 ha) have been newly planted since then. Using the same satellite imagery as BSI, supplemented by interpretation of 1988 aerial photography and fieldwork, we estimated an area of 47,320 ha (116,930 ac) of land used for growing sugar cane (i.e. including the various BSI subdivisions and land seen to be growing another crop such as maize, but which is expected to grow sugar cane as well) (see Current Land Use, p. 116).

Numerically, crop production is dominated by small farmers – those with holdings of less than 50 ac (20 ha). The Agricultural Census of 1984-85 (Ministry of Agriculture, 1987) recorded 1981 holdings in Corozal District, of which 423 had plant cane and 1195 ratoon; (most of those with plant cane probably also had ratoon). In Orange Walk District, the number of holdings was recorded as 2294, of which 431 had plant cane and 1332 ratoon cane. In all cases, the number of holdings of less than 50 ac (20 ha) exceeded 70%. The average sugar area has been estimated as 12 ac (4.9 ha); a few have over 1000 ac (405 ha) (MUCIA, 1988).

Although sugar cane has been grown in Northern Belize since the middle of the 19th Century, most of the development has occurred over the last thirty years – a time of substantial price variations over short periods. A nadir was reached in the mid-1980s, when the quota allocated by the USA was reduced

Table 43

Sugar cane deliveries to Tower Hill factory

Year	Long tons (lgt)	Tonnes (t)
1987/88	777,000	789,500
1988/89	924,801	939,644
1989/90 (est.)	965,000	980,500

and world prices were low – a situation exacerbated by inefficient production and processing (MUCIA, 1988). Substantial areas of cane were abandoned and some 300 cane farmers are believed to have left the area. One of the two factories was sold and converted to the production of high test molasses for ethanol (Petrojam), with a substantial reduction in the price paid for cane: BZ$ 25/ton in 1989, rising to BZ$ 30/ton in 1990. There was considerable disillusionment in the industry and diversification into other crops was considered. Since then, the position has changed substantially with improved prices, the replanting of disease (smut)-affected areas, better husbandry of the ratoon crops, and good weather. The deliveries of cane to the remaining factory at Tower Hill over the last three years is indicated in Table 43. In addition permission has been given to Petrojam to purchase 140,000 lgt (142,000 t) of cane to augment the production from their own estate of 4000 ac (1600 ha).

The total quantity of cane that may be accepted by the Tower Hill sugar manufacturers for processing is limited by government: the 1990 figure was 950,000 lgt (965,000 t), an increase of 100,000 lgt (101,600 t) on the 1989 figure. Individual growers are allocated quotas (varying between 23 and 2000 lgt (23 – 2,032 t)) by the Sugar Cane Board, which limits the maximum quantity they may deliver. Growers must also be members of the Cane Growers' Association. In Orange Walk District, there are 2839 registered cane farmers; in Corozal District, 2342. Several members of a family, although farming together, may have individual quotas. Unregistered growers sell their crop to registered growers unable to meet their quota from their own resources. Such cane was being sold in the 1989/90 season for BZ$ 15-20 lgt as a standing crop or BZ$ 35 – 40/lgt, cut and carried. The final price paid by the factory in 1990 was expected to be BZ$ 52/lgt ($51.18/t).

The maintenance of an acceptable price to growers depends mainly on the preferential markets with the European Community (EC) and the USA (Caribbean Basin Initiative), as indicated by Table 44. The 1990 quotas were expected to be – EC: 41,000 lgt and USA: 14,000 lgt. Local consumption is approximately 7000 lgt. The three outlets thus total 62,000 lgt. With estimated purchases of 965,000 lgt (980,500 t) and an extraction rate of 10.42%, total production will be 100,553 lgt (102,162 t). Thus 30,650 lgt (39,170 t) will have to be sold on the world market.

Sugar cane production, is still largely extensive rather than intensive. Long-established cultivars are grown on a range of soils. Although there have been

Table 44

Sugar cane prices in 1988/89

Purchaser	Total sugar bought (lgt)	Average price (BZ$)
EC	41,600	951.59
USA	15,942	848.89
Others	22,949	427.22 – 487.67

improvements in the last few years, standards of husbandry remain low by international standards. Growers can survive periods of low prices but not obtain the highest yields of sugar per unit area that are now achievable.

Few growers with quotas below 300 – 400 lgt own their own tractor and they therefore depend on contractors for land cultivation prior to planting or replanting – plough, harrow, furrow. The situation is exacerbated by the limited time available – usually February to April/May. Sugar cane is seldom planted now on newly cleared forest, but cultivation requires clearing of secondary forest or the old cane crop (sugar cane is seldom grown in rotation). Inadequate drainage is a major problem on many cane fields, particularly in the low-lying areas of the alluvial wash subunit (W on Map 1). The position may be exacerbated by blockage of drainage lines and the poorly aligned feeder roads.

The most widely grown cultivar is probably B52298 ('white cane') introduced in 1956. It grows on a wide range of soils, tillers well and gives a good yield of cane. If it cannot be sold during the season, it can be held over to the next. In times of low prices, it can be neglected. It is relatively low in sucrose and is susceptible to smut disease. The even older 'bamboo' cultivar, which does well on better-drained land, is still grown.

Cultivar trials have been undertaken in Belize since the mid-1970s and BSI has a collaborative programme with the West Indian Cane Breeding Station in Barbados, involving the importation and testing of true seed. In 1989, 25,000 seedlings were assessed. BSI is now able to recommend improved cultivars to growers through their 400 contact farmers. They are:

B64278 – Released in 1986. Dense tillerer, very high brix, good stalk weight, retains sugar from December to June

BJ7013 – High brix at the end of the season

BR6249 – High brix throughout the season

MEX5932

B67128

A further seven cultivars were released in 1989 to farmers' field trials – two are early ripening, four mid-ripening and one late ripening. Inputs and good management will be needed to exploit all these cultivars to their full potential (Figure 50). Some will probably be most suited to a specific soil type. Time of harvesting will also be more critical.

BSI recognizes five cane-growing soils – Xaibe, Lazaro dark grey sandy clay, Remate, Pixoy sandy loam and 'mottled' clay. Louisville clay is considered the best soil in Corozal District and Lazaro in Orange Walk District; but due to the lack of a detailed soils map and very limited facilities (at the Department of Agriculture's Central Farm, Cayo District) for soil and foliar analyses, the same fertilizers are recommended for all soils. They are: at planting, 200 lb/ac (224 kg/ha) of triple superphosphate, followed, after seven weeks, by 150 lb/ac (168 kg/ha) of urea (if it can be incorporated into the soil) or the equivalent amount of nitrogen in the sulphate of ammonia or ammonium nitrate. For the shallow Consejo Subsuite soils of Corozal District and the Chan Pine Ridge-Trial Farm-San Roman road area mostly on our Guinea Grass soils, a compound fertilizer including potassium is recommended. Trace elements boron, zinc and magnesium are suggested for Pixoy soils. With the rising cane prices of recent years, there has been an increase in the use of fertilizers but the choice is often made on the basis of availability and price. (Formulations available over the last year have included 18:46:0; 28:28:0; 12:12:24; 17:17:17; 19:19:19.)

Frog-hopper (*Aenolamia postica jugata*) was reported as a major pest in the 1960s and 1970s, possibly reducing the crop by 20%. In 1983, it was estimated to have caused the loss of 60,000 tons of crop, and 5,000 tons in 1988. It is now largely arrested by a combination of good natural control, burning trash after harvest and more timely spraying. The stemborer (*Diatraea saccharalis*) is

Figure 50

Improved sugar cane

controlled mainly by natural enemies and by burning before and after harvest (Rancharan and Cawich, 1989). Minor pests include ground moles, field rats and yellow aphids (*Sipha flava*).

The disease, smut (*Ustilago scitaminea*) was considered a major factor in the decline of cane production in the mid-1980s. The new cultivars are resistant but the common cultivar, B52298, is susceptible. Nevertheless, many farmers seem content to accept this because of other characteristics of the cultivar: also, if harvested towards the end of the season, the disease is less prevalent. Other diseases include rust (*Puccinia melanocephala*) and eye spot (*Helminthosporium sacchari*).

The current average yield of cane is 18 lgt/ac (45.2 t/ha). Plant crop yields are from 25-40 lgt/ac (63-100 t/ha): ratoon yields vary between 8 and 30 lgt/ac (20-75 t/ha). An illustration of cost and returns is shown in Appendix 17. With proper cultural practices and adequate drainage, average yields under rainfed conditions could be increased to a minimum of 22-25 lgt/ac (55-63 t/ha) (E. Zetina, 1990, personal communication). If high sucrose cultivars were used, total sugar per unit area "could increase dramatically" (Zetina, 1990) – possibly to 2.5 lgt/ac (6.25 t/ha) compared with the current 1.7 lgt/ac (4.3 t/ha).

The Cane Growers' Association has eight branches in each of the two districts with a (farmer) director for each: he controls the harvesting schedules, deciding in response to requests, which areas will be burned and cut on any given day. Only those farmers to whom a daily quota has been allocated by their director may deliver sugar cane to the factory. This programming is the key to efficient delivery to the factory and thus is an important component of efficient processing. While the scheduling has improved in recent years, lorries, particularly from Orange Walk District, may still wait at the factory for 36 hours or more before delivery is made, with consequent negative effects on the quality of the cane and the effective use of transport (Figure 51).

A random quality test is undertaken every day from both the Orange Walk and Corozal districts separately; from which a price differential between the two districts is calculated over the whole season. The present system discrimates against the producer of a cane with a relatively high sugar to cane ratio, although this should be the objective of both the farmers and the factory.

Figure 51

Trailers of sugar cane queueing at Tower Hill Factory

Replanting on some soils is said to be required after 3-5 years; on others, the crop has been ratooned for 20-30 years. The average period is probably 10 years. The generally accepted ratio of land required to produce setts for planting to the area to be planted is 1:8.

Development potential

In order to present an objective assessment of the viability of cane farming in its simplest, labour-intensive form, we have endeavoured to reconcile input-output relationships derived from demonstration trials with actual small-farmer practices. Data have been obtained from several sources, including BSI Research Department (Zetina, 1990) and Ms A. Quan, who has allowed us to refer to her unpublished research on sugar cane-based farming systems, which she will complete in 1991.

It was indicated in the Population section that cane-farming often depends upon hired labour (mostly immigrant) at critical periods. Nevertheless, a large number of cane-farming families are self-sufficient in labour in every respect except harvesting, and even harvesting and associated haulage can be accomplished by families joining forces during the cane-cutting season. For the farmers who can afford it, Quan identifies group co-operation in hiring contract harvesting crews for the entire season, and the employment of casual labour for weed control and fertilization in years when cane prices have been attractive.

By adapting data from various sources, the costs and returns of a model small cane farmer have been calculated in Appendix 17 to arrive at a break-even price in 1990 of about BZ$ 35 per ton for an industry-average yield of 18 tons/acre (45 t/ha), assuming all inputs, including labour, are fully costed. A price below BZ$ 35 in 1990 could only have been worthwhile where a farmer and his family themselves did much of the fieldwork. Taking the BSI cane price for the two districts over the last four years which has fluctuated between BZ$ 48 and BZ$ 55/t (according to district) (see Table 40) it would appear that farmers have in each year enjoyed a (fully costed) gross margin of around 35-55%, as well as having the benefit of the residual values of ratoons. Indeed the BSI price currently justifies the opening up of new lands for cane cultivation.

We are aware that, in cases where capital has been made available, economies are achieved through mechanization of tillage and the use of chemicals for weed control.

Spreadsheet matrices encompassing a range of cane yield and price assumptions, including different combinations of labour usage, mechanical operations and material inputs can provide a realistic guide to the financial viability of cane farming in each of the respective forms in which it is practiced.

With the possible exception of farmers located close to the Petrojam factory the harvesting of sugar cane for Petrojam's operations is a last-resort option. It can only be justified at the current price of BZ$ 30/ton when a farmer has mature cane in excess of his BSI quota (if quotas remain in force) that he cannot sell to another quota holder, in which case for every dollar spent on harvesting and transport (see Appendix 17) there is a cash profit of about 30 cents to offset production costs.

For several decades, the system of cane-growing has been, *faute de mieux*, extensive with low inputs. This was prodigal in its use of land but the small growers, who were in the majority, were able to produce the crop with minimal capital outlay, and could survive the recurring periods of low prices. It should be noted that the current policy of producing sugar in excess of preferential market quotas enables a larger cane area to be cultivated than is necessary to fulfil these quotas, but results in a lowering of the price of sugar cane on the free market. Research now indicates an alternative system, which would involve a radical change of approach and attitude on the part of the growers. New disease-resistant cultivars are being identified which are capable of giving higher sugar percentages and yields per unit area. It should also be possible to identify cultivars which are particularly suited to each of the major soil subsuites and recommend fertilizer schedules specific for the cultivar and soil. A start has been made in initiating such a system through the BSI Research Department's Sugar cane Extension and Technical Support Service (SETSS), which operates through the Research Department's 400 contact farmers (8% of registered growers). The service includes:

(i) Proper land selection and preparation;

(ii) Use of good seed material;

(iii) Early inter-row cultivation and chemical weeding;

(iv) Pest and disease monitoring and control;

(v) Monitoring of the nutritional status of the cane plant and appropriate fertilizer application.

Full benefits of the system require crop harvest scheduling for the appropriate time and expeditious delivery to the factory.

The advantage of the new system to the country would be that the current level of sugar could be produced from a smaller area of land, particularly in Corozal District where unused, good agricultural land is becoming increasingly limited. Farmers would benefit from a substantially greater quantity of sugar obtained from the present area under the crop. The advantage to the factory would be that the lower cane to sugar ratio would improve processing efficiency.

The cane grower, highly conscious of the great price variations he has experienced over the years and confident of the present system's ability to survive such vagaries, is likely to respond to the suggestion of change with considerable caution, because:

(i) Further investigation would be needed to demonstrate the appropriateness of new cultivars to a given soil, particularly with regard to the sustainability of adequate yields with the successive ratoon crops (about which many growers appear doubtful);

(ii) The present capability for monitoring nutritional status (and assessing the correlation between soil and foliar analysis and fertilizer needs) is inadequate. The industry would require either its own facilities or a central facility offering expeditious analysis;

(iii) Inadequate drainage is a common problem, particularly in Orange Walk District. In many areas, it may not be possible for the individual grower to improve this on his own: satisfactory outfall for the surplus water may require integrated drainage schemes;

(iv) Growers using new cane cultivars which are more specific in their optimum harvesting stage than the current cultivars will require guidance on harvesting dates and perhaps priority in 'reaping schedules';

(v) There will be a need to introduce a differential price scheme so that the grower or groups of growers are paid on the basis of sugar content;

(vi) Many growers will require credit to adopt the new intensive cultivation system, which they may be reluctant to seek, even if it were available at attractive rates, in view of the problems of indebtedness that arose after the credit scheme in the 1970s, which was quickly followed by a fall in cane prices.

The Sugar Cane Board must therefore review the current position before encouraging intensification of production; which if considered desirable, will need decisions on the specific support that should be provided by Government, the Board, BSI and the Cane Growers' Association.

Two additional aspects, linked to the new system, are:

(i) Guidance to sugar cane growers will be more effectively given when details of the size and location of the individual farms are known to the BSI extension worker. A start has been made using satellite imagery (Landsat TM) and natural colour imagery obtained from an airborne video camera, whose value would be enhanced using airbourne infrared imagery. It may then be possible, for example, to monitor growth stages in the various areas or identify disease incidence;

(ii) Irrigation of sugar cane is currently used on only a small scale, for the establishment of the new crop planted in the dry season. Irrigation should also be beneficial after harvest, in order to initiate the ratoon crop, particularly in areas harvested early in the dry season. The economics of the practice deserve field testing;

(iii) Both intensification and diversification are more economic with small holdings.

Livestock

BEES

Present position

Corozal and Orange Walk districts have traditionally been the main areas for beekeeping in Belize. "The floral communities ... and climate ... create a beekeeping paradise with lengthy primary honey flow periods from March into June and secondary nectar/pollen flows that generally allow colonies of honey bees to easily maintain themselves for the remainder of the year" (Burgett and Fisher, 1990). In the last two years, however, there has been a devastating fall in production in Northern Belize (Figure 52), as well as the rest of the country (see Table 45). Production by 1st May 1990 was 14,242 lb (6640 kg), in Corozal District and 23,527 lb (10,672 kg) in Orange Walk District, indicating production continues to fall steeply.

Prior to this precipitous decline, the beekeeping industry had been growing steadily for over thirty years. It was essentially built up through a vertically integrated organization that linked the beekeeper through district co-operatives

Figure 52

Abandoned hives on the Sarteneja road

Table 45

Honey production of co-operative societies

Co-operative	1985 lb	1985 kg	1986 lb	1986 kg	1987 lb	1987 kg	1988 lb	1988 kg	1989 lb	1989 kg
Corozal	186,632	84,654	221,788	100,601	137,806	62,507	176,326	79,980	87,952	39,894
Orange Walk	155,143	70,371	197,308	89,497	196,021	88,913	199,046	90,285	105,199	47,717
National total	398,815	180,898	575,344	260,970	490,656	222,557	474,433	215,198	222,195	100,785

to a national federation which arranged for the export of the crop (to the United Kingdom). A few beekeepers had several hundred hives but the average number was nearer 25 – 30. Biotypes of the European honey bee (EHB: *Apis mellifera*) were introduced in the 1950s and became dominant: today, only a few colonies of the native bee (*A. malipona*) are believed to remain (M. Cal, 1990, personal communication). The African honey bee (AHB), a tropical biotype of *A. mellifera*, was positively identified in Belize in March 1987 and has since become widespread. Burgett and Fisher (1990) forecast the AHB will come to dominate the honey bee fauna of Belize during 1991.

The AHB is potentially more productive than the EHB but is very aggressive when disturbed, will abscond if short of food, and is a rapid breeder liable to frequent swarming if not carefully managed. Belizean beekeepers are unfamiliar with the different management techniques required for the AHB, have no protective clothing and have been much alarmed by news items of the death of animals and even human beings following attacks by swarms of AHB.

Although the AHB seems to be the main cause of the devastating fall in honey production, there is a widespread belief among beekeepers and others that it is also due, directly or indirectly, to herbicidal spraying – initially with paraquat, subsequently with glyphosate – of marijuana areas.

Beekeeping has been an important additional source of income to many small farmers as well as producing a useful export – honey. (No other products are sold by beekeepers.) For the wider agricultural industry a greater loss could be of pollinators (unless wild colonies of AHB remain). Bradbear (1984) stated that "honey can be considered a fortunate by-product to the major and inestimable value of honeybees as pollinators of plants".

Development potential

"If a rehabilitation program directed at the overall beekeeping industry is not undertaken within the immediate future, beekeeping as an agriculturally viable activity may well go out of existence in Belize" (Burgett and Fisher, 1990). Burgett and Fisher go on to identify the components of such a programme:

(i) Development of European honey bee queen sources and import of queens for hybridizing (F_1) with the AHB;

(ii) Establishment of an indigenous queen-rearing programme;

(iii) Development of AHB management programmes and training.

CATTLE

Present position

Orange Walk and Cayo districts have been the major cattle-rearing areas of Belize for decades. It has also long been recognized that, environmentally, these two districts could be the base for a substantial export industry, which potential has never been developed. Today, for some cattle owners, stock are regarded as a form of savings rather than an active income-generating enterprise. Before any detailed planning can be undertaken however, the numbers of calves, 1-2 year olds, 2-3 year olds and adults, sex (females, entires, castrates) and mortality for each age group, age at first calving, calving percentage, offtake for slaughter and other purposes, and herd size distribution for each district, must all be known. The Agricultural Census of 1984-85 (Ministry of Agriculture, 1987) recorded 231 households in Corozal District owning a total of 1644 cattle: 84% of the households had fewer than 10 head. In Orange Walk District, 466 households were shown in the Census as owning 15,328 head of cattle: 77% of the households had fewer than 20 head and 60% less than 10 head. The July 1988 Cattle Census recorded 20,394 head of cattle in Orange Walk District. The annual reports of the Department of Agriculture for 1989 quoted the cattle population of Corozal District as 1600 head and of Orange Walk District as 22,000. The 43% increase in the cattle population in Orange Walk District is probably due to migration from Cayo District (R. Neal, 1991; personal communication). The current (1990) population in Southern Cayo is probably in the region of 1500 head and along the Old Northern Highway, Belize District, 800 – 1000. In October and December 1989, the Belize Livestock Producers' Association (BLPA) imported 43 *Bos indicus* breeding bulls and 123 steers from Guatemala, which have been dispersed among 5 farmers. Individual weights of the steers were recorded for monitoring liveweight gain under Belizean grazing conditions. (J. Alpuche, 1990, personal communication).

There is no dairy industry in the project area apart from one small producer/retailer. In the Mennonite communities of Blue Creek, Shipyard and Little Belize, it is common for families to keep a house cow to supply the household with milk. Oxen are not used as draft animals. The herd is thus essentially kept for beef.

Most owners practise extensive grazing of natural pastures by the whole herd – bulls, heifers, pregnant and lactating cows and young stock. In consequence, there is little controlled breeding, early pregnancy of heifers is likely to be common and there is much in-breeding, partly because of the limited practice of castration.

Figure 53

Cattle on Old Northern Highway

Some of the naturalized pasture species are Para grass (*Brachiaria mutica*), Aleman grass (*Eriochloa polystachys*) (both found on lowland areas), Bahama grass (*Cynodon dactylon*), carpet grass (*Axonopus compressus*) and a wild Guinea grass. The naturalized pasture include a variety of weeds, a number of which are of low productivity and could be poisonous. Stocking rates tend to be low (>3 ac (1.2 ha)/head), both because of the limited pasture carrying capacity, and because of incorrect pasture management and concern of owners about having enough feed for the dry season. By May, many of the pastures will be grazed down and dessicated. There is little or no use of pasture or fodder legumes.

Some years ago, cattle were grazed on the Mountain Pine Plateau. Calderbank (1968) reported calving percentages of 20 – 30% and a realistic carrying capacity was one head to 20 ac (8 ha) or possibly 1 to 10 ac (<4 ha) on better areas. Roberson later managed an extensive system, but although he claimed to have been successful, he pulled out. The metasedimentary valleys have stands of dumb cane (*Tripsacum* sp.) which would offer better grazing but would also be easily killed off with unrestricted grazing. Although the pasture improvement trials on the high plain subunit of the Belize Plain land system (Mile 33 of the Western Highway) have demonstrated how Pine Ridge pasture can be improved, it should be appreciated that they are on one of the best Pine Ridge soils, and considerably better than the soils of the Mountain Pine Plateau.

Where improved pastures are established, the most popular species are African Star (*Cynodon plectostachys*) and Improved African Star (*C. nlemfuensis*); excellent stands of which can be seen on a range of fertile soils, where they have grown vigorously and smothered other grass species (Figure 54). The Improved Star Grass requires a high stocking rate of cattle, rotational grazing and regular fertilization. It is propagated vegetatively which is expensive. A more traditional grass in the past, that can be established from seed, is Jaragua (*Hyperrhenia rufa*) – a coarse, bunch grass of moderate palatability and nutritive value. It tolerates a wide range of soils and is a vigorous coloniser, but the nutritive value declines after flowering, and the deterioration continues through the dry season. Other planted species include Bahia (*Paspalum notatum*) – also of moderate palatability, Guinea grass (*Panicum maximum*) which is believed to be good for weight gain but is easily killed out, and pangola grass (*Digitaria decumbens*). There is a very limited use of fodder grasses, including Sudan grass (*Sorghum sudanse*) and Taiwan grass, a form of Elephant or Napier grass (*Pennisetum purpureum*); and some use of sugar-cane tops and rejected cane (Figure 55).

The earliest breed of cattle in Belize was the Criollo or Creole type, but during the present century, a range of other breeds, *Bos taurus, B. indicus* and their crosses, has been brought in: they included Holstein, Aberdeen Angus, Red Poll,

Figure 54

Cattle grazing Star grass pasture at New River Co-operation

Figure 55

Cattle grazing on rejected cane near Guinea Grass

Jamaica Red, Brown Swiss, Hereford, Santa Gertrudis, Charolais and Brahman. Fortunately, most of the animals in the project area appear to have been upgraded over the years by improved Zebu breeds – Brahman, Indo-Brazil and some Gutzerat – although Holstein, Brown Swiss and Red Poll characteristics are not uncommon. The Brahman is generally sought because it is hardy, thrifty, heat-tolerant and can cope with neglect. Holstein and Brown Swiss are valued in milking animals and it is also believed that European (*Bos taurus*) blood produces milkier dams and greater docility, although the latter characteristic is more likely to be due to better handling.

Most of the calves seem to be dropped between November and February/ March. Data on calving percentages and calf mortality is not available in the project area, except for Yo Creek Agricultural Station. When questioned, most owners said their cows calved every 12 – 18 months, but given the general nutritional status and on visual evidence, the calving percentage is likely to be 50 – 60. On the Department of Agriculture's Yo Creek station, the figure is said to be about 85%, and experience on the large ranches suggests 75% could be generally achieved.

The incidence of diseases and parasites in cattle is very small. Vaccination is recommended against blackleg – an outbreak of which would result in a 6-month quarantine for an area of 15 miles (24 km) radius. The Agricultural Census of 1984-85 (Ministry of Agriculture, 1987) reported only 30% of owners vaccinated then, but the current level seems to be substantially higher. Vesicular stomatitis and rabies is known to occur in Belize but the incidence seems to be sporadic. Tuberculosis and brucellosis are also rare. Most owners control internal parasites and ticks, and treat beefworm incidence. The screwworm eradication programme, involving the release of sterile male flies is making significant progress.

Slaughter animals may be sold to the Belize Meat's abattoir at Ladyville, near Belize City, to town slaughterhouses, butchers or itinerant buyers, both Belizean and Mexican. The April 1990 prices for cattle delivered to the abattoir are indicated in Table 46.

The farm gate price for finished steers varied in 1989/90 from BZ$ 0.90 to 1.25/lb (BZ$ 1.98 – 2.76/kg) – a substantial rise over the prices available a few years ago. The price for barren cows may fall to BZ$ 0.60/lb (BZ$ 1.32/kg) and they may be difficult to sell. Towards the end of the dry season, owners with a shortage of pasture try to dispose of their surplus stock. This factor and the difficulties of the Belize Meat's abattoir resulted in there being several hundred finished steers at Blue Creek in May 1990, for which no market could be found.

The lack of a market for breeding and store cattle also results in the slaughter of such animals. In Orange Walk, between January and November 1989, 398 animals were slaughtered: the average liveweight of the bulls was 660 lb (300 kg). Few sales are made over the scales: weights are usually estimated by weighband or eye.

Table 46

Abattoir prices in April 1990

Steers, young bulls and heifers				Young cows in excellent condition			
Liveweight		Price (BZ$)		Liveweight		Price (BZ$)	
lb	kg	per lb	per kg	lb	kg	per lb	per kg
600-699	272-317	0.85	1.87	500-599	227-272	0.70	1.54
700-749	318-340	0.92	2.03	600-699	272-317	0.75	1.65
750-799	340-362	0.96	2.12	>700	>318	0.80	1.76
>800	>363	1.00	2.20				

Livestock owners can receive advice on animal husbandry, pasture management and feeding, and health matters from the district agricultural offices. Since September 1989, the Belize Livestock Development Project (BLDP) Phase II has also been operating in the project area. This livestock project is a joint venture of the Ministry of Agriculture and Fisheries, United States Agency for International Development, (USAID) and the Belize Livestock Producers' Association; owners of more than five head of livestock are entitled to be members of the Association. The livestock project includes support to genetic improvement of cattle, the screwworm eradication programme and improved pasture/feed management. The project has bought equipment and trained technicians for localized artificial insemination services (30 – 40 farmers per group). Brahman and Simmental semen will be imported from the USA, and Holstein for Blue Creek. The project has also initiated cost-benefit analysis on the basis of individual farm assessments, starting with a pasture evaluation of the existing enterprise, so that farm level data on improvement costs and benefits can be obtained.

Protein banks of legumes are proposed to supplement the native species of most of the pastures. They may be grown either in association with the grass – which would require skilled management – or separately as fodder. Suitable species include Kudzu (*Pueraria phaseoloides*), Centro (*Centrosema pubescens*), Leucaena (*Leucaena leucocephala*), Desmantus (*Desmanthus* spp.), and Desmodium (*Desmodium ovalifolium*) (Valencia and Tergas, 1990). Such an approach is considered particularly appropriate for lactating cows and young stock. Fertilized, improved species of grassland would be needed for fattening steers on pasture. This system has been employed effectively on Central Farm and a commercial holding on the Northern Highway just outside the project area where the stocking rate is 1.3 ac (0.52 ha) per head.

Development potential

It has often been re-iterated that the development of the undoubted potential for beef cattle production in Northern Belize requires owners' confidence of an assured market for their animals offering an economic price. Prices have improved markedly over the last few years but current outlets are limited, and it has been noted above that several hundred head could not be moved in May 1990. A principal requirement needed to gain the owners' confidence is acceptance of the government's commitment to long-term development of the cattle industry, including development of the export market. As the home market for beef is limited, a substantial increase in sales will depend on the export market. Although live animals have been sold to Mexico and, in the past, to Martinique, most exports will be carcase or boneless meat. A dependable abattoir would be essential.

If owners were convinced that there would be an assured market for their product and they accepted that a beef cattle enterprise could become an attractive income-generating activity, they could substantially increase productivity from the existing areas devoted to cattle. Knowledge of sound pasture and herd management is limited. Available information should be disseminated among more farmers, and it is currently insufficient for long-term management. More details are needed for planning the export market.

Generally the returns illustrated by the current steer importation and fattening programme looks uninspiring for large-scale ranching. Nevertheless, considering the relatively low technical risk of steer fattening, this enterprise could be very well suited to small farmers, in which case the labour expense which we project at about BZ$ 65/steer/year can be attributed to the farmer and his family. We recommend a small-farmer trial be established as part of the BLDP, which the Ministry of Agriculture and Fisheries is planning.

Our enquiries have not extended to the costs and returns of cattle breeding. We recommend detailed research into the financial feasibility of integrating this activity with fattening operations.

It was noted earlier than most cattle owners have herds (of all ages) with less than 20 head, and their range of options for husbandry methods is thus limited. The ideal position which can be found on several of the larger estates, is where there is a range of soils on which different pasture/fodders could be established for the various types of stock. The BLDP is starting to strengthen the support services to cattle owners. The support will be needed for several years beyond the time scale of the BLDP for the cattle industry to become one of Belize's major export earners. Improved nutrition is essential both to raise the current low calving percentage and to accelerate growth rates of breeding and store cattle. The BLDP recommendations for grazing management practices, some of which are appropriate for all sizes and levels of enterprise, are indicated in Table 47. Grass/legume pastures require skilled management; and replacing native pastures with fertilized improved species may be beyond the means of the small owners. Nevertheless, improved pasture management, linked to the separation of types of stock, is possible for all sizes of enterprises.

There are many areas of shrubland which have been fenced off but are no longer used for pasture, or have a low carrying capacity. Where possible, it is desirable to bring such areas into production, by controlling the weeds and shrubs using mechanical and chemical methods, rather than encourage the clearing of new areas.

Many farmers will require credit to meet the cost of improving or establishing their pastures. Lending institutions do not accept animals as collateral and loans may be difficult to arrange. The effectiveness of BLDP's short-term credit scheme should therefore be closely monitored to assess its effectiveness.

It has been noted earlier than there has already been considerable progress in upgrading cattle. There is general agreement among owners and extension workers that this upgrading should continue, using Brahman (or *Bos indicus*) for breeding stock. For further upgrading of slaughter stock, the BLDP has selected and recommended the Simmental. An equally valid case could have been made for other *B. taurus* breeds, but it is desirable that the earlier proliferation of breeds should be avoided and confirmation of the Brahman and Simmental as the breeds of choice should be included as government policy.

The BLDP artificial insemination scheme could be a substantial help in upgrading stock, but its implementation will face many practical problems and it remains to be seen whether it proves feasible. Fresh blood is also needed to avoid in-breeding, which is obviously most difficult to achieve among small herds. In Blue Creek, bulls are exchanged within the Mennonite community, but this may

Table 47

BLDP recommended management practices for grazing cattle

Type of pasture	Animal type	Stocking rate animals/ac	Grazing methods
Native	Dry and pregnant cows	0.5	Continuous*
Native+legume bank	Lactating beef cows	0.5	Continuous*
Grass-legume	Young replacing heifers	1.0	Rotational
association	Young feeder calves	1.0	Rotational
Fertilized grass:	Lactating dairy cows	1.2	Rotational
legume bank 2-4 hrs/day	Adult replacing heifers	1.0	Rotational
Fertilized grass	Fattening steers	1.2	Rotational

* except for resting periods

Note Stocking rates are now quoted in 'animals per acre': it would be desirable to convert these to 'adult equivalents'. A simple conversion could be three 0-1 years old or two 1-2 year olds per adult equivalent be difficult to implement elsewhere. However, avoidance of in-breeding is important and should be linked to the introduction of the concept of a breeding programme, which should concentrate on the castration of scrub bulls, and calving in the appropriate period May-July.

The total available export markets to Cancun, Chetumal and the Caribbean Community (CARICOM) countries are believed to total 25,000 head/annum: current exports are in the region of 2000 head/annum (R. Ledesma, 1990, personal communication). The limited size of the national herd and low calving percentage limits Belize to a very slow increase in its level of exports unless more breeding animals are imported. Over the years, a number of such schemes have been prepared, e.g. Jenkin *et al.* (1976) suggested 1000 heifers per year be imported for ten years. Such a scale of imports would be subject to availability of stock at economic prices (? Panama) and of pasture and other facilities for their quarantine and subsequent rearing. Several of the large cattle ranches and the Mennonite communities have the capability of absorbing a substantial number. For the smaller herd owners, purchase might be arranged through BLPA groups. An assessment of the availability of suitable stock and of the industry's ability to absorb them, is needed.

The slaughter weight figures, quoted earlier, show that many animals are slaughtered when they are far too young, frequently because the owner has inadequate feed or is in need of money. His only outlet is often the slaughter-house, so that good breeding stock or store cattle are lost. To overcome this problem, a central marketing facility has been suggested (Mathis, 1990). An alternative, which could also be cheaper to establish and operate, would be to set up periodic local sales in the major cattle areas, organized with the support of the BLPA. Prices at such sales should be left to market forces: an earlier attempt (1969) to establish regional auction centres failed because of buyer resistance to the imposed retail price controls. Slaughter animals could also be sold. In addition they would provide an opportunity for extension work. With such opportunities as these available for the sale of immature stock, it should be possible to facilitate the marketing of underweight animals for finishing or breeding.

The Belize Meat's abattoir requires a throughput of 4000 head of cattle per year to cover its operating expenses; the 1990 level was less than a quarter of this. Given the current size of the national herd, it seems inevitable that it will be several years before the abattoir could become self-financing. Moreover, the relative efficiency is retarded by its outmoded cold storage and refrigeration facilities, raising doubts as to whether it is in the best interests of the cattle industry to encourage continuance of Belize Meat's operations in their present form.

In view of the inevitably limited amount of extension support that can be made available, the low local demand for fresh milk, and the fact that dairy farming requires a much higher standard of husbandry than beef, it seems desirable that beef production should rather be encouraged and that dairy development should be left to such private enterprise as may wish to practice it.

The prospects for the development of sylvo-pastoralism in the Mountain Pine Ridge seem limited.

PIGS

Present position

Pig products, in various forms, are an important component of many people's diet, but over 60% of them are imported. There are no large breeding or fattening enterprises in the project area, although it is common to have a few head, either housed or scavenging, for fattening (Figure 56). Major components of the feed used for both breeding and fattening stock are imported concentrates (brought in through Belize Feeds or Spanish Lookout) and a blend of local maize and sorghum. The cost of producing weaners and fattening stock is thus high relative

Figure 56

Sows and piglets, Chunox

to the price for slaughter stock. More use could be made, with advantage, of such locally available feed as sweet potatoes, cassava, yams, breadfruit, rice bran, molasses, copra cake, banana and plantain surpluses.

The current numbers of breeding stock are limited and there must therefore be a danger of inbreeding. The Department of Agriculture now recommends Duroc x Large White cross and Landrace x Large White or Landrace x crossbred. At Yo Creek station, two litters per year are obtained with nine weaners raised from each. Weaners are also available from several small commercial breeders. They are usually sold at 35-40 days. Piglets should be vaccinated against swine fever (hog cholera).

The second major constraint on the expansion of the pig industry is the difficulty of selling fat pigs and the marginal price received. The April 1990 prices offered by the Belize Meat's abattoir at Ladyville, are indicated in Table 48.

For the stock-keeper with only one or two animals for sale at a time, the cost and difficulty of arranging transport to the abattoir may preclude him from using it. Most pigs appear to be sold at 200-225 lb (90-102 kg) at a liveweight price in April 1990 of BZ$ 0.90 – 1.00/lb (BZ$ 1.98 – 2.20/kg). A higher return may be obtained when individual pigs are killed by the owner and sold among the local community, when almost every part of the animal is saleable.

Table 48

Pig prices offered by Belize Meat in April 1990

Gilts and barrows				Sows			
Liveweight		Price (BZ$)		Liveweight		Price (BZ$)	
lb	kg	per lb	per kg	lb	kg	per lb	per kg
150-180	68-82	1.25	2.75	150-300	68-136	0.90	1.98
181-250	83-114	1.20	2.64	301-350	137-159	0.85	1.87
251-300	114-136	1.15	2.53	351-400	160-182	0.80	1.76
301-350	137-159	1.10	2.42				

Development Potential

Improved housing and greater use of low-cost feed could increase profitability and probably production, which would reduce the current high level of imports of pig products.

SHRIMP MARICULTURE

Present position

The shrimp mariculture industry started in 1982. It has been characterized mainly by foreign ownership. The total national shrimp production from 1990 was 208,810 lb (94 714 kg).

The project area contains two mariculture facilities: located at Ladyville, one of which was established in 1986 and remains a pilot-scale venture. Although no shrimp were being produced at the time of writing, their 10 ac (4 ha) of ponds have recently been expanded to 40 ac (16 ha) and there are plans to secure financing. The other (Nova Companies Belize Ltd) is operating commercially with 200 ac (80 ha) of ponds.

In May 1990 the aggregate pond area for facilities equipped with both complete inlet and outlet structures was 219 acres (88.6 ha) for a total of 11 ponds. Investment in pond construction and selected infrastructure was reported in 1990 to run to some BZ$ 4000 per acre (BZ$ 10,000/ha) (of water), but much greater sums have been spent developing appropriate construction technology in earlier years. Limited success was achieved with shrimp maturation and spawning under artificial rearing conditions. Producers in the project area now import shrimp post larvae from producers in the USA and Panama to satisfy their stocking requirements. Post larvae are usually vaccinated against IHHN and bacillovirus before shipment to Belize.

Experience has been gained principally of three shrimp species, i.e. indigenous *Pennaeus schmitti* and two Pacific species: *Pennaeus vannamei* and *P. stylirostiros*. Early trials with *P. schmitti* (which could be obtained from local hatcheries) failed to provide satisfactory growth rates of feed conversion ratios. *P. stylirostiros* did not perform as satisfactorily as *P. vannamei*, the preferred species in mariculture operation elsewhere in Central America. Producers are currently stocking with *P. vannamei* with the objective of optimizing productivity for this species.

Various purpose-formulated feeds have been tried. The cost of importing feed from the USA to site is BZ$ 0.4-0.6/lb ($0.9-1.3/kg). If the industry expands, feeds should be formulated and marketed in Belize. Seed stock in the form of post larvae is currently sustaining operations. NOVA is establishing a hatchery.

Development potential

The criteria for shrimp production are pH 5-8.5, at least 25% clay, no risk of flooding, not too much vegetation, accessibility, no risk of pollution, access to the sea, salinity of 12-24 parts per thousand for production and 30-36 parts per thousand for the hatchery.

Given these criteria, the most suitable sites are the areas of current development north of Ladyville, in the Tok and especially the Puletan plains. To the north, many of the soils of the Corozal Saline Swamp are probably too shallow. Between Rocky Point and Consejo, the Consejo Plain soils will also be too shallow, but the Xaibe and Puluacax soils in the Xaibe Plain should be suitable although the pH is often above 8 (but according to the limited number of analyses, not above 8.5). South of Ladyville, the coastal land system is mainly Belize Saline Swamp, which is mostly unsuitable due to acidity, cost of vegetation clearance and the need to keep a coastal protection zone of mangrove.

Within the suitable areas, it has been technically demonstrated that shrimps can be grown in Belize. However, there has been under-performance, largely due to unsatisfactory relations between management and labour and unsound management decisions (Fisheries Department, 1990). Operations have generally been underplanned, and the plans that have been made have often not been adhered to. Investors have not realized that construction and development costs are higher than in the rest of Latin America, although these costs are outweighed by the proximity to the US market and access to the Caribbean Community market. Developers should budget for contingency costs.

Processing bottlenecks have also affected revenue. Most processing is done by the Northern Fisherman Co-operative Society Ltd., but it can only process 4000-5000 shrimp/day, whereas ponds produce 25,000-40,000 shrimps/day. Consequently, Nova is building its own plant which should be completed in August 1991.

There is a joint Government of Belize/World Bank shrimp mariculture project, which is considering funding about four medium-scale ventures. The medium and large ventures can afford to have their own technical advice, but an extension service will be needed for the smaller ventures. Belize can be considered to be between Pretto's (1985) third and fourth stages of aquacultural development: between beginning and accelerated development – some programmes are not entirely focussed and there is a shortage of trained personnel, but development is accelerating. The optimum scale of development has not yet been reached. Below average commercial lending rates would aid development.

Other potentially viable aquaculture species include *Tilapia* spp., red fish (*Sianops ocellatus*), catfish (*Ictalurus* spp.), bay snook (*Petenia splendida*) and crocodile (*Crocodylus acutus* and *C. moreleti*).

Central processing facilities for agricultural production

The principal processors of agricultural products in the project area are indicated in Table 49. Processors which ceased operation during the last decade include two winter vegetable cultivation, packing and export operations which went into receivership in 1987 and 1988 respectively; and BSI, Libertad which closed in 1985 to be replaced by Petrojam in 1989.

Whereas the diversity of processing facilities within the project area may be wider than in other parts of the country, it is not a motor for further diversification by existing farmers, but there may be scope to develop downstream production operations such as honey bottling and ethanol manufacture.

We consider national requirements for perishable farmer produce, particularly fresh fruits and vegetables, are already broadly met and that, other than through the development of out-of-season cropping patterns, there is little scope for expanding production for this market. However, should suitable processing facilities for these products, e.g. in the fields of deep freezing, freeze drying, and canning (all of which are energy-intensive), be developed, the potential offtake could be radically increased.

Import statistics (M.Palacio; 1990, personal communication) identify continuing heavy reliance upon imports to satisfy domestic demand for animal fats, shortening and vegetable oils. The imminent commissioning by Belize Soaps and Detergents Ltd. in Orange Walk town of a saponification plant (F. Cuello, 1990, personal communication) to process imported tallows and vegetable oils will lead to a further increase in this reliance, and adds weight to the case for undertaking further field trials to develop a viable oilseed industry. Recent developments in Mexico's and Guatemala's oilseed industries should be reviewed to identify possible opportunities for adapting practices to Belizean conditions.

Table 49

Principal processors of agricultural products

Enterprise	Activity	Location
BSI	Sugar Milling	Tower Hill
Petrojam	High test cane syrup manufacture	Libertad
Belize Farm Center Ltd. Grace Kennedy Belize Ltd.	Packing and export of red kidney beans	Belize City
Belize Meats Ltd* abbatoirs	Cattle & swine slaughter	Ladyville
Municipal and private abbatoirs	Cattle, swine and sheep slaughter	Several urban and rural locations
Sole traders/partnerships	Poultry and egg packing and distribution	Blue Creek Edenthal
Sole traders/partnerships	Rice milling	Shipyard
Northern Fishermen's Co-operative National Fishermen's Co-operative	Seafood processing for export (incl. cultured shrimp)	Belize City
Hummingbird Hershey Ltd.	Cocoa fermenting and drying for export	Good Living Camp, Cayo
San Andres Fruit Co.	Papaya packing for export	San Andres
Orange Walk Beekeepers' Co-operative	Honey purification and packing for export	Orange Walk
Northern Beekeepers' Co-operative	Honey purification and packing for export	Corozal
Gallon Jug Agro-industry Ltd	Grain drying and storage	Gallon Jug
Sole trader	Cashew roasting and retailing	Carmelita

Note: * Outside the project area but important to producers within the project area.

References

BACK, W., HANSHAW, B. B. and VAN DRIEL, J. N. (1984) Role of groundwater in shaping the eastern coastline of the Yucatan Peninsula, Mexico. In: *Groundwater as a Geomorphic Agent,* La Fleur, R. G. ed. Boston: Allen and Unwin, pp. 281-293.

BALDWIN, B. (1986). Geology of Belize. In: *A Collection of Papers Honouring Brewster Baldwin.* Harding, L. E. and Coney, D. J. eds. Middlebury College Press, pp. 15-24.

BARTLETT, A. S. and BARGHOORN, E. S. (1973) Phytogeographic studies of the Isthmus of Panama during the past 12,000 years. (A palynological study of the vegetational, climatic and see-level changes.) In: *Vegetational History of Northern Latin America.* Graham, A. ed. London: Elsevier, pp. 203-299.

BATESON, J. H. and HALL, I. H. S. (1977) *The Geology of the Maya Mountains, Belize.* London: HMSO.

BAUTISTA, A. P. (1987) *Onion Production.* Belmopan: Agricultural Information Unit.

BELIZE AGRI-BUSINESS COMPANY (BABCO) (1989) *Notes on Nursery and Field Operations for Onions.* Orange Walk: BABCO.

BIRCHALL, C. J. (1973) Soils and soil profile descriptions. In: *A Forest Inventory of part of the Mountain Pine Ridge, Belize.* Johnson, M. S. and Chaffey, D. R. eds. Land Resource Study 14, Land Resources Division, Tolworth, 12-13, 87-92.

BIRCHALL, C. J. and JENKIN, R. M. (1979) *The Soils of the Belize Valley.* Tolworth: Land Resources Development Centre.

BRADBEAR, N. (1984) Bees. *Biologist,* **31**: 4.

BURGETT, M. and FISHER, G. (1990) A Review of the Belizean Honey Bee Industry. Report to USAID, Belize.

CALDERBANK, G. (1968). *Mountain Pine Ridge Grazing Project.* Belize City: Department of Agriculture.

CARIBBEAN AGRICULTURAL RESEARCH AND DEVELOPMENT INSTITUTE (CARDI) (1989) *Annual Technical Report: Belize Unit, September 1988-August 1989.* Trinidad: CARDI.

CENTRAL STATISTICAL OFFICE (1989) *Abstract of Statistics.* Belmopan: Central Statistical Office.

CHARTER, C. F. (1940) *Report on the Sugar-cane Soils and Agriculture of the Corozal Region, British Honduras.* Belmopan: British Honduras Department of Agriculture.

CHARTER, C. F. (1941) *A Reconnaissance Survey of the Soils of British Honduras, North of the Central Metamorphic and Igneous Massif, with Special Reference to their Utilisation in Agriculture.* Trinidad: Imperial College of Tropical Agriculture.

CHRISTIAN, C. S. and STEWART, G. A. (1953) *General report on Survey of Katharine-Darwin Region, 1946.* Land Research Series 1, CSIRO, Australia.

CHRISTIANSEN, A. T. (1986) *Assessment and Comments on Soil Properties affecting Vegetable and Fruit Production in Orange Walk and Corozal Districts.* Belize: BABCO/USAID.

CINTRON, G. and SCHAEFFER-NOVELLI, Y. (1982) Mangrove forests: ecology and response to natural and non-induced stresses. In: *Coral Reefs, Seagrass Beds and Mangroves: Their Interaction in the Caribbean.* UNESCO Reports in Marine Science, Paris: UNESCO.

COLES, B. O. (1986) *Diversification in Sugar-cane Growing Areas: Farming Systems in Sugar-cane-Growing Areas of Belize.* Rome: FAO.

CORNEC, J. H. (1985) *Note on the Provisional Geological Map of Belize at the Scale of 1:250,000.* Belmopan: Petroleum Office.

CORNEC, J. H. (1986) *Provisional Geological Map of Belize.* Geology and Petroleum Office, Belmopan: Ministry of Natural Resources.

CORVEN, J., RAISNER, J. and KATHER, M. (1987) *Growing Cocoa in Belize.* Belmopan: Cocoa Development Project.

COX, S. (1989). *Master Plan for Ambergris Caye: Draft Final Report.* Warwick: Shankland Cox.

CUTLER, M. S. (1989) *Report on the United Nations Development Programme Socio-Economic Survey of the Belmopan Periphery Settlements.* Department of Anthropology, Austin: University of Texas Press.

DARCEL, F. C. (1952a) *A Reconnaissance Soil Survey of the South-western Section of the Mountain Pine Ridge.* Belmopan: British Honduras Department of Agriculture.

DARCEL, F. C. (1952b) *A Reconnaissance Soil Survey of the Northern Section of the Mountain Pine Ridge.* Belmopan: British Honduras Department of Agriculture.

DARCEL, F. C. (1952c) *A Reconnaissance Survey of Some Coconut Soils of British Honduras.* Belmopan: British Honduras Department of Agriculture.

DARCEL, F. C. (1952d) *The Characteristics of a Good Banana Soil, with Special References to the Stann Creek Valley, British Honduras.* Central Farm, British Honduras Department of Agriculture.

DARCH, J. P. (1981) The characteristics and orgin of sascab in northern Belize, Central America. *Zeitschrift für Geomorphologie N. F.* **25**: 400-419.

DARCH, J. P. (1981) The soils of Pulltrouser Swamp: classification and characteristics. In: *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture and settlement in Northern Belize.* Turner, B. L. and Harrison, P. D. eds. Austin: University of Texas Press.

DAVIS, J. (1940) The ecology and geologic role of mangroves in Florida. *Publication of Carnegie Institute,* **517**: 693-703.

DAVIS, J. (1943) *The Natural Features of Southern Florida.* Geological Bulletin **25**, Miami: The Florida Geological Survey.

DAY, M., NEAL, M., ROSEN C. and WOYTE, J. (1987a) Natural hazards and development problems. In: *Environment and Resources in the Hummingbird Karst.* Day, M. J. ed. Occasional Paper Series 2, Department of Geography, Milwaukee: University of Wisconsin.

DAY, M., NEAL, M., STEWART, N. and URICH, P. (1987b) Historical and contemporary land use: an overview. In: *Environment and Resources in the Hummingbird Karst.* Day, M. J. ed. Occasional Paper Series 2, Department of Geography, Milwaukee: University of Wisconsin.

DIXON, C. G. (1956) *Geology of Southern British Honduras with Notes on Adjacent Areas.* Belize City: Government Printer.

FANNING, D. S. and FANNING, M. C. B. (1989) *Soil: morphology, genesis and classification.* Chichester: J. Wiley and Sons.

FISHERIES DEPARTMENT (1990) *The Status of Aquaculture up to March 20th, 1990.* Belize City: Fisheries Department.

FLORES, G. (1952) Geology of northern British Honduras. *American Association of Petroleum Geologists Bulletin,* **36**: 404-409.

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO) (1971) *Guidelines to Soil Description.* Rome: FAO.

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO) (1976) *A Framework for Land Evaluation.* Rome: FAO.

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO) (1978) *Belize Forestry Development. Project Findings and Recommendations.* FO:DP/BZE/75/008, Rome: FAO.

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO) (1983) *Guidelines: Land Evaluation for Rainfed Agriculture.* Rome: FAO.

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO)/UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANISATION (UNESCO) (1974) *Soil Map of the World.* Volume 1: *Legend* Paris: UNESCO.

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS (FAO)/UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANISATION (UNESCO) (1988) *Soil Map of the World. Revised Legend.* Rome: FAO.

FORD, A. and FEDICK, S. L. (1988) *Draft Report on the Archaeological Resource Potential and Management of the Programme for Belize Lands, Orange Walk, Belize.* Meso American Research Center, Santa Barbara: University of California.

FOSTER, B. (1989) *Refugees and refugee-affected areas in Belize: Diagnosis and Strategies for Durable Solutions.* International Conference. Belmopan: Government of Belize.

FRANCEK, M. (1988) Earth pillar formation on the Mountain Pine Ridge, Belize. *Earth Surface Process and Landforms,* **13**: 183-186.

FRIEDMAN, G. M. (1964) Early diagnesis and lithication in carbonate sediments. *Journal of Sedimentary Petrology,* **34**: 777-813.

FROST, M. D. (1979) *Soils and Environment in Belize.* Special Belize Report II. San Bernardino: California State College.

FURLEY, P. A. (1968) *General Report, Expedition to British Honduras-Yucatan 1966.* Edinburgh: University of Edinburgh.

FURLEY, P. A. (1974a) Soil – slope – plant relationships in the northern Maya Mountains, Belize, Central America: The sequence over metamorphic sandstones and shales. *Journal of Biogeography,* **1**: 171-186.

FURLEY, P. A. (1974b) Soil – slope – plant relationships in the northern Maya Mountains, Belize, Central America: The sequence over phyllites and granites. *Journal of Biogeography,* **1**: 263-179.

FURLEY, P. A. (1987) The impact of forest clearance on the soils of tropical cone Karst. *Earth Surface Processes and Landforms,* **12**: 523-529.

GARCIA, P. (1989) Annual report for 1989. *Orange Walk Department of Agriculture.* Orange Walk: Department of Agriculture.

GEOLOGY AND PETROLEUM OFFICE (1986) *Petroleum Prospect and Potential of Concession Block-1 in Belize, Central America.* Belmopan: Geology and Petroleum Office.

GLEDHILL, D. (1983) The ecology of the Aberdeen Creek Mangrove Swamp. *Journal of Ecology*, **51**: 693-703.

GOMEZ-POMPA, A. and KAUS, A. (1987) *The conservation of resources by traditional cultures in the tropics*. September 1987, Colorado: World Wilderness Congress.

GOODBAN, J. W. D. (1952) A Report on the Coconut Industry, British Honduras, Belize City: Department of Agriculture.

GRAY, D. A., ZISMAN, S. A. and CORVES, C. (1990) *Mapping the Mangroves of Belize*. Technical Report. Edinburgh: University of Edinburgh.

HANKINS, A. C., QUAN, A. and CANTON, G. (1990) Assessing the direction of further crop diversification activities in Belize – the USAID role and strategy. Belize: USAID.

HARTSHORN, G., NICOLAIT, L., HARTSHORN, L., BEVIER, G., BRIGHTMAN, R., CAL, J., CAWICH, A., DAVIDSON, W., DUBOIS, R., DYER, C., GIBSON, J., HAWLEY, W., LEONARD, J., NICOLAIT, R., WYER, D., WHITE, H. and WRIGHT, A. C. S. (1984) *Belize Country Environmental Profile: A Field Study*. Belize City: Robert Nicolait and Associates Ltd.

HOLRIDGE, L. R. (1967) *Life Zone Ecology*. San Jose, Costa Rica: Tropical Science Centre.

JENKIN, R. N., ROSE INNES, R., DUNSMORE, J. R., WALKER, S. H., BIRCHALL, C. J. and BRIGGS, J. S. (1976) *The Agricultural Development Potential of the Belize Valley*. Tolworth: Land Resources Division.

JOHNSON, M. S. and CHAFFEY, D. R. (1973a) *An Inventory of Part of the Mountain Pine Ridge, Belize*. Tolworth: Land Resources Division.

JOHNSON, M. S. and CHAFFEY, D. R. (1973b) *An Inventory of the Chiquibul Forest Reserve, Belize*. Tolworth: Land Resources Division.

JOHNSON, W. C. (1983) The physical setting: northern Belize and Pulltrouser Swamp. In: *Pulltrouser Swamp: Ancient Maya Habitat, Agriculture and Settlement in Northern Belize*. Turner, B. L. and Harrison, P. D. ed. Austin: University of Texas Press.

JUAN, E., MALKUS, L. and WADE, N. (1983) *Using citrus, cocoa and sugar byproducts to feed cattle in Belize*. Belize: Belize Beef Corporation and Hummingbird Hershey.

KELLMAN, M. C. (1975) Evidence for Late Glacial age fire in a tropical montane savanna. *Journal of Biogeography*, **2**: 57-63.

KELLMAN, M. C. (1979) Soil enrichment by neotropical savanna trees. *Journal of Ecology*, **67**: 565-577.

KELLMAN, M. and MIYANASHI, K. (1982) Forest seedling establishment in neotropical savannas: observations and experiments in the Mountain Pine Ridge savanna, Belize. *Journal of Biogeography*, **9**: 193-206.

KELLMAN, M., MIYANASHI, K. and HERBERT, P. (1987) Nutrient sequestering by the understorey strata of natural *Pinus caribaea* stand subject to prescription burning. *Forest Ecology and Management*, **21**: 57-73.

KING, L. C. (1962) *Morphology of the Earth*. Edinburgh: Oliver and Boyd.

KING, R. B. (1970) A parametric approach to land system classification. *Geoderma*, **4**: 37-46.

KING, R. B., BAILLIE, I. C., BISSETT, P. G., GRIMBLE, R. J., JOHNSON, M. S. and SILVA, G. L. (1986) *Land Resource Survey of Toledo District, Belize*. Tolworth: Land Resources Development Centre.

KING, R. B., BAILLIE, I. C., DUNSMORE, J. R., GRIMBLE, R. J., JOHNSON, M. S. and WRIGHT, A. C. S. (1989) *Land Resource Assessment of Stann Creek District, Belize.* Bulletin 19, Chatham: Natural Resources Institute.

LUGO, A. and SNEDAKER, S. (1974) The ecology of mangroves. *Annual Review of Ecology and Systematics,* **5**: 39-63.

MATHIS, K. (1990) *Central Livestock Marketing Feasibility. Belize Livestock Development Project Phase II.* Stamford: IRI Research Institute.

MCCORMACK, D. E. (1986) *Soils of the Sugar-cane Areas of Northern Belize and Plans for Detailed Soil Survey.* TCP/BZE/4501 CA, Rome: FAO.

MCCORMACK, D. E. (1987) Soil Suitability Yalbac Ranch. In Manuscript.

MCKINZIE, W. E. (1979) *Soil Classification Belize River Valley Soils.* Belmopan: Department of Agriculture.

MIDWEST UNIVERSITIES CONSORTIUM FOR INTERNATIONAL ACTIVITIES INC. (MUCIA) (1988) *An Assessment of Belize's Agricultural Sector.* MUCIA/ USAID/Ministry of Agriculture.

MILLER, T. E. (1981) *Hydrochemistry, Hydrology and Morphology of the Caves Branch Karst, Belize.* Ph.D. Thesis, Hamilton: McMaster University.

MILLER, T. E. (1983) Hydrology and hydrochemistry of the Caves Branch Karst, Belize. *Journal of Hydrology,* **61**: 83-88.

MILLER, W. (1941) Internal Report, Belmopan: Belize Estate Co.

MINISTRY OF AGRICULTURE (1987) *1984-5 Agricultural Census.* Belmopan: Ministry of Agriculture.

MIYANASHI, K. and KELLMAN, M. (1988). Ecological and simulation studies of the responses of *Miconia ablicans* and *Clidemia servicea* populations to prescribed burning. *Forest Ecology and Management,* **23**: 121-137.

MONTERO, R. J. and JUAN, E. E. (1986) *The Feeding of Cocoa Pod Husk to Finisher Pigs.* Belmopan: Department of Agriculture.

MUNRO, D. M. (1983) Conservation of nature in Belize. In: *Resources and Development: An Account of the University of Edinburgh Expedition to Central America.* Furley, P. A. and Robinson, G. M. eds. Occasional Publications NS2, Department of Geography, Edinburgh: University of Edinburgh, pp. 139-156.

MUNRO, D. M. (1989) The secondary hardwood industry of Belize, In: *Advances in Environmental and Biogeographical Research in Belize,* (Furley, P. A. Ed) Biogeographical Monographs **3**, Edinburgh: Biogeographical Research Group.

OVERSEAS DEVELOPMENT ADMINISTRATION (ODA) (1989) *Tropical Forestry Action Plan, Belize.* London: Overseas Development Administration.

POST, T. and HAMSTRA, J. (1989) *Presentation on the Work of the Christian Reformed World Relief Committee Project in Corozal.* Paper presented to the Belize National Agricultural Research and Extension Council.

PRETTO, R. (1985) *Aquaculture and Rural Development: Training and Promotion.* RLAC/85/14-PES-6, Santiago: FAO.

PROGRAMME FOR BELIZE (1990) *Management Plan for the Rio Bravo Conservation and Management Area.* Belize City: Programme for Belize.

PROJECTO INTERNATIONAL INC. (1984) *Final Report: Export Market Survey of Belize Agricultural Products.* Report submitted to the Government of Belize and the Commonwealth Secretariat. Montreal: Projects International Inc.

PURSEGLOVE, J. W. (1968) *Tropical Crops: Dicotyledons.* London: Longmans.

QUINONES, H. and ALLENDE, R. (1974) Formation of the lithified carapace of calcareous nature which covers most of the Yucatan Peninsula and its relation to the soils and geomorphology of the region. *Tropical Agriculture (Trinidad)*, **51**: 94-101.

RABINOWITZ, D. (1978) Early growth of mangrove seedlings in Panama and an hypothesis concerning the relationship of dispersal and zoning. *Journal of Biogeography*, **5**: 113-133.

RANCHARAN, J. and CAWICH, A. (1989) Sugar-cane extension and technical support services to sugar farmers of Belize. Belmopan: *Eighth National Agricultural Research and Development Symposium*.

RDA INTERNATIONAL (1989) *A Feasibility Study for a Land Information System for Belize*. Report submitted to the Government of Belize.

ROMNEY, D. H. (1962) The fertility of lowland soils of British Honduras. *Journal of Experimental Agriculture*, **30**: 95-107.

SANDOM, J. H. (in preparation) *A Forest inventory of the Mountain Pine Ridge, Belize*. London: Overseas Development Administration.

SOIL MANAGEMENT SUPPORT SERVICES (SMSS) (1990) *Keys to Soil Taxonomy*. SMSS Technical Monograph 19, Blacksburg, Virginia: Virginia Polytechnic Institute and State University.

STANDLEY, P. C. and RECORD, S. J. (1936) *The Forests and Flora of British Honduras*. Publication 350, Field Museum of Natural History, Chicago.

STEELE, H., CAWICH, A., HAHN, D. C. and WILSON, L. G. (1988) *Evaluation of the USAID commercialisation of alternative crops project*. AID/LAC Project 505-0008, USAID, Belize City.

STODDART, D. R., BRYAN, G. W. and GIBBS, P. E. (1972) *Inland Mangroves and Water Chemistry, Barbuda, West Indies*. Cambridge: Cambridge University Press.

THOM, B. (1984) Coastal landforms and geomorphic processes. In: *The Mangrove Ecosystem: Research Methods*. Snedaker, S. and Snedaker, J. eds. Paris: UNESCO.

THORNTHWAITE, C. W. (1948) Approach towards a rational classification of climate. *Geographical Review*, **38**: 55-94.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA) (1975) *Soil Taxonomy*. USDA: Soil Conservation Service.

VALENCIA, E. and TERGAS, L. E. (1990) *Tropical Pasture Legumes for Livestock Production in Belize*. Belmopan: Department of Agriculture.

VERSEY, H. (1972) *Groundwater Sources for Public Saftey, Northern British Honduras*. Unpublished report to Water and severage Authority, Belize City.

VINIEGRA-O, F. (1971) Age and evolution of salt basins of south-eastern Mexico. *The American Association of Petroleum Geologists Bulletin*, **55**: 478-494.

VINSON, G. L. (1962) Upper Cretaceous and Tertiary stratigraphy of Guatemala. *The American Association of Petroleum Geologists Bulletin*, **46**: 425-456.

WAGNER, D. P., FOSS, J. E. and SNOW, P. A. (1987) *Soil Survey of the Hershey-Hummingbird Farm*. College Park, Maryland: Geoscience Consultants Inc.

WALKER, S. W. (1971) *Selected Daily Rainfall Data for Stations in British Honduras*. Unpublished reports 105, Tolworth: Land Resources Division.

WALKER, S. H. (1973) *Summary of Climatic Records for Belize*. Supplementary Report 3, Tolworth: Land Resources Division.

WEST, R. (1977) Tidal saltmarsh and mangal formations of middle and South America. In: *Wet Coastal Ecosystems*. Chapman, V. J. ed. Amsterdam: Scientific Publishing Co.

WILSON, K. (1981) *Mountain Pine Ridge Forest Reserve Inventory Update – Interim Report.* Belmopan: Internal Report, Forest Department.

WOLFFSOHN, A. L. A. (1956) *The Mountain Pine Ridge and Chiquibul Forest Working Plan, Period 1957-1963.* Belmopan: Internal Report, Forest Department.

WOOD, C. A. R. (1986) The cocoa tree. *Biologist,* **33**: 22.

WOODS, R. L., REID, S. T. and REID, A. M. (1988). *The Field Guide to Ambergris Caye, Belize, Central America including other Atolls.*

WOOLDRIDGE, S. W. and MORGAN, R. S. (1959) *An Outline of Geomorphology: The Basis of Geography.* London: Longmans.

WORLD BANK (1988) *Belize Economic Report. A World Bank Country Study.* Washington: World Bank.

WRIGHT, A. C. S. (1987) *Report on characterisation of Soils utilised in BABCO Trials, Orange Walk and Corozal Districts.* Unpublished report.

WRIGHT, A. C. S., RONMEY, D. H., ARBUCKLE, R. H. and VIAL, V. E. (1959) *Land in British Honduras.* London: HMSO.

WRIGHT, E. P. (1970) *Report on Urban Water Supplies for Orange Walk and Corozal Towns, British Honduras.* Unpublished, Keyworth, Nottingham: British Geological Survey.

ZETINA, E. (1990) *Sugar Cane Yield Varieties in Belize.* Paper presented to the Sugar Association of the Caribbean Sugar Technologists Meeting.

ZISMAN, S. (1989) *The Directory of Protected Areas and Sites of Nature Conservation Interests in Belize.* Occasional Publications 10, Department of Geography, Edinburgh: University of Edinburgh.

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