

# Forest cover and deforestation in Jamaica: an analysis of forest cover estimates over time<sup>1</sup>

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## SUMMARY

Forest cover and related deforestation data published in reputable international forest assessment documents during the past decade have characterised the island of Jamaica as having one of the world's highest rates of deforestation. An analysis of pre-1990 land use data together with a detailed study of 1989 and 1998 LANDSAT TM imagery of the island revealed that there were fundamental errors in the data used during the 1990s. A study by the Forestry Department and the Trees for Tomorrow Project found that the annual rate of deforestation for the period 1989–1998 was 0.1%, much less than had been previously estimated. This paper seeks to explain the variation in existing forest cover data, its change over time and to point to the need for more accurate and reliable data to be developed internally, based on a rigorous forest cover definition, forest type classification and monitoring methodology.

Keywords: deforestation, forest type classification, forest cover, forest monitoring, Jamaica.

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## INTRODUCTION

The island of Jamaica is located in the north-western Caribbean Sea and is centered on latitude 18° 15' N and longitude 77° 20' W. It is the third largest of the Greater Antillean islands and is approximately 230 km from east to west and 80 km wide with a total area of 10,900 km<sup>2</sup>.

The name 'Jamaica' is believed to be derived from the Taino word, Xaymaca, which means 'Land of Wood and Water'. When Christopher Columbus landed on the island in 1494, most of it was densely covered with forests, except for scattered clearings occupied by the Tainos (Swabey 1945). This dense vegetative growth would have protected the soil and supported the continuous surface flow of the island's many rivers and streams. After centuries of improper land use, the island has lost much of its natural vegetation and, as a consequence, is suffering major environmental problems such as flooding, soil erosion, destruction of wildlife and wildlife habitat, and decreased surface flows in streams and rivers (Cunningham 1993). Better land use management is needed to stop the vegetation loss.

In order to develop policies and plans to better manage the forests of Jamaica on a sustainable basis, timely, accurate and reliable data are needed on the extent and location of forest cover and its changes over time. Since 1972, the Food and Agriculture Organisation of the United Nations (FAO) has been the lead agency documenting areas of forest cover and deforestation rates in Jamaica. In fact, the first major forestland use/cover study in Jamaica was undertaken by a UNDP/FAO Project (Gray and Symes 1972). In recent years it has become evident that the statistics FAO published for many Caribbean countries, including Jamaica, were flawed.

Although the information came mainly from institutions within the countries themselves, there were fundamental problems associated with the data.

These data collection problems were addressed at a European Community/FAO sponsored workshop held in Trinidad in February 2000. The theme of the workshop centred on Data Collection and Outlook Effort for Forestry in the Caribbean, 16 Caribbean countries attended. A summary of some of the problems encountered by the countries and some of the recommendations made are as follows:

- The assessment of forest resources on a regular and systematic basis in most countries was not institutionalised. Most assessments were carried out on an ad hoc basis for specific purposes and with the support of external assistance.
- While all countries have some capacity to conduct forest assessments, institutional cooperation between agencies was not fully developed.
- In general, there is no organised system to collect, analyse and distribute forest resource data. However, in most countries, there exists informal research that needs to be formalised.
- The structure of data gathering and organisation has to follow national requirements and capacities. Well-defined national vegetation classification schemes need to be developed in order to facilitate data aggregation at regional and international levels.
- Local definitions should very clearly state their

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<sup>1</sup> A previous version of this text was presented at the Public Awareness Workshop, United Nations Convention on Desertification (30–31 March 2000) in Kingston, Jamaica.

quantitative and qualitative characteristics to facilitate regional and international data aggregations.

- FAO land use classes are not entirely compatible with the forest vegetation classes that occur in the Caribbean. As a result of this incompatibility, lands with similar woody vegetation were inconsistently assigned to the FAO classes.
- FAO classes must be used with caution and in conjunction with more detailed definitions of the forest classes in each country.

The above observations summarise some of the problems associated with the data FAO used in its publications. Deforestation data published in 1995 by FAO on Jamaica contained some of these problems and has caused much debate and controversy within the country. This has pointed to the need for more accurate and reliable data to be developed.

Factors such as the definition of ‘forest’ and ‘deforestation’, the different techniques used in the various land use/cover studies, and the purpose of these studies, have also led to a wide range of variations and inconsistencies in the data on the rate of change in the forests of Jamaica.

This paper reviews the existing studies on the estimate of forest cover in Jamaica and introduces a methodology for systematic and sustainable evaluation and monitoring of the Jamaican forests.

#### DEFINITIONS OF TERMS ‘FOREST’ AND ‘DEFORESTATION’

Evelyn (1997) pointed out in his report on deforestation in Jamaica that the different definitions of the terms ‘forest’ and ‘deforestation’ used in various land use/cover studies in Jamaica have created problems when comparing results of studies carried out in earlier periods to results of later studies. According to UNEP (1998), there are many definitions in use for what is classified as forested lands

and what definitions can be used to estimate the areas of trees outside forests. Table 1 lists some definitions used in the assessment of forests, particularly in Jamaica.

Similarly, there are many interpretations of the terms ‘deforestation’ and ‘forest degradation’. The following are the FAO definitions (FAO 2001a):

- **deforestation:** the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10% threshold.
- **forest degradation:** changes within the forest that negatively affect the structure or function of the stand or site, and thereby lower its capacity to supply products and/or services.

After reviewing the above definitions, it is clear that any meaningful comparison of two different land use/cover studies requires using the same definition of forest types and the same criteria for the vegetation interpretation and classification. However, almost all of the land use/cover studies carried out in Jamaica used different definitions for ‘forest’ and ‘forestland’. This has made it difficult to compare the results from the various studies, as outlined and analysed below.

#### FOREST COVER CHANGE OVER TIME

Forest cover change in Jamaica is relatively well documented, but the results are highly variable and the estimates of annual deforestation rates range from between 0.03 to 6.7% (Table 2). As hypothesised for Costa Rica’s forest cover estimates by Kleinn *et al.* (2000), the reasons for the differences in the forest cover estimates over time and the related deforestation rate are as follows:

- the definition of forest and the forest classes included (forest and/or wooded land);
- the reference area (entire country or region);
- the reference year (photograph/image production year or study publication year);

TABLE 1 *Definitions of forest*

| Definitions of forest   | Reference   |
|---|---|
| All lands with a forest cover (including bamboo and palm); i.e. with trees whose crown covers more than 20% of the area, and not used primarily for purposes other than forestry. Include areas temporarily unstocked and all plantations established for forestry purposes. Exclude isolated tree groups smaller than 0.5 hectare.   | FAO 1967. Definition used in the Gray & Symes (1972) land use/cover study in Jamaica.   |
| <b>Coniferous</b> – Forest stands including both coniferous and broad-leaved evergreens. The coniferous evergreens are commonly referred to as softwoods. The forest must have a 75% or more crown closure and be in stands of at least 16 hectares or more.<br><b>Deciduous</b> – Forest stands made of a mixture of various broadleaf species. The deciduous forest types must have a 75% or more crown closure and be in stands of at least sixteen hectares or more.  | CRIES 1982. Definition used in the Comprehensive Resource Inventory and Evaluation System (CRIES) Project (1982) and the Rural Physical Planning Department (1988) land use/cover studies in Jamaica. |
| Forest includes natural forests and forest plantations. The term is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m. Young stands that have not yet reached, but are expected to reach, a crown density of 10 percent and tree height of 5 m are included under forest, as are temporarily unstocked areas. | FAO 2001a. Definition used in the Forest Resources Assessment 2000.   |

TABLE 2 Studies of forest cover change in Jamaica

| Period/Region <sup>1</sup>                               | Annual rate (%) | Reference                                     |
|--|-----------------|---|
| ??? / Jamaica  | -3              | FAO/UNEP 1981 <i>In</i> Eyre 1987b            |
| ??? / Jamaica  | -3              | US Congress 1984 <i>In</i> Eyre 1987b         |
| ??? / Jamaica  | -2.05           | Allen & Barnes 1985 <i>In</i> Eyre 1987b      |
| ??? / Jamaica  | -3              | Aiken <i>et al.</i> 1986 <i>In</i> Eyre 1987b |
| 1980–1986 / Jamaica                                      | -3.3            | Eyre 1986, 1987b                              |
| 1980–1986 / Jamaica (Rural districts)                    | -4.3            | Eyre 1986, 1987b                              |
| 1980–1986 / Jamaica (Land altitude > 1000 m)             | -1              | Eyre 1986, 1987b                              |
| CRIES Studies 1981–1987 / Cockpit Country                | -2.8            | Eyre 1989 <i>In</i> Miller 1998               |
| ??? / Jamaica  | -5.3            | WRI 1994 <i>In</i> Eyre 1994, 1996            |
| 1980–1990 / Jamaica                                      | -5.3            | FAO 1995                                      |
| 1982–1993 / Hope & Upper Yallahs watersheds              | -1              | Graaff de 1997                                |
| 1990–1995 / Jamaica                                      | -6.7            | FAO 1998b                                     |
| 1961–1991 / Cockpit Country (Primary rainforest)         | -0.09           | Miller 1998                                   |
| 1961–1991 / Cockpit Country (Including secondary forest) | -0.03           | Miller 1998                                   |
| 1989–1998 / Jamaica                                      | -0.1            | FD-TFT 1999                                   |
| 1990–2000 / Jamaica                                      | -1.5            | FAO 2001a, 2001b                              |

<sup>1</sup> ??? symbol indicates no information concerning the period.

- the type of study (mapping or field sampling or both);
- the precision of the estimates (photographs or satellite imagery or field survey);
- the information sources used (traditional forest inventory or research plots); and
- the objectives of a particular study (agriculture, forestry or conservation).

**Forest cover estimation before 1950**

It is difficult to determine the area of forestlands before 1950 because the means of assessment were very limited and a clear definition of the term ‘forestlands’ or ‘tropical rainforests’ was not stated by the authors. Table 3 lists some estimates of the probable area of forests in Jamaica before 1950.

Eyre (1996) estimated that the depletion of tropical rainforest in Jamaica was 224,350 ha over a period of 300 years (1491 to 1791), which is approximately 748 ha or 0.17% per annum. The depletion of the forestlands area was 104,530 ha between 1886 and 1943, or approximately 0.57% per annum (Hooper 1886, Swabey 1945) and the forested lands covered approximately 20% of the island. It should be noted that Eyre’s figure for 1491 concerned only the forest zone named ‘tropical rainforest’ at that time. This zone was based on an estimation of the mean annual temperature (>23.8°C or <1,250 m in altitude) and rainfall

TABLE 3 Jamaica forest cover estimates before 1950

| Year | Forest lands (ha) | Tropical rainforests (ha) | Reference   |
|------|-------------------|---------------------------|-------------|
| 1491 |                   | 432,500                   | Eyre 1996   |
| 1791 |                   | 208,150                   | Eyre 1996   |
| 1886 | 323,760           |                           | Hooper 1886 |
| 1943 | 219,230           |                           | Swabey 1945 |

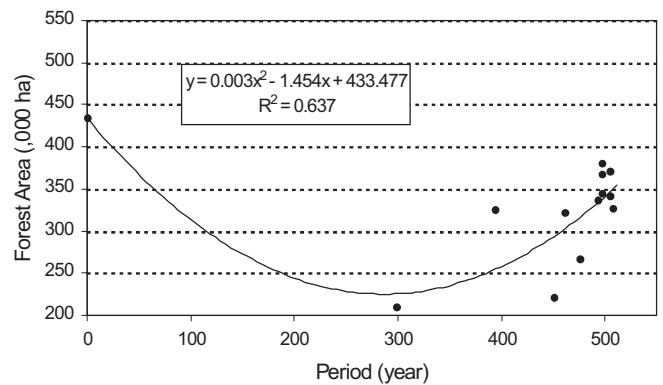


FIGURE 1 Trend of Forest Area Change in Jamaica from 1491 to 2000, excluding 1980 data

(number of weeks with rainfall > 50 mm/week). Therefore the total forest area was probably higher.

According to Eyre (1986, 1987b), there was a wave of forest clearance in the 18th century for plantation establishment in Jamaica. He also stated that ‘in the plantation era many parts of the country were considerably more bare of trees than presently’ (Eyre 1986). Also the mid to late 19th century seems to be the start of a period of substantial regrowth of forests mainly because of the decrease of human economic usage of land (Eyre 1987b; Higman 1988; Satchell 1990), i.e. probably the decrease of sugar cane production. The trend of forest cover change in Jamaica is shown in Figure 1. The same relative trend is hypothesised by Watts (1987) for some other countries in the West Indies.

**Forest cover estimation between 1950 and 1990**

This period was the beginning of systematic land use/cover studies using mainly remote sensing techniques. Four studies were carried out during this time using aerial

TABLE 4 Jamaica forest cover 1954–1985

| Year | Natural forest (ha) (%) | Forest plantation (ha) | Other wooded land (ha) | Total (ha) (%) | Reference                    |
|------|-------------------------|------------------------|------------------------|----------------|------------------------------|
| 1954 | 319,800 (29%)           |                        |                        | 319,800 (29%)  | DOS 1958 <i>In Eyre</i> 1986 |
| 1968 | 260,869 (24%)           | 4,131                  | 226,252                | 491,252 (45%)  | Gray and Symes 1972          |
| 1980 | 504,453 (46%)           | 3,709                  | 23,427                 | 531,589 (48%)  | CRIES 1982                   |
| 1985 | 329,114 (29%)           | 5,930                  | 218,282                | 553,326 (48%)  | RPPD 1988                    |

photographs taken in 1954, 1968, 1980 and 1985 respectively. The analysis of land use/cover changes has been undertaken by Eyre (1986) for the 1954 and 1980 data (with some ground truth investigations), by the Rural Physical Planning Division (RPPD 1988) for the 1980 and 1985 data, and by Evelyn (1997) for the 1968, 1980 and 1985 land use/cover data.

The objectives and the methodologies for the analysis of the land use/cover changes were different in each study. It is therefore very difficult to compare these studies and to form any conclusion about the depletion of forest cover in Jamaica. FAO used the 1980 data (Comprehensive Resource Inventory and Evaluation System (CRIES) Project 1982) and 1985 data (Rural Physical Planning Division (RPPD) 1988) and applied 'a modelling technique ... which makes use of ancillary variables (e.g. population density and ecological zone) correlated with forest cover area and its change in time' to derive the figures for Jamaica (5.29% per annum of deforestation) published in its *Forest Resource Assessment 1990* (FAO 1993).

Analysis of the data from 1980 and 1985 yielded a negative change (-175,339 ha) on the forest cover in Jamaica, that is, 35% depletion of Jamaican forests for the period (Table 4). Evelyn (1997) pointed out that the main problem with this analysis is the misclassification of the 'Dry limestone forest' areas (Portland Ridge in Clarendon, Hellshire Hills in St. Catherine, Long and Dallas Mountains in St. Andrew, and Albion in St. Thomas). Gray and Symes (1972) classified the dry limestone forest areas as 'Other wooded areas', while CRIES (1982) used 'Deciduous forest' (see definition in Table 1). A close analysis of the FAO definitions of what constitute forests would put 'Deciduous forest', as defined by the CRIES report, in the compilation of total forest areas while 'Other wooded' areas would not be included. This explains why the forested area reported for 1980 was so high; it included these 'Other wooded' areas.

In 1988, the RPPD reclassified the dry limestone forests as 'Brush', which is similar to the FAO definition of 'Other wooded', and this time correctly excluded these areas from the reported forested area figure submitted to FAO. The 'change' indicated between the CRIES and RPPD reports was therefore not a real change in forested area but a re-classification. This means that the forested area of 504,435 ha reported by CRIES in 1980 needed to be adjusted downwards by approximately 175,000 ha or the RPPD figure adjusted upwards by the same amount when comparing the figures for the two periods. If this situation had been brought to the attention of FAO, it would not

have reported such a large change in forest cover for Jamaica in its 1990 report.

Another classification anomaly noted in the CRIES study is that although it defines forest as '75% or more crown closure and be in stands of 16 ha or more' (see definitions in Table 1), the study identified the most forest area as shown in Table 4. It would be expected that, given the more restrictive definition of forest used, the CRIES study should have reported less forest areas than the other studies.

Eyre (1986) noted, quite correctly, that the Gray and Symes (1972) study and CRIES (1982) study were totally incompatible for a comparative analysis of the deforestation rate in Jamaica. This is so because the Gray and Symes study was designed to acquire forest data while the CRIES study was oriented to acquiring general land use knowledge of Jamaica. This is another cause for what appears to be an increase in forest cover between the period.

In 1986, Eyre also carried out a field study in 24 Jamaican districts to verify the rate of change in the forests. Using the 1980 data (CRIES 1982) as a baseline, he sampled 687 km<sup>2</sup>, about 13% of the forested area reported and derived an annual rate of deforestation of 3.3% for the period 1980 to 1986. However, as previously mentioned, the CRIES data contained errors and inconsistencies which needed to be accounted for in any analysis of forest cover.

The above discussion of available forest cover data shows that, except for the 1980 CRIES figure (see Table 4), the changes in forested area of Jamaica over the past few decades are not very large. The forested area varies between 24 to 29% of the country over the period of assessment. In fact, the percentage of natural forest for 1954 and 1985 (31 year period) is approximately the same, showing little change.

#### Forest cover estimation since 1990

Since 1990, three land use/cover studies have been carried out based on interpretation of 1989 and 1998 LANDSAT TM satellite images: The Nature Conservancy (TNC) (Grossman *et al.* 1992), the Forestry Department/Trees for Tomorrow Project (FD-TFT) (Forestry Department 1999) and in 2000, a new estimation was undertaken by TNC using the FD-TFT delineation of the 1998 satellite images and a new vegetation classification developed for the Caribbean Atlas Project (Li *et al.* 2000). Although all the studies used LANDSAT TM imagery, they nonetheless used different methods to classify land use/cover and different software for the interpretation, which would require some regrouping as that shown in Appendix 1 in order to compare the data. The compilation and comparison of forested area is set out

in Table 5. The difference in areas between the TNC (Grossman *et al.* 1992; Li *et al.* 2000) and the FD-TFT (1999) analyses is what would be expected and can be explained by the different systems that were used. These differences between the total forest area figures are not significant with only a 3% difference.

The FD-TFT assessment found that, because of the size and mountainous nature of the island, the limitations in image processing and classification techniques of LANDSAT TM technology (Richards 1986; Schowengerdt 1983), LANDSAT TM could only be used for broad national forest classification. The more detailed classification from these broad types, which is needed for operational and forest management plans, require the use of aerial photographs. The classification system that was developed by the FD-TFT, the definitions for the classes, and how they correspond to both the TNC and the FAO

classification systems, are outlined in Figure 2 and Appendix 1, respectively.

The new FD-TFT figure of forest cover has been accepted by FAO. It was used in the regression analysis and extrapolation for the 2000 estimates published in its publications *Forest Resources Assessment 2000 (FRA 2000)* and *State of the World's Forests 2001* (FAO 2001a; 2001b). The areas of natural forest and forest plantation, presented in these publications, represent 29.2% and 0.8% of the island of Jamaica, respectively (Table 5). The FD-TFT, TNC and FAO-FRA 2000 forest area figures show a close correlation.

A comparison between the total forest area estimates for the year 1990 presented in the FRA 1990 (FAO 1993, 1995) and in the FRA 2000 (FAO 2001a, 2001b) shows a difference of 49.2%, i.e. 254,000 ha (FRA 1990) versus 379,000 ha (FRA 2000). This large difference in the estimation is explained by changes in methodology for

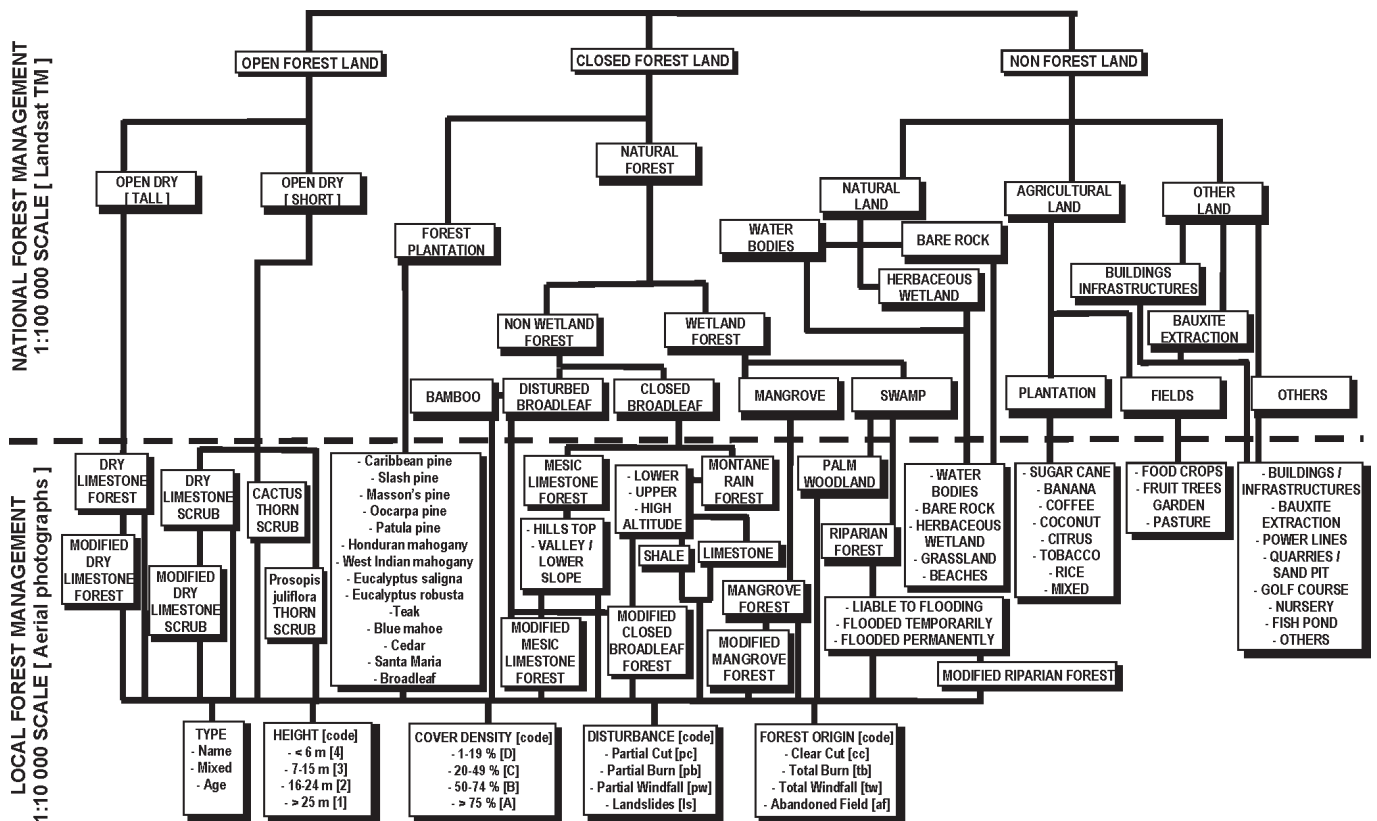


FIGURE 2 Diagram of land use/cover types hierarchical classification

TABLE 5 Jamaica forest cover 1988–2000

| Year    | Natural forest (ha) (%) | Forest (ha) (%)<br>plantation | Total forest (ha) (%) | Reference                         |
|---------|-------------------------|-------------------------------|-----------------------|-----------------------------------|
| 1988/89 | 362,012 (33.0%)         | 3,232 (0.3%)                  | 365,244 (33.3%)       | TNC/Grossman <i>et al.</i> 1992   |
| 1998    | 359,365 (32.8%)         | 10,227 (0.9%)                 | 369,592 (33.7%)       | TNC/Li <i>et al.</i> 2000         |
| 1989    | 335,079 (30.6%)         | 8,856 (0.8%)                  | 343,935 (31.4%)       | FD-TFT 1999                       |
| 1998    | 332,016 (30.3%)         | 8,187 (0.7%)                  | 340,203 (31.0%)       | FD-TFT 1999                       |
| 1990    |                         |                               | 379,000 (35.0%)       | FAO 2001b (FRA 2000) <sup>1</sup> |
| 2000    | 316,000 (29.2%)         | 9,000 (0.8%)                  | 325,000 (30.0%)       | FAO 2001b (FRA 2000)              |

<sup>1</sup> In the FRA 1990 (FAO 1993, 1995): Total forest 1990 = 254,000 ha (239,000 ha + 15,000 ha).

generating forest area change figures for developing countries. The FRA 1990 area and forest area change estimates were generated by means of a deforestation model, i.e. a forest area adjustment model using population density and growth (FAO 1993). The use of the model was discontinued for FRA 2000 after acknowledging that the correlation between forest area change and the demographic parameters used as model input was weak at the national level. The use of the model for forest area estimates may have overestimated deforestation figures for some tropical countries for the 1980s (FAO 2001c). In their study covering six countries of West Africa, including Ivory Coast with a deforestation rate of 7.3% in 1981–85, Fairhead and Leach (1998) suggest that twentieth-century deforestation rate in these countries is probably only one-third of that suggested by the international data in circulation.

For Jamaica, time series information showing high comparability between the observations (12 publications consulted), have been used for estimating the forest area change, i.e. the FRA 2000 area change has been estimated by means of extrapolation of existing data sets from two or more points in time (FAO 2001c). That explains the difference between the area change percentages of the FD-TFT (2 area values in time, 1989–1998) versus the FAO-FRA 2000 (a series of area values in time). The FAO

methodology needs a very careful analysis of each area value in time used to estimate the area change rate, particularly the baseline value.

#### A SYSTEM FOR MONITORING FOREST COVER

To prevent future problems created by using different definitions of land use/cover types and methodologies, the Forestry Department, assisted by the Trees for Tomorrow Project, is establishing protocols to permit the systematic evaluation of changes in forest cover in Jamaica. The Forest Act, 1996 charges the Department with the responsibility of preparing a National Forest Management and Conservation Plan, which should be revised at intervals of 'not more than five years'. The first plan was completed in 2001 and contains 'an inventory and description of forestlands' as the Act stipulated. The Department is therefore the agency mandated for the sustainable collection, analysis and distribution of forest cover data in Jamaica. The steps being taken by the Forestry Department in this direction are as follows:

- developed a national classification system for LANDSAT TM interpretation and aerial photographs;
- beginning in 1999, undertake vegetation interpretation

TABLE 6 Land use/cover change in Jamaica (1989–1998)

| Land use/cover types <sup>1</sup>                                       | 1989<br>(ha)     | 1998<br>(ha)     | Difference<br>(%) | Lost/Gain<br>(%) |
|---|------------------|------------------|-------------------|------------------|
| <b>Forest land use/cover (&gt;75%)</b>                                  |                  |                  |                   |                  |
| BB Bamboo   | 2,791            | 2,979            | 188               | 6.74             |
| MG Mangrove   | 9,751            | 9,731            | -20               | -0.21            |
| PF Closed Broadleaf   | 88,717           | 88,231           | -486              | -0.55            |
| SF Disturbed Broadleaf  | 177,254          | 174,725          | -2,530            | -1.43            |
| SL Short Open Dry   | 12,083           | 12,104           | 21                | 0.17             |
| SW Swamp  | 2,358            | 2,247            | -111              | -4.69            |
| WL Tall Open Dry  | 42,125           | 41,998           | -127              | -0.30            |
| Sub-total   | 335,079          | 332,015          | -3,064            | -0.91            |
| <b>Mixed land use/cover (first class &gt;50%; second class &gt;25%)</b> |                  |                  |                   |                  |
| BC Bamboo and Fields  | 29,818           | 29,047           | -772              | -2.59            |
| BF Bamboo and Disturbed broadleaf                                       | 12,311           | 12,687           | 376               | 3.05             |
| BS Bauxite and Disturbed broadleaf                                      | 1,590            | 2,960            | 1,370             | 86.13            |
| CS Fields and Disturbed broadleaf                                       | 118,898          | 117,966          | -932              | -0.78            |
| PP Fields/Disturbed broadleaf and Pine Plantation                       | 8,856            | 8,187            | -669              | -7.56            |
| SC Disturbed broadleaf and Fields                                       | 166,838          | 165,954          | -884              | -0.53            |
| Sub-total   | 338,312          | 336,801          | -1,511            | -0.45            |
| <b>Non-forest land use/cover</b>  |                  |                  |                   |                  |
| BA Buildings / Other infrastructure                                     | 51,910           | 52,260           | 350               | 0.67             |
| BE Bauxite extraction   | 1,193            | 4,922            | 3,729             | 312.47           |
| BR Bare rock  | 867              | 934              | 67                | 7.72             |
| FC Fields   | 273,176          | 274,479          | 1,303             | 0.48             |
| HW Herbaceous wetland   | 10,914           | 10,914           | 0                 | 0.00             |
| PC Plantations  | 83,145           | 82,341           | -804              | -0.97            |
| WA Water bodies   | 1,656            | 1,586            | -70               | -4.23            |
| SI Small islands  | 164              | 164              | 0                 | 0.00             |
| Sub-total   | 423,025          | 427,600          | 4,574             | 1.08             |
| <b>TOTAL</b>  | <b>1,096,416</b> | <b>1,096,416</b> | <b>0</b>          |                  |

<sup>1</sup> Definition of land use/cover types in Appendix 1.

of satellite images using the classification system developed;

- undertake interpretation using satellite images every 5 or 10 years with the same definition of vegetation types and the same methodology of interpretation;
- carry out periodic detailed analysis using aerial photography for management planning purposes and the monitoring of localised changes; and
- monitor any destructive changes that are taking place in the forests and develop mitigation measures to deal with them.

As a first step, an analysis of forest cover change over the period 1989 to 1998 was carried out by the FD-TFT using the following LANDSAT TM images:

- full scene 012/047 (10 Dec 1989), full scene 011/047 (03 Dec 1989) and quarter scene 011/047 (12 Nov 1990);
- full scene 012/047 (07 April 1998), quarter scene 012/047 (02 Feb 1998) and full scene 011/047 (04 Oct 1996).

The system developed for the LANDSAT TM interpretation was limited to a mapping scale of 1:100,000. The smallest area or polygon to be resolved was 25.0 ha. A supervised classification system was used and over 100 locations island-wide were visited for 'ground truthing' purposes (and photographed) and the coordinates taken by GPS for verification purposes. Aerial photographs (1991–92 1:15,000 and 1999 1:40,000) were also used to verify seven large blocks, which were very difficult to interpret because of

clouds and shadows. Table 6 gives the 1989 and 1998 land use/cover areas derived from the analysis.

The total change in the forestland use/cover classes over the period is a decrease of 3,064 ha or 0.91%. This gives a decrease of approximately 0.1% per annum (Table 6). The largest increase among all land use/cover classes is in the bauxite areas, which shows an overall increase of 5,099 ha (3,729 ha plus 1,370 ha). Approximately one-half of the new bauxite areas were probably originally agriculture fields (non-forestlands). This is understandable due to the fact that bauxite is traditionally extracted in the valleys, covered by pasture, citrus orchard, crops, evergreen forest or forest plantation, between the limestone hills (Scholten and Andriess 1986). In addition to the increase of the bauxite areas, the detailed study shows a net degradation of the forest cover, i.e. an increase of the mixed forest type with agriculture fields (Table 7). For instance, a significant area changes from the 'disturbed broadleaf forest' type to the 'disturbed broadleaf forest and fields' mixed type (2,018 ha). There has also been a significant increase in the proportion of agriculture fields in the mixed types, for example, 1,301 ha of 'disturbed broadleaf forest and fields' mixed type was re-classified to the 'fields and disturbed broadleaf forest' mixed type.

Over the last ten years a positive change in the forest areas has been noted in some Caribbean islands such as Cuba and Guadeloupe (FAO 2001a, 2001b). This has also been observed in Jamaica in the Buff Bay/Pencar Rivers watershed located in the north-eastern section of the island.

TABLE 7 Interchange matrix of land use/cover area in Jamaica (1989–1998)

| Land use/cover types <sup>1</sup> |    | Land use/cover 1989 |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | Total Gain (ha) | Difference 1998-1989 (ha) |    |        |   |
|-----------------------------------|----|---------------------|----|-----|-------|-----|-----|-------------|-------|-----|----|-------|-----|-------------|----|----|----|-------|----|-----------------|---------------------------|----|--------|---|
|                                   |    | Forest              |    |     |       |     |     | Mixed       |       |     |    |       |     | Non-forest  |    |    |    |       |    |                 |                           |    |        |   |
|                                   |    | BB                  | MG | PF  | SF    | SL  | SW  | WL          | BC    | BF  | BS | CS    | PP  | SC          | BA | BE | BR | FC    | HW | PC              | WA                        | SI |        |   |
| Forest                            | BB | 3                   |    |     |       |     |     | 139         |       |     |    |       |     | 46          |    |    |    |       |    | 188             | 188                       |    |        |   |
|                                   | MG |                     |    |     |       |     |     |             |       |     |    |       |     | 1           |    |    |    |       |    | 42              | -20                       |    |        |   |
|                                   | PF |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 0               | -486                      |    |        |   |
|                                   | SF | 396                 |    |     |       |     |     |             |       |     |    |       |     | 106 7       |    |    |    |       |    | 571             | -2,530                    |    |        |   |
|                                   | SL |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 227             | 21                        |    |        |   |
|                                   | SW |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 0               | -111                      |    |        |   |
|                                   | WL |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 6               | -127                      |    |        |   |
| Mixed                             | BC |                     |    |     |       |     |     | 193         |       |     |    |       |     | 16          |    |    |    |       |    | 299             | -772                      |    |        |   |
|                                   | BF |                     |    |     |       |     |     | 156         |       |     |    |       |     | 172         |    |    |    |       |    | 569             | 376                       |    |        |   |
|                                   | BS |                     |    |     |       |     |     |             |       |     |    |       |     | 230 911     |    |    |    |       |    | 1,370           | 1,370                     |    |        |   |
|                                   | CS |                     |    |     |       |     |     | 378         |       |     |    |       |     | 385 1,301 1 |    |    |    |       |    | 2,541           | -932                      |    |        |   |
|                                   | PP |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 0               | -669                      |    |        |   |
|                                   | SC | 90 2,018            |    |     |       |     |     |             |       |     |    |       |     | 357         |    |    |    |       |    | 2,573           | -884                      |    |        |   |
| Non-forest                        | BA | 85 31 105           |    |     |       |     |     | 27          |       |     |    |       |     | 76          |    |    |    |       |    | 351             | 350                       |    |        |   |
|                                   | BE |                     |    |     |       |     |     |             |       |     |    |       |     | 1,725 250   |    |    |    |       |    | 3,729           | 3,729                     |    |        |   |
|                                   | BR |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 67              | 67                        |    |        |   |
|                                   | FC | 62                  |    |     |       |     |     | 167 109 111 |       |     |    |       |     | 372         |    |    |    |       |    | 3,491           | 1,303                     |    |        |   |
|                                   | HW |                     |    |     |       |     |     |             |       |     |    |       |     | 979 89 947  |    |    |    |       |    | 0               | 0                         |    |        |   |
|                                   | PC |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 123             | -804                      |    |        |   |
|                                   | WA |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       |    | 47              | -70                       |    |        |   |
| SI                                |    |                     |    |     |       |     |     |             |       |     |    |       |     |             |    |    |    |       | 0  | 0               |                           |    |        |   |
| Total loss (ha)                   |    | 0                   | 62 | 486 | 3,101 | 206 | 111 | 133         | 1,071 | 193 | 0  | 3,472 | 669 | 3,457       | 1  | 0  | 0  | 2,188 | 0  | 931             | 117                       | 0  | 16,197 | 0 |

<sup>1</sup> Definition of land use/cover types in Appendix 1.

This area was selected as a pilot area by the Trees for Tomorrow Project in which detailed land use and socio-economic studies were undertaken. The area was mapped at a scale of 1:10,000 using aerial photographs and the land use analysis showed a positive change in forest areas of 0.26% per annum for the period of 1991 to 1999 (Forestry Department 2001b). These changes are mainly attributable to an increase of Caribbean pine (*Pinus caribaea* mor. var. *Hondurensis* Barr and Golf.) plantations (or areas regenerated) and an abandonment of cultivation fields (coffee and food crops).

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## APPENDIX 1 Definition of land use/cover types (1:100 000 scale – LANDSAT TM 1998)

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

<sup>1</sup> Grossman, Iremonger and Muchoney (1992), Muchoney, Iremonger and Wright (1994).<sup>2</sup> FAO (1998a, 1998c).

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