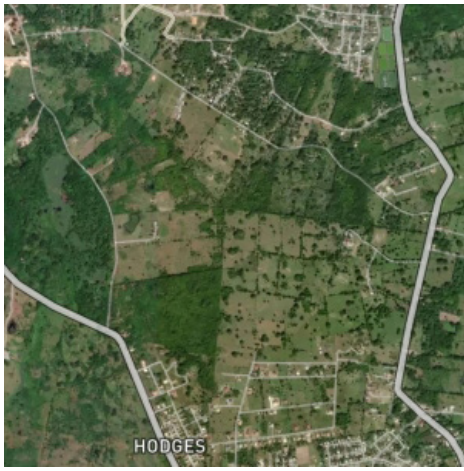


Forestry Department

Protecting our Forests; Sustaining Lives

STATE OF JAMAICA'S FORESTS 2024

A Comparative Assessment of Forest Change between 2013 & 2023

Telephone: (876) 618-3205
E-mail: fdinfo@forestry.gov.jm
Website: www.forestry.gov.jm

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

Jamaica's forest landscape has experienced transformative land use and cover changes driven by natural and human activities. The 2023 Land Use/ Land Cover change assessment comprehensively evaluates these changes, offering critical insights to support sustainable management, conservation, and urban planning efforts. This assessment builds on earlier initiatives, such as the foundational 1972 FAO study, which set baseline data for forest cover. Addressing historical discrepancies in deforestation rates, the Forestry Department adopted rigorous methodologies as mandated by the Forest Act of 1996, to enable this data-driven analysis.

Jamaica has seen significant shifts in forest cover over the decades, marked by both declines and recoveries. Between 1989 and 1998, forest cover declined slightly by 0.91%, largely due to increased bauxite extraction. However, the trend reversed between 2013 and 2023, with forest cover experiencing a remarkable 7.9% increase, reaching 527,394.51 hectares, which now accounts for 47.9% of the mainland's total area. A major factor in this recovery has been the regeneration of secondary forests on underutilized agricultural lands, adding approximately 7,380 hectares of forest annually. Jamaica's ecological and geospatial diversity is reflected in the distribution of various forest types across the island. Broadleaf Forests dominate parishes such as Trelawny, Portland, and St. Ann, while Kingston recorded no Closed or Disturbed Broadleaf Forests. Bamboo saw an extraordinary expansion of 473%, indicating significant vegetation changes. Additionally, unique forest types, such as

Swamp Forests, Mangroves, and Open Dry Forests, are concentrated in specific parishes, further showcasing the island's rich ecological diversity.

For the first time, urban tree cover was distinctly categorized in this assessment, separating green spaces within urban environments from infrastructure. This more accurate classification provides critical insights for advancing urban greening initiatives, essential for enhancing biodiversity, resilience and livability in urban areas.

While the increase in forest cover is encouraging, several challenges remain. Urban greening initiatives face significant gaps, with core urban areas underserved despite peri-urban areas meeting or exceeding the international recommendation of 30% tree cover. This highlights the need for targeted strategies to enhance tree coverage in densely populated urban centres. The recovery demonstrated by the expansion of Secondary Forests, remains vulnerable to external pressures, such as infrastructure expansion and renewed agricultural activity. These factors threaten the sustainability of regrowth areas, emphasizing the urgency for protective policies and sustainable land management practices. Furthermore, the rapid pace of land use changes in urban and agricultural regions necessitates regular updates to the dataset to maintain its relevance and accuracy for decision-making.

Strengthening forest management practices is crucial to sustain and build on recent gains in forest cover. Expanding protection and management efforts for secondary forests and regrowth areas will be key to preserving these positive trends. Urban greening initiatives must prioritize increasing tree cover in core urban areas to address biodiversity gaps and enhance sustainability. These efforts should align with international urban sustainability goals and contribute to national strategies like Vision 2030 Jamaica.

The LU-LC dataset is a robust foundation for evidence-based decision-making, supporting national and international environmental commitments, such as the Sustainable Development Goals (SDGs) and climate action frameworks. Protecting critical ecosystems like mangroves and swamp forests will strengthen Jamaica's resilience to climate change while preserving biodiversity.

The 2023 LU-LC assessment is a foundational tool for understanding Jamaica's evolving land use and forest dynamics. It provides actionable insights to guide evidence-based policymaking, conservation strategies, and urban planning. While the findings highlight positive trends, they also underscore the importance of sustained investment in forest management, urban greening, and data monitoring to ensure continued progress. By leveraging these insights, Jamaica can secure a sustainable and resilient future, meeting national and global environmental goals.

CHAPTER ONE
INTRODUCTION

INTRODUCTION

Jamaica possesses a diverse range of geographical features, including coastal plains, mountain ranges, and valleys. However, this beautiful landscape faces challenges such as deforestation, forest degradation and fragmentation, and the impacts of climate change. To address these issues, advanced technologies and robust methodologies were employed in the 2023 LU-LUCF Assessment to thoroughly examine the distribution, extent, and changes in land cover types across the country. By providing detailed insights and strategic guidance, this assessment aims to inform and shape sustainable land management practices, ensuring the preservation of Jamaica's environmental integrity and enhancing resilience in the face of evolving environmental challenges.

1.1 Background

The island of Jamaica, located in the Caribbean Sea between latitudes 17.9° N and 18.5° N and longitudes 76.2° W and 78.4° W and with a land area of 1,098,951.20 hectares (10,989 sq. km.), including the mainland and Goat Island. The Jamaica Information Service (JIS) however reports that the nation's total area is approximately 10,991 sq km (4,244 sq mi). The territory of Jamaica which is designated as an archipelagic state under the Maritime Areas Act, extends beyond its coastline to include about 66 islands, rocks, and cays. According to the Statistical Institute of Jamaica (2019), the country has a population of over 2.7 million people thus being the third most populous country in the Caribbean region. Administratively, Jamaica is divided into 14 parishes with its capital being Kingston.

While most of Jamaica's terrain is mountainous, with rugged landscapes and fertile valleys, there are also coastal plains and wetlands, particularly along the south of the island. The climate is predominantly tropical, characterized by warm temperatures year-round and distinct wet and dry seasons. Among the most important climatic influences are the Northeast Trade Winds, the central range of mountains which run east-southeast to west-southwest, the warm waters of the Caribbean Sea, and weather systems such as upper/low-level, low-pressure centres, troughs and cold fronts. This results in the island experiencing a humid subtropical climate along the coastline, while the interior mountainous regions a more temperate climate.

Although the Island boasts natural beauty with diverse ecosystems, Jamaica is confronted with a multitude of environmental challenges, such as deforestation and the dangers associated with the impacts of climate change. The effects of the changing climate

including, but not limited to, increasing temperatures, shifting rainfall patterns, warming oceans and more frequent extreme weather events, present significant threats to Jamaica's ecosystems, people, and economy. Specifically, the coastal regions of the country are at risk from sea-level rise, coastal erosion, and storm surges, endangering crucial infrastructure, agricultural lands, and coastal ecosystems. (Climate Studies Group Mona, 2021).

To address these environmental challenges, timely and accurate data on forest cover and deforestation rates in Jamaica is of utmost importance. Since 1972, the Food and Agriculture Organisation of the United Nations (FAO) has played a pivotal role in documenting forest cover and deforestation rates in Jamaica, with the first major land use/cover study undertaken by a UNDP/FAO Project in 1972. However, an analysis conducted by the Forestry Department and the Trees for Tomorrow Project (FD-TFT) found discrepancies in the data used during the 1990s, leading to the conclusion that Jamaica's annual deforestation rate from 1989 to 1998 was significantly lower than previously estimated (Evelyn & Camirand, 2003). This emphasised the importance of developing intra-organisational data that is both accurate and reliable, founded on rigorous methodologies and definitions.

The Forestry Department, mandated by the Forest Act of 1996, initiated conventions for the systematic evaluation of forest change and cover in Jamaica, culminating in the inaugural land use/land cover assessment in 1998. This 2023 LU-LUCF assessment aims to provide valuable updates and insights into Jamaica's land-use by analyzing the distribution, extent, and changes in land cover types across the nation. Given rapid urbanization and Kingston's impending climate departure, effective land use planning, zoning regulations, and ecosystem conservation measures are increasingly imperative in urban areas. This assessment presents an opportunity to initiate efforts in addressing the challenges through the mapping of Urban Tree or "Forest" Cover.

By leveraging advanced remote sensing technologies, Geographic Information Systems (GIS), and field surveys, researchers and policymakers can gain a comprehensive understanding of Jamaica's land cover dynamics to guide efforts at sustainable development.

1.2 Policies and Legislation

Jamaica's forests are managed by policies, laws and regulations designed to promote its sustainable usage and preservation. The Forestry Department collaborates with key governmental entities including but not limited to the National Land Agency (NLA), the Commission of Lands (COL), Jamaica Bauxite Institute (JBI) and the National Environment and Planning Agency (NEPA) to ensure the sustainable management, conservation,

revitalisation and utilization of forest resources.

The primary piece of legislation driving Jamaica's sustainable forest management efforts is the Forest Act of 1996 (currently being reviewed) which established the Forestry Department and provides the authority to enforce regulations, conduct forest assessments, and implement National Forest Management and Conservation Plans (NFMCP). The Act, supported by The Forest Regulations (2001) and the NFMCP, emphasises conserving biodiversity, protecting watersheds, and community involvement in forest management initiatives. Its primary objective is to strike a balance between preserving the environment and achieving socio-economic development goals. That is, ensuring that forest resources are used sustainably for both present and future generations.

Aligned with the National Forest Management and Conservation Plan is the Jamaica Forest Policy (2001), which provides a comprehensive framework for guiding forest management practices and decision-making processes. It recognises the significance of integrated approaches to land use planning, stakeholder engagement, and capacity building in addressing critical issues such as deforestation and the impacts of climate change (Forestry Department, 2001). The Forest Policy, 2001, also elaborates the GOJ's commitment to sustainability through the "no- net-loss" policy statement.

The Agency manages estates, which are held by the Commissioner of Lands at the National Land Agency (NLA) who is responsible for overseeing land tenure and the administration of state-owned lands. The duties of the NLA also encompass land registration, valuation, and management, along with overseeing the distribution and sale of these lands.[1]

The National Environment and Planning Agency is empowered through Natural Resources Conservation Authority and the Town and Country Planning Authority as the premier entity tasked with the wholistic protection of the natural environment in Jamaica.[2]

The mutual aim of these agencies, policies, and legislations is to give priority to the conservation and protection of forest cover, the attendant biodiversity, and the range of ecosystem functions. Additionally, the legal framework enables active collaborative partnerships, community participation, and the integration of sustainable development principles in land use planning.

1 The Crown Property Act, The Registration of Titles Act and The Land Valuation Act - are the legislative framework under which the Commissioner of Lands operate.

2 The Natural Resources Conservation Authority Act (1991), The Wildlife Protection Act (1945), The Town and Country Planning Act (1958), The Watershed Protection Act 1963), and The Endangered Species (Protection, Conservation and Regulation of Trade) Act (2000) are the legislative framework under which the NEPA operates in its role of protecting Jamaica's natural resources inclusive of Forests to guide their decision-making processes and foster the implementation of sustainable development practices.

1.3 The Importance of Forest Cover in the Jamaican Context

The significance of forests, forest and tree cover in Jamaica cannot be overstated as it has always played a crucial role in the country's history, environmental sustainability, and economic well-being. From the time of the indigenous Taino people to present day Jamaica, forests have provided essential resources for survival, protection, community and spiritual connection.

Unfortunately, the advent of colonization and the introduction of sugar plantations and other 17th century agricultural practices/production led to widespread deforestation. This period of significant reduction in forest cover and entrenched legacy of land conversion continues to affect Jamaica's forests, due to agriculture and infrastructure development in support of urbanisation.

Culturally, the fusion of African spiritual traditions and herbal practices from the plethora of ethnicities in Jamaica resulted in a syncretic belief system that emphasized the importance of nature in healing and safeguarding individuals. Within forests, valuable ancestral wisdom was preserved, with medicinal remedies handed down from one generation to the next to promote overall health and wellness.

The significance of forests and their resources in Jamaica is therefore deeply rooted in the country's history and culture. They have been integral to the cultural identity and societal resilience of Jamaica, reflecting a synergy of indigenous wisdom, colonial exploitation, and cultural resilience. As custodians of Jamaica's natural heritage, it is crucial to acknowledge the historical importance of forests and adopt sustainable management practices that respect their ecological and cultural value.

In addition to their cultural, spiritual and medicinal importance, forests in Jamaica have played a vital role in sustaining the country's agrarian economy. Rural communities have relied on forest resources for subsistence farming, gathering wild fruits, and hunting game. These forests have provided essential ecosystem services such as promoting soil fertility, facilitating water regulation, and climate moderation. These services have always supported agricultural productivity and rural livelihoods in forest-dependent communities.

Jamaica's forests have also made substantial contributions to the economy, as the island's natural beauty, including its forests, beaches, and waterfalls, attracts tourists from all over the world making them particularly important for the tourism and ecotourism sectors. Forest Reserves like the Blue and John Crow Mountains (which include the National Park) and the Cockpit Country are popular destinations for eco-tourists seeking adventure and

nature-based experiences. Additionally, Jamaica's forests support the local timber industry, providing valuable resources for construction, furniture-making, and craft production.

1.4 Historical Forest Cover, 1989-2013

The modern assessment, analysis and investigation of Jamaica's forest cover commenced in 1989 with the seminal work done by the UNDP/FAO which catalysed the Forestry Department to enshrine the documentation of forest cover and deforestation rates in Jamaica.

Jamaica's forest landscape has undergone significant changes in land use and land cover over the years and between 1989 to 2013, the Agency conducted two Land Use/Land Cover change assessments: one in 1998, analyzing changes between 1989 and 1998, and another in 2013, assessing changes between 1998 and 2013. Historical data regarding forest transformation offers valuable perspectives and background that allow for the recognition of enduring patterns in forest cover and land use. This in turn assists in evaluating previous conservation strategies, predicting future changes, and guiding the decision-making process.

In 1989, the total forest cover on the island was recorded at 343,935 ha., less than ten years later in 1998, there was a decline of 0.91%, equivalent to an average deforestation rate of 0.1% per annum. As a result, the forest cover in 1998 was 340,202 ha. Bauxite extraction had the most significant impact on this trend, with a 312% increase during this decade due to increased international demand for bauxite, which led to both agricultural and forested land being impacted. Some of the new bauxite mining areas were established by the clearing of forested areas, as such, bauxite mining was responsible for the largest removal of forest cover. There was also a noticeable deterioration in forest cover, marked by the shift from "disturbed broadleaf forest" to a mixed type of "disturbed broadleaf forest and fields".

Despite these challenges, positive changes were observed in certain regions, such as the Buff Bay/Pencar Rivers watershed, where the forest area expanded on average by 0.26% annually. This was mainly due to the expansion of Caribbean pine plantations and the abandonment of cultivation fields.

Conversely, the period 1998 to 2013 was marked by an average annual 0.4% gain in forest cover, with approximately 40% (431,611.78 hectares) of the mainland categorized as forest, in comparison to the 30% (332,015 ha) recorded in 1998.[3] Nevertheless, this expansion was

3 Note: Bamboo, an invasive grass species, was not included in the 2013 forest cover percentages but was geospatially determined.

attributed to advancements in technology and the application of higher-resolution satellite imagery rather than actual expansion of forested areas. These advancements facilitated the detection and classification of secondary forest as a new land cover class. Disturbed broadleaf forests made up a significant 59% of the overall forest cover in 2013, whereas Closed Broadleaf Forests, representing ~19% of the total land area, declined by 4.1% when compared to the 1998 data. The period 1998 to 2013 also saw the transformation of Swamp Forests into non-forest land uses, primarily due to the expansion of agriculture and the addition of physical infrastructure (tourism and transportation).

Table 1: Jamaica Forest Cover 1989-2013

Year	Natural Forest (ha) (%)	Plantation Forest (ha) (%)	Total Forest (ha) (%)	Mean Annual Rate Change	Source
1989	335,079 (30.6%)	8,856 (0.8%)	343,935 (31.4%)	-	FD-TFT
1998	332,015 (30.3%)	8,187 (0.7%)	340,202 (31%)	-0.1%	FD-TFT
2013	431,611.7 (39.3%)	8,318 (0.8%)	439,929.6 (40%)	0.4%	FD

1.6 Emissions Profile

Climate change refers to any significant departure from the average measurement recorded for climate markers such as precipitation and temperature. Over the last decade, climate change has proven to be among the most urgent and far-reaching environmental emergencies affecting the global community. Its ability to create complex disasters that simultaneously affect social, financial, and environmental systems underscores the need for swift action to achieve stated targets of Net Zero emissions by 2050.

Historical exploitation of fossil fuels to support industrialization and urban development has resulted in climbing emissions levels, with carbon dioxide increasing globally from 315 ppm in 1958 to 423 ppm in January 2024 (NASA 2024). As the primary greenhouse gas emitted from human activities, this marked increase holds implications for climate projections. Forests are recognised as playing a crucial role in achieving Net Zero emissions by offsetting emissions from human activities. Utilization of policies, frameworks and international agreements provides support for regulations, incentives and actions that can drive sustainable management practices and promote global cooperation to mitigate the impacts of climate change.

Historically, Jamaica has relied heavily on imported petroleum products for power generation. In 1994, 99% of commercial energy consumption was provided using petroleum and coal (National Environment and Planning Agency, 1995). The country has, however,

made progress in tackling climate change and cutting emissions by implementing a range of policies, strategies, and becoming a signatory to various international agreements. The country's dedication to shifting towards a low-carbon and resilient economy is evident through initiatives including the 1995 Energy Policy, Jamaica's National Energy Policy 2009 – 2030, the National Policy on Climate Change, the National Development Plan Vision 2030, and active participation in global efforts such as the Paris Agreement. According to the National Renewable Energy Laboratory (2015), by 2013, only 77% of energy generated was reliant on heavy fuel oil (p.2).

Furthermore, the outcomes of these initiatives can be seen in the UNFCC Emission Summary Report (n.d) which showed a steady decline in overall GHG emissions, excluding Land Use, Land Use Change, and Forestry (LU-LUCF) or Land Use Change and Forestry (LUCF) from 1994 to 2012. There was a 24.47% decline in total GHG emissions from 1994 to 2008, indicating a positive downward trend. Similarly, CO2 emissions dropped by a further 30.71% from 2008 to 2012, demonstrating continuous progress in emission control efforts. Unfortunately, during the period from 1994 to 2008, the net CO2 and GHG emissions associated with LU-LUCF exhibited a considerable increase, reaching 877.25%, there was however, a slight decrease of 0.37% by 2012, indicating potential challenges in managing land use and forestry during that timeframe.

Internationally, the REDD+ framework was created after 2012 as a solution for climate change mitigation by the parties involved in the United Nations Framework Convention on Climate Change (UNFCCC). REDD+ is an optional approach for climate change mitigation supported by the UN-REDD Programme, which encourages developing countries to decrease CO2 and GHG emissions from deforestation and forest degradation. Additionally, it promotes the protection of forest carbon stocks, responsible management of forests, and increasing forest carbon stocks. Developing countries, that are parties to the agreement, are assisted in building the necessary technical capabilities to carry out REDD+ and fulfil the UNFCCC criteria for receiving payments based on REDD+ results. Jamaica is a beneficiary and is in the preliminary phase of the "Readiness" stage.

Jamaica's efforts to curb GHG emissions, particularly in sectors contributing to CO2 emissions is evident and despite ongoing challenges such as fluctuations in land use and forestry practices, the data indicates a positive trajectory towards achieving emission reduction goals and fostering sustainable development. The sustainable management of forests and tree/forest cover will play an increasingly important role in these efforts and will enhance the resilience of both the built and natural environments in Jamaica.

CHAPTER TWO
MATERIALS AND METHODOLOGY

MATERIALS AND METHODOLOGY

2.1 Image Acquisition And Processing

The Forestry Department procured 2019-2021 satellite images from Airbus, which were used to assess changes in land-use and land-cover. These images, provided as single-scene, pan-sharpened satellite imagery with a resolution of 0.5 m and a size of 1TB, were carefully chosen for regions in Jamaica that were experiencing high land use conversions. The decision to use images from 2019-2021 was based on cost considerations and cloud coverage. Subsequently, the Agency used its EBX drone to capture additional images in 2022 for Grid 27E and 27F, which encompassed sections of Falmouth and its surrounding areas. It should be noted that during the 2023 LULC pilot study, the land use/land cover for this region was previously classified and hence provided a solid basis for comparison of methods.

In areas with lower rates of change, NICFI images with a resolution of 5m, distributed as a grid of Geo TIFF files called "base map quads," were utilized. All aerial images were projected into the JAD2001 coordinate system. The Airbus and NICFI satellite images were subset and mosaiced into 142 tiles using a 1:2500 Jamaica index grid and subsequently grouped into three blocks delineating the eastern, central, and western parts of the island.

These tasks were executed using the Erdas Imagine software and then the Pix4D was used to conduct aerial triangulation, orthorectification and mosaicking of all UAV images. **Table 2** provides a summary of imagery used in the 2023 LU-LUCF Assessment.

Table 2: Summary of Imagery used in the 2023 LU-LUCF Assessment

Source	Resolution	Capture Period	Description
Airbus	50 cm	2019-2022	Single-scene pan-sharpened satellite imagery with a resolution of 50 cm. Used for regions undergoing obvious land use conversions
Forestry Dept -EBEEX Drone	12 cm	2022	UAV images captured in 2022 for Grid 27E and 27F, covering sections of Falmouth and its surrounding areas. Previously classified during the 2023 LULCA pilot study.

Table 2: Summary of Imagery used in the 2023 LU-LUCF Assessment

Source	Resolution	Capture Period	Description
NICFI Images	5m	2022	GeoTIFF files, known as "base map quads," are distributed as a grid with a resolution of 5m. Utilized in regions with lower change rates.

2.2 Classification Methodology

2.2.1 Supervised Classification

The ArcMap extension 'Feature Analyst' facilitated supervised classification and automatic feature extraction enabling accurate mapping and analysis of land cover features. The first step of supervised classification involved training the algorithm of the feature analyst tool to classify pixels based on predefined spectral signatures. During this process, known spectral signatures representing various land cover classes were used to teach the tool to recognise and classify similar features within the imagery. The previous 2013 Land Use, Land-Use Change, and Forestry (LU-LUCF) assessment conducted by the Agency was a guide for developing spectral signatures for the 2023 assessment.

2.2.3 Automatic Feature Extraction

The second step, automatic feature extraction, relied on the trained algorithm to automatically analyze, identify, and delineate land cover types such as water bodies, forests, and buildings into distinct classes. Areas of distinct features were delineated and assigned codes according to the national classification system established by the Agency **(Appendix 1)**. A total of 28 land cover and land use classes were detected.

For this assessment, a minimum mapping unit (MMU) of 0.5 ha was established for Forest Cover, Mixed Land Use and Cover, and Non-Forest Land Use and Cover. However, in recognition of the heightened significance of precise delineation of land use and cover in urban landscapes, particularly for features such as Urban Tree Cover, Buildings and Other Infrastructure, a finer MMU of 0.0025 ha was applied.

2.2.4 Manual Editing And Digitization

Following the 2023 pilot study, achieving 85% or higher accuracy of the land use/land cover dataset necessitated manual editing after automatic extraction. This task was done using the ArcMap editing toolset from the ArcGIS Suite. The output of the land use and

land cover classes was thoroughly examined through the QA/QC stage, rectifying any misclassifications and manually digitizing complex features that might not have been precisely captured by the automated algorithm.

2.3 Reliability And Accuracy Assessment

To ensure the reliability and accuracy of the assessment, the island of Jamaica was divided into four (4) blocks on which the accuracy assessment was conducted **(Figure 1)**. The accuracy of the land use/cover dataset was evaluated using the confusion matrix and kappa coefficient.

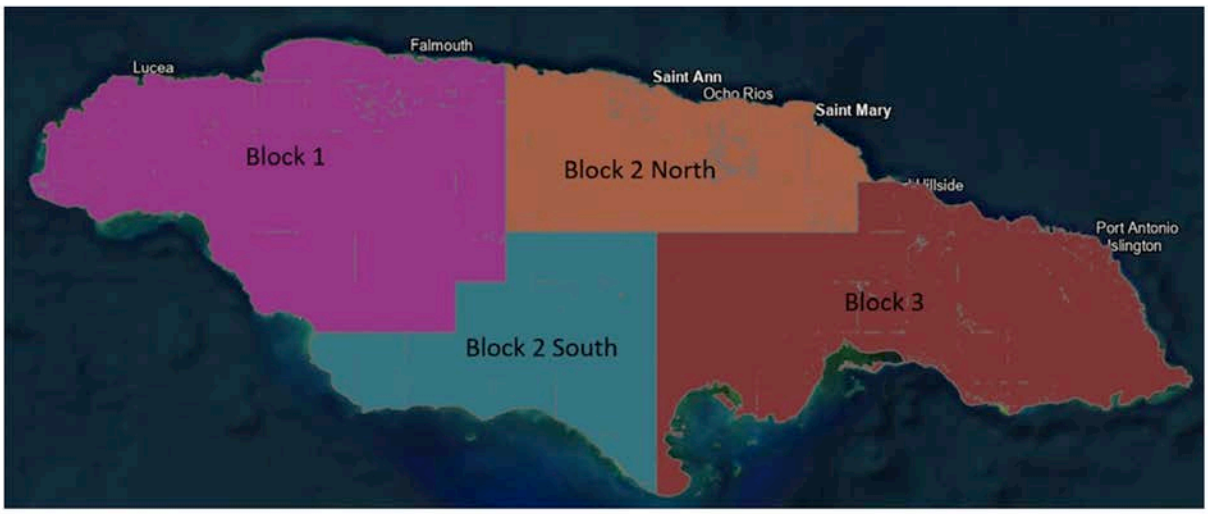


Figure 1: The study area is divided into four (4) Classification and Assessment Blocks.

The confusion matrix offers a comprehensive breakdown of all land use and land cover classifications, comparing them to ground truthed or referenced data. It shows the accurate number of pixels classified correctly for each class, along with any instances of misclassifications (Foody, 2002). The Kappa Coefficient is a statistical measure that quantifies the agreement between observed and expected classification results while accounting for the agreement that would be expected by chance alone (Congalton & Green, 2020). Essentially, the confusion matrix produces the raw data needed for computing the kappa coefficient. The kappa coefficient in turn offers a concise and understandable metric for assessing classification accuracy while considering the distribution of classification errors among various classes.

The results and discussion of the confusion matrix and kappa coefficient can be viewed in **Appendix 2**.

2.4 Data Validity

To guarantee precision, comprehensiveness, uniformity, and data integrity, three tiers of verification/validation were conducted, before, during, and after the classification process. This procedure involved evaluating the data's structure, characteristics, topological, spatial, and attribute uniformity. Subsequently, any identified inconsistencies or irregularities were rectified and re-verified. In-house data collected by the field team was used as a part of the verification process. Areas of uncertainty were sent for field verification. These areas included regions of previous uncertainty or where clouds or shadows and transition zones between high and low change areas obscured features on the ground.

The next step in the accuracy assessment involved estimating the image classification accuracy by comparing the classified map with a reference. The assessment encompassed overall accuracy, user accuracy, and producer accuracy. These results were analyzed using the confusion matrix and Kappa coefficient (Tewabe & Fentahun, 2020). If a Kappa value of 85% or higher was attained, validation would not be necessary. A range of 3-34 pixels per class was observed, with these values contributing to the final statistical results.

Finally, in cases where the achieved Kappa value fell below the desired threshold, areas were cross-referenced with satellite imagery and archival data to inform the accuracy of the classification. Any misclassified areas were adjusted by splitting, merging, or relabeling to represent the respective classes accurately. Figure 2 below shows the breakdown of the LU-LUCF production line.

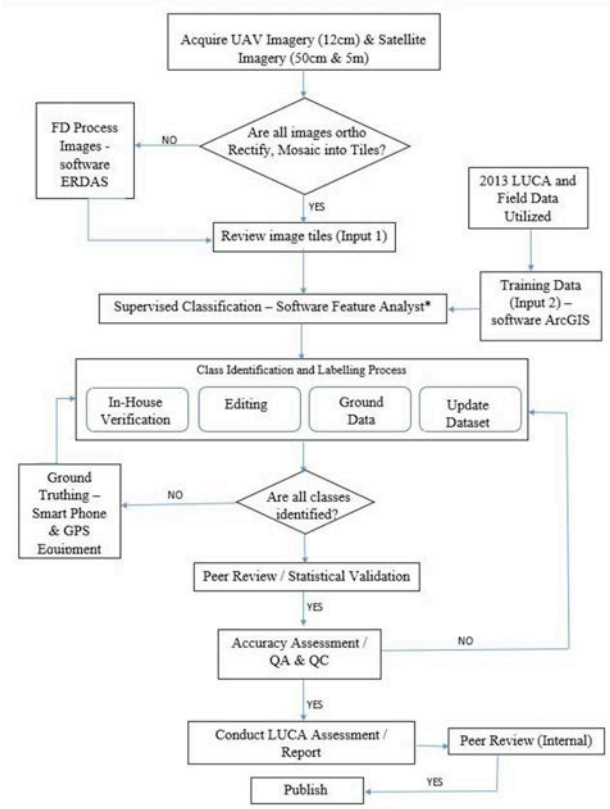


Figure 2: The Breakdown of the LU-LUCF Prodcuction Line

2.5 Reference Data

Reference sources were consulted to establish appropriate thresholds for assessing the confusion matrix and kappa coefficient. The reference dataset must be a representative sample of points or polygons with known land cover classes. The study used ground verification points, Google Earth Open-Source time-series imagery, provided by Maxar Technologies and CNES/ Airbus, and the 2013 land use land cover dataset as reference sources. In the 2023 LU-LUCF assessment, four main land cover classes required verification, namely, mangrove, secondary, broadleaf and open dry forest.

2.6 Sample Design

The confusion matrix was carried out by using individual pixels as the sampling unit. It is crucial to carefully determine the sample size to ensure statistical validity throughout the process. Any accuracy assessment requires enough samples to statistically validate the accuracy of land use/land cover classification. A total of 396-pixel point samples was calculated to fill the error matrix across Jamaica through a random stratified sampling approach. Random stratified sampling is preferred over other methods for calculating the kappa coefficient because it ensures that the observations included in the sample are

diverse and representative of the entire LU-LUCF, which is crucial for obtaining accurate estimates of agreement between raters. The minimum sample size was determined by applying the multinomial distribution formula provided below:

$$n = \frac{(z^2 \times p \times (1-p))}{E^2}$$

Where:

n = required sample size
z = z-score corresponding to the desired confidence level
p = probability of success for each LULC class
E = margin of error

2.7 Land Use And Cover Change Matrix

The Land Use and Cover Change (LULC) matrix was conducted to examine spatial changes in land use patterns between 2013-2023. An overlay analysis was performed using the intersect tool from ArcMap's Spatial Analyst Toolbox to merge the land use/land cover datasets for 2013 and 2023. These datasets were classified, with each land use/cover class assigned a distinct identifier or code, as shown in **Appendix 8**. The intersect tool merges the attribute data of the datasets where they spatially overlap, facilitating the comparison of land use/cover categories between the two time periods. The area for each unique transition was computed using attribute data and then summarised as a table using the summary function within the software.

Subsequently, the LULC matrix was populated with this data, enabling insights into significant land use/cover changes, determination of net changes, and comprehension of the driving factors behind these changes.

CHAPTER THREE

RESULTS, ANALYSIS AND INTERPRETATION OF DATA

RESULTS, ANALYSIS AND INTERPRETATION OF DATA

3.1 Land Use/Cover Distribution Trends – National Level

3.1.1 Forest Cover Distribution Trends

Over the decade, from 2013 to 2023, land use trends within Jamaica have undergone shifts, reflecting both natural and anthropogenic changes. Forested areas dominate the landscape, with Secondary Forests and Disturbed Broadleaf Forest, representing the largest forest cover class, extensively distributed throughout the island **(Figure 3)**. The distribution of Closed Broadleaf Forests is primarily within protected zones, whereas Mangrove Forests are concentrated on the island's southern extent and Open Dry Forests (Tall)–Woodland/ Savannah are concentrated in the southern and south-eastern sections of the island.

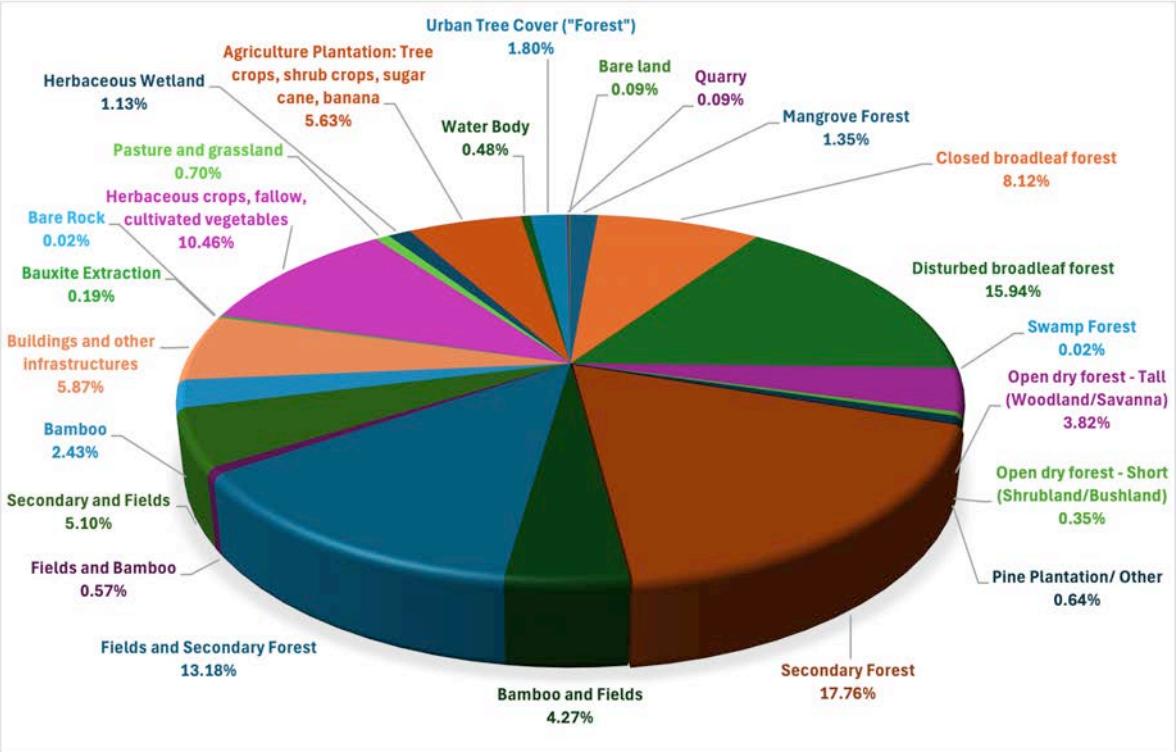


Figure 3: The distribution of Land Use and Land Cover across the Island

3.1.2 Mixed Forest Land Use And Land Cover Distribution Trends

Comparatively there has been a decrease in "Mixed Forest" land use and land cover category, but it remains prominent with a relatively even distribution across the entire island. Fields and Secondary Forest is the dominant classification within this category at 13.18%.

3.1.3 Non-Forest Land Use Land Cover Distribution Trends

Over the period the 'non-forest' land use and cover category recorded a decrease in the 'Agricultural Plantation' and 'Field' classes. It should however be noted that, herbaceous crops, fallow land, cultivated vegetables, and agricultural plantations (including tree crops, shrub crops, sugar cane, and banana) collectively occupy 16% of the island's land area. It was also observed that bamboo is noticeably dominant in the eastern section of the island. Additionally, the buildings and other infrastructure classifications showed growth, particularly around towns and tourist centres across the island.

3.2 Land Use/Cover Distribution Trends – Parish Level

3.2.1 Forest Land Cover

The findings of the 2023 LU-LUCF revealed notable trends in the spatial distribution of land cover across the various parishes. The forest cover varied across the various parishes; Trelawny and St. Catherine recorded the highest cover with more than 60,000 ha in each, this was followed by Clarendon which has the distinction of being the only parish with more than 50,000 but less than 60,000 ha. The parishes of St. Thomas, St. Elizabeth, St. Ann and Portland all recorded greater than 40,000 ha, while St. James, St. Mary and Westmoreland recorded more than 30,000 but less than 40,000. Manchester and Hanover recorded more than 20,000 but less than 30,000 and St. Andrew was the only parish with more than 10,000 but less than 20,000. The 2023 LU-LUCF also recorded forest cover on the Goat Islands for the first time and at 485.45 ha it dwarfed the forest cover of Kingston at 295.92 ha.

Trelawny, Portland, and St. Ann are highlighted for their extensive Closed Broadleaf Forests. These three parishes collectively account for almost three-fourths (72%) of the Closed Broadleaf Forests on the island, while only Kingston and St Mary recorded no areas with this forest type. Additionally, Disturbed Broadleaf Forests are distributed across all parishes except Kingston, with significant coverage identified in Trelawny, St. Catherine, St. Elizabeth, and St. James.

Secondary Forest cover is identified in all parishes and prominent in several, and this trend appears to be driven by the reversion of former agriculture areas in St. Mary, Clarendon, and

St. Catherine. Mangrove forests are primarily located along coastal regions in St. Catherine and Clarendon but have been identified in all parishes, while swamp forests were identified in only the parishes of Clarendon, St. Ann, St. Elizabeth and St. Thomas which had 60% of this forest cover.

The extent of Open Dry Forest - Short is modest, covering an area of 3,870.18 hectares with 90% concentrated in the parishes of St. Catherine and St. Elizabeth. Comparatively, the Open Dry Forest - Tall (Woodland/Savannah) spans 41,940.27 hectares, covering a significantly larger portion of the island's landscape. This category is predominantly distributed across the parishes of Clarendon and St. Catherine, which account for 70% of its coverage. It is worth mentioning that only three parishes, Hanover, Portland and St Mary, recorded no areas with open dry (tall or short) forests.

Additionally, over the years timber plantations have been established in eight of the fourteen parishes, with only Hanover, Kingston, Manchester, St. Catherine, St. James and Westmoreland not recording. The distribution of forest cover across the island is detailed in **Figure 4.**

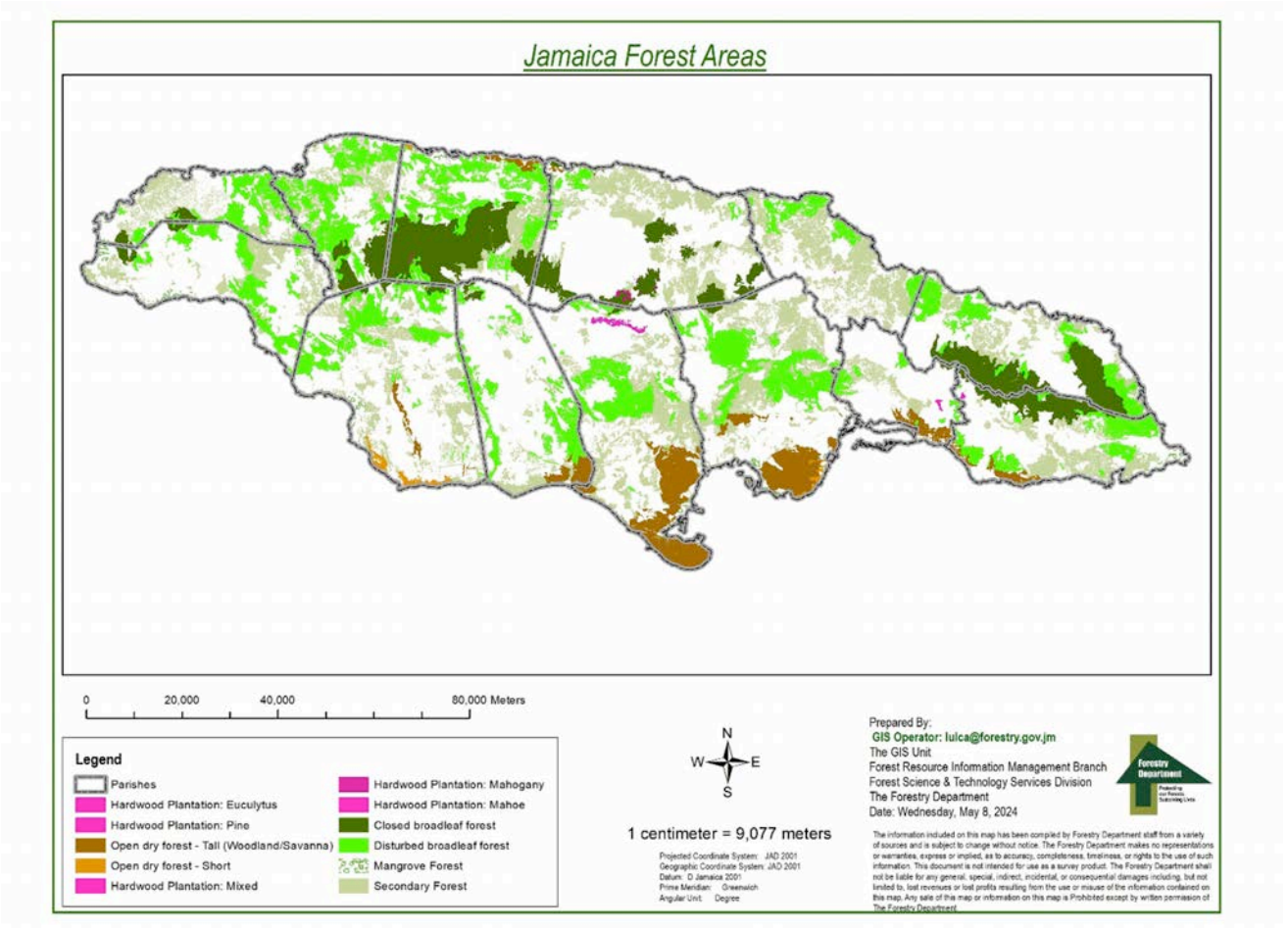


Figure 4: 2023 Island Distribution of Forested Areas

3.2.2 Mixed Forest Land Use and Land Cover

The 2023 assessment introduced a new land use class - "Secondary Forest and Fields". The mapping of this category was deemed necessary as it was recognised that there was an island wide shift in land use patterns, due to regrowth of trees in underutilized agricultural lands which have been left fallow.

3.2.3 Non-Forest Land Use Land Cover

Significant changes in land use and cover are observed in non-forest categories. Herbaceous crops, fallow land, and cultivated vegetables are prevalent in St. Elizabeth, St. Ann, Manchester, and Clarendon, collectively accounting for 60% of the small-scale farming carried out across the entire island. The Agriculture Plantation class represented by tree crops, shrub crops, sugar cane and banana is dominant in the parishes of Clarendon, St. Catherine and Westmoreland making up 64% of the plantation agriculture in Jamaica.

The building and other infrastructure class shows that 83% of Kingston's total area has been so classified, demonstrating significant increases in the levels of urbanization and infrastructure development. Concomitantly, there has also been observed an expansion of buildings and other infrastructure in higher elevations in St. Andrew. Conversely, the most evident infrastructure development in St. Ann, Trelawny and Hanover is located along the coastline. **Table 3** below provides a detailed breakdown of land use and land cover by hectare for each parish.

Table 3: 2023 Land Use/Cover distribution by Parish

2023 Land use/ cover by Parish (Hectares)																
	Parish															
Classify	Clarendon	Hanover	Kingston	Manchester	Portland	St Andrew	St Ann	St Catherine	St Elizabeth	St James	St Mary	St Thomas	Trelawny	Westmoreland	Goat Islands	Total
(Forest Land Use/Cover >75%)																
Mangrove Forest	2,781.35	753.78	0.64	264.43	53.93	304.04	101.91	2,901.79	1,773.66	137.35	84.67	1,638.64	896.68	2,913.83	236.56	**14,843.27**
Closed broadleaf forest	505.13	1,844.64	0.00	845.31	19,781.15	379.72	14,321.45	1,254.56	1,767.83	7,188.27	0.00	9,865.47	29,678.04	1,760.74	0.00	**89,192.30**
Disturbed broadleaf forest	14,530.92	11,117.96	0.00	13,315.87	13,328.89	3,351.47	3,369.83	21,506.24	18,583.72	20,909.32	7,833.61	11,772.84	22,347.61	13,199.96	0.00	**175,168.24**
Secondary Forest	22,900.07	10,273.49	42.26	7,083.57	10,363.84	4,535.26	26,864.06	23,779.14	20,955.90	9,474.49	24,511.17	13,336.23	8,612.89	12,411.42	0.00	**195,143.78**
Swamp Forest	26.74	0.00	0.00	0.00	0.00	0.00	25.85	0.00	109.44	0.00	0.00	8.81	0.00	0.00	0.00	**170.84**
Open dry forest – Short	0.00	0.00	0.00	0.00	0.00	0.00	49.15	975.09	2,503.39	103.74	0.00	0.00	238.81	0.00	0.00	**3,870.18**
Open dry forest - Tall (Woodland/Savanna)	18,070.84	0.00	253.02	3,158.87	0.00	3,071.26	451.68	11,174.55	1,461.62	0.00	0.00	2,478.47	1,549.94	21.13	248.89	**41,940.27**
Hardwood Plantation	9.40	0.00	0.00	0.00	0.00	155.14	29.75	0.00	30.83	0.00	0.00	0.00	84.20	0.00	0.00	**309.32**
Pine Plantation	945.83	0.00	0.00	0.00	1,560.47	1,217.35	329.92	0.00	4.50	0.00	1,279.19	1,395.97	23.06	0.00	0.00	**6,756.29**
Subtotal	**59,770.28**	**23,989.87**	**295.92**	**24,668.06**	**45,088.27**	**13,014.24**	**45,543.60**	**61,591.38**	**47,190.90**	**37,813.16**	**33,708.64**	**40,496.44**	**63,431.23**	**30,307.07**	**485.45**	**527,394.51**
Mixed Land Use/Cover (first class> 50%, second class> 25%)																
Secondary Forest and Fields	701.18	1,505.08	0.00	2,046.84	5,816.11	851.09	4,287.58	7,464.12	7,695.18	1,888.77	1,594.55	11,563.77	4,168.75	6,514.96	0.00	**56,097.98**
Bamboo and Fields	13,691.73	53.86	0.00	392.64	9,447.61	7,447.10	505.78	6,534.77	0.00	2,517.30	5,077.37	372.86	179.12	728.01	0.00	**46,948.14**
Fields and Bamboo	213.80	182.56	0.00	24.21	928.96	344.88	1,148.48	1,158.40	63.78	818.90	777.63	528.43	5.01	48.61	0.00	**6,243.66**
Fields and Secondary Forest	8,914.43	3,823.72	0.00	30,927.48	13,614.73	7,741.98	43,354.69	5,318.36	13,402.79	105.88	0.00	5,104.21	2,644.07	9,886.77	0.00	**144,839.11**
Subtotal	**23,521.14**	**5,565.23**	**0.00**	**33,391.18**	**29,807.41**	**16,385.06**	**49,296.53**	**20,475.64**	**21,161.75**	**5,330.84**	**7,449.56**	**17,569.26**	**6,996.95**	**17,178.34**	**0.00**	**254,128.90**
Non-Forest Land Use/Cover																
Bauxite Extraction	345.04	0.00	0.00	966.75	0.00	0.00	393.45	176.37	236.83	0.00	0.00	0.00	0.00	0.00	0.00	**2,118.44**
Bamboo	1,660.36	7,890.18	0.00	121.85	1,037.39	671.41	23.36	2,510.04	195.71	1,239.84	5,925.64	3,819.50	63.95	1,593.36	0.00	**26,752.60**
Bare Rock	0.83	9.76	0.00	0.00	18.86	0.26	19.81	4.23	15.19	0.00	74.77	27.67	3.29	23.66	0.00	**198.32**
Buildings and other infrastructures	6,132.50	1,545.58	1,087.05	5,300.04	1,624.90	8,758.23	5,370.96	11,814.37	5,651.15	5,629.81	2,931.23	2,035.70	3,350.08	3,229.87	0.00	**64,461.47**
Bare Land	19.22	186.45	8.00	3.17	7.59	18.17	22.36	81.45	79.33	142.38	157.46	9.07	101.17	89.45	11.82	**937.08**
Herbaceous crops, fallow, cultivated vegetables	13,250.14	1,502.73	0.00	14,792.88	897.33	2,728.54	18,062.58	3,490.33	33,273.77	5,795.04	7,885.96	2,069.21	5,115.18	6,054.13	0.00	**114,917.84**
Pasture and grassland	256.62	378.77	5.99	450.28	99.64	0.00	1,860.69	1,016.54	734.52	158.51	169.10	807.93	429.78	1,282.96	0.00	**7,651.32**
Herbaceous Wetland	551.09	1,113.97	0.00	245.00	104.74	164.34	64.28	601.95	7,921.35	0.00	5.05	371.49	96.68	1,134.75	0.00	**12,374.68**
Agriculture Plantation: Tree crops, shrub crops, sugar cane, banana	11,619.76	1,583.43	0.00	12.08	1,439.11	0.00	131.11	13,648.75	6,066.98	939.43	1,577.30	4,584.42	6,012.39	14,303.79	0.00	**61,918.55**
Quarry	197.35	11.48	32.85	100.14	20.37	93.88	116.87	81.70	109.08	105.89	19.09	90.52	31.97	19.39	0.00	**1,030.55**
Water Body	798.13	65.28	1.84	5.33	653.65	249.57	46.56	802.05	634.74	96.38	382.46	1,238.43	131.34	176.82	12.03	**5,294.62**
Urban Tree Cover ("Forest")	1,040.48	1,194.19	166.62	2,737.65	419.99	1,899.02	0.00	2,575.83	1,458.17	1,849.41	839.81	937.93	1,666.14	2,987.08	0.00	**19,772.33**
Subtotal	**35,871.50**	**15,481.82**	**1,302.35**	**24,735.17**	**6,323.58**	**14,583.43**	**26,112.02**	**36,803.61**	**56,376.82**	**15,956.70**	**19,967.87**	**15,991.87**	**17,001.98**	**30,895.24**	**23.85**	**317,427.80**
Total	**119,162.93**	**45,036.91**	**1,598.27**	**82,794.41**	**81,219.26**	**43,982.72**	**120,952.16**	**118,870.63**	**124,729.47**	**59,100.71**	**61,126.06**	**74,057.57**	**87,430.16**	**78,380.66**	**509.30**	**1,098,951.20**

3.3 Land Use and Cover Change (2013-2023) – National Level

The 2023 LU-LUCF assessment revealed that 527,394.51 ha (48%) of the island is 'Forested' land cover. The 'Mixed' land use classes represent 254,128.9 ha (23%), and the remaining classes designated as 'Non-Forest' land use represent 317,427.8 (29%) of the island.

3.3.1 Forest Land Cover Change

The forest cover on Jamaica's mainland now accounts for 47.9% of the land area, up from 40% in 2013. This expansion from 439,929.63 hectares in 2013 to 527,394.51 hectares in 2023 represents a notable increase of 87,464.88 hectares in the forest cover category over the decade, as detailed in Table 4. Secondary Forest is the largest forest category (195,143.78 ha) expanding at an average rate of 7,380.03 ha per annum. Closed Broadleaf Forest now occupies 8% or 89,192.30 ha of forested land, a 5.37% increase since 2013. Conversely, Disturbed Broadleaf Forest covering 15.9% of the island has declined from 175,590.44 ha in 2013 to 175,168.24 ha in 2023.

The category, Mangrove Forests, accounting for 1.35% or 14,843.27 hectares of the island, is 5,105.05 hectares more than previously recorded. This increase does not however signify an actual increase in the area covered by Mangroves; rather, it is the outcome of an extensive mangrove field mapping program conducted by the Forestry Department in 2022. This initiative confirmed and allowed for the reclassification of certain areas, previously misclassified (primarily due to deforestation) as herbaceous wetlands in 2013, as Mangrove Forests in 2023.

It should be noted that Bamboo and Urban Tree Cover "Forest" are not included as a part of the forest land cover category. The distribution of forest cover and island-wide land use and cover change is illustrated in **Figure 5** and **Table 3**, respectively.

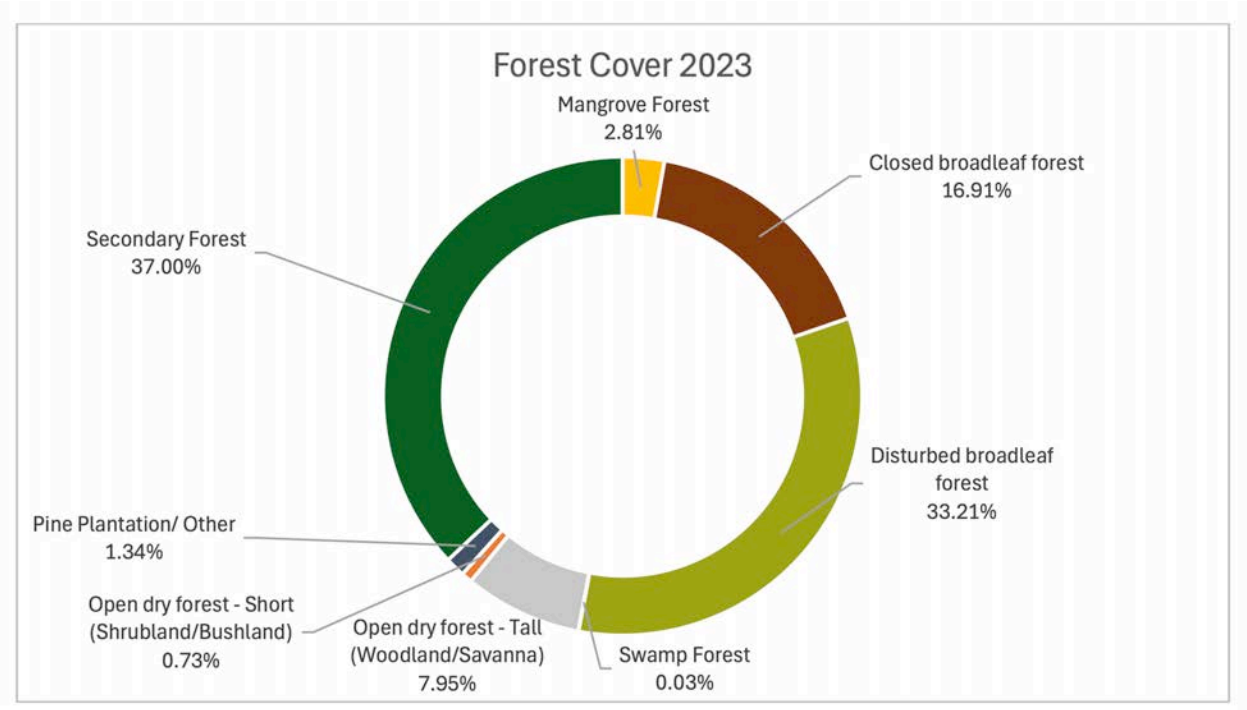


Figure 5: The distribution of Jamaica's Forest Cover

3.3.1 Forest Land Cover Change

The mixed land use/ land cover category, characterized by the combination of natural and anthropogenic land use/cover shows 'Fields and Secondary Forest' as its predominant class. Occupying 13% or 144,839.11 ha of the island's territory, this land use category increased from 132,140.63 ha in 2013. Additionally, the newly included land use classification 'Secondary Forest and Fields,' comprises 5.1% (56,097.98 ha) of the mainland.

3.3.3 Non-Forest Land Use Land Cover Change

In the 'non-forest' land use category, 'Pasture and grassland,' 'Agriculture Plantation' and 'Fields' occupy 184,487.71 ha of the total land area representing 17%. This marks a 4% decline from 2013, with Herbaceous crops, fallows and cultivated vegetables having the largest reduction of 25%. Buildings and other infrastructure represent 64,461.47 ha (5.8%) of the landscape, a reduction of 61,250.56 ha or 5.6% of the island's total area **(Table 4)**. This reduction is attributed to the reclassification of some secondary forest and Urban Tree Cover "Forest" previously classified as building and other infrastructure in 2013. However, the change matrix **(Appendix 8)** indicates a 33.8% increase in building and other infrastructure, from 48,170.88 ha to 64,461.47 ha. The change matrix provides an exact figure by accounting for both the reclassified areas that were formerly buildings and infrastructure, and the newly developed infrastructure added since 2013.

The implementation of a smaller MMU facilitated more precise mapping of small target features such as urban tree cover. As a result, Urban Tree Cover "Forest" now constitutes 1.8% (19,772.33 ha) of Jamaica's total land area. In addition, Bamboo has observed a 473% increase from 4,667.41 ha in 2013 to 26,752.60 ha in 2023, representing 2.2% of the landscape. Of this 26,752.60 ha, 972.69 ha are in the forest reserves.

Table 4: Breakdown of Land Use and Cover Change between 2013 and 2023

LU-LUCF Assessment in Jamaica, 2013-2023				
Forest Land Use/Cover >75%)				
Land Use/Cover Classification	**2013 LU Hectares**	**2023 LU Hectares**	**Difference in Hectares**	**Percent (%) Loss/Gain**
Forest Land Use				
Mangrove Forest	9,738.22	14,843.27	5,105.05	52.42
Closed broadleaf forest	84,643.01	89,192.30	4,549.29	5.37
Disturbed broadleaf forest	175,590.44	175,168.24	-422.20	-0.24
Swamp Forest	122.93	170.84	47.91	38.97
Open dry forest - Tall (Woodland/Savanna)	37,558.81	41,940.27	4,381.46	11.67
Open dry forest - Short	2,614.84	3,870.18	1,255.34	48.01
Pine Plantation/Other	8,317.92	7,065.62	-1,252.30	-15.06
Secondary Forest	121,343.46	195,143.78	73,800.32	60.82
Subtotal	**439,929.63**	**527,394.51**	**87,464.88**	**19.88**
Annual Rate (%)				**1.99***
Mixed & Non-Forest Land Use				
Mixed Land Use/cover (first class> 50%, second class> 25%)				
Bamboo and Fields	36,109.71	46,948.14	10,838.43	30.02
Fields and Secondary Forest	132,140.63	144,839.11	12,698.48	9.61
Bamboo and Secondary Forest	30,257.95			
Fields and Bamboo	37,326.55	6,243.66	-31,082.89	-83.27
Secondary Forest and Fields		56,097.98		
Subtotal	**235,834.84**	**254,128.90**	**18,294.06**	**7.76**
Mixed Land Use/cover growth rate%				**0.78**
Non-Forest Land Use/Cover				
Bamboo	4,667.41	26,752.60	22,085.19	473.18
Buildings and other infrastructures	125,712.03	64,461.47	-61,250.56	-48.72
Bauxite Extraction	3,393.05	2,118.44	-1,274.61	-37.57
Bare Rock	2,290.44	198.32	-2,092.12	-91.34
Herbaceous crops, fallow, cultivated vegetables	153,486.92	114,917.84	-38,569.08	-25.13
*Pasture and grassland	6,617.49	7,651.32	1,033.83	15.62
Herbaceous Wetland	14,363.95	12,374.68	-1,989.27	-13.85
Agriculture Plantation: Tree crops, shrub crops, sugar cane, banana	69,963.22	61,918.55	-8,044.67	-11.50
Water Body	5,099.70	5,294.62	194.92	3.82
Urban Tree Cover ("Forest")		19,772.33	19,772.33	
*Quarry	720.33	1,030.55	310.22	43.07
*Bare land	41,503.00	937.08	-40,565.92	-97.74
Subtotal	**423,336.74**	**317,427.80**	**-105,908.94**	**-25.02**
Non-Forest land Use/Cover growth rate%				**-2.50**
Total	**1,099,101.21**	**1,098,951.20**	**-150.01**	**-0.01**

*includes 485.5ha on Goat Island

3.4 Land Use And Cover Change (2013-2023) – Parish Level

An analysis conducted at the parish level reveals a heterogeneous pattern of changes in land use and cover across all parishes, exhibiting a mixture of both losses and gains over the past decade. The details with respect to net change figures for land use and land cover for individual parishes are presented in **Table 5**.

Disturbed Broadleaf Forests have changed across various parishes, with St. Ann

3.4.1 Forest Land Cover Change

experiencing the most substantial decrease from 11,158.31 ha in 2013 to 3,369.83 ha in 2023, resulting in a net decline of 7,788.48 ha. Likewise, Closed Broadleaf Forests have shown both losses and gains, with Trelawny recording the largest net decrease of 385.44 hectares and St. Ann recording the largest net gain with 4,636.06 ha. It may however be inferred that a proportion of the decrease in Disturbed Broadleaf Forest observed in St. Ann may be attributed to natural recovery and hence the conversion of some Disturbed Broadleaf Forests into Closed Broadleaf Forests.

Concurrently, the largest expansion in Secondary Forest, was recorded for St. Mary with an increase of 18,651.95 ha. This apparent expansion may however be due to improvements in the methodology applied, i.e. the separation of the mixed-class Bamboo and Secondary Forest into distinct categories. Additionally, St. Elizabeth recorded the largest gain in Mangrove Forest, an increase of 1,508.89 ha. This expansion is not, however, attributed to actual growth, rather, it stems from a correction in classification as verified by field visits. On the other hand, Clarendon recorded the largest net loss of 993.72 ha, a 26% decrease, and this too may be due to the boundary refinement through field verification and mapping. The mangrove boundaries in the 2013 LU-LUCF assessment were more generalized because of lower-resolution imagery and insufficient field mapping data.

Lastly, Open Dry Forest - Tall has seen its largest increase in Clarendon, expanding by 4,799.61 ha over the decade. This expansion has been confirmed through field data verification, which documented the shift from agricultural plantation between sections of Rocky Point, Mitchel Town and Lionel Town. Overall, since 2013 eleven of the fourteen parishes have recorded a net increase in forest cover, with St. Andrew, St. Ann, and Portland being the notable exceptions where net losses have been observed.

Table 5: The Net Change in Land Use and Cover for each Parish between 2013-2023

LULUCF Parish Change- Hectares Loss/Gain (2013-2023)															
	Parish														
Classify	Clarendon	Hanover	Kingston	Manchester	Portland	St Andrew	St Ann	St Catherine	St Elizabeth	St James	St Mary	St Thomas	Trelawny	Westmoreland	Goat Islands
(Forest Land Use /Cover >75%)															
Mangrove Forest	-993.72	606.62	0.64	-48.33	-75.18	8.08	100.86	325.38	1,508.89	12.90	-18.81	1,314.91	256.71	1,869.53	236.56
Closed broadleaf forest	207.08	15.94	0.00	0.42	-18.19	-0.47	4,636.06	195.19	-124.90	-11.82	0.00	12.98	-385.44	22.45	0.00
Disturbed broadleaf forest	2,586.61	1,124.63	0.00	-448.16	-1,384.50	314.96	-7,788.48	-71.13	97.86	648.41	-258.12	1,415.35	1,369.94	1,970.43	0.00
Secondary Forest	10,971.23	7,572.46	42.26	3,102.41	-455.16	-210.99	2,687.41	6,311.05	15,343.06	5,631.64	18,651.95	2,205.21	787.50	1,160.30	0.00
Swamp Forest	26.74	-114.12	0.00	0.00	0.00	0.00	25.85	0.00	109.44	0.00	0.00	0.00	0.00	0.00	0.00
Open dry forest - Short	0.00	0.00	0.00	0.00	0.00	-72.10	0.68	975.09	267.06	103.74	0.00	0.00	-19.13	0.00	0.00
Open dry forest - Tall (Woodland/Savanna)	4,799.61	0.00	31.98	-38.53	0.00	614.24	-405.83	183.14	-203.27	0.00	0.00	248.00	-142.86	-953.91	248.89
Hardwood Plantation	0.00	0.00	0.00	0.00	0.00	-3.40	-1.08	0.00	-0.07	0.00	0.00	0.00	0.00	0.00	0.00
Pine Plantation	550.45	0.00	0.00	0.00	-268.49	-1,343.33	0.29	0.00	0.00	0.00	-56.72	-132.96	3.00	0.00	0.00
Subtotal	**18,148.00**	**9,205.53**	**74.88**	**2,567.82**	**-2,201.53**	**-693.01**	**-744.24**	**7,918.73**	**16,998.08**	**6,384.86**	**18,318.30**	**5,063.50**	**1,869.72**	**4,068.79**	**N/A**
Mixed Land Use/Cover (first class> 50%, second class> 25%)															
Secondary Forest and Fields	701.18	1,505.08	0.00	2,046.84	5,816.11	851.09	4,287.58	7,464.12	7,695.18	1,888.77	1,594.55	11,563.77	4,168.75	6,514.96	0.00
Bamboo and Fields	9,926.10	-1,132.16	0.00	10.01	1,653.79	4,544.79	219.35	501.67	-136.23	1,214.67	-1,342.95	-3,429.89	-12.03	-1,178.68	0.00
Fields and Bamboo	-5,910.74	-13,522.30	0.00	-34.55	-546.93	-1,556.63	-228.20	-371.44	-227.65	-3,108.53	-1,137.23	-2,472.33	-3.20	-1,963.17	0.00
Fields and Secondary Forest	-2,497.08	1,817.03	0.00	4,472.10	3,939.20	2,600.88	4,202.99	-1,385.69	4,082.45	-1,779.76	-3,680.73	-2,557.20	-3,430.73	6,915.02	0.00
Bamboo and Secondary Forest	-578.32	0.00	0.00	-1.03	-2,688.07	-2,090.59	-60.65	-5,872.89	0.00	-1,414.24	-15,609.89	-1,938.05	-4.22	0.00	0.00
Subtotal	**1,641.14**	**-11,332.34**	**0.00**	**6,493.38**	**8,174.10**	**4,349.55**	**8,421.07**	**335.76**	**11,413.75**	**-3,199.10**	**-20,176.24**	**1,166.29**	**718.57**	**10,288.12**	**0.00**
Non-Forest Land Use/Cover															
Bauxite Extraction	286.02	0.00	0.00	-947.09	0.00	0.00	-588.24	176.37	-201.67	0.00	0.00	0.00	0.00	0.00	0.00
Bamboo	-2,820.44	7,890.18	0.00	121.85	1,037.39	671.41	23.36	2,510.04	195.71	1,239.84	5,739.03	3,819.50	63.95	1,593.36	0.00
Bare Rock	-1,363.59	-4.06	0.00	-0.30	0.92	-82.93	9.72	-420.55	-244.99	0.00	24.03	-31.06	2.13	18.57	0.00
Buildings and other infrastructures	-7,863.01	-4,153.87	-288.32	-3,361.82	-1,483.03	-5,439.72	-3,555.79	-5,677.14	-8,858.77	-6,400.71	-1,766.26	-1,571.82	-1,290.63	-9,539.67	0.00
Bare Land	-6,351.31	-568.35	8.00	-3,269.89	-2,995.00	-1,303.64	-6,820.22	-5,647.15	-2,803.58	-907.68	-1,588.09	-3,131.43	-2,122.57	-3,076.82	11.82
Herbaceous crops, fallow, cultivated vegetables	-510.27	-2,561.31	0.00	-4,103.34	-1,795.89	821.04	-3,326.69	-5,696.01	-15,802.82	51.29	4,794.08	-903.82	-1,529.55	-8,005.81	0.00
Pasture and grassland	-420.85	292.37	5.99	10.60	99.64	0.00	407.45	-89.62	123.67	-0.12	-312.31	140.61	-359.44	1,135.85	0.00
Herbaceous Wetland	-352.04	-355.71	0.00	39.49	-14.16	164.34	-15.17	548.50	565.82	0.00	5.05	-1,293.02	70.09	-1,352.45	0.00
Agriculture Plantation: Tree crops, shrub crops, sugar cane, banana	-5,299.92	56.00	0.00	-31.25	-69.85	-37.22	-159.16	1,283.25	-573.77	-603.80	-65.97	-793.34	-1,046.56	-703.08	0.00
Quarry	121.65	1.30	32.85	-14.22	-5.81	-112.83	86.71	69.74	37.82	47.80	8.01	52.84	-8.90	-6.70	0.00
Water Body	-245.99	-3.48	1.84	3.31	-125.70	34.46	-31.21	583.62	259.04	62.92	-176.00	-280.94	-9.87	110.88	12.03
Urban Tree Cover ("Forest")	1,040.48	1,194.19	166.62	2,737.65	419.99	1,899.02	0.00	2,575.83	1,458.17	1,849.41	839.81	937.93	1,666.14	2,987.08	0.00
Subtotal	**-19,298.49**	**1,787.26**	**-73.02**	**-8,815.01**	**-4,931.49**	**-3,386.06**	**-13,969.25**	**-9,783.12**	**-25,845.37**	**-4,661.04**	**7,501.38**	**-3,054.55**	**-4,565.20**	**-16,838.81**	**N/A**

3.4.2 Non-forest Land Use Land Cover Change

Over the past decade, the agriculture sector has experienced a decline in small scale farming across 79% of the parishes. This has resulted in reductions in the areas classified as herbaceous crops, fallow land, and cultivated vegetables. Among these parishes, St. Elizabeth stands out with the largest net loss of some 15,802.82 hectares.

Between 2013 and 2023, the parish of St. Ann exhibited the highest rate of increase in buildings and infrastructure, with a growth rate of 59%, corresponding to an addition of 1,993 hectares. In contrast, St. Catherine experienced the largest absolute increase in buildings and infrastructure, adding 2,865.07 hectares during the same period, though its growth rate was lower at 32%. This indicates that St. Ann's development in buildings and infrastructure is the most rapid of all parishes, while St. Catherine has observed the largest expansion in hectares of buildings and other infrastructure **(Table 6)**.

Table 6: Net Change in Building and Other Infrastructure Land Use for each Parish Between 2013-2023

Building and other Infrastructure Parish Change (2013-2023)				
Parish	2013 LU Hectares	2023 LU Hectares	Difference in Hectares	% Gain
St Catherine	8947.21	11812.28	2865.07	32%
St Ann	3387.61	5380.68	1993.07	59%
St Andrew	8192.26	8757.88	565.61	7%
Portland	1199.01	1623.55	424.54	35%
Manchester	3633.39	5292.03	1658.64	46%
Kingston	1081.19	1085.46	4.27	0%
Hanover	1103.24	1544.29	441.05	40%
Clarendon	4191.56	6126.67	1935.11	46%
Westmoreland	2267.69	3226.48	958.80	42%
Trelawny	2194.18	3323.22	1129.05	51%
St Thomas	1314.59	2033.18	718.59	55%
St Mary	1894.64	2927.59	1032.95	55%
St James	4678.24	5630.04	951.80	20%
St Elizabeth	4085.76	5649.43	1563.67	38%

3.5 Forest Cover Change and Distribution (2013-2023) – Forest Estates

The land managed by the Forestry Department spans 121,823.53 hectares and accounts for 23% of the island's forest cover[4], the majority (88%) of these managed lands are forested areas. Since 2013, forest estates have recorded a net gain of 973.26 hectares or a 1% increase in forest cover, primarily attributed to the expansion of 2,150.08 ha in Closed Broadleaf Forest. Of the 89,251.21 hectares island wide covered by Closed Broadleaf Forest, 64,154.26 hectares (72%) are situated within forest estates, the majority of which are in Cockpit Country, Blue Mountain, Litchfield-Matheson's Run, and Stephaney John's Vale. There are also 15,418.17 hectares within forest estates which are classified as Disturbed Broadleaf Forest.

In contrast, both Disturbed Broadleaf Forest and Secondary Forest have experienced reductions of 748.14 hectares (-4.63%) and 1,285.55 hectares (-13.95%), respectively (refer to **Table 7**). The decline in Disturbed Broadleaf Forest may however be attributed to its natural conversion into Closed Broadleaf Forest, thus contributing to the overall increase in Closed Broadleaf Forest. This transition has been notable in the Stephney John's Vale Forest Reserve. Furthermore, Pine plantations/other category has decreased by 19.76% and Open Dry Forests, both tall and short, experienced some increase with Open Dry Forests – Tall (Woodland/Savannah) expanding by 12.62% and Short Open Dry Forests from 101.4 ha to 1,011.597 ha. Please see **Figure 6** for the distribution of forest cover within forest estates.

Table 7: Forest Cover Types managed by the Forestry Department

Forest Land Use/ Cover >75%				
Land Use/Cover Classification	**2013 LU Hectares**	**2023 LU Hectares**	**Difference Hectares**	**% Percent loss/gain**
Closed broadleaf forest	62,004.18	64,154.26	2,150.08	3.47%
Disturbed broadleaf forest	16,166.31	15,418.17	-748.14	-4.63%
Mangrove Forest	2,266.83	1,990.27	-276.556	-12.20%
Open dry forest - Short	101.40	1,011.60	910.197	897.63%
Pine Plantation/ Other	5,637.85	4,524.02	-1,113.83	-19.76%
Open dry forest - Tall (Woodland/Savanna)	10,594.49	11,931.55	1,337.06	12.62%
Secondary Forest	9,212.88	7,927.33	-1,285.55	-13.95%
Grand Total	**105,983.94**	**106,957.20**	**973.261**	**0.92%**
Average Annual Growth Rate %				**0.1**

4 Jamaica's forest cover is 527,394.51

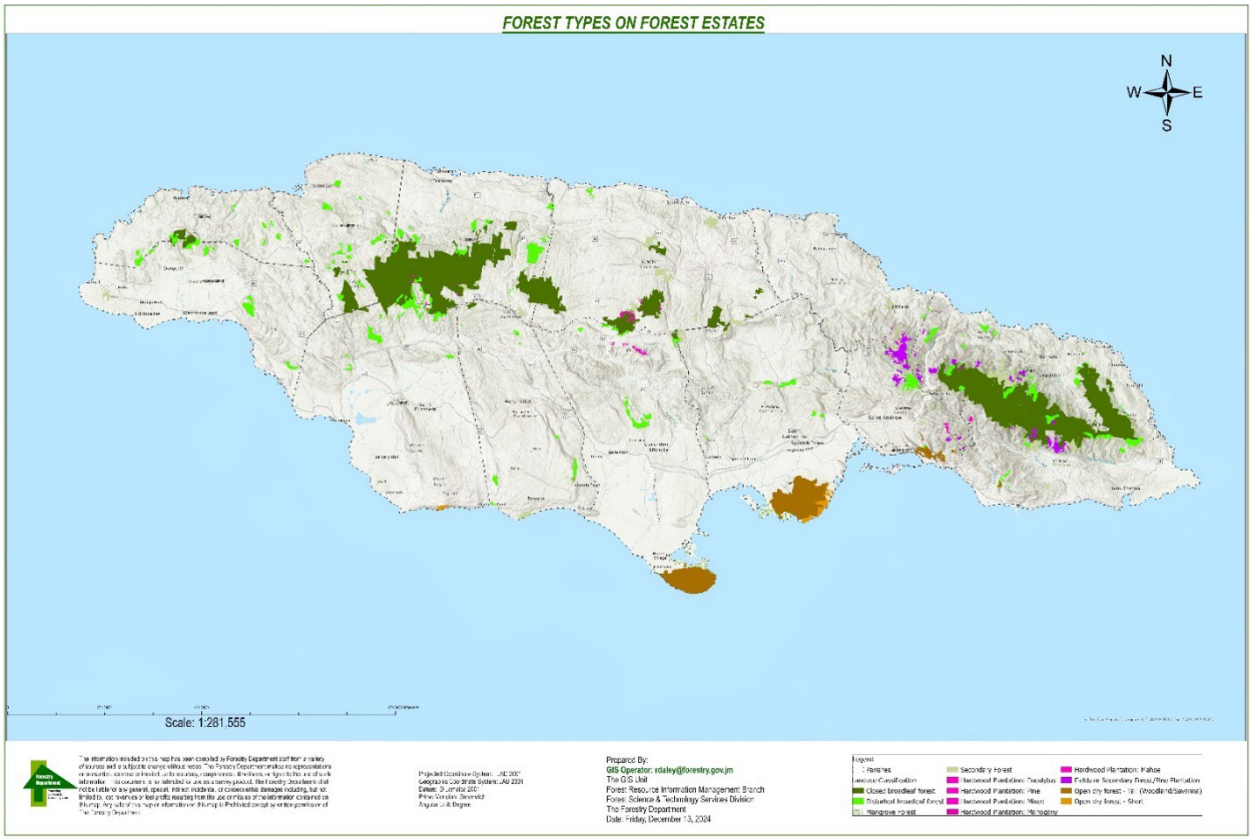


Figure 6: Forest Cover by Type within Forest Estates

3.6 Bamboo Land Cover – Change and Distribution

Bamboo is one of the fastest-growing plants globally, exhibiting an average growth rate of 20-40 tons per ha per year (Pan et al., 2023). The 2023 assessment revealed a significant increase in the distribution of bamboo across Jamaica, rising from 4,667.41 ha identified in the 2013 due to an annual average growth of 2,208.51 ha between 2013 and 2023, to approx. 22,085.19 ha in 2023. This represents a cumulative growth rate of 473.18% over the ten-year period, indicating that bamboo has expanded more rapidly than any other land use or cover on the island (see **Table 4**).

Initially, bamboo was predominantly concentrated in Clarendon, encompassing 4,505.04 ha (96.52%), with only 162.37 ha (3.48%) located in St. Mary. However, the 2023 assessment indicates that bamboo is now distributed throughout the island, with notable concentrations in Hanover and St. Mary, replacing the previous dominance in Clarendon, as illustrated in **Figure 7**. The favorable conditions in St. Mary—such as nutrient-rich soil, abundant sunlight, a consistent water supply, and temperatures ranging from 18 to 35 degrees Celsius—along with increased land clearing for farming, are likely contributors to the rapid proliferation. Additionally, smaller bamboo areas have been identified in Trelawny, St. Ann, Manchester, and St. Elizabeth, also depicted in **Figure 7**.

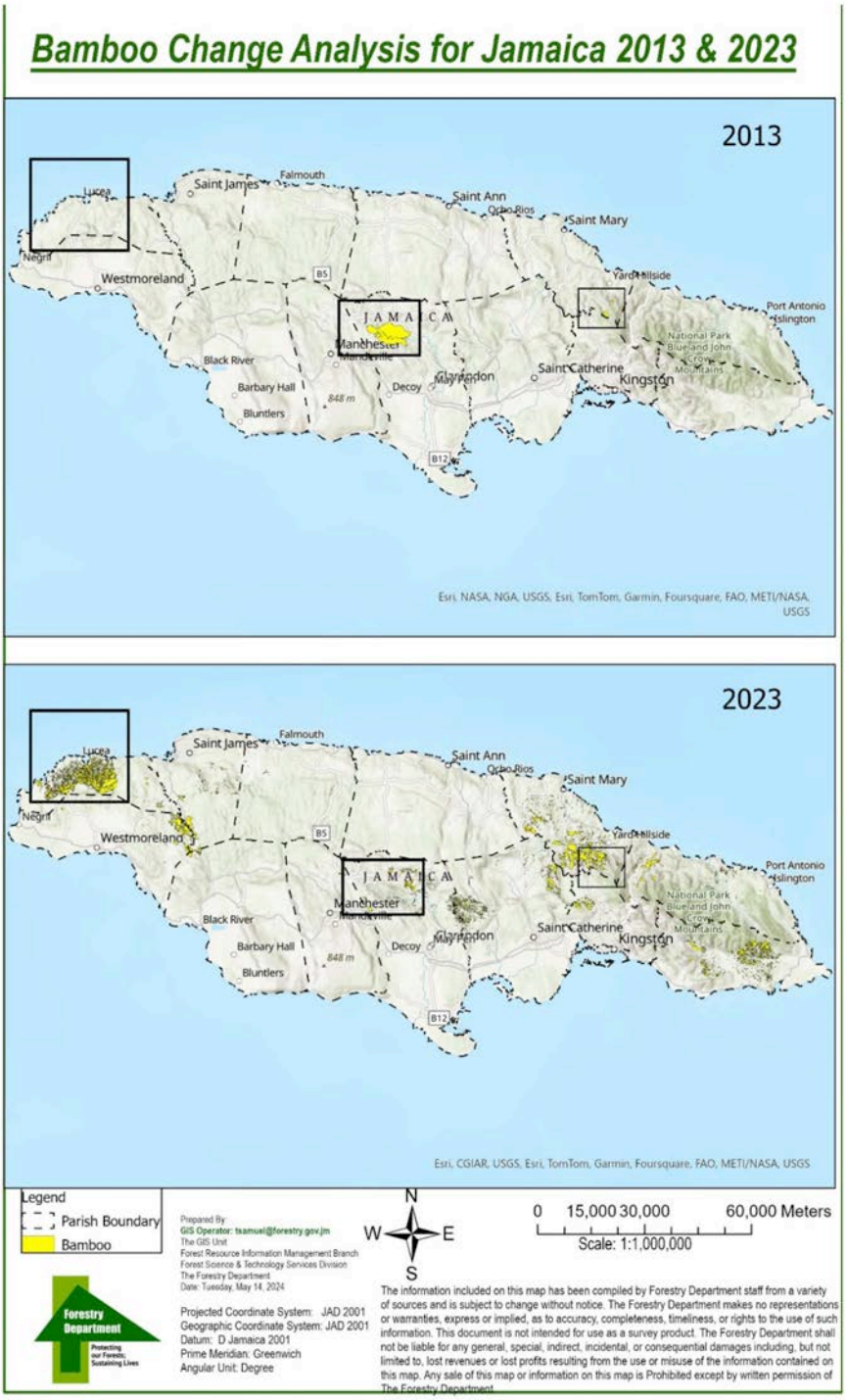


Figure 7: Change and Distribution of Bamboo across the Island

3.7 Urban Tree Cover "Forest"

Urban forests provide a wide range of essential benefits, especially in the context of current global challenges, such as climate change and environmental degradation. Recent public health challenges (such as the recent COVID-19 pandemic) have resulted in an increased awareness of the importance of urban trees and green spaces.

Previously, it was recommended that a target of 40% urban tree canopy target was desirable. This is, however, no longer adhered to as a universal rule, Astell-Burt & Feng (2019) posited that urban areas with suboptimal conditions are advised to maintain a minimum of 30% canopy cover. The FAO supports this 30% canopy cover recommendation as a baseline for urban tree coverage, reinforcing its significance in urban planning (FAO, 2021).

Specific national circumstances are complex and varied and hence guidelines cannot be slavishly adhered to, consequently, Cecil Konijnendijk (co-director of Nature Based Solutions Institute) launched a new rule of thumb for urban forestry and urban greening in early 2021: the 3+30+300 rule. This rule focuses on the crucial contributions of nature in urban spaces to our health and wellbeing, as well as climate change adaptation, while recognising that many different aspects of the urban forest must be considered to make it accessible to all. It provides clear criteria for the provision of urban trees in urban communities by setting the following three minimum requirements:

- 3 mature trees from every home
- 30 percent tree canopy cover in every neighbourhood
- 300 metres from the nearest high-quality public park or other green space

The LU-LUCF assessment provided a visual depiction of the spatial distribution of tree coverage within urban centres throughout the island. **Table 8** and **Figure 8** give a baseline of total tree cover within established city limits[5] and the distribution at the parish level. The 2023 LU-LUCF Assessment focuses primarily on examining the country's progress towards achieving a 30% threshold for urban tree cover. The urban spaces in Jamaica are referred to as Local Planning Areas (LPA) in this document.

5 City limits are defined by the Local Planning Area (LPA) provided by NEPA as the TCPA

Table 8: Urban Trees and Forest Coverage per Local Planning Area Boundary (LPA) in Parishes

Parishes	Area within LPA Boundaries (ha)	Urban Tree Cover (ha) within LPA Boundaries	% Urban Tree Coverage within LPA Boundaries.	Forest Cover (ha) within LPA	% Forest Coverage within LPA Boundaries	Total Tree Cover (%) within LPA
Clarendon	15,829.92	1,040.48	7%	7,223.42	46%	52%
Hanover	4,609.39	1,207.65	26%	1,413.64	31%	57%
Kingston & St. Andrew	8,508.00	2,067.45	24%	3,250.44	38%	63%
Manchester	15,686.68	2,737.57	17%	1,438.65	9%	27%
Portland	13,202.27	417.88	3%	4,844.36	37%	40%
St. Ann	21,569.20	22,16.18	10%	7,599.03	35%	50%
St. Catherine	22,641.13	25,12.85	11%	7,040.15	31%	46%
St. Elizabeth	9,399.42	14,48.34	15%	4,215.28	45%	42%
St. James	17,747.86	18,54.64	10%	9,249.24	52%	60%
St. Mary	6,862.08	595.62	9%	3,407.31	50%	63%
St. Thomas	6,290.06	935.30	15%	1,804.36	29%	58%
Trelawny	18,372.11	1,628.58	9%	9,060.26	49%	44%
Westmoreland	12,158.88	2,993.39	25%	2,597.64	21%	58%

*N.B. LPA boundary (urban peripheries) was provided by NEPA

On the face of it, and as demonstrated in Table 8, most parishes appear to have met or exceeded the 30% baseline for total tree cover within LPAs. While this suggests a positive movement towards urban sustainability, it must be recognised that this high tree coverage is mainly attributed to the dense forest cover in peri-urban areas rather than in the core urban areas. Peri-urban areas, characterised by a blend of urban and rural landscapes, often contain extensive natural forests that contribute significantly to the overall tree coverage statistics. This results in a somewhat inflated perception of urban tree coverage.

When focusing specifically on the densely urbanised regions within LPAs, it becomes evident that none of these areas meet the 30% tree coverage recommendation (Table 8). This discrepancy highlights a critical challenge in urban planning and environmental management. True urban areas are typically more densely populated and developed, leaving limited space for greenery, a trend observed in 72% of parishes.

Manchester deviates from this pattern and is the only parish where the total tree cover percentage within the LPA is not greater than 30% and with its urban tree coverage surpassing forest coverage. This is indicative of the extensive development in Manchester's local planning areas, which has led to the removal of significant amounts of forest cover.

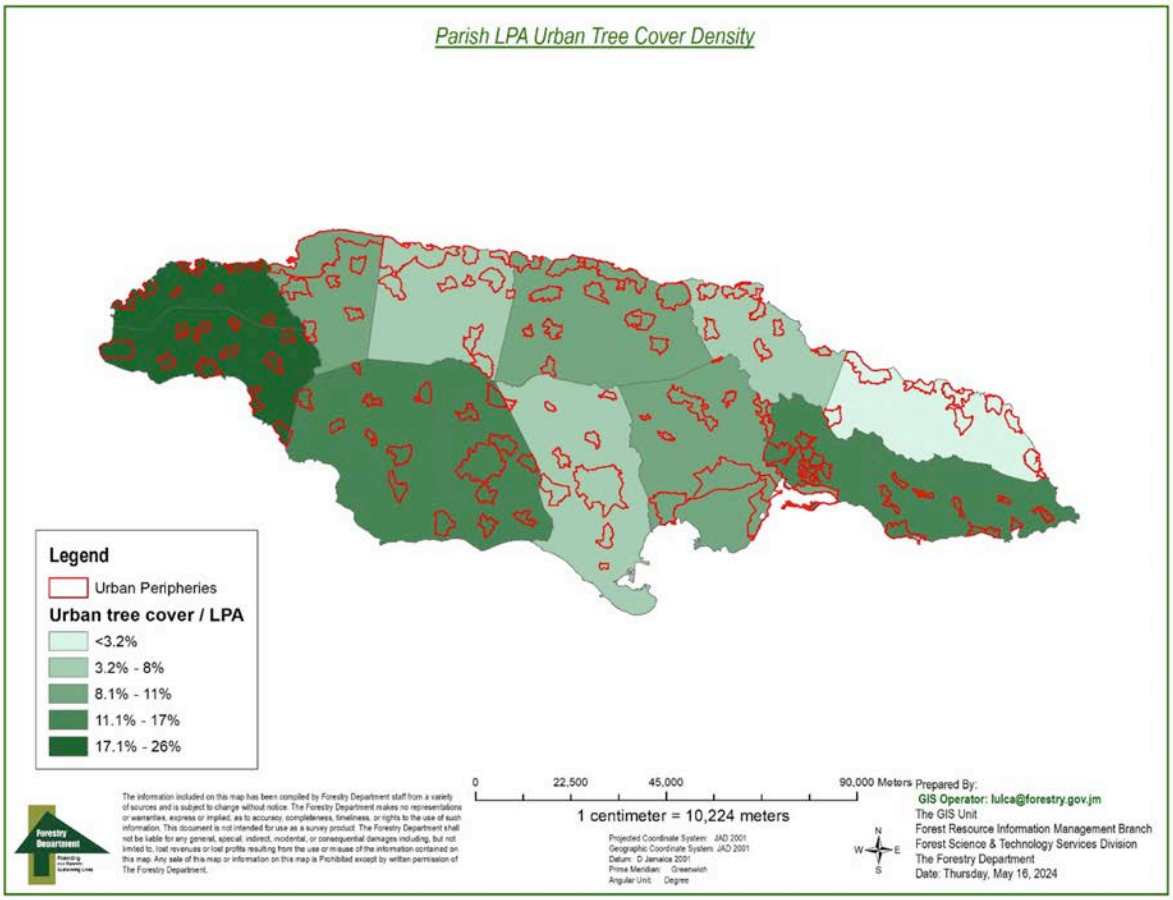


Figure 8: Preliminary Urban Tree Cover Density by Parishes

3.7.1 Kingston Metropolitan Area - A Case Study of Urban Tree "Forest" Cover

The Kingston Metropolitan Area (KMA) reflects a similar trend of having significant forest cover in peri-urban areas while coverage in core urban areas lag. The KMA spans approximately 13,217 hectares, with urban trees and forest cover totaling about 4,614.77 hectares **(Table 9)**, which represents roughly 35% of the metropolitan area being covered by trees. While this percentage is relatively high, it is misleading as the KMA boundaries include forested areas such as Plantation Heights, Red Hills, Stony Hill, Long Mountains, Jacks Hills, and parts of the Port Royal Mountains **(Figure 8)**. These forested areas are categorised into four forest types, with secondary forests being the most prevalent and is primarily associated with the mountain ranges and hills mentioned earlier. A more detailed assessment of the broader KMA reveals that "Urban Forest"/Urban Tree Cover within the KMA is only 2,802.92 hectares or 21.2% of the total KMA area.

In fact, at very best, having eliminated the secondary forests in Kingston 9, which is arguably rural, and eliminated the Open Dry Forests of the long mountain area, true urban tree cover in Jamaica's capital city of Kingston would be more accurately stated to be approximately 15.38% which is marginally more than half of what is the globally

recommended amount. This presents an unassailable case for an increased emphasis on urban tree planting and the use of nature-based solutions especially with due consideration for the climate change projections which have Kingston among the first cities worldwide entering climate departure.

Table 9: Classification of Forest Cover within the KMA

Classification	Total Hectares	Coverage (%)
Disturbed broadleaf forest	3.55	0.03
Mangrove Forest	221.35	1.67
Open dry forest - Tall (Woodland/Savanna)	1,131.10	8.56
Secondary Forest	1,446.92	10.95
Tree coverage outside forests (urban forests)	1,811.85	13.71
TOTAL	4,614.77	35 .00

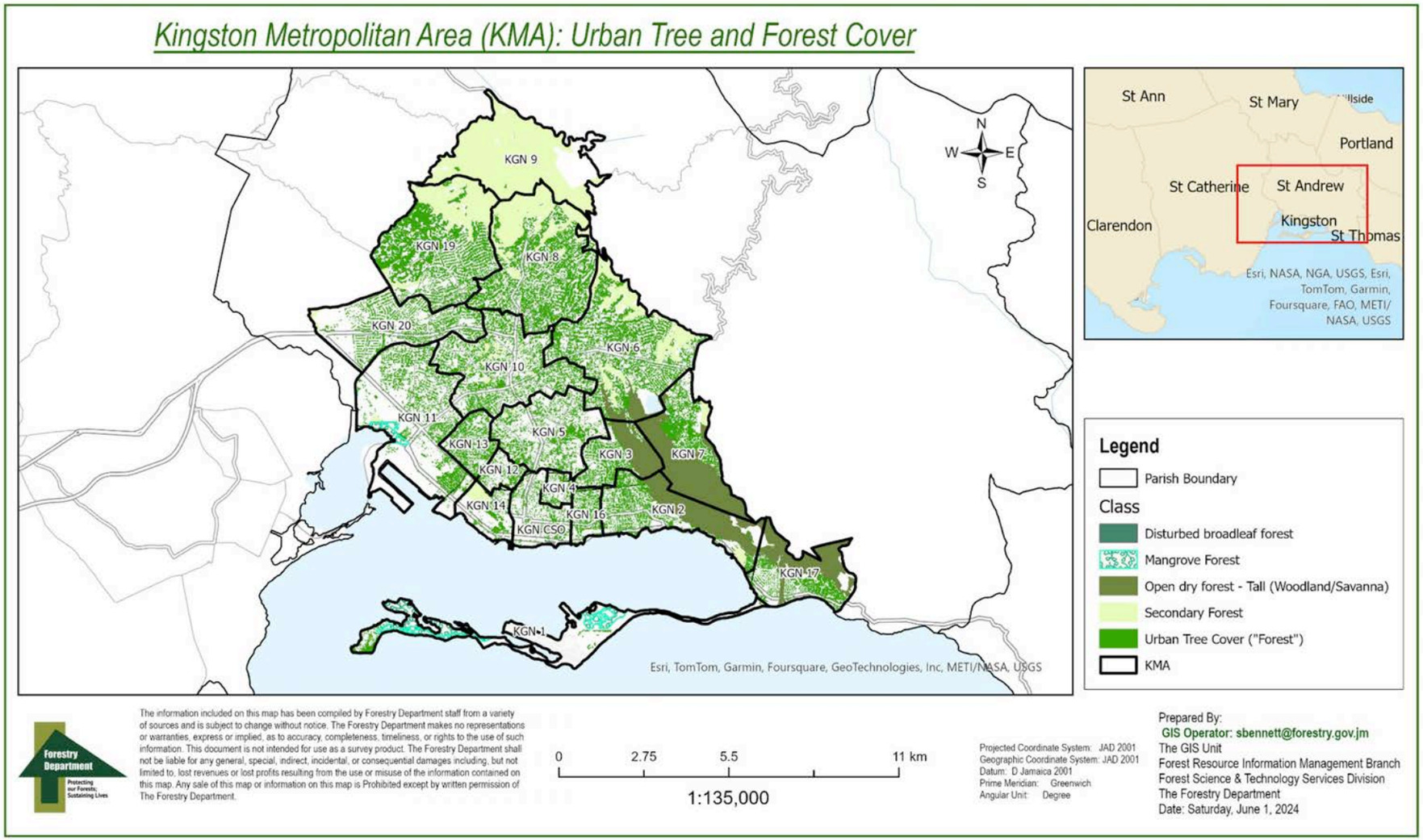


Figure 9: Urban Tree and Forest Cover in KMA by Zone and Forest Type

3.8 Regrowth

Over the past decade, Jamaica's forest recovery rate has averaged 1.98% annually, marking a significant increase over the previous rate of 0.41% observed between 1998 and 2013. Lands managed by the Agency have also recorded a mean regrowth rate of 0.1% per year, it should be noted that most of the lands managed by the Agency are already forested which explains the low regrowth rate. Expectedly, this overall expansion in forest cover is primarily attributed to the growth of Secondary Forests, which have experienced a 7% increase over the same period.

Over the period, eleven of the fourteen parishes recorded forest gain with the Parishes of St. Elizabeth, Hanover, and St. Mary exhibiting the highest annual mean forest recovery rates, over the past decade. One parish in particular, St. Mary has the distinction of being the only parish to record double-digit forest gain over the period. Encouragingly, the parish of St. Ann, which was previously identified with the highest deforestation rate of 13% in the 2013 assessment, has experienced a significant improvement over the past 10 years with the current deforestation rate having been reduced to 1.61% as of 2023.

Please refer to **Table 10** and **Figure 10** provided below for any comparative analysis of forest gains and deforestation rates between 2013 and 2023.

Table 10: Forest Gain and Deforestation Rates for each Parish between 2013-2023

2013-2023 LU-LUCF Forest Gain/Deforestation Rate by Parish (Hectares)					
Parish	**2013 (ha)**	**2023 (ha)**	**Difference (ha)**	**Forest Gain/Deforestation Rate %**	**Mean Annual rate %**
Clarendon	41,622.28	59,770.28	18,148.00	43.60	4.36
Hanover	14,784.34	23,989.87	9,205.53	62.27	6.23
Kingston	221.04	295.92	74.88	33.88	3.39
Manchester	22,100.24	24,668.06	2,567.82	11.62	1.16
Portland	47,289.80	45,088.27	-2,201.53	-4.66	-0.47
St Andrew	13,707.25	13,014.24	-693.01	-5.06	-0.51
St Ann	46,287.84	45,543.60	-744.24	-1.61	-0.16
St Catherine	53,672.65	61,591.38	7,918.73	14.75	1.48
St Elizabeth	30,192.82	47,190.90	16,998.08	56.30	5.63
St James	31,428.30	37,813.16	6,384.86	20.32	2.03
St Mary	15,390.34	33,708.64	18,318.30	119.02	11.90
St Thomas	35,432.94	40,496.44	5,063.50	14.29	1.43
Trelawny	61,561.51	63,431.23	1,869.72	3.04	0.30
Westmoreland	26,238.28	30,307.07	4,068.79	15.51	1.55
Goat Islands	N/A	485.45	N/A	N/A	N/A
Total	**439,929.63**	**527,394.51**	**86,979.43**	**19.77**	**1.98**

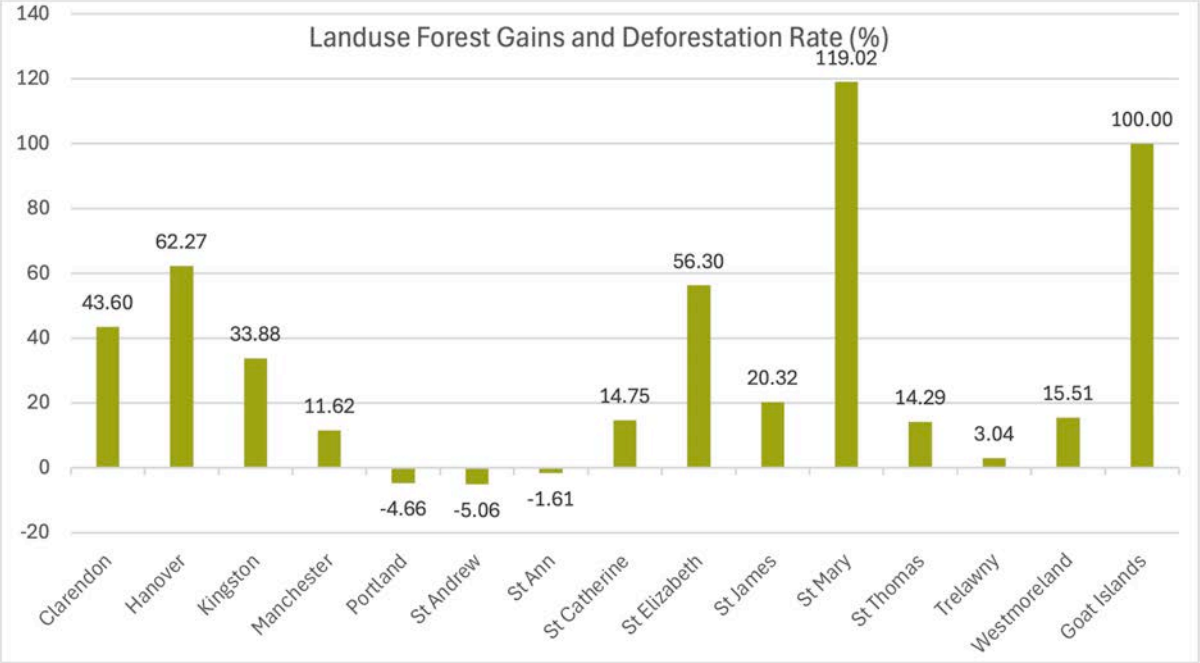


Figure 10: The Rates of Forest Gains and Deforestation Rate per parish

3.9 Deforestation and Degradation – Portland

An analysis of Table 10 reveals that only three parishes Portland, St Andrew and St Ann recoded mean annual rates of deforestation. Portland and St. Andrew are now recognised to be experiencing the highest rates of deforestation, at 4.66% and 5.06%, respectively. This is in direct contrast with the regrowth rates in 2013, which were recorded at 6.23% and 14.76%, respectively.

The rapid and negative turnaround in the situation in Portland, is being led by the deforestation and degradation of Disturbed Broadleaf Forests which seem to have occurred primarily due to agricultural activities **(Table 11)**. The landscape exhibits a transition from broadleaf forests to mixed land classes, such as Fields and Secondary Forests, along with Secondary Forests and Fields, indicating land clearance for agriculture. This deforestation is evident in areas like Spring Garden, Orange Bay, Black Hill, and Hope Bay **(Figure 11)**, where agricultural expansion has encroached upon previously forested areas. Moreover, degradation of Disturbed Broadleaf Forest has been recorded with large hectares being converted into Secondary Forests and Bamboo-dominated land cover. In **Figure 11**, the Buildings and Infrastructure class was generalized in 2013, but in 2023, a more robust classification method was applied, leading to a significant improvement in building classification accuracy. Additionally, the expansion of secondary forests due to regrowth caused a classification shift from "field and secondary forest" to "secondary forest and field." According to the methodology, a mixed land use field is classified based on the predominant vegetation type if it covers at least seventy-five percent (75%) of the area.

Table 11: Land Use Change and Hectares Loss for Disturbed Broadleaf Forest in Portland

Change	Change Hectares
Disturbed Broadleaf Forest - Fields and Secondary Forest	930.36
Disturbed Broadleaf Forest - Secondary Forest	679.97
Disturbed Broadleaf Forest - Secondary Forest and Fields	389.69
Disturbed Broadleaf Forest – Bamboo	160.45
Disturbed Broadleaf Forest - Buildings and other infrastructures	91.18
Disturbed Broadleaf Forest - Fields and Bamboo	52.65
Disturbed Broadleaf Forest - Fields or Secondary Forest/Pine Plantation	49.75
Disturbed Broadleaf Forest - Agriculture Plantation: Tree crops, shrub crops, sugar cane, banana	46.35
Disturbed Broadleaf Forest - Herbaceous crops, fallow, cultivated vegetables	28.26
Disturbed Broadleaf Forest - Water Body*	14.59
Disturbed Broadleaf Forest - Bamboo and Fields	9.94
Disturbed Broadleaf Forest - Urban Tree Cover ("Forest")	1.89
Disturbed Broadleaf Forest - Closed broadleaf forest	1.60
Disturbed Broadleaf Forest - Bare Land	0.94
Disturbed Broadleaf Forest - Herbaceous Wetland*	0.85
Disturbed Broadleaf Forest – Quarry	0.20

*The reduction in hectares results from improved classification methodology.

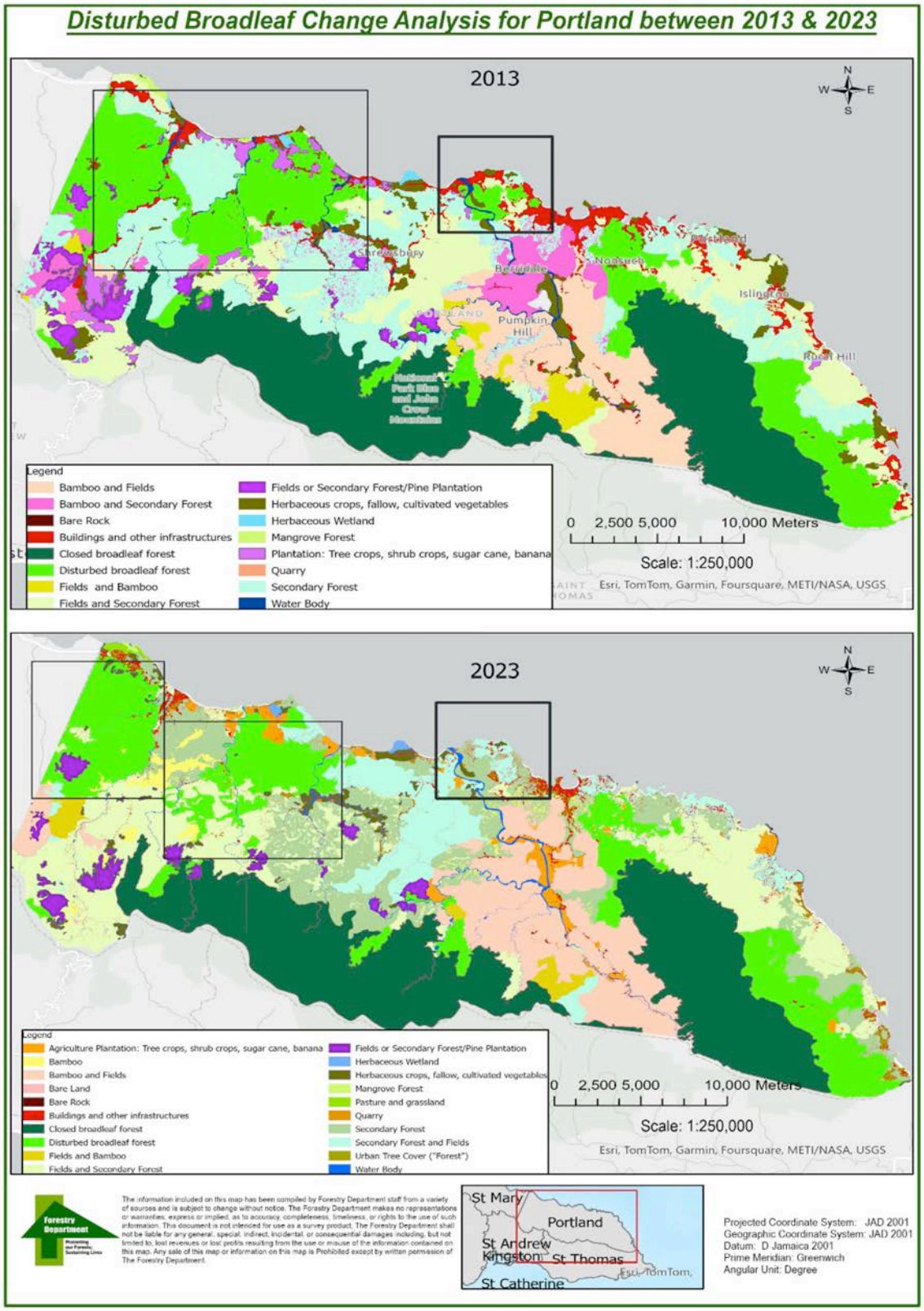


Figure 11: Portland Parish Forest Cover Changes Between 2013 and 2023

CHAPTER FOUR
DISCUSSION

DISCUSSION

4.1 Drivers of Change — An Interplay of Urbanization, Deforestation and Agriculture

During the period under review, it is noted that the drivers of the change in land use, land and forest cover was a complex interplay between urbanization, including infrastructure development, deforestation and the rise and fall of the agriculture sector.

The phenomenon of natural regeneration of forests has emerged as a significant driver of the observed increase in forest cover across Jamaica from 2013 to 2023. This is most evident via the noticeable trends associated with unutilised and/or under-utilized agricultural lands. The agriculture sector has always been a complex interplay of socioeconomic and environmental factors, with economic hardship being a primary factor contributing to agricultural land abandonment in Jamaica. According to Stanberry & Meadowcroft (2013), fluctuations in global markets, changes in trade policies, and economic downturns can render agricultural activities less profitable for farmers. Consequently, small-scale farmers often struggle to compete in an increasingly competitive market, leading them to abandon unviable landholdings. This has no doubt been exacerbated by the increasing frequency and intensity of extreme weather events.

Climate change-induced disturbances may also result in crop failures and the loss of livelihoods, causing farmers to cease agricultural operations (Campbell & Gornall, 2018). These challenges contribute to the migration of people from rural areas to urban centres in search of jobs and economic benefit. Population growth in urban centres has led to an associated increase in housing demand, land scarcity and pressure on the built infrastructure and the natural environment. Invariably, efforts to alleviate population pressures in the city result in the maximum utilization of available land through vertical construction to provide adequate and more affordable housing solutions to individuals. Even with vertical construction, high rents within the corporate area continues to force increasing numbers of people into nearby parishes forming quasi-commuter towns and driving the real estate markets within these areas.

The land use and its resulting change over time can be explained by the phenomenon of spatial equilibrium and can be observed in the cycle of land conversion from non-forest to secondary forest back to non-forest. In these situations, hectares of abandoned plantations undergo forest regeneration and then are re-converted to building and other infrastructure, primarily housing development and roads in the case of St. Andrew. Consequently, despite the consistent rate of forest growth over the past 23 years, secondary Forests remain vulnerable to ongoing land use pressures, mainly urban growth, and as such, secondary forests, while contributing to an increase in forest cover, should not be viewed as a permanent gain in forest cover.

4.2 Opportunities

4.2.1 Moving towards Conservation and Sustainability

Permanent gains in forest cover require concerted effort, this includes the designation of specified areas, the development of management and use plans and the long-term monitoring and protection of the area. The government of Jamaica is on course to achieve Target 3 of the Kunming- Montreal Global Biophysical Framework (The Biodiversity Plan) by protecting 30% or 329,685.30 hectares[6] of Jamaica's land and water by 2030.

The Agency contributes to this national objective, through the implementation of the National Forest Management and Conservation Plan (NFMCP), by continuously expanding its management portfolio and gazetting lands under management. A key example of this effort is the GEF-7 Mangrove Plus project, which aims to designate at least 7,600 hectares of mangrove land as protected forests. This initiative could bring 9,590.27 hectares (80%) of the island's mangroves under the Agency's protection and increase the forested lands managed by the Agency to 129,423.53 hectares, resulting in 24.5% of Jamaica's forests being protected. The Agency continues to strive for the increased protection of key biodiversity areas, aiming to raise its coverage from 24.5% of forested lands under its protection and management, ultimately contributing to Jamaica's achievement of Target 3 of The Biodiversity Plan.

Conservation efforts must also extend to protecting trees and green spaces in urban areas from encroaching development to ensure their longevity for future generations and the resilience and livability of our urban spaces. Improving tree cover and green spaces in urban areas has many advantages as it relates to reducing the impacts of climate change (Spence, 2024). The NFMCP prioritizes the planting native and climate-resilient tree species and maintaining healthy urban tree canopy cover to counter the impacts of the urban heat island effect, enhance air quality, and manage stormwater runoff. The Agency, with the support of the CityAdapt project has finalized a "Establishment and Maintenance of Urban Trees Guidelines", and this coupled with the urban tree cover "forest" spatial dataset available through the 2023 LU-LCAF, planners and policymakers will be better equipped to facilitate sustainable urban development.

The Agency has a goal to enhance Jamaica's urban tree cover within populated urban centres to eventually meet or exceed the international baseline of 30% coverage.

4.2.1.1 Achieving 30% Forest Cover Conservation by 2030

The LU-LUCF assessment serves as a valuable resource for the Forestry Department in formulating evidence-based strategies to increase both forest cover generally and increasing the area of forest under protection. The Agency presently oversees 121,823.53 hectares of forested lands **(Table 12)**, with an additional 7,600 hectares of wetland

6 The figure represents 30% of terrestrial area and inland water.

earmarked for inclusion under its management. Therefore, to achieve the target of conserving 30% of forest cover, the Forestry Department must safeguard an additional 28,811.54 hectares of forest.

Table 12: Total number of Parcels in the Forest Estate Dataset, the Corresponding Hectares, Legal Status and Forest Cover.

Lands in Forest Estate Dataset	Number of Parcels	All Lands under management (ha)	Percentage (%) breakdown of forest estate by status	Forest Cover (ha)
Gazetted (1950-2016)	130	104,897.22	86.11%	91,095.06
Pipeline for Declaration (2019-2023)	20	1,404.66	1.15%	1,025.83
Verified 23-24 Submitted for Declaration 24-25	5	35.67	0.03%	7.8
Others To be declared	93	15,485.98	12.71%	7,396.21
Total	**248**	**121,823.53**	**100%**	**99,524.9**

Table 13 shows that the Agency can leverage both government and privately owned forests through collaborative planning and management between government and private stakeholders, policy development and capacity building, along with public awareness and engagement. Engaging private landowners is particularly beneficial, given their ownership of a significant portion of high-quality forests, including disturbed broadleaf forests, as highlighted in **Table 13** and **Figure 12** and **Figure 13**.

An analysis of **Table 13** shows that there are three underrepresented forest types within the portfolio being managed by the Agency, these being, Mangroves, Secondary Forests and Disturbed Broadleaf Forests. These forest types therefore represent the greatest potential for anchoring forest cover in Jamaica in support of the implementation of REDD+ through the expansion of forest protection. The Jamaica Mangrove Plus Project (GEF *7) has as a primary objective the designation of mangrove forests, approx. 7,600 ha identified as being on other government lands. The Agency will thus focus efforts to engage private land holders with Disturbed Broadleaf Forests to engage in conservation of these areas. Similarly, the largest portion of lands identified as secondary forest is on other government owned lands and here too efforts will be enhanced to increase the area under conservation in support of biodiversity targets and in support of REDD+ implementation.

Table 13: The distribution of Forest Cover across Various Forest Types on Government and Private Lands.

Forest Type	Lands managed by Forestry Department (ha)	Other Government Lands (ha)	Private Lands (ha)
Closed broadleaf forest	64,154.26	0	19,768.77
Disturbed broadleaf forest	15,418.17	18,009.50	131,495.91
Pine Plantation/Other	4,524.02	0	0
Mangrove Forest	1,990.27	7,599.45	6,584.25
Open dry forest - Short	1,011.60	1,310.19	2,127.68
Open dry forest - Tall (Woodland/Savanna)	11,931.55	14,654.58	1,7801.93
Secondary Forest	7,927.33	227,44.56	147,144.93
Total Forest Cover	**106,957.20**	**64,318.28**	**324,923.47**

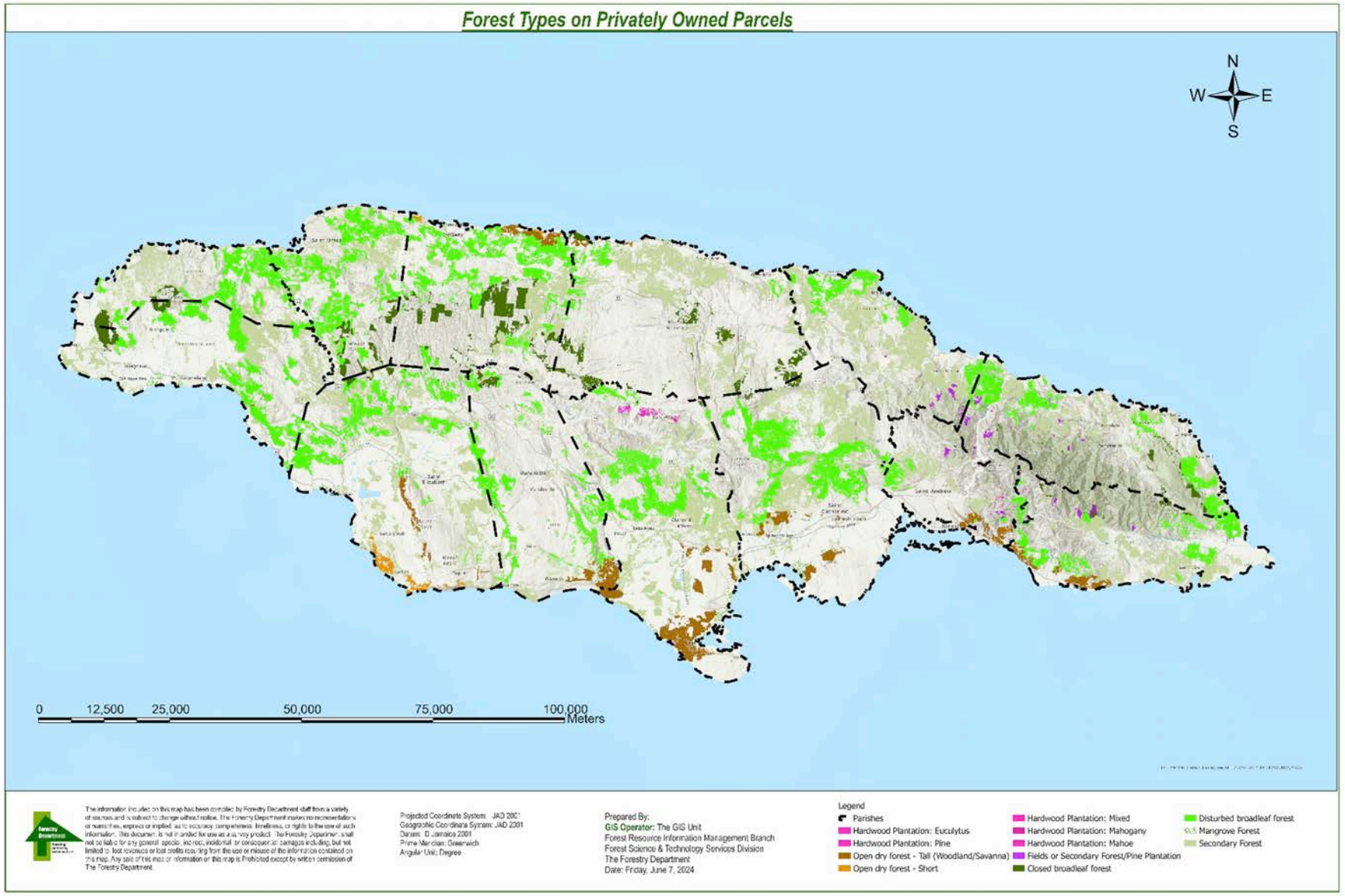


Figure 12: Forest Types on Privately Owned Lands

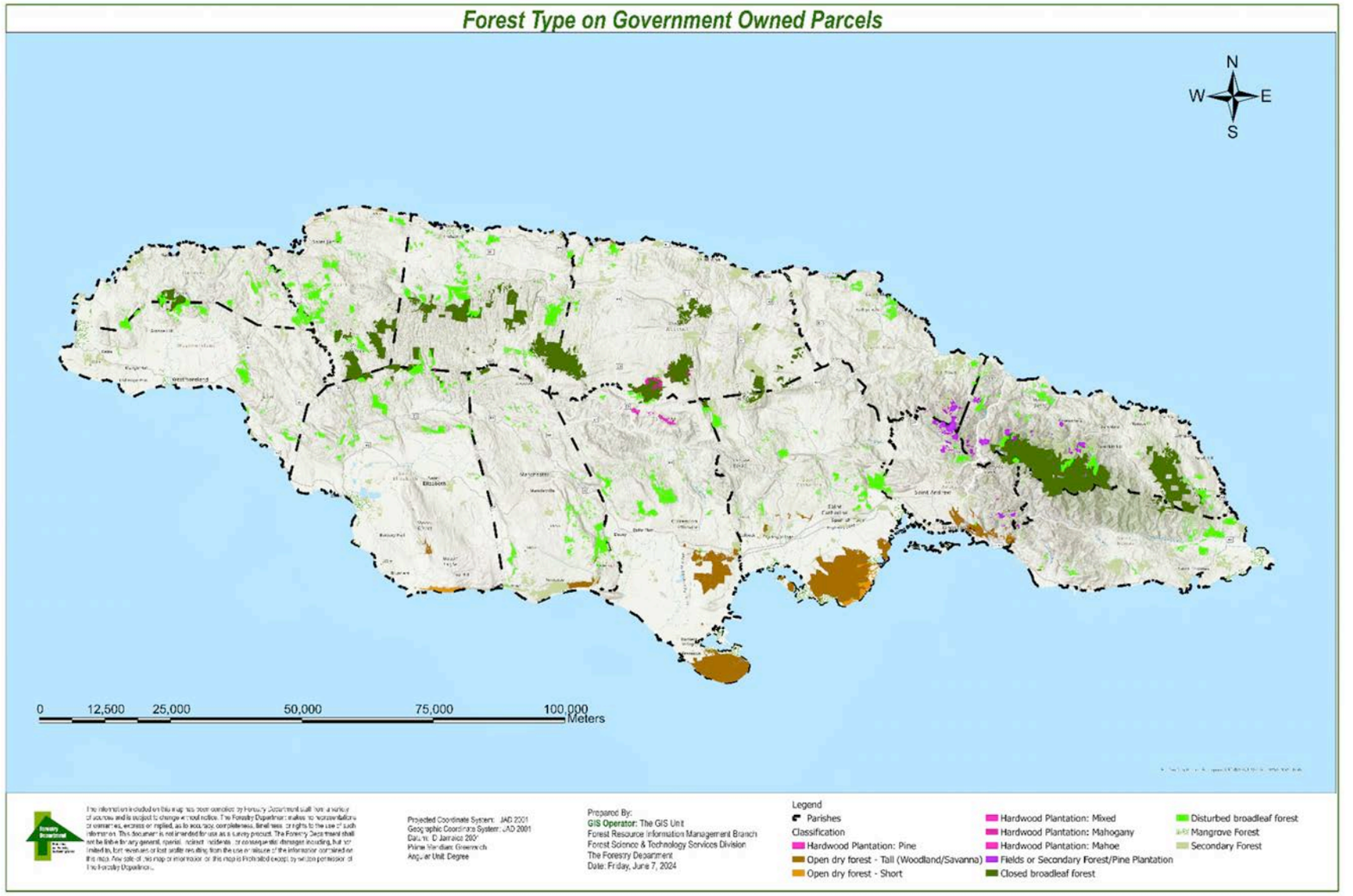


Figure 13: Forest Types on Government-owned Lands

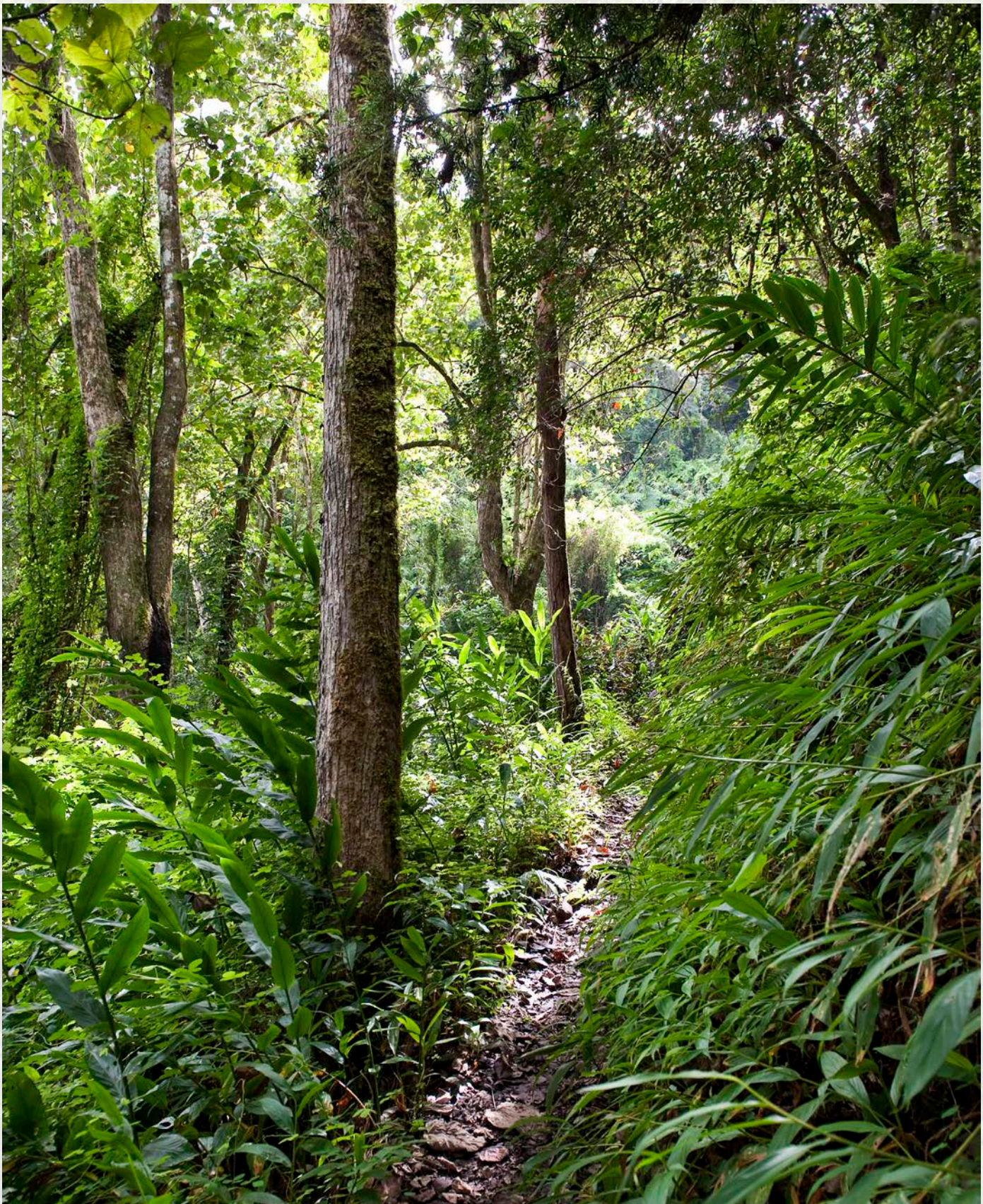
4.2.3 Harnessing Bamboo: A Sustainable Substitute for Wood in Jamaica

Bamboo, distributed throughout Jamaica, has proliferated rapidly and poses challenges as an invasive species, out-competing native plants. While the removal of bamboo demands significant resources, it presents an opportunity to harness its benefits as an alternative to traditional wood products. Wood has been integral to Jamaican culture, serving purposes such as craft production, yam sticks, fence posts, and fish pots, as well as providing fuel and charcoal. Furthermore, wood plays a fundamental role in shelter construction and household use, from durable housing structures to essential furniture and utensils.

Recognising bamboo's strength, durability, and versatility, it may be a viable substitute for various wood-based applications, notably fuel/charcoal and yam sticks which are major drivers of deforestation and defragmentation of forests in Jamaica. Its rapid growth and regenerative properties can contribute to sustainability efforts by reducing pressure on natural forests and promoting responsible land management practices.

The Agency is integral in the process of enforcing environmental standards and promoting responsible management practices and through the development of an Interim National Standard approved by the Forest Stewardship Council, it has laid the groundwork for a thriving bamboo industry in Jamaica, which utilizes existing acreages in a sustainable and managed way.

CONCLUSION



CONCLUSION

Prior to 1998, there was a deficiency in timely and accurate data on forest cover and deforestation rates in Jamaica. Recognising the critical role of forests in Jamaica's society, economy, and history, the Forestry Department was mandated as the authoritative body for all forest-related data. To achieve this, the Forestry Department employs high-resolution imagery, field verification, and statistical testing to ensure data accuracy and reliability. With climate change and the need to reduce CO2 emissions, Jamaica is dedicated to enhancing and protecting its forests.

In 1998 forest cover was reported at 30%, in 2013 at 40% and with this assessment it now stands at 47.9%As part of this overarching goal, the extensive mapping of Urban Tree Cover marks a notable advancement in realizing the goal of "green" urban centres. Moreover, Jamaica is recording consistent rates of regrowth primarily of its secondary forests. The Agency continues under the guidance of the NFMCP to align its efforts to sustainably manage and utilise Jamaica's forest resources to enhance social and economic development and to contribute to building the country's climate resilience.

APPENDICES

Appendix 1: Definitions of Land Use and Forest Cover Types used in Broad Classification

Land Use/Cover		Definition
Class	**Sub-class**	
Forest	Closed Broadleaved (PF)	Forest cover consisting of broadleaf trees at least at least 5 m tall and crowns interlocking with minimal human disturbance. This is as close to a primary forest one can get.
	Disturbed Broadleaved (SF)	Forests with broadleaf tresses at least 5 m tall and species that are indicators of disturbance include *Cecropia peltata* (Trumpet Tree). This category has less than 15% disturbance.
	Tall Open Dry (WL)	Open natural woodland or forest with trees at least 5 m tall and crown not in contact in drier parts of Jamaica with species-indicators such as *Bursera simaruba* (Red Birch) and *Coccothrinax jamaicensis* (Silver Thatch).
	Short Open Dry (SL)	Open scrubs, shrubs, bushes or brushland with trees or shrubs 1-5 m tall and crowns not in contact in drier parts of Jamaica with species-indicators such as *Prosopis juliflora* (Cashaw) or *Stenocereus hystrix* (Columnar cactus).
	Swamp (SW)	Edaphic forest (waterlogged soils) with a single tree storey with indicator species such as *Symphonia globulifera* (Hog Doctor) and *Roystonea princeps* (Royal Palm).
	Mangrove (MG)	Edaphic forest (areas with brackish water) composed of trees with stilt roots or pneumatophores with indicator species such as *Rhizophora mangle* (Red Mangrove), *Avicennia germinans* (Black Mangrove), *Laguncularia racemosa* (White Mangrove) and *Conocarpus erectus* (Button Mangrove).
	Secondary Forest (DS)	Classification identified (2013) having broadleaf forest equal or greater than 75% with disturbance levels between 10 - 25%. This level of disturbance distinguishes it from disturbed broad-leaf forests.
	Plantations (Forest (PP)	Forest cover re-established by reforestation or natural regeneration consisting of hardwood species such as Mahogany & Mahoe and Softwoods such as Caribbean Pine.
Mixed	Fields and Secondary Forest (SC)	>50% fields, >25% Secondary Forest
	Secondary Forest and Fields	>50% Secondary Forest; >25% fields
	Bamboo and Fields (BC)	>50% bamboo: >25% fields
	Fields and Bamboo	>50% field; >25% Bamboo
Non-Forest	Agricultural Plantation	Tree crops, shrub crops like sugar cane, bananas, citrus and coconuts.
	Fields	Cultivated herbaceous crops, shrub crops, fallow, legumes or grasslands/pastures.
	Bamboo	*Bambusa vulgaris* (Bamboo brakes) on the lower shale hill (disturbed forest). Not considered a forest type. Removed in reforestation programmes administered by the Agency
	Quarry	any open excavation made with the intention of searching for or removing any soil, sand, gravel, stone or clay
	Herbaceous Wetland	Edaphic vegetation (soil waterlogging) with herbaceous plants.
	Water Bodies	Lakes, rivers & streams, ponds etc.
	Small Islands	Mostly sand/limestone, un-vegetated small islands (cays)
	Bare Rock	Bare sand/rock
	Bauxite Extraction	Surface mining/bauxite
	Buildings and Other Infrastructure	Buildings and other constructed features such as airstrips, roads, bridges etc.
	Urban Forest	Urban forests can be defined as networks or systems comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas; they include, forests, street trees, trees in parks and gardens, and trees in derelict corners.

Appendix 2: Land Use Land Cover Classification - Accuracy Assessment

The kappa coefficient statistical test was employed in this accuracy assessment exercise as this methodology is commonly utilized in land use classification accuracy assessment for varying purposes. In land use classification, agreement between the observed and predicted classes is thought to occur by chance. The kappa coefficient adjusts for this chance agreement, providing a more accurate measure of agreement between the observed and predicted classifications. This methodology also accounts for the distribution of observations across different classes, providing a more balanced classification accuracy assessment. Calculating the Kappa coefficient outputs a single metric, simplifying the evaluation process and facilitating communication of results to stakeholders. Although, simplistic in its result generated, it is a robust assessment approach, in that it ensures that the prevalence of certain classes does not overly influence the classification accuracy assessment.

Appendix 3: Accuracy Assessment

A total of 28 LU classes were captured, with 26 assessed across four (4) classification blocks and using 396 sample points. Classification accuracy was evaluated using the confusion matrix to establish the accuracy of the user and producer. As an end product, the Kappa coefficient statistical test was generated against sample points required to complete the LU accuracy assessment. Block 1 & 3 comprised 26 classes, of which 24 were sampled as they had relevant ground-truthed sampling data associated with their respective locations and/or satellite imagery that provided an unobstructed view of sampled areas. The remaining two (2) classes were not sampled as relevant verification data was unavailable at this assessment.

Additionally, based on the total hectares of said classes, these would not be suitable for assessment within any block. These classes were Hardwood Plantation: Mahoe and Hardwood Plantation: Mixed. Block 2 North and South comprised 26 and 22 classes, respectively, of which all except Bare Rock, Fields & Bamboo, Hardwood Plantation: Mahoe and Pasture & Grassland were sampled.

Appendix 4: Confusion Matrix

The overall accuracy for the confusion matrix, obtained via random sampling and averaged across all blocks, was 88% (Table 1), with Block 1 achieved at 89%, Block 2 North at 93%, Block 2 South at 89%, and Block 3 at 82%. This suggests that Land use/cover classes generated for all areas are reliable. Initial sampling and calculations presented moderate results (69%-79%); therefore, reclassification occurred in several areas. Following reclassification, all Blocks were resampled, and the accuracy assessment was recalculated to determine a result.

User accuracy ranged from 70.78% to 100%, while producer accuracy ranged from 58.93% to 100%. The broad range of accuracy indicates some uncertainty and potentially high subjectivity in modelling Fields & Secondary Forest and Secondary Forest & Fields when compared with other land cover classes. Moreover, the producer accuracy (Sensitivity) measure reflects the accuracy of the prediction of the particular category. The user accuracy reflects the reliability of the classification to the user. User accuracy is the more relevant measure of the classification's utility in the field (Rwanga & Ndambuki, 2017). Several classes, including Closed Broadleaf and Quarry, were more reliable with 100% of user accuracy.

The overall accuracy provides the complete result of the confusion matrix. It is calculated by dividing the total number of correct pixels by the total number of pixels per class. Ahmad (2014) suggests that the minimum accuracy value for reliable LU classification is 85%. It is essential to highlight that much manual digitization was done following the Modelling output from Feature Analyst to achieve 88% accuracy for the classification exercise. This manual digitization provided advantages and disadvantages; however, as the reclassification exercise employed a manual method, this significantly contributed to the increase in overall accuracy.

Appendix 5: Kappa Coefficient

The Kappa statistics measure the agreement between two sets of categorizations of a dataset; the closer the value is to 1 (or 100%), the closer the agreement across categories is. Following the reclassification, the measured value from the Kappa Coefficient yielded an average value of 87%, with Block 1 achieved at 88%, Block 2 North at 92%, Block 2 South at 88%, and Block 3 at 81% (See appendix 1-4). This result exceeded the recommended accuracy value, suggesting the reclassification exercise proved critical in achieving excellence. McHugh (2012) explains that the kappa coefficient provides a more realistic view of the predictive model's performance. It removes the possibilities where the user and producer agreed by random chance and instead measures actual agreement. This accuracy can be described as strong, with 87% of land use/cover being classified correctly and only 13% being misclassified. (McHugh, M. L., 2012). See Appendix 1-4 for kappa coefficient interpretation.

Appendix 6: Kappa Reliability

Value of Kappa	Level of Agreement	% of Reliable Data
0–.20	None	0–4%
.21–.39	Minimal	4–15%
.40–.59	Weak	15–35%
.60–.79	Moderate	35–63%
.80–.90	Strong	64–81%
Above.90	Almost Perfect	82–100%

Appendix 7: Summary of Accuracy Assessment across all blocks

Classification	User's Accuracy %	Producer's Accuracy %
Agriculture Plantation: Tree crops, shrub crops, sugar cane, banana	83.93	100.00
Bamboo	78.10	100.00
Bamboo and Fields	100.00	70.09
Bare Land	100.00	91.67
Bare Rock	100.00	100.00
Buildings and other infrastructures	87.22	100.00
Closed broadleaf forest	100.00	100.00
Disturbed broadleaf forest	93.37	93.93
Fields and Bamboo	88.89	100.00
Fields and Secondary Forest	70.78	84.48
Fields or Secondary Forest/Pine Plantation	100.00	100.00
Hardwood Plantation: Mahogany	100.00	100.00
Herbaceous Wetland	93.75	100.00
Herbaceous crops, fallow, cultivated vegetables	85.00	93.65
Mangrove Forest	100.00	80.24
Open dry forest - Short	100.00	83.33
Open dry forest - Tall (Woodland/Savanna)	96.88	93.75
Pasture and grassland	77.78	70.00
Quarry	100.00	100.00
Secondary Forest	82.76	94.38
Secondary Forest and Fields	75.95	58.93
Urban Tree Cover ("Forest")	91.67	74.31
Water Body	91.67	100.00

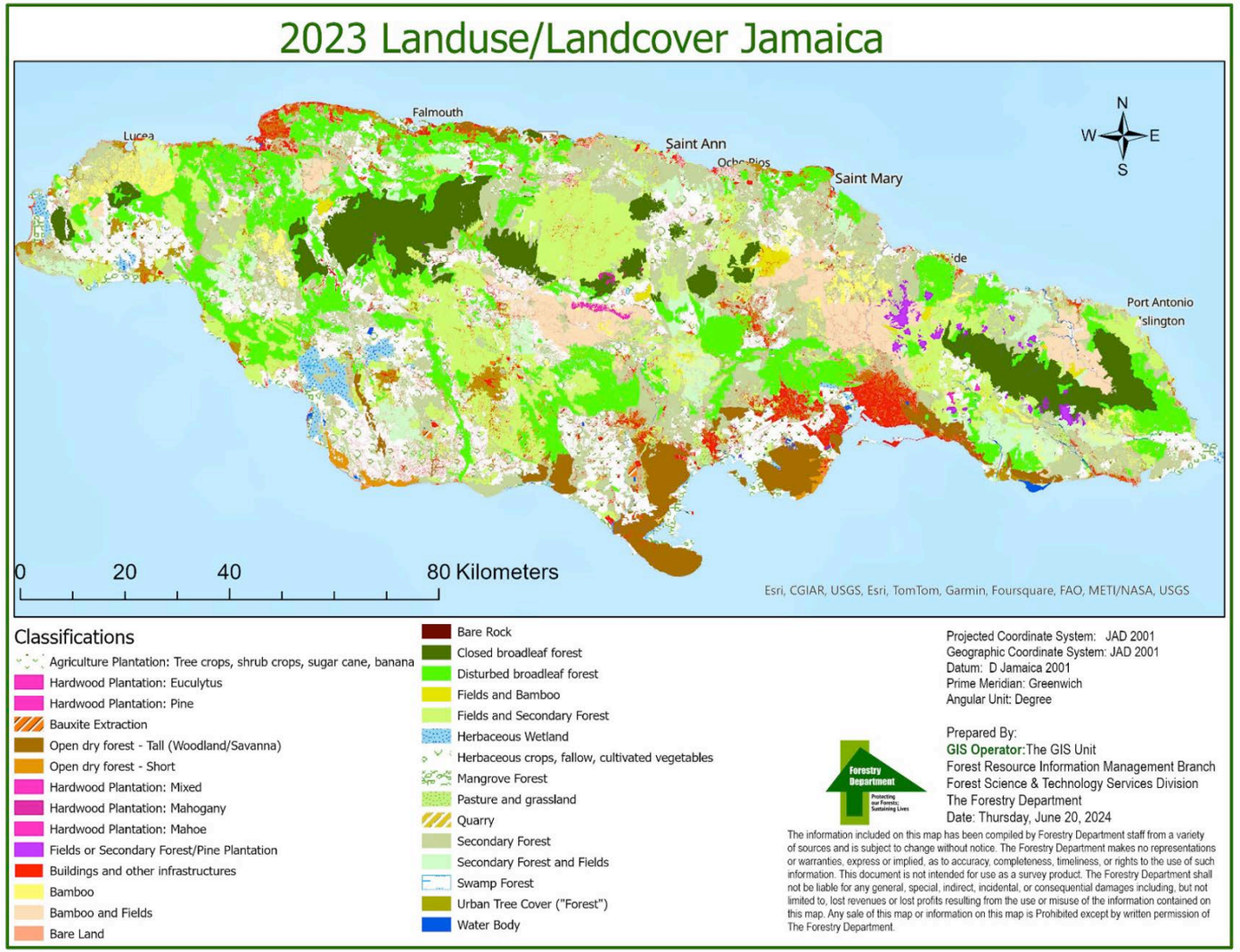
Appendix 8: Land Use/Land Cover Change Matrix

Land use/Cover Matrix 2013-2023 (ha)

2023 Landcover	2013 Landcover																													
		Forest Cover												Mixed Land use					Non-Forest											
	Classes	MG	PF	SF	DS	SW	SL	WL	HP:E	HP:MA	HP:M	HP: MI	HP:PI	BC	CB	CS	FB	BF	BE	BB	BR	BA	BL	FC	PA	HW	PC	QA	WA	Total Gain (ha)	Difference 2013-2023
	Forest Land use /Cover >75%)																													
	MG	7,128.63	3.91	219.84	134.57	108.57	50.17	130.84							1.61	124.97					24.41	490.42	27.73	1,130.56	26.10	4,895.60	114.65	6.95	209.30	**14,828.82**	**5,740.41**
	PF		83,756.61	6,602.88	398.26			348.78					2.90	0.11	5.38	28.94	6.00	1.88	0.50			13.76		162.25	17.99		43.83	3.82	0.20	**91,394.11**	**6,765.50**
	SF		297.48	150,522.67	7,201.85		0.02	1,149.97					25.09	413.88	231.51	2,474.44	481.07	2,077.25	57.60	808.11	1.21	4,680.24		3,434.53	178.33	2.40	998.34	13.39	103.77	**175,153.17**	**-558.79**
	DS	164.39	156.21	6,353.66	78,090.12	0.00	26.41	106.17					371.20	3,494.12	6,980.22	16,842.86	11,077.57	14,181.53	336.23	278.67	11.74	20,627.41	4,949.15	22,884.21	987.77	506.69	6,136.93	65.66	493.19	**195,122.12**	**59,499.13**
	SW					8.81		2.66														0.85		143.39		14.63			0.50	**170.84**	**48.52**
	SL	34.45		0.02	0.00		2,384.56	56.02													361.16	265.96	550.51	174.27		15.74	26.32	0.00	0.05	**3,869.07**	**1,261.30**
	WL	737.71		358.12	42.90		69.19	34,705.37								49.27			0.58		1,593.44	1,421.83	213.45	156.77	23.49	261.33	2,113.78	135.47	55.46	**41,938.15**	**4,396.08**
	HP:E								82.18																					**82.18**	**-1.68**
	HP:MA									2.24	81.47	1.84																		**85.55**	**82.22**
	HP:M										68.64																			**68.64**	**-81.55**
	HP: MI											72.96																		**72.96**	**-3.57**
	HP:PI				29.25								692.48	21.48	189.50	0.29	34.11	12.78				66.24		262.06			69.56		0.21	**1,377.96**	**-6,626.97**
	Mixed Land use/cover (first class> 50%, second class> 25%)																													
	SC	15.83	28.08	1,826.46	15,429.00		7.52	70.87			0.01		79.28	1,204.64	3,526.40	13,657.98	253.58	3,764.57	4.32		6.27	6,474.47	22.88	8,397.07	468.37	6.65	638.45	8.58	189.07	**56,036.44**	**56,036.44**
	BC		0.10	98.08	1,638.67		1.79	11.26					653.33	19,380.45	7,827.17	1,109.60	9,084.34	1,737.81		3,339.09		1,487.58		843.25	0.13		95.57		40.70	**47,348.81**	**18,030.88**
	CB		20.18	58.80	429.93								154.33	255.52	4,887.79	339.13	159.80	20.26				184.29		157.85			1.40		5.56	**6,654.66**	**-31,067.13**
	CS	58.09	189.40	3,312.41	22,457.79		0.80	14.91		1.08			302.94	605.64	2,524.01	80,788.86	386.71	1,166.43	1,862.32		13.60	14,031.13	593.48	14,431.78	126.47	155.54	1,714.72	28.37	98.10	**144,617.09**	**15,675.71**
	PP			87.38	424.27								4,500.23	53.50	17.54	19.74	168.40	68.38		21.61		0.32		16.11			0.29		0.57	**5,378.34**	**5,378.34**
	Non-Forest land use/cover																													
	BE		1.65	377.16	247.59			6.49								157.24			572.60			538.56		217.12						**2,118.41**	**-1,235.42**
	BB	6.87	24.15	872.39	1,788.43								73.06	2,574.17	9,221.28	1,119.60	6,559.82	2,381.02		114.50		463.22		1,287.71	16.42		204.51		38.34	**26,745.50**	**22,078.07**
	BR	3.72		4.02	13.87		3.17	0.46						0.09	1.18	9.72	0.42				98.83	20.73	0.50	19.38		5.46	8.94	2.95	0.83	**194.26**	**-1,998.99**
	BA	62.68	78.26	2,007.96	2,413.21	0.32	11.51	552.82	1.68		0.07	1.73	29.97	304.73	481.21	2,590.34	431.68	245.95	136.42	37.16	29.46	48,170.88	125.44	4,156.72	251.64	87.31	2,104.98	40.23	58.77	**64,413.11**	**-69,769.72**
	BL	13.22	3.35	74.78	44.83	1.32	0.01	1.74						3.22	39.90	165.44	13.78	9.89			34.11	380.29	11.12	77.62	0.00	10.13	27.36	1.56	21.42	**935.11**	**-6,094.55**
	FC	114.06	33.82	1,875.05	3,922.29		35.14	208.92					1,116.50	662.08	1,437.09	8,107.30	1,381.03	357.13	326.50	51.80	4.17	13,334.42	298.20	77,768.10	526.66	197.63	3,004.47	32.76	124.81	**114,919.94**	**-33,102.61**
	PA	25.47		108.94	328.93			3.89						6.88	59.93	375.92	8.58	15.54			3.58	490.97	24.87	2,665.85	3,418.21	9.66	91.77	3.78	7.54	**7,650.30**	**1,126.53**
	HW	641.67		21.87	13.97	2.60		19.12								11.92					0.28	477.95	43.32	2,319.21	2.73	8,488.83	206.32		119.26	**12,369.05**	**-2,429.72**
	PC	6.37	2.46	322.56	248.40		9.70	15.69						253.26	209.45	542.63	33.78	62.05	0.86	1.81		1,525.25	151.03	6,334.64	364.69	54.50	51,678.24	0.15	99.76	**61,917.27**	**-7,952.05**
	QA		3.24	54.13	84.24			64.00							1.37	55.17	0.69	0.19	39.78		4.51	101.34		207.05	2.19		15.91	371.08	25.55	**1,030.44**	**308.74**
	WA	65.28	16.52	82.43	82.40		0.88	18.97					3.63	78.97	40.71	94.65	71.45	58.55	13.40	14.67	0.43	1,043.06	16.95	339.24	14.11	75.14	351.96	4.74	2,785.35	**5,273.48**	**765.95**
	UF	9.97	13.19	470.34	158.22	0.68	6.91	53.14						5.21	38.53	275.37	3.35	1.96	2.71		6.04	17,891.66	1.04	435.82	98.47	11.54	221.00	2.21	29.22	**19,736.59**	**19,736.59**
	Total Loss	**9,088.41**	**84,628.60**	**175,711.97**	**135,623.00**	**122.32**	**2,607.77**	**37,542.07**	**83.85**	**3.32**	**150.19**	**76.52**	**8,004.93**	**29,317.94**	**37,721.79**	**128,941.38**	**30,156.17**	**26,163.17**	**3,353.83**	**4,667.43**	**2,193.26**	**134,182.83**	**7,029.66**	**148,022.55**	**6,523.77**	**14,798.77**	**69,869.32**	**721.70**	**4,507.53**		

MG- Mangrove, **PF-** Closed Broadleaf, **SF-** Disturbed Broadleaf, **DS-** Secondary Forest, **SW-** Swamp Forest, **SL-** Open Dry Forest short, **WL-** Open Dry Forest tall, **HP:E-** Eucalyptus Plantation, **HP: MI-** Mixed Plantation, **HP:PI-** Pine Plantation, **HP:MA-** Mahoe Plantation, **HP:M-** Mahogany Plantation, **SC-** Secondary Forest and Fields, **BC-** Bamboo and Fields, **CB-** Fields and Bamboo, **CS-** Fields and Secondary, **PP-** Fields or Secondary Forest/Pine Plantation, **BE-** Bauxite Extraction, **BB-** Bamboo, **BR-** Bare Rock, **BA-** Building and Infrastructure, **BL-** Bare land, **FC-** Herbaceous crops, fallow, cultivated vegetables, **PA-** Pasture and Grassland, **HW-** Herbaceous Wetland, **PC-** Agriculture Plantation: Tree crops, shrub crops, sugar cane, banana, **QA-** Quarry, **WA-** Waterbody, **UF-** Urban Tree Cover.

Appendix 9: LU-LUCF Map of Jamaica 2023



REFERENCES

Astell-Burt, T., & Feng, X. (2019, November 13). Urban green space, tree canopy and prevention of cardiometabolic diseases: a multilevel longitudinal study of 46 786 Australians. International Journal of Epidemiology, 49(3), 926–933. https://doi.org/10.1093/ije/dyz239

Brown, D. G., Pijanowski, B. C., & Duh, J. D. (2017). Modeling the relationships between land use and land cover on private lands in the Upper Midwest, USA. Landscape and Urban Planning, 69(2-3), 183-199.

Campbell, D., & Gornall, J. (2018). Climate change impacts on agriculture in Jamaica: A review. Climate, 6(2), 35.

Climate Studies Group, Mona. (2021). Climate Change and Variability in Jamaica: Synthesis of Current Climate Knowledge. Retrieved from http://www.mona.uwi.edu/climate/sites/default/files/Climate%20Change%20Synthesis%20%282021%29.pdf

Congalton, R. G., & Green, K. (2008). Assessing the Accuracy of Remotely Sensed Data: Principles and Practices (2nd ed.). CRC Press.

Evelyn, O., & Camirand, R. (2003, December). Forest cover and deforestation in Jamaica: an analysis of forest cover estimates over time. International Forestry Review, 5(4), 354–363. https://doi.org/10.1505/ifor.5.4.354.22659

FAO. (2021). Forest and Landscape Restoration: A Guide to the Restoration Opportunities Assessment Methodology (ROAM). Food and Agriculture Organisation of the United Nations.

Foody, G. M. (2002). Status of land cover classification accuracy assessment. Remote Sensing of Environment, 80(1), 185-201.

Forestry Department. (2001). Forest Policy of Jamaica. Kingston, Jamaica: Forestry Department.

Konijnendijk, C. C. (2022, August 26). Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: Introducing the 3–30–300 rule. Journal of Forestry Research, 34(3), 821–830. https://doi.org/10.1007/s11676-022-01523-z

NASA. (2024). Vital Signs of the Planet. NASA Global Climate Change. Retrieved March 5, 2024, from https://climate.nasa.gov/vital-signs/carbon-dioxide/

National Environment and Planning Agency. (1995). State of the Environment, Jamaica1995, Part 2. Retrieved March 5, 2024, from https://websitearchive2020.nepa.gov.jm/publications/SoE/SOE/soe2.htm

National Renewable Energy Laboratory (NREL). (2015, April). Energy Transition Initiative, Island Energy Snapshot - Jamaica (Fact Sheet). Retrieved March 5, 2024, from https://www.nrel.gov/docs/fy15osti/63945.pdf

Pan, C., Zhou, G., Shrestha, A. K., Chen, J., Kozak, R., Li, N., Li, J., He, Y., Sheng, C., & Wang, G. (2023). Bamboo as a nature-based solution (NbS) for climate change mitigation: Biomass, products, and carbon credits. Climate, 11(9), 175. https://doi.org/10.3390/cli11090175

Stanberry, D., & Meadowcroft, M. R. (2013). Jamaica's Agricultural Sector: Issues and Policy Directions.

Statistical Institute of Jamaica. (2019). Population Statistics. https://statinja.gov.jm/. Retrieved March 5, 2024, from https://statinja.gov.jm/Demo_SocialStats/PopulationStats.aspx

Tewabe, D., & Fentahun, T. (2020, January). Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia. Cogent Environmental Science, 6(1). https://doi.org/10.1080/23311843.2020.1778998

United Nation Framework Convention on Climate Change (UNFCCC). (n.d.). Emissions Summary for Jamaica. Retrieved March 5, 2024, from https://di.unfccc.int/ghg_profiles/nonAnnexOne/JAM/JAM_ghg_profile.pdf


Forestry
Department
Protecting
our Forests;
Sustaining Lives