Food and Agriculture Organization of the United Nations

SCALA Private Sector Engagement Facility

Feasibility Assessment of Compost Potential in Grenada



ABSTRACT

Waste management is a growing concern in Grenada. Moreover, in the context of increasing severity of climate change, the country is actively looking for solutions to limit exposure to external market shocks and reduce its dependence on imported fertilizers. Mitigation of emissions from the waste sector is a key goal of the latest Nationally Determined Contribution of Grenada. Using compost as an organic soil amendment can support these efforts while enhancing the resilience of local agriculture to the impacts of the changing climate. To date, a few attempts at establishing composting businesses have been carried out in Grenada; however, an actualized assessment of the feasibility of such investments is lacking. This report researched organic waste volume and disposal routes and their potential valorization through composting. Several potential scenarios have been modeled and tested to assess the strengths and weaknesses of each business model. Diverting organic waste away from the landfill to the fields through composting could cover at least 16% of the macronutrient needs of Grenada's agrifood sector, while reducing greenhouse gas emissions from the organic waste used for composting by 98%. A commercial compost plant capable of turning 6,500 tonnes of segregated organic waste into 2,500 tonnes of high-quality compost would be environmentally and technically feasible, as well as a financially viable option with positive economic indicators such as IRR and NPV. A sensitivity analysis and risk assessment analysis in the study highlight the need to support market penetration through demonstration projects and awareness-raising campaigns.

KEY MESSAGES

- Grenada has the potential to substitute at least 16% of nutrients used in agriculture with domestically produced compost
- Compost production is possible at Perseverance landfill using segregated organic waste and in several decentralized small-scale plants to supply nearby communities
- Composting could reduce GHG emissions from organic waste decomposition by 98% when compared to the baseline
- Composting has positive climate change mitigation and adaptation benefits for Grenada
- Small-scale decentralized plants require financial support to be competitive with chemical fertilizers, but are a key solution to enable local markets and develop profitable commercial scale market uptake
- Commercial-scale plant shows a strong financial performance and is a profitable investment option for the private sector
- Biomass separation and segregation activities need to be introduced and expanded to mitigate risks related to waste management.
- It is recommended to support market penetration through demonstration projects and awareness-raising campaigns

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FOREWORD

Over the years, climate change has emerged as a growing threat to many Small Island Developing States (SIDS), with Grenada among the most vulnerable. Rising temperatures, erratic weather patterns, and environmental degradation are jeopardizing our agriculture, ecosystems, and the very foundation of our livelihoods. As a nation heavily dependent on agriculture for food security and economic stability, these impacts place our communities and future generations at significant risk.

Recognizing these urgent challenges, the Government of Grenada, through the Ministry of Climate Resilience, the Environment and Renewable Energy, in collaboration with the Ministry of Agriculture and Lands, Forestry, Marine Resources and Cooperatives, has taken decisive steps to safeguard the nation's future. Our commitment under the Nationally Determined Contribution (NDC) 3.0 and the National Adaptation Plan (NAP) places climate adaptation and mitigation at the heart of sustainable development, with a particular focus on transforming Grenada's food systems and improving waste management. These priorities are essential for reducing greenhouse gas emissions from waste, strengthening resilience, and building a climate-smart economy.

This feasibility study, developed under the Scaling up Climate Ambition on Land Use and Agriculture (SCALA) Private Sector Engagement (PSE) Facility programme, reflects Grenada's strategic vision. By actively engaging the private sector in climate adaptation initiatives, we aim to foster innovation, enhance adaptive capacity, mobilize investment, and co-develop scalable climate solutions. In a land-constrained context such as ours, private sector participation is indispensable to accelerate progress and demonstrate the potential of collaborative action. The study focuses on three interlinked components: the estimation of potential compost production, the assessment of suitable composting technologies, and a cost-benefit analysis of a pilot composting facility. These findings support the achievement of targets outlined in Grenada's NAP and NDCs and contribute directly to the global Sustainable Development Goals, including sustainable agriculture and food loss and waste reduction. Importantly, the insights generated serve as a model for Grenada and other Caribbean nations exploring the valorization of organic waste within a circular economy framework.

Grenada remains firmly committed to resilience, innovation, and sustainability, embracing a vision that addresses the immediate challenges of climate change while laying the foundation for a thriving, self-reliant future. This commitment seeks to empower communities, restore ecosystems, and position agriculture as a pillar of hope in the face of global uncertainty.

Ministry of Climate Resilience, the Environment, and Renewable Energy

INTRODUCTION

1.1. Background and objective of the study

Grenada is an island country of the West Indies in the eastern Caribbean Sea. It consists of three major islands including mainland Grenada, Carriacou, and Petite Martinique, and several smaller islands. The economy of Grenada is largely based on tourism, also its main source of foreign exchange, followed by construction, wholesale, and retail trade sectors. In the last twenty years, the country's economy has primarily shifted from agricultural production to the provision of services. In 2022, services accounted for 63% of the country's GDP, followed by industry at 15.15% and agriculture at 4.2%. An important contributor to the local economy and exports, the agriculture sector, which employs 24% of the labour force, has been experiencing a protracted decline. Local production accounts for about 30% of food consumption, and the remaining 70% is imported (GCF, 2021)[1]. Grenada is the world's second largest producer of nutmeg, one of its largest exports. Other major exports include bananas, cocoa beans, fish, wheat flour, and spices such as mace, cloves, and cinnamon (FAOSTAT, 2025)[2].



Figure 1. Freshly harvested nutmeg and mace

Grenada is characterized by a humid tropical climate and a mountainous terrain with extensive corals and mangroves surrounding the islands. The country is highly vulnerable to climate change, as evidenced by recent extreme events. These events include increased forest fires, crop loss, water shortages, groundwater depletion, protracted droughts, coastal erosion, contamination and

[1] National Adaptation Planning for Improved Food Security in Grenada | Green Climate Fund
[2] FAOSTAT

sedimentation, inadequate solid waste management, flooding, and a higher incidence of pests and disease.

Small island communities are also susceptible to saltwater intrusion into freshwater sources, making the country highly vulnerable to rising sea levels. Grenada's key economic sectors, like agriculture and tourism, are extremely vulnerable to climate change impacts, which poses challenges to water supply for agriculture and tourism[3],[4]. Hurricanes Ivan and Emily, and more recently Beryl (2024), had devastating impacts on these sectors, and abnormal weather patterns have negatively affected major crops. An increase in the sea level of half a meter would destroy up to 83 per cent of the beaches. Much of the infrastructure, including ports, power stations, roads, and many homes is also at risk[5]. Climate change vulnerability also impacts all components of the food value chain, and particularly the livelihoods of the most vulnerable communities. Extreme weather events can lead to crop failures, water scarcity, agricultural soil erosion, and reduced agricultural productivity. This directly affects food availability and security, economic stability, farmers' incomes, and livelihoods dependent on tourism, fisheries, and coastal agriculture, and ecosystem services. It also leads to increased fertilizer runoff, which is a threat to the integrity of the marine environment, including marine protected areas[6]. Addressing these challenges requires comprehensive adaptation and mitigation strategies, including sustainable land management practices, diversified livelihood options, and improved infrastructure to build resilience to climate change impacts. Empowering communities to make decisions about their livelihoods, and natural resources is essential in helping them adapt and thrive in a changing climate[7,8].

Recognizing climate change as an existential threat to Grenada, the government is leading several programs to promote climate resilience. In 2017, the country submitted its National Climate Change Adaptation Plan (NAP) for Grenada, Carriacou, and Petite Martinique 2017-2021, providing a strategic coordinating framework for building climate resilience, recognizing the need to develop an enabling environment for climate change adaptation. It also aimed to address programmatic priorities and difficulties in attracting private sector investors and securing finance. Farmers have been supported in establishing composting sites and implementing sustainable land management practices. Climate-Smart Agriculture (CSA) approaches have also been integrated into the 2016 workplan of the Corporate Plan of the Ministry of Agriculture and prioritized by the NAP. This includes resilient and sustainable land management (b designing, locating, and maintaining infrastructure to withstand climate change, along with sustainable land management), food security (ensuring 60% of agricultural officers advise farmers on Climate-Smart Agriculture (CSA) practice), and management and conservation of protected areas and ecosystems (protecting and managing 20% of Grenada's marine, coastal, and terrestrial ecosystems by 2021). In 2015, Grenada submitted its first NDC, focusing on energy, transport, waste, and forestry as the main sectors for mitigation. In 2020, the country submitted its second NDC,

[3] https://www.undp.org/sites/g/files/zskgke326/files/migration/bb/undp-bb-Small-Smart-States-Grenada-Final-Report.pdf
[4] https://documents1.worldbank.org/curated/en/099062823113524552/pdf/BOSIB0fdb5b3590ec0887608de2e525a0e3.pdf
[5] https://www.giz.de/en/projects/programme-integrated-adaptation-strategies-grenada
[6] https://unfccc.int/sites/default/files/resource/NAP_Grenada_2019.pdf
[7] https://www.imf.org/en/Publications/CR/Issues/2019/07/01/Grenada-Climate-Change-Policy-Assessment-47062
[8] https://www.thegef.org/projects-operations/projects/9577?utm_source=chatgpt.com

confirmed[9] the goal of a 40% reduction from 2010 emission levels by 2030, adding the Industrial Processes and Product Use (IPPU) sector and leveraging mitigation co-benefits of adaptation efforts[10].

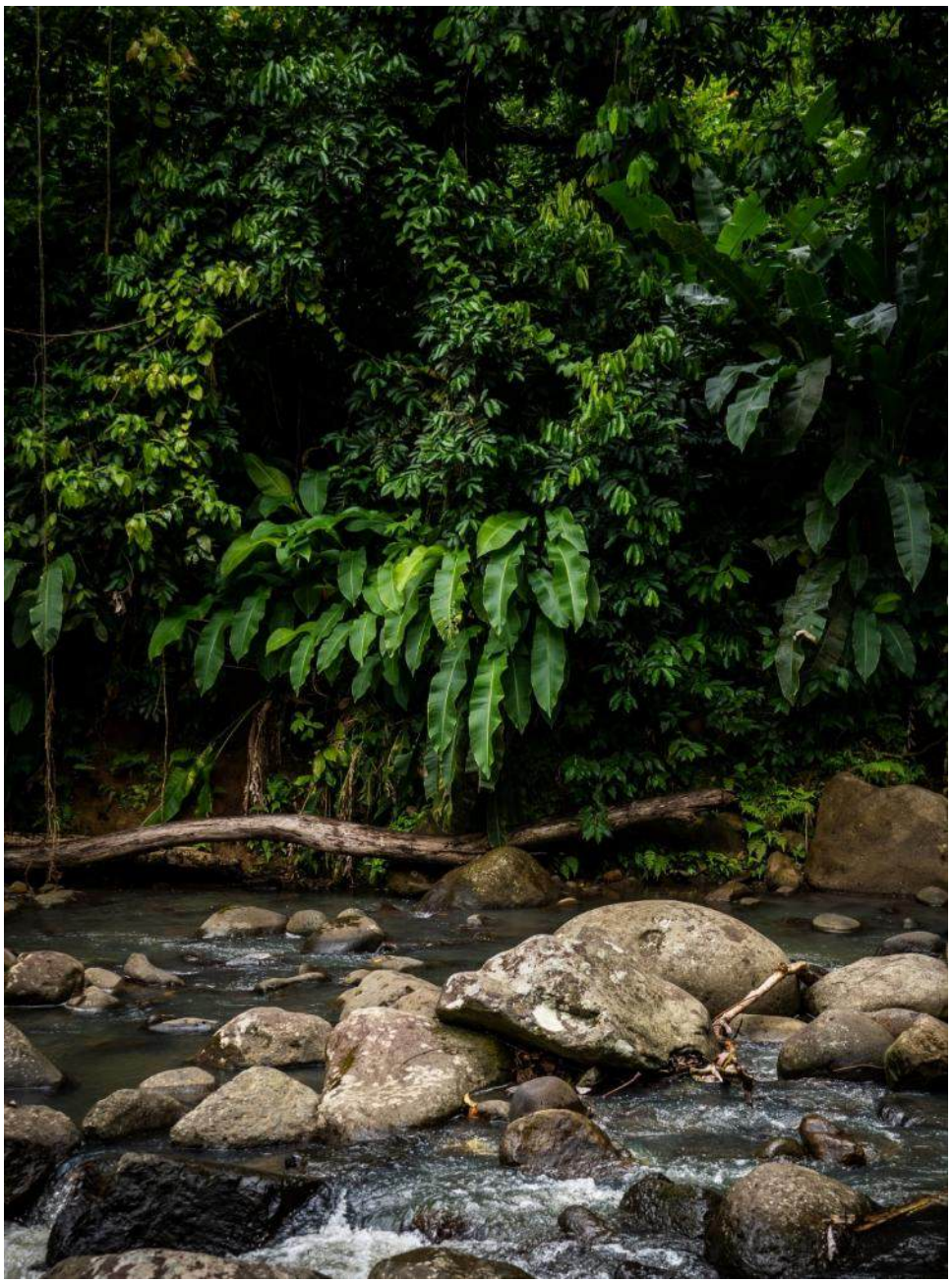


Figure 2. The lush vegetation of the inland of Grenada

The NDC also outlines the commitments to creating a more robust economy and resilient communities by strengthening the coordination between the national and local level authorities to build capacity and spread knowledge and strong community level networks (Government of Grenada 2015). Objectives of the Grenada National Sustainable Development Plan (NSDP) 2020-2035 include facilitating climate smart infrastructure planning, design and maintenance, sustainable land management, and greenhouse gas (GHG) emissions reductions from various sectors including waste. Along these lines, organic waste

[9] https://unfccc.int/sites/default/files/NDC/2022-06/GrenadaSecondNDC2020%20-%2001-12-20.pdf
[10] https://climatepromise.undp.org/what-we-do/where-we-work/grenada

management and composting could play an important role in building climate resilience in vulnerable populations by enriching soil fertility and improving resilience to extreme climate events. In turn, this would enhance the country's capacity to face regional and global food market shocks, given its increasing dependency on food imports.

Grenada has a relatively low financial and technical capacity to prevent climate change[11]. According to the International Monetary Fund (IMF), the Grenadian Government will require large increases in international support, both financial and technical, to convert climate resilience plans into action. To meet its adaptation and mitigation plan, Grenada will need to rely heavily on private sector investment and gradually expand a market for the private sector to scale climate-friendly technologies through various instruments, including public private partnerships (PPPs) supported by clear regulations. In terms of climate change adaptation, the economic potential of organic waste and composting extends across various sectors, including waste management, agriculture, and soil health. It also offers opportunities for revenue generation, landfill disposal volume reduction, resilience building, local development, and long-term cost savings for farmers.

Aligned with these priorities, in September 2023, the Government of Grenada expressed their interest in receiving support from the Scaling up Climate Ambition on Land Use and Agriculture (SCALA) programme which supports countries to build adaptive capacity and reduce greenhouse gas emissions to meet targets set out in their NAPs and Nationally Determined Contributions (NDCs). The government of Grenada has specifically applied to receive support from the SCALA Private Sector Engagement (PSE) Facility, which aims to strengthen private sector participation in adaptation initiatives across selected non-SCALA countries. The SCALA PSE Facility offers targeted support through three broad service lines, which include: i) outreach, opportunity mapping and facilitating multi-stakeholder engagement, ii) assessing risks and business opportunities, and iii) de-risking and enabling private investment.

A meeting with the Global SCALA PSE Team and Focal Points (FPs) at UNFCCC, Ministry of Environment, FAO, and UNDP in Grenada took place in November 2023 to discuss the scope of work in line with the scope of PSE Facility support that can strategically contribute towards attaining national objectives, providing evidence-based research for the NAP, NDC and the NSDP.

[11] https://ndcpartnership.org/knowledge-portal/good-practice-database/strengthening-climate-resilience-case-grenada

1.2. Scope of the work and case studies

This study focuses on investigating the possibility of using organic residues generated in Grenada to produce compost and replace chemical fertilizers. Like many other Small Island Developing States (SIDS), Grenada faces the consequences of waste management due to land constraints. Grenada's Solid Waste Management Authority (GSWMA) disposed of approximately 45,000 tons of waste in 2017 and is facing a challenge with managing its disposal at Perseverance landfill, a site a few miles outside the Capital St. George, that is quickly reaching its capacity. Despite GSWMA's efforts in locating a new site for an additional landfill, more sustainable solutions are needed to support Grenada's ambition towards the achievement of its NAP and NDC targets. GSWMA is currently aiming to have an "Integrated Solid Waste Management" approach. This strategy, incorporating the principles of the circular economy, emphasizes reducing, reusing, and recycling waste, followed by converting it into energy and finally sending the remainder to the landfill. Robust waste management systems prevent contamination of water sources and reduce flooding risks, thereby contributing to climate adaptation efforts. Moreover, these strategies also conserve resources such as water, energy, and materials, reducing the need for resource-intensive production processes and the demand for virgin materials, while lowering GHG emissions and providing a renewable energy source from organic waste (biogas).

Waste management is a crucial issue in Grenada's environmental policy, requiring support and offering potential business opportunities. Converting organic waste into compost or organic fertilizers is a well-accepted form of organic waste valorization. Composting is a process that utilizes microorganisms naturally present in organic matter and soil to decompose organic material. It produces a compound rich in organic matter that is similar to humus. Compost is a soil conditioner rich in nutrients, and its specific composition depends upon various factors, including the type and composition of the original biomass and the composting procedure. High quality compost can be a valuable aid to agriculture as it can deliver nutrients and organic carbon to soils, thus displacing chemical fertilizers and reducing GHG emissions. During the composting process, a portion of its carbon compounds is emitted into the atmosphere as carbon dioxide (CO_2), while the remaining share of organic carbon is stabilized into the final product. When the same biomass or organic waste is piled in a landfill, it goes through an anaerobic process called methanogenesis driven by methanogenic microorganisms, because of which methane gas is released into the atmosphere. Methane is a powerful GHG that has 27 times more Global Warming Potential (GWP) than CO_2. Moreover, compost is one of the pillars of CSA as it can improve food security and increase water retention capacity of soils, as well as soil biodiversity, thus fostering soil resilience to the changing climate. This is in line with Plan of Action 4: Food Security of Grenada's NAP[12], which expressly calls for actions to disseminate and scale up CSA activities, including composting use as a climate change adaptation priority of the country. Organic fertilizers such as compost are among the most effective Nature-based Solutions (NbS) for supporting plant development[13], particularly on degraded lands and high pH soils[14].

[12] Grenada_National Adaptation Plan_ 2017-2021.pdf
[13] Nature-Based Solutions | CH4 Climate
[14] Nature-based solutions using organic amendments for biorestoration of alkaline spoil material

Based on this the Government of Grenada requested assistance to the SCALA PSEF to carry out a feasibility study on organic waste composting starting from the available amounts of organic waste generated and collected in Grenada, to assess sustainable business opportunities for the local private sector. The assessment encompassed the following aspects:

- An estimation of compost production potential in Grenada based on validated organic waste availability and potential GHG emission reduction and expected adaptation benefits.
- An assessment of the most suitable composting technology for Grenada and associated cost-effective composting plant design and guidelines.
- A Cost-Benefit Analysis (CBA) of composting at a case-study facility, considering production costs and market conditions (e.g. compost demand and fertilizers market) with an emphasis on adaptation benefits for agriculture and land rehabilitation through compost and CSA.
- A final meeting/workshop with key private sector representatives, investors, government officials, researchers, and other relevant stakeholders will be organized to share the results and lessons learnt from the exercise and present a roadmap for business opportunities and facilitate the ideation of potential future interventions.
- The presentation to local stakeholders and youth on the methodological approach for assessing the technical, economic, and environmental feasibility of composting conversion of organic waste.

The proposed approach provides market-based information on the feasibility of valorizing organic waste produced in Grenada through composting, and on how to implement it through private investments that contribute to the sustainable development of the country. Private sector actors have been engaged through discussions and training to disseminate the potential mitigation benefits of compost production from organic waste and adaptation benefits of compost use in agriculture. These include increased yields, organic food production, reduced food waste and associated emissions, more nutrient-rich food availability, increased food security and sovereignty, and enhanced soil resilience to stresses, droughts, floods, and reduced land degradation. This assessment will evaluate the potential of domestically produced organic fertilizers to scale-up CSA practices, and its contribution to adaptation in line with current agricultural conditions in Grenada. The resulting proposed strategy aims to optimize valorization potential and broaden informed investment opportunities within the private sector in sustainable and resilient agriculture. Economies of scale and multiple criteria have been considered in the analysis, as the choice of technology depends largely on the size of the composting plant. Finally, the study has produced several investment scenarios that apply to different realities in Grenada, and related opportunities for the sustainable management of organic waste resources. The results of this work will also contribute towards SDG Indicators 2.4.1 (proportion of agricultural area under productive and sustainable agriculture) and 12.3 (reducing by half per capita global food loss and waste losses by 2030). It will also inform other Caribbean countries (and possibly SIDS in other geographical areas) on the potential for valorization of organic waste within a circular economy framework.



Figure 3. The Perseverance landfill in St. George's, Grenada receives approximately 45,000 tons of mixed waste per year.

2. COUNTRY OVERVIEW

2.1. Background

Grenada is an island country of the West Indies. It is the southernmost island of the north-south arc of the Lesser Antilles, in the eastern Caribbean Sea, about 160 km north of the coast of Venezuela. Oval in shape, the island is approximately 34 km long and 19 km wide. The southern Grenadines - the largest of which is Carriacou, about 32 km north-northeast, with an area of 34 square km - are a dependency.



Figure 4. The map of Grenada[15]

The capital, St. George's, on the southwest coast, is also the main port, with a natural harbour, and its picturesque pastel-coloured houses rise on the hillsides on the waterfront. In 1974, Grenada attained

[15] Grenada-map - Grenada - Wikipedia

independence within the Commonwealth and membership in the United Nations. It was the first of the six West Indies Associated States to do so.



Figure 5. One of the beaches on the main island of Grenada.

The island has equable temperatures, varying with altitude and averaging 28 °C year-round. Rainfall is adequate, except in the Point Salines area in the southwest; it varies from an average of 1,500 mm in coastal districts to more than 3,800 mm in the mountainous, inland regions. The rainy season lasts from June to December. November is the wettest month, but showers occur frequently during the other months. Grenada lies south of the usual track of hurricanes, but when they do occur, they often cause extensive damage.

Agriculture and tourism are the most important sectors of the economy, with fishing and agrifood industries rapidly growing their share of the country's GDP. Like many other Small Island Developing States (SIDS), Grenada partly relies on international financial support to bolster its economy[16].

2.1.1 Climate change

Grenada faces severe risks from climate change, including increased intensity of tropical storms, sea-level rise, prolonged droughts, and coastal erosion, which threaten its economy, infrastructure, and population. As a small island nation, it is highly vulnerable to these impacts and has been implementing adaptation strategies such as improving coastal management, enhancing water resource management

[16] Grenada | History, Geography, & Points of Interest | Britannica

through rainwater harvesting, and fostering climate resilience in its tourism and agriculture sectors to protect its economy and communities[17].

Regional Climate Model (RCM) projections indicate an increase in mean annual temperatures in the range of 2.4˚C to 3.2˚C by the 2080s in the scenario with higher emissions. In the near term, General Circulation Model (GCM) projections of rainfall span both overall increases and decreases, ranging from -40 to +7 mm per month by 2080. Most projections tend toward a decrease in rainfall. Projections also indicate increases in sea surface temperature throughout the year. Projected increase ranges from +0.9˚C and +3.1˚C by the 2080s.[18] Of the 182 countries in the Climate Risk Index, Grenada was in the top 2 percent for losses related to climate-related natural disasters as a percent of GDP during 1997–2017 and in the top 5 percent of climate-related disaster fatalities.[19]

The majority of infrastructure and settlements in Grenada are located on or near the coast, including government, health, commercial, and transportation facilities. These areas already face pressure from natural forces (wind, waves, tides, and currents) and human activities (beach sand removal and inappropriate construction of shoreline structures). The impacts of climate change, in particular sea level rise, will magnify these pressures and accelerate coastal erosion. Hurricane Ivan in September 2004 devastated the tree-crop economy, destroying an estimated ninety percent of nutmeg trees and causing catastrophic losses in cocoa and other perennials.

Hurricane Emily in 2005 compounded those losses before replanting had progressed. It took years for tree crops to return to bearing age, and even in the 2010s, the age structure of nutmeg and cocoa orchards still reflected that shock. Hurricane Beryl took another toll on the already fragile cocoa and nutmeg orchards, and the harvested area in 2025 is projected to be between 40 and 50 percent less compared to pre-Beryl harvests. The lingering effect shows up in long-run export series and in the composition of farm incomes, which had to rely more on short-cycle crops and off-farm work during the recovery period. Today, hurricane preparedness practices such as windbreaks and staking to pruning regimes that reduce crown exposure are a top priority. However, climate risks are no longer limited to cyclones. Projections and empirical experience point toward hotter and drier dry seasons, with longer episodic droughts, and more intense rainfall events that can overwhelm drainage and water intakes. The Green Climate Fund's G-CREWS program[20], implemented with the Government of Grenada and partners, was launched specifically because water security had become a binding constraint across sectors, including agriculture. Its vulnerability assessment projected a water demand–supply gap of 2.7 million cubic meters by mid-century if no resilience investments are made. This gap is driven by reduced rainfall and higher temperatures. The program's documentation also noted that during heavy rains, water turbidity spiked frequently, which interrupts surface water abstraction. Farmers directly experience these disruptions when household and on-farm storage are insufficient. The project portfolio, which includes storage tanks, watershed management, leakage reduction, and incentives for water-saving

[17] Grenada INDC.pdf
[18] CARIBSAVE Climate Change Risk Profile for Grenada (2012).
[19] Global Climate Risk Index 2017/2018. https://germanwatch.org/en/14638
[20] 2022-Climate-Proofing-in-GCREWS-Water-Infrastructure.pdf

irrigation and on-farm practices illustrates how water management is a key requirement for agricultural adaptation and continuity of market supply[21,22].



Figure 6. A cocoa bean dryer in a farm in Grenada. The machinery has been abandoned after Hurricane Beryl destroyed the majority of the trees on the farm, severely damaging the cocoa industry and making the dryer useless.

These hydro-climatic realities are directly reflected in the agronomy of Grenadian soils. Clay loams and shallow soils on slopes are suitable for under-tree crops and mixed agroforestry but are vulnerable to erosion where vegetative cover is disturbed. Conservation agriculture principles are becoming a necessary protective infrastructure. These include organic fertilizer use, mulch cover, minimum tillage on slopes, contour hedgerows, gully plugging, and the maintenance of shade canopies in cocoa. Since 2011, the Eastern Caribbean has witnessed a dramatic increase in massive sargassum blooms, a phenomenon once localized to the Sargasso Sea. These sargassum mats—spanning up to 8,850 kilometers form the so-called Great Atlantic Sargassum Belt (GASB), transporting huge volumes of floating brown algae toward Caribbean shores each year[23].

[21] Making water management and use in Grenada climate-resilient (giz.de)
[22] Funding_Proposal_-_FP059_-_GIZ_-_Grenada.pdf
[23] US EPA, Great Atlantic Sargassum Belt (GASB). https://www.epa.gov/habs/great-atlantic-sargassum-belt-gasb

Ecological, economic, and health impacts have been severe. When stranded, sargassum decomposes rapidly: within 48 hours, it emits hydrogen sulfide and ammonia, foul-smelling and toxic gases that irritate the eyes, respiratory system, and even pose neurological risks—especially for vulnerable populations, such as children, those with asthma, cleanup workers, and coastal residents[24]. Decomposing mats also smother coral reefs and seagrass beds, impair turtle hatchlings' beach access, reduce oxygen levels, and leach heavy metals such as arsenic, continuing to raise concerns for disposal and potential reuse[25].

The socio-economic toll is equally severe. Tourism and fisheries suffer as beaches become foul, fishers face clogged nets and engines, and vital species like the flying fish population is declining. For example, in Barbados, flying fish landings dropped by 50 percent, and mahi-mahi by 37 percent[26]. Public health incidents (e.g. headaches, breathing difficulties, etc.) have forced evacuations and emergency responses in affected islands[27]. The GASB's unprecedented scale was highlighted in May 2025, when satellite data detected a record 37.5 million metric tons of sargassum floating in the Atlantic, exceeding previous peaks[28].

Science increasingly attributes this surge to the confluence of climate-linked drivers. Warmer sea surface temperatures, signatures of anthropogenic climate change, prolong bloom seasons. Simultaneously, nutrient inputs from river runoff (notably the Amazon and Orinoco) and dust deposition from the Sahara enrich surface waters, fueling growth. Altered ocean currents and atmospheric dynamics, such as shifts in the North Atlantic Oscillation (NAO), are also key, with research highlighting vertical mixing processes that bring deeper nutrients upward, supporting proliferation and transport of sargassum into the tropics[23, 24].

In essence, what was once a moderate ecological feature has transformed into a chronic hazard—a manifestation of interconnected climate, land-use, and oceanographic changes. Adaptation efforts like FAO's CC4FISH initiative, which supports forecasting, fisheries adaptation, and value-chain responses, highlight the urgency of coordinated regional action. Moreover, decentralized, uncoordinated actions are also emerging in the area, including specifically in Grenada, to manage Sargassum beaching and find possible solutions to the problem. Organic fertilizer production is a key component of this strategy.[29]

2.1.2 Country's NDCs targets

In November 2020, Grenada submitted its second NDC, reaffirming its ambition to reduce greenhouse gas (GHG) emissions by 40 percent below 2010 levels (216.9 GgCO2e) by 2030[30], conditional on

[24] Escape from Sargasso Sea: Tremendous Sargassum Blooms Challenge Caribbean and Atlantic Communities | Environmental Health Perspectives | Vol. 131, No. 9
[25] https://www.sargassoseacommission.org/publications-a-news/atlantic-sargassum-belt
[26] https://www.fao.org/newsroom/story/Seeking-solutions-to-sargassum-algae-in-the-Caribbean/en
[27] https://www.theguardian.com/environment/2024/apr/11/toxic-gas-livelihoods-under-threat-and-power-outages-how-sargassum-seaweed-causes-chaos-in-caribbean
[28] https://nypost.com/2025/06/04/us-news/sargassum-seaweed-invasion-in-atlantic-caribbean-threatens-to-foul-beach-resorts
[29] Sargassum digestate as fertiliser in Grenada. Lina Bengtsson, 2023.
[30] GrenadaSecondNDC2020 - 01-12-20.pdf

receiving external support. This target aligns with and expands upon its earlier commitment: an aspirational aim for a 30 percent reduction by 2025, with a progression toward 40 percent by 2030[31].

Grenada's NDC outlines targeted actions across key sectors concerning mitigation commitments[32].

- Energy and Electricity: The target includes expanding renewable energy penetration from a modest baseline to at least 10 percent of national electricity by 2025 and enhancing energy efficiency in buildings by at least 20 percent for existing structures, and up to 30 percent for new construction. As part of this effort, the country envisions deploying solar power (10 MW), geothermal energy (15 MW), and wind energy (2 MW).
- Transport: To reduce CO_2 emissions by 20 percent by 2025, Grenada plans to implement measures such as promoting biofuels (including blends with LNG), raising fuel taxes, and introducing fuel-efficiency standards for vehicles.
- Waste Management: The NDC targets a 90 percent reduction in methane emissions by capturing landfill gas and repurposing it for electricity generation, complemented by waste reduction strategies, including composting organic waste.
- Forestry: Grenada pledges to double carbon storage in protected areas by planting fast-growing indigenous species and strengthening fire management and forest conservation practices.
- Industrial Processes & Product Use (IPPU) and F-gases: The updated NDC notably expands the mitigation scope to include F-gas emissions—commonly used in air-conditioning and refrigeration—and the IPPU sector, signaling a broader approach to emission sources beyond the traditional pillars

While mitigation receives some degree of quantification, adaptation is addressed more qualitatively but illustrates depth in scope. The NDC references priority areas such as coastal resilience, water resource management, community resilience, health, and education as part of its adaptation strategy.

To support implementation, Grenada has crafted sectoral investment plans and a resource mobilization strategy, with support from the NDC Partnership. These plans focus on energy, transport, waste, forestry, and include adaptation and cross-cutting outcomes such as improved institutional capacity, monitoring, evaluation, and stakeholder engagement[33].

2.1.3 National Adaptation Plan (NAP)

Grenada's National Climate Change Adaptation Plan (NAP), officially adopted in 2017 for the period 2017–2021, represents a milestone as the first Cabinet-approved NAP in the Caribbean region. This is a result of two years of broad-based consultations involving over 160 participants drawn from

[31] https://climatepromise.undp.org/what-we-do/where-we-work/grenada
[32] https://www.elibrary.imf.org/view/journals/002/2019/193/article-A001-en.xml
[33] https://ndcpartnership.org/country/grd

government, civil society, and the private sector[34] [35]. The NAP's overarching vision is articulated around the concept that Grenada should become "a resilient nation that continuously adapts to climate change by reducing its vulnerability through comprehensive adaptation strategies[33].

The NAP sets a robust multi-sectoral agenda Encompassing twelve interlocking Programmes of Action, supported by fourteen goals and twenty indicators: strengthening institutional arrangements; integrating adaptation into national development planning; ensuring water availability; safeguarding food security; building ecosystem resilience; implementing integrated coastal zone management; promoting resilient infrastructure and sustainable land use; enhancing disaster risk reduction and disease prevention; improving climate and sea-level rise data systems; fostering public education and participation; mobilizing climate finance; and establishing monitoring and evaluation systems**.**

The NAP's sectoral focus reflects Grenada's climate vulnerabilities. It addresses chronic water stress by promoting broader uptake of rainwater harvesting and improved water management strategies. The plan identifies water as a crucial adaptation priority with significant food and health security implications. Similarly, it addresses food security through climate-smart interventions in agriculture and fisheries, including local seed distribution and resilience-building for vulnerable households.

In coastal and ecosystem dimensions, the NAP highlights the importance of restoration of mangroves, living shorelines, and integrated coastal zone planning to counter beach erosion, habitat degradation, and storm surge threats. Resilient infrastructure proposals seek to secure roads, bridges, and community structures while advancing sustainable land management and disaster preparedness.

Recognizing that adaptation must be backed by a solid institutional footing, the NAP also commits to fortifying governance frameworks, mainstreaming climate considerations into public planning processes, securing climate financing, and building public awareness. The inclusion of robust monitoring and evaluation mechanisms ensures that adaptation progress remains transparent and trackable.

The financial foundation of the NAP was estimated at approximately USD 260 million (2017 value), signaling its massive scale and ambition. It also serves as a strategic tool to attract international climate finance, with early successes including a climate-resilient water sector project approved by the Green Climate Fund and strengthened climate finance readiness through GIZ support.

Since the original plan expired in 2021, Grenada has been actively revising the NAP for the period 2025–2030. This revised edition aims to be more inclusive by incorporating gender-responsive, disability-sensitive, and child-aware measures. It adds a new Programme of Action focused on climate mobility, a response to the fallout from Hurricane Beryl, and strengthens integration with disaster risk reduction and health resilience strategies. At the time of writing this report, however, the updated NAP is not available and could not be fully evaluated, but the Ministry of Environment has a summary page with a live link to be populated with the actual report once it is ready for publishing[36].

[34] https://www.international-climate-initiative.com/en/iki-media/news/grenada_leading_the_way_for_adaptation
[35] https://thecpag.org/grenada-national-adaptation-plan-2017
[36] Ministerial Policies Legislation & Plans – Climate Resilience Portal

The NAP, under Programme of Action 4 (Food Security), prioritizes the promotion of Climate Smart Agriculture by building capacity and providing technology options that ensure food security. These include establishing 4 climate-smart agriculture demonstration sites highlighting different technologies and techniques, design and implementing a response to the results of the mapping of soil fertility for sustainable agriculture in Grenada

2.2. Agriculture sector

Grenada's agronomy is characterized by its diverse agricultural production, with a strong emphasis on spice crops and a focus on sustainable practices. Key crops include nutmeg, mace, cocoa, bananas, and various fruits and vegetables. The country faces challenges related to climate change, market access, and the need for modernization of agricultural practices.

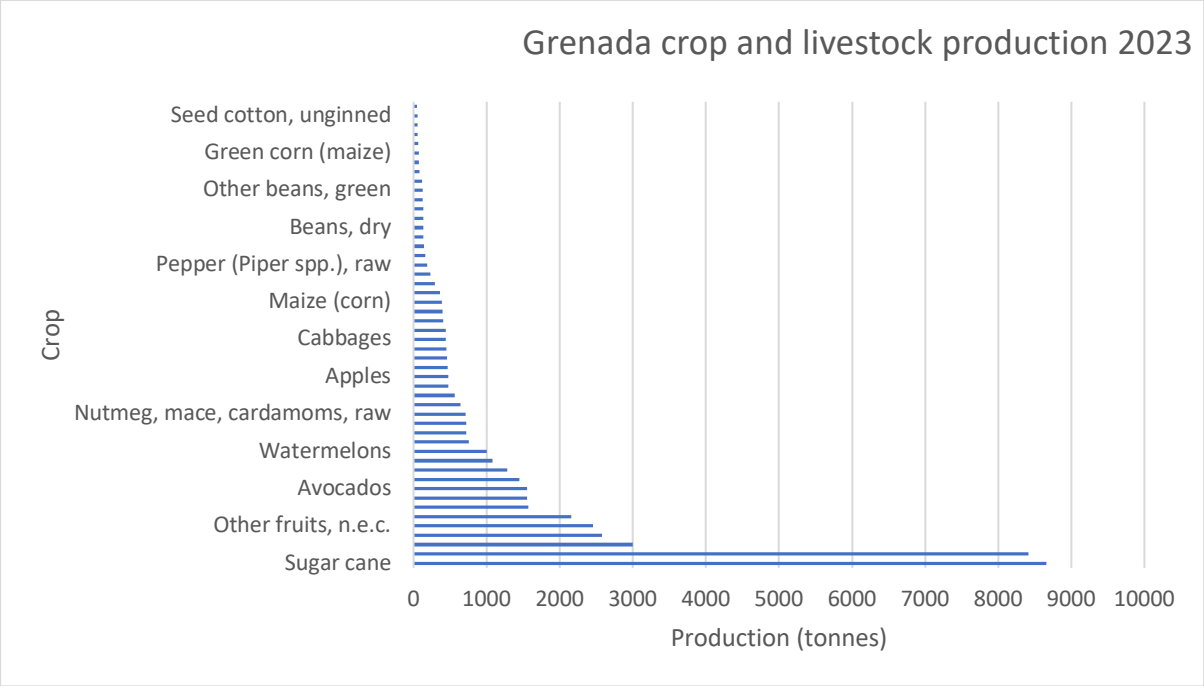


Figure 7. Primary crop and livestock production (2023 data). Source: FAOSTAT

Grenada's agriculture sector is at the intersection of tradition and transition. It is culturally and strategically important for rural livelihoods and food security, even though tourism and services dominate national income. By 2023, agriculture, forestry, and fishing accounted for roughly 3.3 percent of GDP and about 14 percent of employment (latest modeled estimate 2021). This modest macro share, however, understates the sector's important role in exports, landscape stewardship, and resilience planning for a small island state exposed to climate shocks. These headline figures are consistent

across the World Bank series[37] and FAO's country drought portal profile for Grenada[38], which highlights the Country's dependence on food imports and the predominance of smallholder farms.

The production and trade structure of Grenadian agriculture has long been anchored in three export staples—nutmeg, mace, and cocoa—supported by a mosaic of fruits, roots, vegetables, and livestock for domestic markets (figure 11). Official trade statistics from the Central Statistical Office (CSO) show that in 2023, exporters shipped approximately 530 thousand tonnes of nutmeg, 41 tonnes of mace, and 340 tonnes of cocoa.



Figure 8. Nutmeg in its husk. The bright-red part of the nut is the mace, and the darker nut is the nutmeg.

While production volumes remain well below pre-2004 levels because of hurricane damage and tree-crop cycles, the series demonstrates steady post-disaster recovery, with nutmeg and cocoa once again providing the bulk of agricultural foreign exchange. The CSO's time series "Main Export Crops in Quantity and Value, 2000–2023" is the most granular public source for these volumes.[39]

Small-island agriculture is shaped by biophysical constraints, and in Grenada, those constraints are as distinctive as they are diverse. The tri-island state (Grenada, Carriacou, Petite Martinique) lies just north of the equator with a humid tropical climate, a pronounced wet season from June through December, and a drier season from January to May. This seasonal rhythm governs planting windows, pest and

[37] Agriculture, forestry, and fishing, value added (% of GDP) - Grenada | Data

[38] https://www.fao.org/in-action/drought-portal/preparedness/vulnerability-and-impact-assessment/national-case-studies/grenada/en?utm_source=chatgpt.com

[39] Main Export Crops, 2000 to 2023 -

disease pressure, and water management decisions for still dominant rainfed crops. Climate references compiled for Grenada describe annual rainfall totals averaging around 2,300 to 2,400 millimeters (but with great variability between lowland coastal and mountain inland areas), with interannual variability that has intensified in recent decades, increasing the frequency of agricultural drought during late dry-season months and the risk of storm-related damage during the wet season[40].

Soils, slopes, and microclimates differ sharply within short distances, partly a legacy of the island's volcanic origin and rugged topography. Agricultural soils are dominated by clay loams and cobbly loams (collectively over 80 percent by area), with shallow lithosols on steeper slopes and deeply weathered kaolinitic tropical soils in older formations. This mix supports permanent tree crops on slopes and annual or short-cycle crops in the gentler coastal and interior valleys, but it also makes erosion control, drainage, and the careful use of inputs essential for sustained productivity. The same assessments flag that steep terrain and intense rainfall events can trigger rapid runoff and landslides, eroding topsoil and stripping nutrients unless contouring, mulching, and agroforestry practices are maintained.[41]

The poultry sector in Grenada faces significant import dependence, production shortfalls, and needs ambitious policy reforms. Local production currently meets only about 5% of national demand, while imports of poultry meat are valued at roughly USD 9.7 million annually to satisfy the remaining 95%.[42] Grenada imports live fowls valued at around USD 483,000 in 2023.[43]

Recognizing this gap, the government in September 2024 approved a revised National Poultry Policy that guarantees a 40% market share for local producers and sets a target for local production of 8 million pounds (3.6 million tonnes) by 2027.[44] The policy is intended to reduce import dependence, support rural livelihoods, and strengthen food security.[45]

Despite strong political will, the sector faces structural challenges: heavy reliance on imported feed and inputs, exposure to disease and natural disasters (e.g. Hurricane Beryl damaging layer flocks), and limited processing infrastructure. The revised policy also includes plans to decentralize feed depots and improve extension services to assist farmers in scaling up production.

Grenada's poultry sector remains largely import-driven, but recent policy changes and production targets mark a strategic shift toward greater self-sufficiency and support for domestic producers. A notable example is the emergence of commercial hatcheries with considerable production capacity in St. Andrew's parish, like Chick Inn Farm. This farm produces 7,000 chicks/month and houses 40,000 broilers year-round in two hens. The project comprises two hens with the capacity to house 25,000 birds each, a hatchery that can house about 80,000 chicks in each 3-week cycle, and a processing and storage facility.

[40] TheGlobalEconomy.com

[41] https://www.fao.org/fileadmin/user_upload/GSP/docs/Central_America_WS/Grenada_Presentation.Soil_situation.pdf

[42] https://nowgrenada.com/2024/09/poultry-industry-at-crucial-junction-under-new-executive/

[43] https://wits.worldbank.org/trade/comtrade/en/country/GRD/year/2023/tradeflow/Imports/partner/ALL/product/010511

[44] Cabinet approves national poultry policy

[45] https://caricom.org/remarks-by-ambassador-david-prendergast-at-the-national-consultation-on-the-revised-national-poultry-policy-2023-of-the-ministry-of-economic-development-planning-agriculture-and-lands-fisheries-and



Figure 9. Aerial view of Chick Inn Farm.

Chick Inn Farm is a modern hybrid hatchery and broiler farm. It is located in the hilly landscape of Grenada, like several other agricultural businesses, and is constrained by poor road infrastructure of the area. The two large hens host at least 20,000 broilers each (max capacity 25,000 each), the green-roofed building in the center of Figure 9 hosts the hatchery, and the red-roofed top houses the offices, slaughterhouse, and the meat packing facilities.

Organic waste generated by the farm consists of around 35 tonnes of organic residues per year from the hatchery and around 300 tonnes of chicken manure per year. Like most chicken farms in Grenada, Chick Inn is equipped with a meat-packing plant. This plant produces an additional 160 tonnes per year of slaughter residues (offal, beaks, feathers, bones, etc.). Most manure is dumped informally on the remaining farm's land down the hill, whereas the residues from the hatchery plant and the meat packing plant are incinerated, and a small portion is sold as fresh pet food. Organic waste disposal is a net cost for the farm; however, due to transport costs and the difficult road infrastructure of the area, no waste collection service is provided to the farm.

Apart from a few commercial farms, Grenada's agricultural holdings are predominantly small. Both FAO's country profile and the national agricultural census show that most producers operate tiny, often fragmented and intercropped plots, mostly under 1 hectare. The FAO drought portal cites that around 80 percent of producers are small-scale, with plots under 0.2 hectares (about half an acre). The 2012

Agricultural Census (the latest comprehensive enumeration of holdings) reported over 12,000 farms and tens of thousands of plots, with most holdings in the smallest size classes and a long tail of mid-sized mixed farms. Prevalence of fertilizer use and irrigation was low at the time of the census, and though input use has selectively increased over time, rainfed production remains the norm. These structural realities result in a production ecology built on labor-intensive mixed gardens, agroforestry (with spice trees and shaded cocoa), and diversified cropping patterns designed to manage seasonal risk and cash flow.[19]

Within this structure, nutmeg and mace are emblematic of agriculture in Grenada. The Grenada Cooperative Nutmeg Association and private exporters source from thousands of smallholders, drying and grading kernels and arils for specialty markets. In 2023, exporters shipped roughly 540 tonnes of nutmeg and nearly 41 tonnes of mace, with values fluctuating with international prices, quality grades, and currency movements. Cocoa is the other pillar of the Grenadian agrifood sector. The Grenada Cocoa Association and newer private estates have pushed quality upgrading and niche branding, with the island's fine flavor cocoa commanding premiums in artisanal chocolate supply chains. Grenada's Central Statistics Office (CSO) data records show that about 340 tonnes of cocoa were exported in 2023, with the value per tonne increased by quality differentiation and direct trade relationships. While banana exports once mattered more, the cocoa crop now plays a larger role in domestic food supply, along with plantain, root crops such as dasheen and yam, and an expanding range of horticultural products for hotels and local markets.



Figure 10. A smallholder farm displaying the mixed nature of permanent crops such as cocoa, plantains, and nutmeg in intercropping.

Input markets are small but critical, particularly for fertilizers, which remain the main lever for boosting yields of annual and some perennial crops where soil fertility is limited. Grenada's fertilizer consumption intensity is modest by international standards, reflecting smallholder practices, mixed cropping, the use of organic amendments where available, and cost constraints. On the trade side, mirror statistics compiled by the Observatory of Economic Complexity indicate that in 2023, Grenada imported about US$1.8 million in fertilizers across HS Chapter 31 categories, with sourcing typically from regional neighbors and the United States. Import composition varies year to year among nitrogen, phosphate, and potash products, with compound NPK formulations commonly used by smallholders for fruit trees and vegetables. As input prices spiked globally in 2022–2023, these costs were transmitted into local markets, putting pressure on margins for small farmers and dampening application rates.[46]

Cropping seasons align with rainfall patterns and market cycles. Farmers typically grow short-cycle vegetables and roots at the start of the wet season to take advantage of moisture, while managing disease risk with spacing and organic matter to improve drainage. Tree crops such as cocoa and nutmeg are less synchronized with monthly rainfall, but flowering and pod set in cocoa, and the maturation and harvesting of nutmeg pods align with peaks in soil moisture and subsequent drying periods. The practical "calendar" reported by extension officers and producers places a heavier field work, planting, and weeding in the June–October window, with harvesting and post-harvest drying and curing continuing into the drier months when ambient humidity is lower and solar drying is easier to manage. Seasonal labor demand spikes accordingly.

Export crops are channeled through specialized associations and licensed buyers that provide grading, aggregation, and access to shipping. Domestic horticulture feeds a small but quality-sensitive market, amplified by tourism's demand for fresh produce. This has catalyzed investment in greenhouse and tunnel systems in recent years, especially at elevations where temperature moderation improves quality. However, fragmentation of holdings raises logistics costs, complicates extension outreach, and impedes mechanization. The 2012 census and subsequent policy documents keep highlighting the same binding constraints: limited irrigation, high unit costs for inputs and transport, and the need for better post-harvest handling, cold storage, and marketing to reduce losses and meet hotel and export specs consistently.[47]

The fertilizer market provides a useful lens for these constraints. Because volumes are small, Grenada lacks the scale economies of larger Caribbean markets. Importers bring in blended NPKs and single-nutrient products according to seasonal demand, international prices, and shipping opportunities. In 2023, total fertilizer imports measured by customs value were on the order of US$1.8 million, down slightly by 2024 when mirror data showed about US$1.6 million. For a sector dominated by tree crops and mixed smallholdings, application rates remain fairly conservative. Horticultural producers who have reliable water and market access improve use efficiency and quality outcomes through targeted fertigation and split applications. Other farmers who lack these resources stretch applications or

[46] The Observatory of Economic Complexitytradingeconomics.com
[47] GRD_ENG_REP_final_2012.pdf

substitute with organic materials. Volatility in global fertilizer prices during 2022–2023 tightened margins and likely reduced application rates on non-export crops, with knock-on effects for yields.[48,49]

Policies and programs increasingly reflect "climate-smart" framing. The government's economic reviews and project documents emphasize resilience, water security, and the modernization of value chains. International partners have supported seedling distribution for hurricane recovery, soil and water conservation training, and investments in small irrigation and on-farm storage. The logic is straightforward: diversified, climate-resilient agroforestry anchored in cocoa and spices, complemented by irrigated horticulture near markets, can raise farmer incomes while stabilizing export earnings. The success of that strategy depends on the dissemination of practical technologies such as shade and windbreak design, pruning schedules tied to storm windows, disease-resistant planting material, low-pressure micro-irrigation, rainwater harvesting, and protected cultivation for high-value vegetables. It also depends on better aggregation to achieve scale in marketing and logistics.[50]

2.2.1 Challenges and opportunities

Against this backdrop, the sector faces five main interlinked challenges. The first challenge is climate and disaster risk. Hurricanes remain the benchmark for loss scenarios, but creeping changes—hotter dry seasons and more erratic rainfall—now erode yields and raise water stress even in non-disaster years. Several studies warn of growing supply shortfalls without infrastructure upgrades and demand management. These shortfalls will impact agriculture through higher irrigation costs and more frequent water disruptions.[51] Therefore, adaptation in Grenada is not optional; it is key to business continuity.[52]

The second is water availability at the farm level. Rainfed fields face longer moisture deficits, and surface water intakes suffer turbidity events after intense rains. On-farm water storage and efficient distribution—tanks, gutters, first-flush systems, gravity lines, and low-pressure drip—are essential, but capital-intensive for smallholders. Public programs that co-finance these investments, together with watershed measures that reduce sediment loads, are key to protecting both domestic supply and agricultural use.[53] Soil amendments like compost have a strong role to play in maintaining soil moisture in tropical areas.[54]

The third interconnected challenge is soil fertility and erosion. Clay-rich tropical soils can be productive but require careful management due to their complex structure and nutrient dynamics. On the slopes, the cost of losing even a few centimeters of topsoil is prohibitive. Erosion control and organic matter rebuilding through organic fertilizers and soil amendments are the safest long-term investments for a small farm. Given the cost and dependence on imports of mineral fertilizers, integrated nutrient management that blends modest mineral doses with composts and mulches is both a resilience and a

[48] https://oec.world/en/profile/bilateral-product/fertilizers/reporter
[49] Grenada Imports of Fertilizers - 2025 Data 2026 Forecast 1993-2024 Historical
[50] https://www.finance.gd/docs/2022/2022%20Annual%20Economic%20Review.pdf
[51] https://gcfwatch.org/wp-content/uploads/2017/03/Funding_Proposal_-_FP059_-_GIZ_-_Grenada.pdf
[52] Making water management and use in Grenada climate-resilient | GIZ
[53] https://climateresilience.gov.gd/wp-content/uploads/2024/04/2022-Climate-Proofing-in-GCREWS-Water-Infrastructure.pdf
[54] Soil management: compost production and use in tropical and subtropical environments

profitability strategy. Biodiversity and land-use profiles for Grenada reinforce that these practices are not generic; they are tailored to a landscape where more than four-fifths of soils are loamy, and many plots are on steep slopes.

Market scale and logistics are the fourth key challenge. Tiny lots and scattered production sites make it difficult to move produce and to deliver extension services. Aggregation through cooperatives, out-grower schemes with hotels and processors, and shared post-harvest facilities can reduce unit costs. A similar pattern should be applied to the production and distribution of plant nutrients in the form of compost. This indicates the potential for a cooperative-led smallholder composting plant that captures available agricultural residues and waste from a relatively small catchment area (10 km radius), processes them into high-quality compost, and sells it to local farmers.

The fifth challenge is input affordability and technology adoption. When fertilizer prices spike, smallholders either cut application rates or skip them entirely, undermining yields and quality. That pattern showed up globally in 2022–2023 and echoed in Grenada's small market[55]. A domestically produced alternative, like compost, can support the resilience of Grenadian agriculture to external shocks of the fertilizer market, ensuring more stable cropping conditions and, in turn enhanced food security and reducing external currency deficit.

Despite these headwinds, the sector has substantial and distinctive opportunities. Quality-differentiated cocoa and spices, branded with origin stories and agroforestry credentials, already command premiums. Agro-tourism and farm-to-table linkages allow horticultural producers to transport higher-value produce with shorter supply chains and less waste. Climate finance projects are building the water and risk-management infrastructure that agriculture needs to thrive under new climatic regimes. Finally, a new cohort of agro-processors and craft chocolate makers has emerged, creating local demand for high-grade beans and seasoning exports with value-added products. As the CSO time series shows, volumes are not yet back to the island's historical highs before hurricane Beryl, but the trajectory is positive, and the value per unit for spices and cocoa exports is rising.

Looking ahead, three priorities would consolidate gains. First, accelerate the transition from vulnerability to resilience in tree-crop systems, specifically in terms of plant nutrients. Extension services and farmer-to-farmer networks can disseminate best practices rapidly because they build on what many smallholders already do or are seeking to do. Secondly, changes in water availability need to be adequately addressed. On-farm storage, micro-irrigation, and water-efficient varieties will yield cost savings and higher returns through reduced losses and boosting the quality of vegetables and fruit. Figure 13 (below) shows a farm in an inland mountainous part of Grenada. Water availability is becoming a limiting factor for efficient crop production even in these once water-abundant parts of the island, and farmers are adapting by providing drip irrigation systems once unnecessary.

[55] https://oec.world/en/profile/bilateral-product/fertilizers/reporter/grd



Figure 11. A vegetable farm in the mountainous region of Grenada equipped with drip irrigation system.

It is also key to continuously build on the quality and traceability advantage in export crops while simultaneously increasing the supply of high-quality, organic produce to hotels and local supermarkets in Grenada. Smallholders can be key players in advancing organic agriculture through knowledge of, and access to reliable organic inputs and pricing contracts that reward high-quality organic products.

In summary, Grenada's agriculture sector is small in macroeconomic share but large in significance. It is dominated by small farms, rooted in agroforestry traditions on loamy tropical soils, synchronized with a wet–dry seasonal dance, and exposed to climate risks that are now structural rather than cyclical. The data point towards recovery and renewal with over 500 metric tons of nutmeg exported in 2023, cocoa exports approaching 300 tonnes, and mace continuing to leverage the island's unique spice heritage, while the domestic demand for vegetables is largely met internally. Fertilizer imports are an indicator of the sector's exposure to external price shocks and the importance of efficient, independent, and soil-conserving nutrient management. By scaling water security projects, deepening quality-led branding, and spreading practical resilience investments, Grenadian agriculture can achieve its full potential: transforming a challenging landscape into a resilient, high-value mosaic of farms that nourish households, sustain rural incomes, and reach both local and global markets.

2.2.1 Composting and organic fertilizer use

Private investors in Grenada have shown interest in organic amendments for agriculture, specifically compost production. Based on the results of a survey carried out by FAO in May 2025, though local

agricultural input stores sell compost, it is not widely available in the market. This might be due to several factors, such as relatively high prices compared to chemical fertilizers and the lack of awareness about compost among farmers. However, agricultural entrepreneurs in the mountainous inland areas of the country are beginning to experiment with the processing of various feedstocks into compost as an alternative to chemical fertilizers. During the survey in May 2025, interviews were conducted with a few of these pioneers who are active in St. Patrick's parish. Specifically, one compost-making initiative was started by a female entrepreneur in the countryside of Gouyave. The owner, Liselle McPhie, is determined to produce an alternative organic fertilizer to limit her farm's reliance on imported chemical fertilizers. Together with her husband, she cleared a flat portion of the farm to create a small-scale composting site. Ultimately, she wants to turn this initiative into an economic activity and an additional revenue stream for her farm.

The farm is located in the North-west side of the island of Grenada, about two hours away from Perseverance landfill and St. George's main markets. The main activities in this area are subsistence and commercial agriculture, and the farmers interviewed are a part of a group of approximately 30 local farmers receiving support from an extension service station of the Ministry of Agriculture located in St. Patrick's parish. Composting and the provision of locally produced organic fertilizer are a priority for all farmers in this group. Collectively, they could retrieve approximately 300 – 400 tonnes of organic waste per year to be processed into compost.

However, farmer groups in Grenada lack knowledge of the technology and standards necessary to produce high-quality compost, and technical assistance is required to turn empirical efforts into a scientific approach to compost production. The surveyed farmer intends to produce 20 kg bags of compost and sell it directly on the nearest market for around EC$20/bag, the equivalent of USD 0.37/kg. The agricultural entrepreneur preliminarily identified (also somewhat empirically) this price as the sweet spot to obtain customer buy-in for a new and alternative product, based on expected crop productivity. It is important to note that the entrepreneur did not determine this pricing based on an analysis of the costs, a business plan, or market conditions.

In addition to small-scale investors and compost makers, a private company named Grenada Grows formed in a public-private partnership (PPP) with the GSWMA, and a U.S. agriculture company is currently pursuing the development of a first-of-a-kind composting facility in the country. The proposed business model consists of a soil enhancement facility at the Perseverance landfill, where organic waste would be processed into soil amendments, including soil mixes enhanced with compost. These products will be sold at a dedicated retail shop, located at a separate site in Grenada, to gardeners and farmers.

The company is interested in building a compost facility on a portion of the space available at Perseverance landfill. In 2024, the company commissioned a pre-feasibility study to assess the costs and benefits of such a business plan. However, a proper market assessment was not carried out, and measures to sustain and foster the market uptake of compost are not yet planned. The company is currently looking for the necessary financing to start its operations in the country.

2.2.2 Chemical fertilizer use

The fertilizer market size and imports in Grenada are relatively small but strategic for the country's economy. Since the island's farms are predominantly small (average size less than 2.5 ha) with limited on-farm nutrient stocks, imported chemical fertilizers remain the quickest way to increase yields for annual vegetables, and to supplement nutrients in tree-crop systems like cocoa-nutmeg-plantain. Official trade aggregates show that fertilizer imports into Grenada amounted to roughly USD1.8 million in recent years (USD1.61 million in 2024, USD1.8 million reported for 2023 in mirror datasets)[56], with principal suppliers from Trinidad and Tobago, the Dominican Republic, and the United States. Considering an average international wholesale market price for urea of around USD 496/tonne[57], approximately 3,200 – 3,400 tonnes have been imported into Grenada each year since 2023. According to FAOSTAT, Grenada's fertilizer consumption was 92.5 kg per hectare of arable land in 2022, a decrease from 99.9 kg per hectare in 2021. This measure of fertilizer use represents the total quantity of plant nutrients (nitrogenous, phosphate, and potash) used per unit of arable land. These values are the most consistent cross-year indicators for fertilizer expenditure available in public sources. Despite contacts with the Ministry of Agriculture, more accurate figures on overall fertilizer imports and use in the Grenadian agriculture sector could not be obtained. Questionnaires for agricultural producer associations and farmers have been distributed by FAO in spring of 2025. During a survey mission in May 2025, primary data on fertilizer use collected was then validated through interviews with key agricultural producers and associations. Moreover, a survey on fertilizer retail prices was conducted during the same period.

Because Grenada's import market is modest in size, unit prices and availability are more sensitive to shipping, exchange-rate swings, and global price shocks than they are in larger markets. Global fertilizer prices spiked during 2021–2022 and remained elevated in 2023, increasing the local landed cost for N, P, and K products. That global shock was transmitted into the Grenadian market via higher import bills and, according to government statements and agricultural reports, contributed to tighter farmer margins and reduced application intensity on some crops. The Ministry of Agriculture provides support to farmers to mitigate input price pressures, including on fertilizer purchases, via targeted subsidies. Subsidies ranged between 50 to 65 percent of its wholesale price, depending upon budget availability, and since 2014, the Ministry of Agriculture was able to sell directly some 180 tons of discounted fertilizer every year via a subsidy which accounted for EC$540,000/year (USD 200,000/year), or USD 1.11/kg of fertilizer. The remaining 3,200 tons of fertilizer imported in 2024 did not enjoy the subsidy and have been sold at retail at full price, averaging USD 1.65/kg.

Comprehensive crop-level application rates in Grenada are not published in a national handbook or database. Data collection is a challenge in the country, and agrifood systems would benefit from increased digitalization. In practice, agronomists and extensionists rely on a mix of local guidance for tree crops and internationally established fertilizer recommendations adapted to local conditions and soil tests. The Ministry of Agriculture of Trinidad and Tobago produced a handbook that could be

[56] Grenada Imports of Fertilizers - 2025 Data 2026 Forecast 1993-2024 Historical

[57] Global nitrogen fertilizer prices have risen to almost a 3-year high, but may soon fall again

adapted for use in Grenada and although soils have different characteristics, general agricultural trends can be identified. For cocoa, relevant agronomic literature and regional practice recommend annual nutrient packages in the order of 90–100 kg N/ha, 40–70 kg P2O5/ha, and 100–150 kg K2O/ha in instances where soil or leaf tests indicate deficiency[58]. These fertilizer rates can be applied as split dressings or via fertigation for small, irrigated holdings. Cocoa generally requires low amounts of phosphorous, high amounts of potassium, and an average amount of nitrogen when plants are mature. Nutmeg, a key Grenadian export, requires only modest fertilization. Published horticultural guidance suggests that, when translated to a per-hectare scale, mature trees need only a few kilograms of balanced NPK annually. An interview with the Cocoa and Nutmeg Producers Association of Grenada in May 2025 revealed that farmers typically apply 250 kg/ha of a specific synthetic fertilizer (12:0:42 NPK) for cocoa production, which contains only Nitrogen (12%) and Potassium (42%) but no Phosphorus (0%). These requirements align with agricultural literature, specifically confirming that no Phosphorus is needed for Grenadian soils. Consequently, each hectare of a cocoa-nutmeg-plantain farm receives approximately 30 kg of Nitrogen (N) and 105 kg of Potassium (K) per year. Nutmeg production in the mixed system with cocoa is not considered to have specific separate nutrient needs, a finding that is also in line with agricultural literature.

For vegetables and root crops (the highest-turnover crops in domestic markets), recommended application rates vary according to the crop. In higher input systems, high-demand vegetables like bell peppers, cucumbers, zucchini, and sweet potatoes may seasonally receive 250–300 kg N/ha, with corresponding balanced P and K adjustments. However, in Grenada, most smallholders apply considerably less fertilizer than in high-input commercial agricultural operations due to higher costs and limited water supply. This trend was confirmed through the results of the May 2025 survey. It was found that farmers were using only around 80 kg of N fertilizer per ha and around 110 – 120 kg/ha of P fertilizer and K fertilizers (NPK 15:15:15). Given the average nutrient concentration in the chemical fertilizer used, Table 1 presents the nutrient requirements of major crops produced in Grenada. More common chemical fertilizers are formulations of NPK, and in fact have relatively low nitrogen content and balanced P and K rates (Figure 13).

	Nutrient		
Crop	Nitrogen kg/ha	Phosphorous kg/ha	Potassium kg/ha
Cocoa	30	0	105
Nutmeg	12	2	24
Vegetables	12	16.5	18

Table 1. Nutrient requirements of main crops in Grenada

[58] Production-of-Cocoa-20-dEC-2013.pdf



Figure 12. Retail fertilizer prices range between 100 and 120 EC$ per 25 kg bag.

Grenada does not have a centralized public bulletin that posts average market prices for specific chemical fertilizers; therefore, price discovery depends on importers, agro-dealers, and government procurements. Retail prices vary broadly and are generally much higher than wholesale prices. This reflects the many steps and difficult logistics involved in transporting wholesale fertilizers to retail outlets. A survey of agricultural input retailers shows average NPK prices ranging from EC$100 (USD 37) and EC$120 (USD 44.40) per 25 kg bag, depending on the producer and composition. When compared to international wholesale prices (around USD 500/tonne), the retail price is more than three times at USD 1,480 to USD 1,776 per tonne. The corresponding cost per unit of nutrient can be determined with certain limitations, due to the lack of accurate data on actual volumes of each fertilizer type imported and its actual final market price in Grenada.

Commonly sold NPK formulations have an average nutrient concentration of around 15% for each macronutrient (NPK 15:15:15), although with broad variability (from 7:21:21, 10:10:10, 12:0:42, etc.). Considering this average concentration and the average retail price for these fertilizers sold in Grenada, an average unit cost per kg of pure nutrient contained in the chemical coformulations was calculated (USD 41.25 per 25 kg bag, or USD 1.65/kg). It should be noted that these are average values (ranging between USD 37 and 44.40 per 25 kg bag) and that deviations from these may be relevant in both directions; however, a nutrient content equivalence calculation has been performed to frame the fertilizer market and derive a competitive retail price point for compost as a complement to synthetic nutrients.

Given the average retail price (USD 1.65/kg) for 15:15:15 NPK (which contains 150 grams of Nitrogen, 150 grams of Phosphorus, and 150 grams of Potassium per kilogram of product), a competitive retail price point for compost must deliver comparable amounts of each macronutrient for a similar price.

2.2.3. Scaling-up composting solutions: Economic and climate rationale

In Grenada and the Caribbean, compost quality standards, which include their chemical composition and nutrient content, are not enforced. At the time of writing this report, CARICOM, the regional organization promoting economic integration and cooperation in the Caribbean, is developing its first quality standards for commercially produced compost. This assessment uses international standards to determine the chemical composition of high-quality compost that can be potentially produced in Grenada. According to Annex I of EU Regulation 2019/1009[59], on Product Function Categories (PFCs) of EU fertilizing products, if a compost product is classified and marketed as a solid organo-mineral fertilizer, it must meet specific minimum nutrient content requirements. When declaring multiple primary nutrients (Nitrogen, Phosphorus, Potassium), the minimum content is 2% by mass for total nitrogen (N), 2% total phosphorus pentoxide (P_2O_5), and 2% total potassium oxide (K_2O). These measurements for nutrient content will be used to establish the minimum viable composition for potential compost products to be marketed in Grenada.

The comparable price point calculated for compost with the necessary minimum nutrient content compared to average nutrient concentrations of chemical fertilizers sold in the country is USD 0.22/kg. To provide the same quantity of macronutrients with compost, about 7.5 kg of organic fertilizer is needed to replace 1 kg of chemical product. At this price point, farmers in Grenada would be able to purchase the same amount of nutrients in the form of compost as they would in the form of chemical fertilizers.

Composting has several climate-related benefits. From a mitigation standpoint, composting can prevent GHG emissions from organic waste decomposition in landfills, as well as sequester organic carbon into agricultural soils. The application of compost to soil increases its organic matter content, which helps to lock away atmospheric carbon dioxide. Moreover, as an organic amendment that is rich in nutrients, compost increases microbial succession, ecological niche, and increases necromass in soil for enhanced carbon sequestration.[60] From an adaptation perspective, compost improves a community's ability to adapt to extreme weather by helping soil absorb more water and prevent runoff of pollutants during floods. It also helps soil hold more water for longer, mitigating the effects of drought. Most importantly, compost application strengthens sustainable, local food production as locally generated food scraps and other organic materials are used to create a valuable soil amendment that supports plant growth.[61.]

Composting is a perfect example of a Climate Smart Agriculture (CSA) practice. CSA addresses the challenges posed by climate change to agricultural production. It is a pathway towards sustainable development and food security and is built on three pillars:

- Increasing agricultural productivity and income
- Enhancing resilience or adaptation of livelihoods and ecosystems towards climate extremes

[59] Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 (Text with EEA relevance)

[60] Carbon sequestration and soil responses to soil amendments – A review - ScienceDirect

[61] Composting | US EPA

- Reducing and removing GHG emissions from the atmosphere[62]

Composting is an agricultural technique that contributes to the achievement of these pillars, therefore, can be considered climate-smart practice. Adoption of composting in agriculture is a central part of the National Adaptation Plans of Grenada. The NAP suggests several actions, such as creating incentives, to support the deployment of CSA practices like composting. The goal is to establish four climate-smart agriculture demonstration sites highlighting different technologies and techniques and allocate 60% of the agricultural extension services advising farmers on implementing CSA practices. Compost is already a CSA technology being studied by national and regional research centers, including CARDI, and it is seamlessly aligned with the NAP and the NDC. To boost the uptake of this practice at a larger scale, as outlined in the NAP, the establishment of demonstration projects to familiarize farmers with the medium and long-term benefits of compost as a soil amendment is necessary.

[62] Climate Smart Agriculture. Training Manual for Extension Agents in Kenya. FAO, Ministry of Agriculture, Livestock and Fisheries - State Department of Agriculture. FAO Kenya, 2015

2.3. Waste sector

The Grenada Solid Waste Management Authority (GSWMA) is the sole authorized waste manager in Grenada. As a statutory body, it is ultimately accountable to the Government of Grenada and is therefore the only institution responsible for recording waste collection data. The Waste Management Act formed GSWMA and governs its operations. Unpublished data from the GSWMA was provided to FAO and UNDP for this study for the period 2022 to 2025. The “Environmental levy” is the main government funding instrument for waste management in the country, covering around 80% of the Authority’s needs. GSWMA works with private waste contractors who collect co-mingled waste and transport it to the only active landfill in the country for final disposal. GSWMA is responsible for managing the collection and disposal service, while the Ministry of Health enforces the waste management policy. Starting from 2022, GSWMA started moving towards integrated solid waste management, emphasizing more on reducing, reusing, and recycling waste. Interest in waste-to-energy and alternative solutions to landfilling, like composting, is clearly on GSWMA’s agenda.

The history of waste disposal in Grenada dates back to the early 1960’s, when the very first dumpsite at Perseverance was formally used to contain waste generated on the island. The dumpsite was not designed for sanitary waste disposal and reclaimed approximately 7 ha of mangroves bordering Halifax Bay on the western side of the island. The dump was in use until the year 2000, when the first Perseverance Landfill was created. This site was only in operation for 9 months, until February 2001, when it collapsed due to stability issues created by accumulating waste on the sloped terrain chosen for the landfill.



Figure 13. The old dumpsite at Perseverance, now covered and secured.

The old dumpsite was put back into service, but suffered several fires over the years, limiting the use of this site and requiring a definitive change in technology.

In 2023, the new Perseverance landfill, a sanitary, semi-aerobic landfill, was established. This landfill, still in operation today, is fitted with features that are a requirement for semi-aerobic landfill, such as geotextile liners and a network of stormwater and leachate collection pipes, drainage, and gas venting systems. A network of underground perforated flexible pipes allows for the exchange of air and gases within and around the site. It also directs the flow of leachate from the cell to the leachate treatment facility located on the opposite side of the Western Main Road, located at the base of the old dump.



Figure 14. Aerial view of the 8.4 ha site hosting the new Perseverance sanitary landfill in Grenada.

The design has taken into consideration the need for the pre-treatment of all waste to be dumped in the landfill. It also allows for waste separation by GSWMA and recycling, and processing into added-value products. For instance, separate designated areas of the landfill are allocated for different types of waste, including biomass waste. The landfill is therefore equipped with a biomass shredder to ease the handling and disposal of voluminous organic waste.

The network also consists of PVC storm water collection pipes which collect water from surface and underground drainage systems throughout the site and divert it to the wastewater treatment pond.



Figure 15. The leachate collection system of the New Perseverance landfill in Grenada. A liner collects the leachate and channels it through a system of perforated pipes down to a waste treatment pond.

The GSWMA provided data on total and disaggregated waste disposal at the new Perseverance site, from 2022 to mid-2025. The total volume of waste delivered in 2024 was 67,513 tonnes of mixed waste. An assessment carried out by GSWMA in 2018 provides a breakdown of the composition of the waste.

Type of waste	Share
Organic	28,70%
Paper	13,90%
Plastic	13,70%
Street sweepings	8,10%
Glass	7,90%
Metals	6,50%
Special care waste	6,40%
Hazardous waste	6,00%
Textiles	5,90%
Construction/demolition waste	2,70%
Household bulky waste	0,20%

Table 2. Waste composition at Perseverance landfill in 2024.

Given the country's population of about 117,000, in 2024, the estimated total solid waste generation rate in Grenada is 1.57 kilograms per person per day, including both household and non-household waste. A total of 19,376 tonnes of organic waste was delivered to the landfill in 2024. Crucially, one third of the total amount of organic waste delivered to the landfill is already segregated, as it is sourced from contractors collecting biomass from street and garden maintenance, coconut sellers, and local food markets. This organic waste material is thought to have minimal contamination of plastics and other non-compostable materials in it. In 2024, about 6,500 tonnes of segregated organic waste was delivered to Perseverance and the management of GSWMA has a dedicated pit on the site for this material.



Figure 16. A contractor's truck unloading mixed solid waste (MSW) at Perseverance landfill in St. George's, Grenada.

The bulk of the organic waste generated in Grenada, around 12,800 tonnes/year, is not separated at source and is dumped at the landfill. This, in turn, leads to methane generation, odour formation, risk of fires, and risks attracting animals and insects. At the time of writing this report, the country had no legislation in place that demanded separate waste collection and disposal. In these conditions, the substantial fraction of organic waste in the municipal solid waste delivered at Perseverance landfill poses substantial management difficulties and contributes to shortening the lifetime of the site. In fact, GSWMA is already actively engaged in developing plans for an additional future landfill site, since Perseverance will likely reach capacity in the short term.

3. METHODOLOGY

3.1. Compost feasibility assessment

A compost feasibility assessment involves a phased approach that includes data collection, process design, techno-economic and environmental analyses, and market evaluation. The methodology includes literature review, site selection, waste stream characterization, process design (e.g. composting method and equipment), an economic analysis comparing costs and benefits, and an evaluation of market potential for the finished compost. The feasibility assessment presented in this report is the result of the application of FAO methodologies and data collection from the field. A team of international experts from the Office of Climate, Biodiversity and Environment of FAO, with several years of experience in carrying out biomass availability assessments in different contexts, was supported by the UNDP office in Grenada, which recruited a national consultant for data collection and liaison, logistical and technical support. Below is a schematic presentation of the methodological approach applied to this assessment.

3.1.1 Literature research and data collection

The team of experts built an information baseline on composting in Grenada. First, they described the impacts of climate change and main climate-related policy instruments and targets to understand the coherence of investing in compost production within the context of Grenada's climate action plans. Subsequently, the background research included the key features of the waste and agriculture sectors and specifically focused on fertilizer use and markets, as these are relevant for the assessment of compost production potential. This information is condensed in Chapter 2 of this report.

Research on composting technologies, equipment, and operational requirements for various waste materials has been conducted, and technology providers in the United States, Europe, and various countries in Asia were contacted to build an updated compendium of machinery, producers, and related equipment characteristics, costs, and performances.

A detailed analysis of existing feasibility studies on composting in Grenada followed this initial baseline study. Previously conducted feasibility studies on composting potential have been screened and evaluated to build a knowledge base, highlight areas needing specific consideration, and avoid repetition. The literature review highlighted a handful of studies revolving around waste management in Grenada, with only a few specifically targeting compost production potential and its feasibility. Most notably, a study conducted by ImplementaSur in May 2024 under the Recycle Organic (RO) Program, with financial support from Environment and Climate Change Canada (ECCC), looked at a pre-feasibility assessment of a hypothetical public-private-partnership between a local private company, Grenada Grows (GG), and the GSWMA. The overarching goal of the program is to accelerate the implementation of methane mitigation projects in the waste sector and to create enabling conditions for a sustained expansion of organic waste management technologies that bring significant environmental, economic, and social benefits. In the specific case of the pre-feasibility assessment mentioned above,

GG provided concrete plans and proprietary data that configured a likely investment scenario. This framework was carefully considered for this assessment, and information derived from this study has been validated by FAO and UNDP. Information and data that could not be validated were excluded from the SCALA assessment.

In addition to data from existing studies on composting facilities and assessments, a data collection campaign was initiated to collect information on:

i. potential organic waste supply sources, and
ii. potential compost demand.

Research on waste supply included data on waste availability and the characterization of generated volumes. The research involved collecting and discussing primary data from GSWMA regarding total waste volumes disposed of at the new Perseverance landfill from 2022 to 2025, including the disaggregated category of organic waste and biomass. This was complemented by a desk review of secondary information on pre-2022 volumes and waste composition from literature.

Once data on waste volumes and composition was collected and validated, existing composting systems were reviewed to highlight the suitability of each technology for the intended scope of the case study. Moreover, questionnaires we redistributed to key stakeholders and their associations that have the potential to produce organic waste that could be used for compost production. These include farmers' associations, livestock producers, fishermen's associations, tourism (hotels and resorts), and the food and beverage industry.

3.1.1.1 Composting technologies

Composting is defined as a natural bio-degradation process that transforms organic waste, such as plant remains and kitchen refuse, into nutrient-rich compost through microbial decomposition over time. It is a method of waste disposal that converts unsafe organic materials into safe compost, primarily used in organic farming[63]. As the definition implies, practically any plant or animal material can be composted.

Composting methods fall into three general categories:

- Passively aerated systems
- Actively aerated systems
- In-vessel systems.

Passively aerated systems include traditional methods like windrow and static pile composting, while actively aerated and in-vessel systems are more advanced techniques. Notably, vermicomposting and anaerobic digestion are additional technologies worth considering for their added value and co-product[64] generation. Innovative technologies like smart aerobic composting, which uses sensors for real-time monitoring and optimization, and mechanical systems that automate waste processing, are also emerging. The selection of the most appropriate technology depends on factors like scale, waste volume, desired compost quality and efficiency, and most importantly, market conditions. The following section discusses each method and presents the advantages and disadvantages of each.

3.1.1.2 Passively aerated systems

Passive aeration is best used for slowly decomposing feedstocks like leaves, brush, bark, wood chips and residues like horse manure and bedding[65]. It is also the primary composting method for livestock mortalities and slaughterhouse waste in Grenada, where offal and other animal waste are piled and covered with soil, or buried under a thin layer of soil.

Static piles rely on natural convection for aeration, where air heated by microbial decay rises out of the pile and is replaced by cooler air migrating inwards from the sides. Advantages of the static pile method include low costs and simplicity: it requires minimal capital, operating costs, equipment, and staffing, and needs no electric power for its upstream operations (except for bagging and handling, for which power and equipment is still required). There are several disadvantages to this method, including the inevitable production of odors, the unsuitability for putrescible materials (like offal, as happens in Grenada), a large area required, a slow decomposition rate, and the risk of spontaneous combustion and fires.

[63] Waste management strategies in fashion and textiles industry: Challenges are in governance, materials culture and design-centric - ScienceDirect

[64] Biodigestate is a co-product of anaerobic digestion and is used as organic fertilizer due to its relevant nutrient content.

[65] Rynk, R., et. al., The Composting Handbook, Elsevier Publishing, 2022.

The other form of passive aeration is windrow composting, the most common composting system used in large scale composting facilities across the US and the EU[66], due to its suitability for a wide variety of materials and capacities and low capital and operating costs. Windrow composting involves forming long, narrow, and low compost piles known as windrows that are about twice as wide as their height. The length can be as long as the available space. Windrows are built using front-end loaders, skid-steer loaders, and excavators. Space requirements for a windrow composting pad vary depending on the method of turning, as windrows can be turned with a loader or with a drum turning machine, commonly referred to as a "compost turner". These turners are either a pull-behind type towed with a loader or a tractor, or a self-propelled straddle-type machine. Turning with a loader or pull-behind turner requires 3 to 4 meters (15 to 20 feet) of space between each windrow, where straddle-turned windrows can be as close as 0.5 to 1 meter (2 to 3 feet) apart. Requirements for a tractor-pulled turner include a minimum power of at least 80 horsepower (hp) at the shaft, or a power take-off (PTO) of at least 60 hp, and the presence of a transmission equipped with ultra-low speed gear, known as a "creeper gear" to allow it to drive slowly when pulling a turner through a windrow.

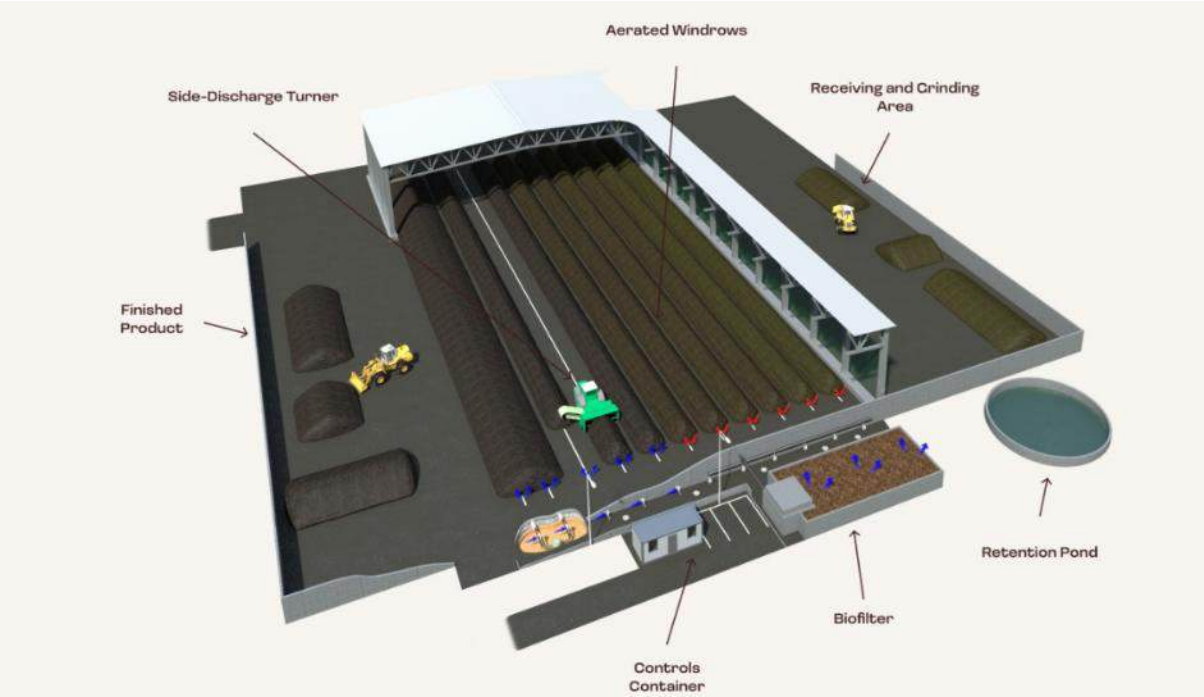


Figure 17. Turned Aerated Pile scheme. Source: Green Mountain Technologies[67]

Windrow composting[68] is commonly used to process yard trimmings (grass, leaves, brush), woody materials, kitchen waste, and many other biomass types. Turning the windrow can help break down the particle sizes in these more heterogeneous feedstocks, depending on drum design (flail-based designs are better than auger-based designs for particle size reduction). Food scraps, industrial residuals (i.e., food processing or paper wastes), manures, and biosolids are also composted in windrows, but these

[66] Platt, B., et.al., "State of Composting in the U.S.", Institute for Local Self-Reliance, 2014.
[67] Turned Aerated Pile (TAP) - Green Mountain Technologies
[68] Diaz, L., G. Savage, and L. Eggerth, Modern Composting Technologies, The JG Press, Inc., 2005, p. 49.

facilities are usually located in more arid, warmer regions to minimize impacts from weather and climate, and/or use fabric or nets to deter birds, dogs, raccoons, and rodents drawn to the more putrescible feedstocks. The main advantages of the windrow composting method include the possibility to handle putrescible feedstocks without generating odors, their relatively low capital and operating costs, the comparably low technology and training requirements, and the vast industry experience with this technology. However, these plants require a large area for windrow turning, are labor intensive, and the exposure to weather or to wild or stray animals can be problematic.

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3.1.1.3 Actively aerated systems

Actively aerated composting systems use fans and blowers to move air through a composting pile to maintain aerobic conditions. There are generally three types of aeration systems: positive (or forced draft), negative (or induced draft), and bi-directional.

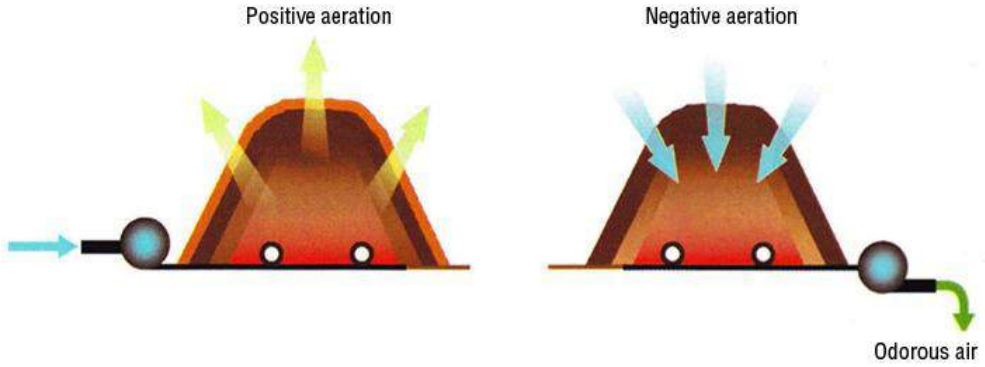


Figure 19. Positive and Negative aeration in composting

In a positive aeration system, air is introduced through perforated pipes at the base of the pile and allowed to migrate up through the pile, carrying entrapped gases and moisture up and out of the pile. In some positively aerated systems, a layer of compost or a fabric cover is used to help manage odors and retain heat and moisture in the pile.

Negatively aerated systems pull air downward through the pile and into the aeration pipes. This “exhaust” air has high temperature and moisture content, so it is usually cooled prior to entering an odor control system. Cooling the air condenses the moisture, so condensate management systems are needed. It is important to have efficient condensate traps between the piles and the air extraction blowers to keep the corrosive condensate moisture out of the blower mechanisms. Odor control systems are usually either biofilters or chemical scrubbers. Bidirectional systems have more advanced ducting and controls, and switch between positive and negative air flow to better control temperatures in the piles.

The advantages of this method include the reduced space requirements compared to passively aerated systems, the maintenance of higher and more uniform oxygen levels, thus a more homogenous

compost is produced, and above all, significantly shorter composting times. However, this comes at a cost, including higher capital costs, the need for an industrial site, three-phase electricity supply, and higher training requirements for personnel.

3.1.1.3 In-vessel systems

Irrespective of their size, in-vessel systems are considered “bioreactors.” A bioreactor is an enclosed, rigid structure or vessel used to contain the material undergoing biological processing. These systems tend to have integrated control systems that monitor process parameters like temperature and oxygen (or carbon dioxide). A mixing and loading hopper/conveyor and a biofilter for exhaust odor management are often included. Material is moved through the bioreactor by various means, including moving floors, spinners, augers, and similar devices that transport dry materials. The sizes of these units vary by capacity, with smaller units able to fit into one parking stall, while larger units are the size of shipping containers (20 or even 40 feet long). Bioreactors can be classified by their configuration (horizontal, vertical, with channels, with cells, with containers, with tunnels, and with rotating drums), by operational mode (continuous or batch), and by static or dynamic movement of material within the reactor[9]. Many bioreactors are dynamic systems, in that forced aeration is supplemented by internal turning or agitation, and typically operated in continuous mode, rather than in batch mode. Some vendors have smaller capacity systems and are modular, so they are suitable for community, on-site, and on-farm applications. These systems are suited to capacities of less than 10 tons/day of source-separated organics[69]. Once capacity is reached, additional vessels need to be procured.

Advantages of using in-vessel composting include the low space requirements, high degree of odor control, reduced labor costs, and a modular system that allows for future scaling.

[69] Environment Canada, “Technical Document on Municipal Solid Waste Organics Processing,” 2012, p. 5-13.



Figure 20. In-vessel composter. Source X-Act systems.[70]

However, these systems inevitably have some disadvantages, as they are not suitable for large-scale operations and incur high capital costs.

[70] Images Bioreactor In-Vessel Composter - XACT Systems Composting

3.1.2 Scenario definition, site selection and process design

A major goal of this feasibility study is the engagement of the private sector in climate-friendly investments. During the project, several stakeholders were contacted and presented with unique needs and objectives related to waste management and compost production, and use. To ensure full representation and relevance for every stakeholder, the study selected independent production scenarios that accounted for both stakeholder expectations and the verified realities on the ground. A scenario-based approach is a common practice in feasibility assessments, as it presents alternative routes while exploring different opportunities and evaluating specific risks. However, this drawback of this approach is that it complicates the analysis, and it is naturally exposed to additional assumptions.

The study identified two main scenarios for compost production in Grenada:

- **Commercial compost plant**: 6,500 tonnes of organic waste/year (2,600 tonnes/year of compost)
- **Smallholder compost plant**: 400 tonnes of organic waste/year (180 tonnes/year of compost)

The first scenario consists of a facility with a capacity of processing about 6,500 tonnes of waste biomass per year, corresponding to the amount of segregated organic waste already available each year at Perseverance landfill. This specifically includes organic waste that does not need separation and pretreatment except for shredding and composting-specific actions. Such a facility could deliver approximately 2,600 tonnes/year of mature compost. It delivers a product in the form of densified pellets in 25 kg bags intended for commercial use.

The second option examines a smaller, decentralized plant that has the capacity to process around 400 tonnes per year of segregated organic waste, as a pilot unit that could be replicated by farmer groups in different agricultural areas. This scenario is motivated by the existing and verified interest of several farmers in the inland areas of Grenada who have engaged at various levels in compost production. Multiple composting plants of this size could be deployed in the country since there are several commercial farms, including livestock farms, that generate substantial waste streams that are not valorized. Each of these 400 tonnes/year plants could produce up to 160-180 tonnes of high-quality compost per year.

Based on the information and a site survey carried out in May 2025, the identification of suitable locations for the compost plant was carried out for each of the main scenarios, considering factors like space, proximity to waste sources and markets, and accessibility.

The location of the Commercial plant (6,500 tonnes/year) was based on communications with GSWMA and existing studies and supported by an aerial survey at the new Perseverance landfill. The aerial survey created a 3D map of the landfill using a process known as “photogrammetry”. The elaboration of available maps and field measurements requires extensive work and often subsequent verification of measurements and repetition of the surveys. Traditional surveying involves the direct measurement of distances, angles, and elevations using specialized equipment. Surveyors physically walk around the

area, taking measurements at specific points to create accurate maps, plans, and land records. This method has been the industry standard for many years, as it delivers precise results in projects. The high accuracy of this method is often overshadowed by its costs and time requirements necessary to carry out a mapping exercise with surveys. Taking measurements of every item, angle, and distance within a case study area is a tedious and time-consuming task, often requiring several days to complete. Moreover, if the surveyors are not residents of Grenada, any missing information noticed during data processing cannot be quickly verified or corrected. On the other hand, photogrammetry uses the power of imagery and computer algorithms to extract spatial data. By capturing photographs from various vantage points and angles, photogrammetry constructs 3D models and maps, often without the need for physical contact with the surveyed area. This use of modern technology returns impressive results in a fraction of the time and resources, when compared to traditional surveys.

The result of the photogrammetric survey is a high-fidelity 3D model of the Perseverance site (Figure 18) and the related set of orthophotos that are used to measure surface areas, volumes, and distances.



Figure 21. 3D model of the new Perseverance landfill site.

Considering the background research in Chapter 2, and the analysis of the scenarios to be evaluated, the most appropriate composting process and technology were identified. The selection considered factors like waste type, scale, and required product quality.

The vast majority of the organic waste generated in Grenada, including the share reaching the Perseverance landfill, is composed of yard and garden waste, made predominantly of grass clippings, twigs, pruning clippings, and fruit dropped from trees, food scraps, and agricultural waste. This “green” biomass has a high nitrogen content compared to woody, or “brown”, biomass. Woody biomass,

inherently rich in carbon, is essential for the sound process of composting. At Perseverance, waste wood, coconut shells, and tree pruning waste are delivered in large quantities and mostly already segregated.

The selected composting process for this feasibility assessment is windrow composting, a competitive form of passive aeration composting that has shown the highest suitability in the context of Grenada. This is due to its flexibility in utilizing a wide variety of mixed biomass materials and capacities, and relatively low capital and operating costs. Site selection is predominantly dictated by the availability and volumes of segregated organic waste, delivered at the new Perseverance landfill. The specific location of the composting area at Perseverance was established via orthophotos generated through the photogrammetry exercise of the landfill. To process 6,500 tonnes of organic waste per year with a windrow method, approximately 3,000 m^2 of land needs to be levelled and cleared to host the concrete slab and shed under which windrows and machinery will be hosted.

Thanks to the photogrammetry 3D model of Perseverance landfill, areas suitable for hosting the composting plant have been mapped.



Figure 22. Orthophoto (3D non-perspective projection) of the new Perseverance landfill. The drop-shaped area in the bottom left corner is the biomass pit, the area where currently 6,500 tonnes of segregated organic waste is dumped every year

The mapping inputs required a minimum continuous area of at least 3,000 m^2 and a maximum positive slope of 15%. This is in line with the requirement for the minimum footprint calculated for the treatment of 6,500 tonnes/year of biomass and the practical need to level the ground and build the concrete slab.

Two areas within the borders of the Perseverance landfill that meet both requirements have been identified. Both options offer at least 3,000 m^2 of quasi-flat terrain. Option 1 (aqua box in Figure 22) is found in an area that hosts a junkyard for scrap metal and vehicles.

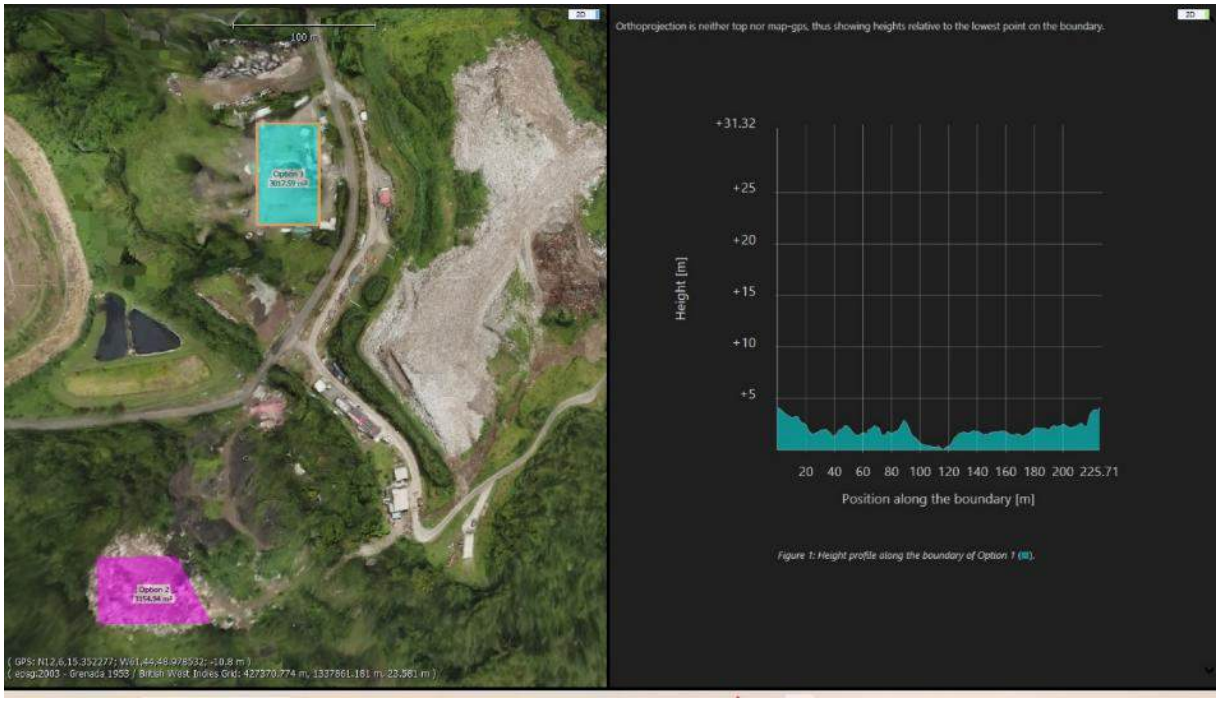


Figure 23. Two options for the construction of the Commercial compost plant are identified within the borders of Perseverance landfill in Grenada.

Option 1 is located across the road from the new Perseverance landfill site, in the area under the pertinence of the old dumpsite of Perseverance. Trucks would be required to enter the premises of the new Perseverance landfill, weigh on the scale, and exit the premises to unload the biomass outside the borders of the current, active landfill. This additional step might create issues of liability, as organic waste would technically leave the landfill to be treated. Moreover, the area of Option 1 has a horizontal profile (righthand side of Figure 22) with elevation changes (rough terrain) swinging more than 4 meters, which would require heavy civil work for clearing and levelling. Considering the uncertain legal implications and increased need for civil work, Option 2 (magenta in Figure 22) is selected as the designated area for the construction of the composting plant.

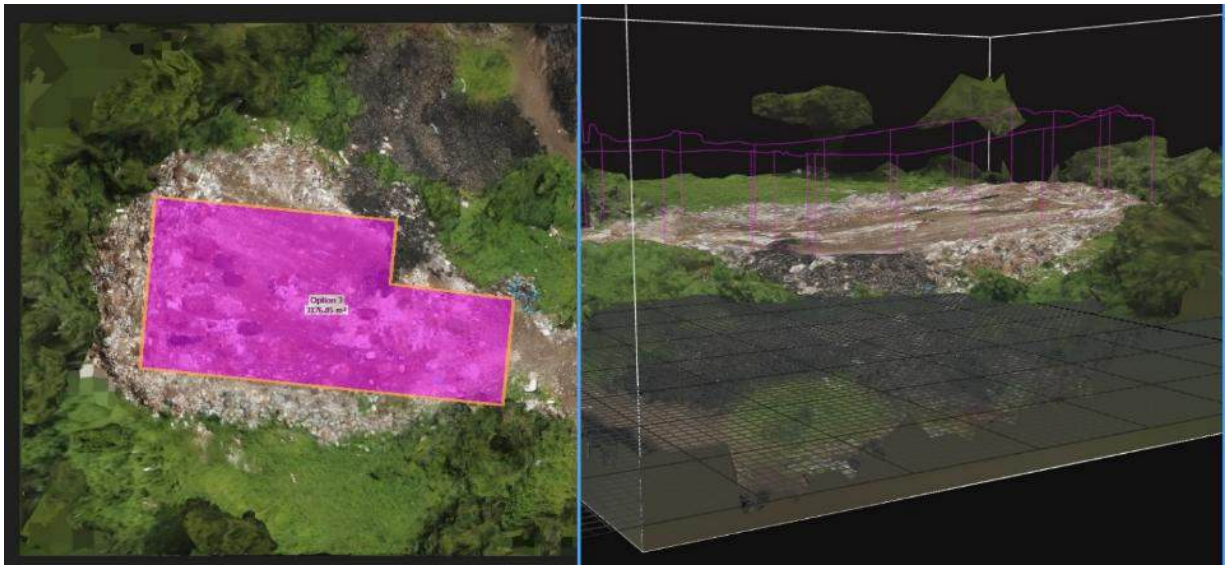


Figure 24. The most appropriate spatial arrangement for the composting plant is presented above corresponding to the biomass pit currently used to dump the segregated organic waste delivered at Perseverance landfill.

The area is currently used as the biomass pit at the new Perseverance landfill. It has a total area of approximately 4,933 m^2 and a flat profile (average elevation changes are <2 meters). Within the border of this area, a regular-shaped flat surface of more than 3,000 m^2 can easily be identified. This surface will be paved with a concrete slab, sealing the soil underneath, and will host all composting operations, from maturation to bagging of the final product.

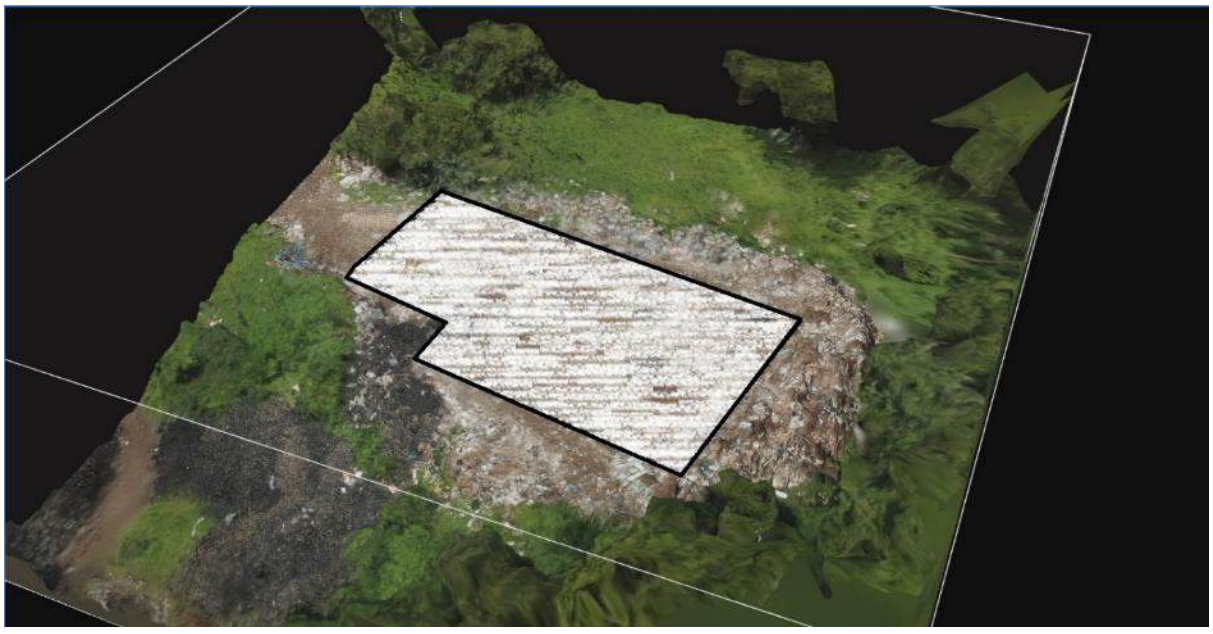


Figure 25. A mock-up of the concrete slab to host windrow composting operations of the commercial scale plant at Perseverance landfill in Grenada.

The appropriate equipment and workflow design for this composting method are described below. Biomass received is already segregated at the gate of Perseverance landfill. After registration of the delivery contractor, the load is weighed and delivered to the area designated as Option 2, the

composting plant. The first station of the composting plant is the shredding and grinding station. A shredder is a machine that reduces waste biomass into particles of approximately the same size, ranging from 1 to 3 cm (chips). The shredded material is conveyed to the composting area. This makes up most of the surface of the plant. The composting process starts with the piling of the shredded material, using a tractor with a front loader. The loader is used to form long rows of shredded material, called windrows. Each row is about 2-3 meters high and 50 meters long with a triangular cross-section. A flat space about 3 m wide is left between each row to allow vehicles to move along the length. The same tractor is used to power the windrow turner.



Figure 26. Example of a tractor with a compost turner. The turner is equipped with a water tank (the white drum shaped tank in the picture) to spray water on the compost pile during operations. Photo courtesy of Samtra Tractors.

After a windrow is laid in place, the material is turned and simultaneously dampened by the turner equipped with a water tank as the tractor moves along the row. The water aids in the composting process and helps minimize wind-blown dust. Every few weeks, the turner straddles each windrow and moves along its length to turn and agitate the material. This breaks down the material into even smaller pieces and exposes it to oxygen, which supports the aerobic decomposition process. After the windrow is turned, it is sprayed with water again. This process continues for two to three months. During decomposition, the internal temperature of the pile may reach 54° C, which controls the surge of pathogens and deactivates most of the weed seeds that might be present in the compost. The raw compost is scooped up with the front loader and moved to a dedicated pile where it is allowed to finish

the decomposition process over a period of four weeks. This process called curing allows the carbon and nitrogen in the compost to adjust to their final levels. After the compost has cured, it is scooped up with the front loader and dumped into the hopper of a rotary screen. This device consists of a large cylindrical screen rotating on an axis that is slightly inclined above the horizontal. The openings in the screen are about 1 cm in diameter. The compost is fed into the raised end of the rotating screen from the hopper by a conveyor belt. As the compost tumbles its way down the length of the rotating screen, the smaller material falls through the screen and is moved to a storage pile by a conveyor belt. The larger material that cannot pass through the screen falls out of the lower end of the cylinder and is either returned to the compost piles for further decomposition or is sold as mulch.

Another important stage of compost production in the commercial scenario studied in Grenada is pelletization. This process uses a compactor or granulator, a piece of equipment that presses and extrudes the compost into pellets of less than 1 cm in diameter and around 2 cm long. Compost pelletization is the process of mechanically pressing compost into dense, uniform pellets to improve handling, storage, and transport, while also enhancing its fertilizing properties and reducing dust and odors. Compost pellets have a density[71] of around 1,000 – 1,200 kg/m^3 as opposed to 400-600 kg/m3 of regular compost[72]. Densification through pelletization enables farmers to reduce transport costs when purchasing the bagged product.

The last station in the commercial compost plant is the bagging area. Compost pellets are bagged by a machine in 25 kg bags, ready for retail.

3.1.3 Economic and financial analysis

A Cost-Benefit Analysis (CBA) was conducted to evaluate the project's overall financial and economic feasibility. The assessment focused on key indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period to determine long-term profitability and efficiency. Different scenarios and options were compared, highlighting strengths, weaknesses, and overall robustness under varying conditions. Additionally, the analysis considered the project's attractiveness to investors and financial institutions, ensuring it meets funding expectations. A sensitivity analysis was also performed to test the impact of changes in critical variables, thereby providing a comprehensive understanding of risks and uncertainties linked to investing in compost production in Grenada. In line with the methodology presented in the European Commission's *Guide to Cost-Benefit Analysis of Investment Projects* (EC, 2014), project profitability was assessed by estimating project revenues and costs (which will be analyzed in the next paragraph). This evaluation is expressed through two main indicators: the financial Net Present Value (NPV) and the financial Internal Rate of Return (IRR) on investment.

The NPV represents the sum of expected future cash flows, discounted to reflect the time value of money. In this analysis, the discount rate was set at 12% over a 20-year horizon, which is a standard timeframe for projects of this type. This level was selected as a cautious and realistic assumption, taking

[71] Assessing the potential for producing compost pellets with binders from cassava industry by-products and supplemented with Trichoderma - ScienceDirect
[72] https://www.researchgate.net/publication/275153175_CHEMICAL_AND_PHYSICAL_PROPERTIES_OF_COMPOST

into account the specific risks of small island economies, such as limited market size and exposure to external shocks. The rate is also in line with benchmarks found in the literature and with values commonly applied in similar projects in the Caribbean region.

Equation 1 shows the NPV calculation:

$$NPV = \sum_{t=1}^{20} \frac{F_t}{(1+r)^t}$$

where **F***t* is the annual cash flow, *r* is the discount rate, and *t* is the year.

The IRR, in contrast, is the discount rate that makes the NPV equal to zero. In simple terms, it shows the return that the project itself is expected to generate.

Equation 2 shows the IRR calculation:

$$0 = \sum_{t=1}^{20} \frac{F_t}{(1+IRR)^t}$$

In addition, the use of NPV and IRR supports two further objectives of this cost-benefit analysis: testing the soundness of different scenarios and assessing the project's attractiveness for investors and financial institutions.

As a second part of the CBA, a sensitivity analysis was carried out to examine how changes in key parameters may affect the results and to highlight which factors have the strongest influence on the project's performance. Finally, the last part of the assessment focused on risk identification, evaluation, prevention, and mitigation, with the aim of reducing uncertainties and strengthening the overall reliability of the project.

Reference values, conversion factors, prices, and other relevant information used in the analysis are presented in the relevant figures and tables, with details provided in the corresponding sections.

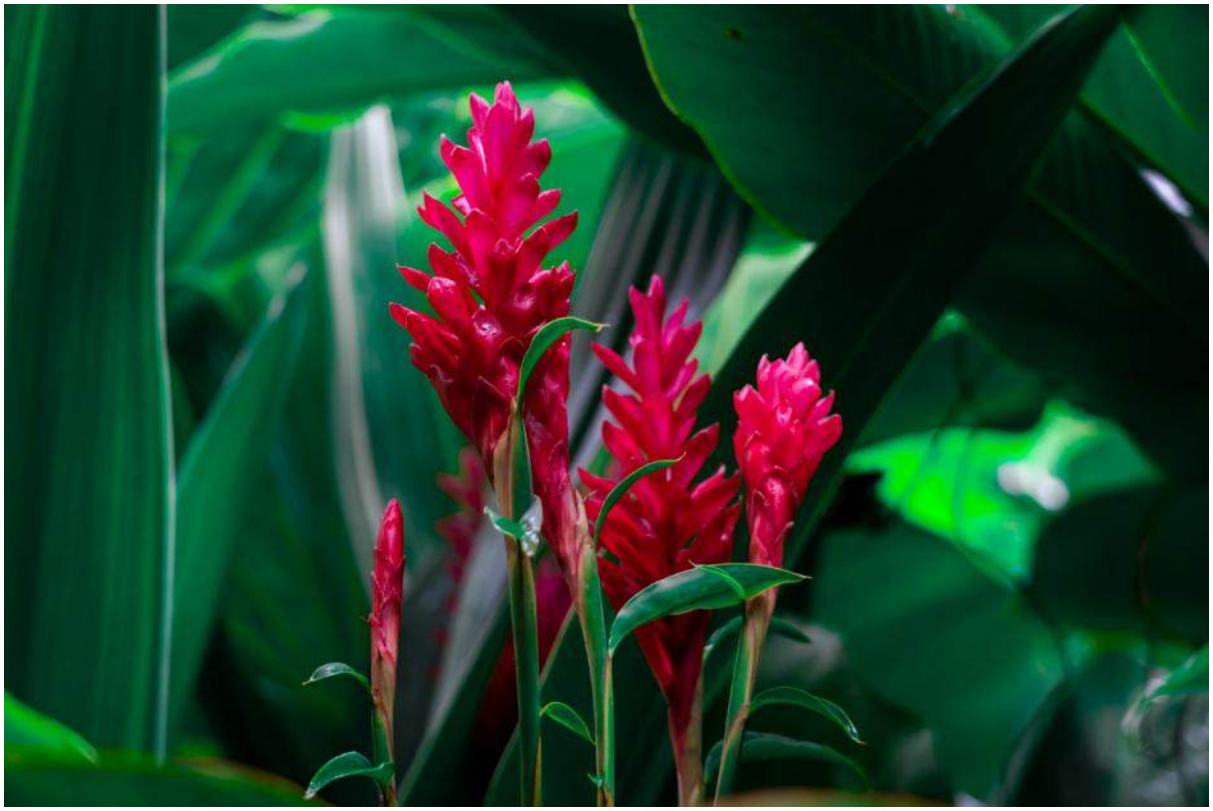


Figure 27. One of Grenada's main assets is its pristine environment and biodiversity.

3.2. Private sector engagement strategy

Engaging private sector stakeholders in the agrifood and waste disposal sectors to participate in climate change-related projects requires a multifaceted approach. SCALA's Private Sector Engagement Facility (PSEF) approach highlights the importance of private sector engagement in building resilience to climate change and achieving sustainable development goals. This sees engagement actions through the lens of three main groups of actions:

- Outreach, Opportunity Mapping, and Facilitating Multi-Stakeholder Engagement
- Assessing Risks and Business Opportunities
- De-risking and Enabling Private Sector Investments

The Government of Grenada requested support in the Assessing Risks and Business Opportunities area, specifically in the field for conducting feasibility and evidence-based studies on relevant private sector-oriented initiatives within the land use and agriculture sector that contribute to meeting climate action goals.

To connect with the private sector, there is a need to deeply understand the country and the business environment in which these entities operate and formulate sensible proposals that capture their interest. Given the diverse array of priorities among entrepreneurs and private business operators, conducting a comprehensive analysis of the country and business contexts can offer valuable insights into their key concerns and priorities.

Any private business, by nature, is devoted to achieving economic benefits from its operations. This is why showcasing potential economic benefits is instrumental in ensuring an effective connection with private sector representatives. Highlighting the economic advantages of participating in climate change projects, such as cost savings through efficiency improvements or new technology implementation, as in the case of compost, can gain interest and trust from private sector operators.

A detailed financial analysis showing the economic viability of producing and acquiring compost as a soil amendment is instrumental to demonstrate the positive impact of climate change initiatives on business performance, resilience, and to build the reputation of compost as a competitive alternative to chemical fertilizers. Concrete evidence of ROI can persuade hesitant stakeholders to participate and scale up the use of composting technologies in Grenada. Private sector engagement is essential for effective mitigation and adaptation planning and implementation. By leveraging the expertise, resources, and innovation of the private sector, countries can build resilience to climate change and achieve sustainable development objectives.



Figure 28. Knowledge sharing with a local farmer in Grenada on sustainable yield and soil quality enhancements through compost use

The lessons learned from past UNDP and FAO projects provide valuable insights for policymakers, practitioners, and stakeholders seeking to enhance private sector engagement in adaptation efforts, as demonstrated by the high receptivity of private sector stakeholders in Grenada. Smallholder farmers reported high interest in switching away, even partially or fully, from chemical fertilizer use. These farmers have a clear understanding of the added value of organic inputs into their farming practices and stand proudly as soil stewards with the clear intent to preserve and improve the health of their farms and the quality of their products.

During the survey, it emerged that private stakeholders in Grenada (both large farmers and agricultural entrepreneurs, as well as investors) are inclined towards investing in compost-making projects and other climate-resilient ventures. Among those interviewed, there were large farmers who were already engaged in the business, although without any experience or solid knowledge base. These agricultural entrepreneurs have the necessary assets to start composting organic waste generated on the farm, as well as gathering different biomass and organic waste generated in their parish but would benefit from the provision of capacity building and risk sharing operations. This assessment considers the feedback from these key stakeholders, and through the analyses presented, it intends to provide guidance on how to deploy such investments while mitigating entrepreneurial risks associated with them.

4. CASE STUDY ASSESSMENT

4.1. Background and scenario definition

The main objective of the study was to assess the economic viability of substituting the disposal of organic waste at the Perseverance landfill with the local production of compost, which can partially replace the demand for imported synthetic fertilizers.

This analysis considers two possible scenarios linked to different plant sizes. The scenarios are named starting from the amount of organic waste to be processed into compost, as this parameter dictates the size of all components and consequent capital and operational costs, as well as production output and related economic and non-economic benefits.

The first scenario examines a small, decentralized facility capable of processing around 400 tons per year of segregated organic waste. Designed as a smallholder unit, this plant could be replicated by farmer groups in different agricultural areas across Grenada and could solve the logistical difficulties of transporting large amounts of organic waste to a centralized commercial compost plant. Throughout this report, the reference to the smallholder-scale plant will be made as the “400 tonnes/year plant” referring to the raw materials processing capacity rather than to the final product production capacity. Such product output is generally 40% of the initial biomass volume, thus in the case of this scenario, 160 tonnes of compost per year can be produced each year from the 400 tonnes of organic waste (t_{ow}) processed.

The second scenario refers to a medium-sized commercial facility processing 6,500 tons of biomass per year, corresponding to the amount of segregated organic waste reported by GSWMA to be delivered each year at Perseverance. Throughout this report, reference to the commercial-scale plant will be made as the “6,500 tonnes/year plant”.

A third option of a much larger plant capable of processing approximately 70,000 tons of mixed waste delivered annually to the Grenada landfill was discussed with stakeholders. Interest in this scenario is motivated by the needs of GSWMA to reduce the volume of organic waste deposited in its landfill to the greatest extent possible, and for the Government of Grenada to reduce GHG emissions from its waste sector by up to 90%, as per its second NDC. Mixed Municipal Solid Waste generated in Grenada contains an organic fraction of 25-28% equivalent to 17,000 – 19,500 tonnes of organic waste. Once processed, this could generate about 7,400 tonnes of compost.

A project of this magnitude would require a capital expenditure (CAPEX) of over USD15 million. Evidence from literature and from similar projects shows that facilities of this scale tend to face structural, economic, and financial sustainability issues. Investment costs for this kind of plant tend to be high and more importantly, operating costs are unlikely to be covered by revenues from the sales of compost and other recovered materials. In fact, worldwide, such plants reach economic breakeven when their operations are supported by a considerable waste disposal fee, which is not the case in

Grenada. This fee must usually be at least USD 140/tonne of mixed waste to ensure that the plant operates in a positive economic framework without losses. For the reasons above, this option is not regarded as viable in the Grenadian context, and the study focuses on the segregated organic waste identified at Perseverance landfill, which represents a concrete and immediately available resource for composting.

4.2 Technical and environmental viability

The first calculation in this study looks at assessing the compost production potential of the two main scenarios and the capacity of the agriculture sector to absorb the product. The fertilizer market of Grenada absorbs around 3,400 tonnes of chemical fertilizers, which is assumed as the maximum capacity of the agriculture sector, or market cap. Since actual, disaggregated data of macronutrients imported as fertilizers are not available, averages and estimates were carried out to assess the actual amount of nutrients that enter the agrifood system in Grenada. Chemical fertilizers sold in the country have various concentrations of their fundamental macronutrients. As discussed in previous chapters, the main agricultural activities relying on fertilizers in Grenada are cocoa and vegetable production.

Cocoa production is characterized by a peculiar nutrient profile: mature plants require lower than average phosphorous, and higher than average potassium amounts. Vegetables production, instead, is characterized by a more traditional nutrient profile, with balanced shares of all major macronutrients and in concentrations of around 15% each (NPK 15:15:15). By using this reference to calculate the mass balance of nutrients used in agrifood systems in Grenada would be around 500 tonnes of N, P, and K, or a total sector capacity of 1,530 tonnes/year. Compost products have a minimum nutrient content of 2% N, P, and K, thus approximately 7.5 times less than the average chemical compound sold in the country. To supply 1,530 tonnes of macronutrients through compost, 25,500 tonnes of organic amendments would be necessary. The commercial plant tested (6,500 tonnes of waste and 2,600 tonnes of compost) is capable of meeting about 10% of the macronutrient requirements. Distributed, decentralized smallholder plants are estimated to be able to produce about 160 tonnes of compost per year and based on a survey carried out by FAO in May 2025, up to 10 of these facilities could be built in the parishes of Grenada. These facilities could produce about 1,600 tonnes of compost, equal to an additional share of 6% of the total demand for nutrients of the agriculture sector. Cumulated compost production in Grenada could meet up to 15-16% of the demand for macronutrients of the country's agriculture sector. Therefore, it is unlikely that the entire agriculture sector of Grenada could rely solely on compost as its source of plant nutrients; however, a substantial share of the synthetic fertilizers imported into the country could be displaced by locally produced compost. The existing legislation on agricultural inputs[73] and plant management[74] in Grenada does not define a specific product as fertilizer,

[73] https://faolex.fao.org/docs/pdf/grn7861.pdf
[74] https://faolex.fao.org/docs/pdf/grn38853.pdf

nor does it exclude any specific organic compound from being treated as a fertilizer. This means that compost production and sale are technically viable in Grenada. In most international agricultural legislations, compost is not classified as a *fertilizer* but rather as a *soil amendment,* and it is expected that Grenada and the rest of the CARICOM states will align themselves to this definition once the compost standards are finally published. This will ensure the production and commercialization of the product, safeguarding its use as a support for plant nutrient management

As described in previous chapters, windrow composting is a technically viable method for large-scale organic waste management in Grenada. The process involves piling biodegradable materials into elongated rows, which are periodically turned to maintain aerobic conditions, optimize temperature, and accelerate microbial decomposition. It is cost-effective, scalable, and adaptable to diverse climates, though it requires adequate land, machinery, and monitoring to control moisture and leachate[75]. Studies demonstrate that windrow composting can stabilize organic waste, reduce pathogens, and produce nutrient-rich compost, supporting sustainable soil management and circular economy practices.[76] This assessment confirmed the technical viability of compost technologies, in particular, windrow composting, for the context of Grenada.

From an environmental perspective, the viability of compost production involves various factors: air quality (including greenhouse gas emission reductions), soil and water quality, biodiversity and pest control.

Landfilling the organic fraction of municipal solid waste (OFMSW)—food scraps, garden trimmings, paper and other biodegradable materials—creates a cascade of environmental impacts that extend far beyond the landfill fence line. The most notable consequence is methane (CH_4) generation and emission. Under anaerobic conditions inside a landfill, microorganisms convert degradable organic carbon in OFMSW into biogas (roughly 50–60% CH_4 and the rest largely CO_2). The Intergovernmental Panel on Climate Change (IPCC) provides the standard first-order decay framework and defaults for key parameters such as degradable organic carbon (DOC) and the fraction of DOC that actually decomposes (DOCf), which together determine long-term methane generation ("methane commitment"). The 2019 Refinement to the 2006 IPCC Guidelines updates these parameters and guidance (e.g. DOCf by waste type, methane correction factors by site management), underscoring that composition and site practices drive emissions over decades.[77]

A calculation of GHG emissions from OFMSW delivered at Perseverance was carried out using the IPCC guidelines and subsequently checked against several authoritative sources.

[75] Tchobanoglous, G., Theisen, H., & Vigil, S. (2002). Integrated Solid Waste Management. McGraw-Hill.
[76] Haug, R. T. (2018). The Practical Handbook of Compost Engineering. Routledge.
[77] IPCC. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories—Volume 5: Waste (esp. Chapter 3: Solid Waste Disposal). IPCC TFI, 2019. ipcc-nggip.iges.or.jp

EQUATION 3.2
DECOMPOSABLE DOC FROM WASTE DISPOSAL DATA

$$DDOCm = W \bullet DOC \bullet DOC_f \bullet MCF$$

Where:

DDOCm = mass of decomposable DOC deposited, in tonnes

W = mass of waste deposited, in tonnes

DOC = degradable organic carbon in the year of deposition, fraction, tonne C/tonne waste

DOCf = fraction of DOC that can decompose (fraction)

MCF = CH_4 correction factor for aerobic decomposition in the year of deposition (fraction)

In the first scenario, the mass of waste deposited is 6,500 tonnes. This is the biomass disposed off every year at Perseverance landfill and left to decompose (W). The characterization of this biomass was never carried out by GSWMA, and its exact DOC can only be empirically estimated as being 50% of the waste. While some fraction of the biogenic carbon, primarily cellulose and hemicellulose, is converted to carbon dioxide and methane, lignin is essentially recalcitrant. The composition of the organic waste reaching the landfill is a mix of less decomposable wastes (e.g. wood, engineered wood products, tree branches), moderately decomposable wastes (e.g. paper, textile, nappies), and above all, highly decomposable wastes, including food scraps, grasses, and trimmings (garden and park waste excluding tree branches). The fraction of DOC that is decomposed is 60%, and since the landfill operates in managed, anaerobic fashion, the MCF is equal to 1.0.

*DDOCm = 6,500 tonnes * 0.5 tonne C/tonne of waste * 0.6 * 1.0 = 3,250.6 tonnes*

To calculate the methane emission potential of the biomass waste delivered at Perseverance landfill then, equation 3.3 of IPCC guidelines is to be applied.

EQUATION 3.3
TRANSFORMATION FROM DDOCm TO L_o

$$L_o = DDOCm \bullet F \bullet 16/12$$

Methane (CH_4) generation potential (Lo) equals the product of DDOCm, the CH_4 concentration in the gas (F) which is taken at 50% by default, and the molecular weight ratio of CH_4 and C (16/12). Applying the formula to the calculated DDOCm, the result would be the following:

*Methane generation = 3,250.6 tonnes * 0.5 * 16/12 = 2,167 tonnes of CH_4 per year*

Applying the global warming potential conversion factor for biogenic methane (27 according to IPCC AR6[78]), the organic waste delivered at Perseverance landfill is responsible for the emission of approximately 58,500 tonnes of CO2eq/year. This baseline emission was then compared to the GHG emission potential of windrow composting. In fully aerobic biomass composting, in theory, no methane is generated. However, in practice, even the most modern and effective composting plants experience the presence of some anaerobic decomposition pockets that lead to the generation of small amounts of methane.

Emissions depend heavily on compost type (e.g. food waste, manure, grass trimmings, etc.), process management, and the frequency and magnitude of anaerobic pockets. The majority of methane is often released early in the composting process, and there are best management practices that can limit this phenomenon, like frequent waste turning in the early stages of composting. However, the lack of existing and long-lasting experience with composting in Grenada calls for a conservative approach to estimating GHG emissions in the scenarios with windrow composting.

IPCC published guidance on calculating CH_4 and N_2O emissions from composting[79]. On average, 4 kg of methane and about 0.24 kg of N_2O (nitrous oxide) are emitted per tonne of organic waste (on a wet basis) treated with aerobic composting. Therefore, the 6,500 tonnes of organic waste treated in the commercial-scale composting plant scenario could emit some 1,128 tonnes of CO2eq/year (702 tCO2eq as CH_4 and 426 tCO2eq as N_2O).

The net GHG emissions reduction achievable with a commercial-scale composting project in Grenada would then be 57,372 tCO2eq/year. Over a 20-year period, the composting plant could displace 1.15 million tonnes of CO2eq.

The production and sale of compost as a nutrient-rich soil amendment is also intended to substitute at least in part, the chemical fertilizers used by farmers in Grenada. However, this substitution would not entirely displace GHG emissions related to the use of chemical nitrogen fertilizers because the N application rates through compost would stay constant. For this reason, this study does not factor in the equation, the potential but uncertain GHG emission changes attributable to the substitution of chemical nitrogen in the fertilizers used with organic nitrogen in compost.

Beyond climate, OFMSW in landfills drives odor, vector, and public-health nuisances. Reduced sulfur compounds (notably hydrogen sulfide, H_2S), mercaptans, and volatile organic compounds form during anaerobic decomposition and from interactions with sulfur-bearing materials (e.g. gypsum drywall). Field measurements at large landfills report detectable H_2S fluxes and co-occurring CH_4 plumes; such emissions are strongly associated with odor complaints.[80] Investigations have specifically linked drywall

[78] IPCC_AR6_WGIII_Annex-II.pdf
[79] CHAPTER 1
[80] https://www.mdpi.com/2073-4433/13/8/1251

disposal to elevated H_2S and other sulfurous odorants; the odor threshold for H_2S is extremely low, so even modest fluxes can be highly perceptible downwind.[81]

The presence of large piles of untreated organic waste also fuels the proliferation of animal and insect pests in the landfill and nearby areas. Open tipping faces with readily accessible food attract gulls, corvids, and raptors. The resulting aggregations raise local disease-vector concerns and present documented aviation hazards when landfills are sited near airports. Peer-reviewed work[82], regulatory guidance, wildlife-management literature converges on the aviation risk pathway and the need for operational controls (e.g. daily cover, bird deterrents, siting buffers).[83]



Figure 29. Birds' abundance near the Perseverance landfill.

Reviews in tropical medicine and environmental health literature note landfill-associated surges in pest insects and potential disease vectors. Rodent populations similarly respond to food availability and cover created by active fills, with concomitant zoonotic risks if not controlled through integrated pest management.[84]

81 https://semspub.epa.gov/work/05/222393.pdf
82 Landfills, nocturnal foraging, and risk to aircraft - PubMed
83 https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1003&context=birdstrike2001
84 https://www.sciencedirect.com/science/article/abs/pii/S0001706X20310214

Given the climate urgency and local environmental burdens, the most effective sustainability strategy is upstream: diverting OFMSW from landfills altogether. Composting, anaerobic digestion with energy recovery, and other circular approaches avoid the long-lived methane commitment and reduce odorous, pest-attracting putrescibles at the working face. Comparative life-cycle studies consistently find substantially lower global warming potential for organics management via composting diversion relative to landfilling when methane is not fully captured.[85]

Based on the environmental benefits discussed earlier, compost production from organic waste is deemed an environmentally viable option in Grenada.

4.3 Financial Cost Benefit Analysis (CBA) of compost production

4.3.1 Composting costs and revenues: Data collection and validation

The data collection process for composting costs and revenues was based on two main components: a review of existing literature and surveys. The literature review provided a solid base of existing knowledge. Questionnaires were prepared and tailored for different stakeholder groups, including producer associations, farmers, and economic and financial institutions. These were guided by existing questionnaires shared with farm owners and producer associations to collect direct and relevant information. Although the questionnaires were completed by a limited number of respondents, they provided useful insights that were discussed and validated on site during a survey mission carried out in May 2025. Data collected through literature and questionnaires was verified and validated on site and then refined in the following weeks through deeper analysis, additional email exchanges with key stakeholders, and the use of additional datasets and studies. The support of a national UNDP consultant was instrumental throughout the process: in liaising with national stakeholders, collecting additional data, and validating and confirming available information. During the survey in Grenada, activities were carried out for the collection and validation of economic and technical data to prepare a preliminary cost-benefit analysis for a potential composting plant. This included meetings with local authorities, field visits, inspections of existing facilities, and direct discussions with farming businesses, trade associations, and the credit sector.

Grenadian agriculture is heavily reliant on imported synthetic fertilizers, which are sold on the local market at around EC$116 (USD 43) per 25kg bags. This dependence exposes the sector to external price fluctuations, supply chain disruptions, and increases vulnerability to global market shocks. In addition, the long-term use of chemical fertilizers contributes to soil degradation, reduced biodiversity, and water contamination.

In this context, locally produced compost represents a strategic alternative. By replacing part of the demand for chemical fertilizers, compost can help reduce import dependence, improve soil health, and

[85] https://apps.ecology.wa.gov/publications/documents/1307066.pdf

strengthen the resilience of the agricultural sector. Promoting compost use would also align with Grenada's national commitments to sustainable agriculture and climate adaptation, while fostering local circular economy models and generating employment opportunities along the waste management chain.

Value	Source
EC$116.95 per 25 kg bag (USD 43.27)	Market data

An exhaustive database on waste disposal at the new Perseverance landfill site was shared by GSWMA to evaluate waste availability for this study. Approximately 6,500 tons/year of segregated organic waste is currently delivered to the Perseverance landfill every year. This data represented one of the starting points for preparing the scenario for a commercial plant and carrying out the Cost-Benefit Analysis.

Value	Source
Segregated organic waste: 6,500 tons/year	GSWMA

Additional potential organic waste flows were identified during the field survey of May 2025. About 35 tons/year of fish scraps from the Melville Fish Market could be diverted from the current informal disposal to a compost plant. In addition, a commercial poultry business was also surveyed. This 50,000 head hatchery generates around 300 tons/year of manure, 160 tons of slaughter waste, and 35 tons of hatchery waste that are currently disposed off on the farm or incinerated. The transportation of farm waste is currently economically unsustainable, with costs estimated at approximately EC$3.50 (USD 1.30) per ton per kilometer. Furthermore, the inadequacy of the road network significantly constrains the efficient transfer of low-value biomass to a centralized processing facility situated more than 10 kilometers from the primary points of waste generation. The abundance of decentralized agricultural residue and waste generated in Grenada led to the identification of an additional scenario, where smallholder composting plants could absorb the waste biomass generated and process it into an added-value product to be sold locally. An average of 400 tonnes of waste per year is generated by a handful of commercial farms across the main island of Grenada, and a dedicated scenario modeled the financial viability of smallholder-led composting plants.

The information on financing instruments currently available in the country was provided by the Grenada Development Bank (GDB). The bank indicated that, at the time of writing this report, it can offer concessional loans of up to EC$40,000 (USD 10,000) at an interest rate of 1%, repayable over 12 years, mainly targeted at small, climate-friendly initiatives. For larger projects, financing lines of up to EC$2 million (USD 750,000) are accessible under a Green Climate Fund programme managed with GIZ, at an interest rate of 7.5%, with a grace period of one to two years and a minimum equity

contribution of 20%. In addition, standard commercial loans for agriculture are generally offered at an interest rate of around 9%, with no grace period and a repayment schedule of five years. The bank also noted the possibility of considering tailored products, conditional on the submission of a convincing and well-prepared business plan.

Value	Source
EC$40,000 (USD 10,000), 1% interest, 12 years	Grenada Development Bank
EC$2 million (USD 750,000), 7.5% interest, 1–2 yrs grace, 20% equity	
Commercial interest rate for agriculture project 9%, no grace period, 5 years	Local commercial bank

Information about investor expectations was collected through a consultation with the Grenada Investment Development Corporation (GIDC). According to the institution, potential private investors generally expect a breakeven period between 6 and 10 years for investments in Grenada. In addition, most of the investors currently engaged with GIDC have expressed interest in agriculture and in climate-resilient operations in the country, which is a priority sector for the institution and the Government.

Value	Source
Expected breakeven point: 6–10 years	Grenada Investment Development Corporation (GIDC)

Capital Expenditures (CAPEX) for the project cover the necessary civil works and the purchase of key machinery required for both compost production and sales. Specifically, machinery includes windrow turners, biomass shredders, compost compactor/densifier (pelletizers), and compost bagging machines. Civil works necessary to enable compost production include the preparation of the site, soil leveling, covering the ground with a concrete slab to host composting operations, the construction of shed covers over the concrete slab, and potentially the installation of a photovoltaic system to power, at least in part, the machinery, on the roof of the shed. Quotations were received from multiple international suppliers, including details on purchase and shipping costs, technical specifications, warranties, and expected operating costs. Accurate cost information related to civil construction works was also obtained with the support of a UNDP country office consultant and the pre-feasibility report provided by ImplementaSur. The unitary cost of EC$175.50/m² (USD 65/m²) for concrete slabs was quoted and validated. Metal shed covers cost around EC$261.90/m² (USD 97/m²). Civil works such as excavation, levelling, compaction, drainage & access works, were quoted collectively at around EC$190/m² (USD 70/ m²).

Value	Source
EC$175.50/m² (USD 65/$m^2$) concrete slab EC$261.90/m² (USD 97/m^2) shed covers EC$190/m² (USD 70/$m^2$) other activities	ImplementaSur 2024 pre-feasibility report, UNDP National Consultant
Prices of machinery and equipment (Windrow turner, shredder, compactor, bagging machine, PV + battery)	Supplier quotations, Market analysis

In all scenarios, the CAPEX includes an item for initial working capital, which covers operating costs during the first six months of operation. This provision accounts for the absence of revenues at the start-up stage, since the composting process requires time for maturation before sales can begin.

On the operational expenditure (OPEX) side, electricity costs were validated with the local provider GRENLEC at US$0.40 per kWh, and diesel costs were verified on site (US$1.21 per liter). Land lease costs, according to the Ministry of Agriculture, are estimated at around US$1,000 per acre per year. Personnel costs were taken from the ImplementaSur report and updated for 2025, considering the average inflation rate of the past four years. Maintenance and repair costs were considered as a percentage of the machinery acquisition cost.

Value	Source
Electricity price: US$0.40 per kWh	GRENLEC
Diesel price: US$1.21 per liter	On Site validation
Personnel costs: Plant operator USD 6,900/year Machinery operator USD 8,700/year Plant supervisor USD 12,600/year	ImplementaSur pre-feasibility report, UNDP National Consultant
Land Lease price: US$1,000 acre/year	Ministry of Agriculture, Grenada

A rate of inflation of 2% in Grenada will be applied in the analysis. This estimate is slightly above the four-year average inflation rate of approximately 1.9%[86], according to data published by the Eastern Caribbean Central Bank.

[86] Eastern Caribbean Central Bank, official website: www.eccb-centralbank.org

Value	Source
Average inflation rate: 2%	Eastern Caribbean Central Bank data (avg. 1.9% over 4 years)

In terms of monetary benefits, the main source is represented by the sale of compost. International wholesale compost prices for medium-quality compost are around 0.05 USD/kg. However, retail prices are affected by several additional costs which significantly increase the final price, including:

- Maritime transport to Caribbean ports,
- Customs clearance and related tariffs,
- Inland logistics for road transport and island-wide distribution,
- Storage and handling costs,
- Margins of local intermediaries and distributors.

When combined, these factors make imported compost uncompetitive and barely accessible for local farmers. By contrast, local production makes it possible to reduce such costs, ensuring a more affordable price while contributing to the security and independence of the national agricultural sector.

As presented in Chapter 2, a survey of agricultural input retailers shows average NPK prices ranging between EC$100 (USD 37) and EC$ 120 (USD 44.40) per 25 kg bag, depending on the producer and composition. When compared to international wholesale prices (around USD 500/tonne), the retail price more than triples at USD 1,480 to USD 1,776 per tonne. Deriving the corresponding cost per unit of nutrient is possible, with certain limitations, due to the lack of accurate data on actual volumes of each fertilizer type imported and its actual final market price in Grenada.

Commonly sold NPK formulations have an average nutrient concentration of around 15% for each macronutrient (NPK 15:15:15), although with broad variability (from 7:21:21, 10:10:10, 12:0:42, etc.). Considering this average concentration and the average retail price for these fertilizers sold in Grenada (USD 41.25 per 25 kg bag, or USD 1.65/kg), an average unitary cost per kg of pure nutrient contained in the chemical coformulations was calculated. It should be noted that these are average values and that deviations from these may be relevant in both directions, however, to map the fertilizer market and derive a competitive retail price point for compost to complement synthetic nutrients, a nutrient content equivalence has been calculated.

Given the average retail price (USD 1.65/kg) and composition of chemical fertilizers is for NPK 15:15:15 (150 grams of Nitrogen, 150 grams of Phosphorus, and 150 grams of Potassium per kilogram of product), a competitive retail price point for compost would be the value that delivers comparable amounts of each macronutrient for a comparable price. Compost quality standards, and therefore their chemical composition and nutrient abundance, are not enforced in Grenada and in the Caribbean. At the time of writing this report, CARICOM, the regional organization promoting economic integration and cooperation in the Caribbean, is developing its first quality standards for commercially produced

compost. To derive the chemical composition of high-quality compost potentially produced in Grenada, international reference standards are used for the assessment. According to Annex I of EU Regulation 2019/1009[87], on Product Function Categories (PFCs) of EU fertilizing products, if a compost product is classified and marketed as a solid organo-mineral fertilizer, it must meet specific minimum nutrient content requirements. When declaring multiple primary nutrients (Nitrogen, Phosphorus, Potassium), the minimum content is 2% by mass for total nitrogen (N), 2% total phosphorus pentoxide (P_2O_5), and 2% total potassium oxide (K_2O). Such nutrient content will be used in this assessment to establish the minimum viable composition for the hypothetical compost product to be marketed in Grenada.

The comparable price point for compost, calculated based on its actual minimum nutrient content compared to average nutrient concentrations of chemical fertilizers sold in the country is USD 0.22/kg.

While chemical fertilizers may offer higher short-term yields, compost is environmentally sustainable and provides long-term benefits by improving soil health. Integrating compost into farming systems is a viable and recommended practice for enhancing crop yields and fostering sustainable agriculture in the Caribbean[88]. However, while compost is widely regarded as a positive soil amendment and nutrient booster in various agrifood systems, there are several constraints to its full deployment. Some of these constraints are technical and agronomic, whereas others are socio-cultural and behavioral. To provide the same quantity of macronutrients to the fields with compost, about 7.5 kg of organic fertilizer is needed to replace 1 kg of chemical product. At a USD 0.22/kg price point for compost, farmers in Grenada would be able to purchase the same amount of nutrients in the form of compost instead of chemical fertilizers. The complete financial analysis contained in this assessment considered a conservative range for retail compost prices between USD 0.10 and 0.20 per kg of product.

Value	Source
Compost price range: 0.10–0.20 USD/kg	Baseline market analysis, conversions, and calculations.

This comprehensive framework provides a solid base for the planned detailed cost-benefit analysis.

[87] Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 (Text with EEA relevance)

[88] Jacky Paul, Jorge Sierra, François Causeret, Loïc Guindé, Jean-Marc Blazy, 2016. Factors affecting the adoption of compost use by farmers in small tropical Caribbean islands, Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2016.11.168.

4.3.2 Case study: Smallholder composting plant (400-tonnes of waste processed per year)

This scenario considers a small, decentralized composting facility designed to process approximately 400 tonnes of segregated organic waste per year, yielding around 160 tons of compost annually.

The entire compost output is assumed to be sold at a market price of USD 0.20/kg, generating expected revenues of about USD 32,000 per year. This option aims to assess the viability of a pilot-scale unit that could be replicated by farmer groups in different agricultural areas. The total capital expenditure (CAPEX) amounts to about USD 62,000. Of this cumulated amount, civil works represent the largest component (around USD 32,200). This is an area that deserves particular attention, as it accounts for more than half of the overall investment. This analysis includes external workforce and materials; however, it is likely that smallholder farmers who intend to invest in compost production possess some of the resources that have been considered external for this assessment. Moreover, the concrete slab is usually necessary when operating with machinery, and to avoid the leakage of leachate into the soil and aquifers. Plastic films are replacing concrete slabs in small-scale composting plants if these use strictly manual turning instead of a mechanical turner. It is therefore reasonable to consider it as a cost element where some optimization could potentially reduce the financial burden of the project.

Machinery expenditures amount to USD 14,200, including the construction of a small solar PV system with battery storage and a compactor to pelletize the compost. The compactor has been included in the investment precisely because of the logistical challenges that may arise in transporting larger quantities of compost from a decentralized facility. Its use would help reduce the volume of material, easing storage and transport needs, while still delivering about 7.5 times as much compost as chemical fertilizer to the same field. Additional items include an initial working capital (USD 12,400) to cover the first three to six months of operation when compost is still maturing, as well as minor expenses for taxes and shipping.

Annual operating costs (OPEX) are estimated at around USD 24,700, with labour (USD 20,100) and packaging (USD 3,600) being the dominant components, while maintenance expenditure remains marginal.

400 T/Y Plant Cost Overview		
Category	**Cost Item**	**Estimated Cost**
CAPEX	**MACHINERY**	**14,200**
	Compost Compactor (USD)	*10,000*
	Solar PV system (20KW) (USD)	*3,000*
	Battery Storge (20KWh) (USD)	*1,200*
	CIVIL WORKS	**32,208**
	Other activities (Excav.,levell.,compact.,drain.,access) (USD)	*4,441*
	Concrete Slab (USD)	*10,034*
	Shed (coverage) (USD)	*17,733*
	INITIAL WORKING CAPITAL (6 MONTH)	**12,359**
	TAX & FEES	**500**
	SHIPPING & CUSTOMS	**3,000**
	TOTAL	**62,267**
OPEX	Labour (USD)	20,100
	Machinery Maintenance (USD)	710
	Infrastructure Maintenance (USD)	278
	Packaging (Bags) (USD)	3,630
	TOTAL	**24,718**

Figure 30. Distribution of investment and operating costs for the 400 tonne/year plant

From a financial perspective, the project does not achieve fully satisfactory results. The analysis shows a negative Net Present Value (NPV) of –USD 28,700, an Internal Rate of Return (IRR) of 4.3%, and a Payback Period of 16 years.

Composting Plant GRENADA (400T)

Year	0	1	2	3	4	5	20
Compost production		160	160	160	160	160	160.00
CAPital EXpenditures							
Compost Facility	- 58,067						
▪ Asset Depreciation		- 2,773	- 2,773	- 2,773	- 2,773	- 2,773	- 2,773.36
Photovoltaic Solar Panel	- 4,200						
▪ Asset Depreciation		- 210	- 210	- 210	- 210	- 210	- 210.00
OPerational EXpenditures							
Equipment operations and Maintentance		- 988	- 1,007	- 1,028	- 1,048	- 1,069	-1,438.85
Diesel		-	-	-	-	-	0.00
Electricity			-	-	-	-	0.00
Labour		- 20,100	- 20,502	- 20,912	- 21,330	- 21,757	-29,281.90
Packaging (bags)		- 3,630	- 3,703	- 3,777	- 3,852	- 3,929	-5,288.22
Revenues							
Compost Revenues		32,000	32,640	33,293	33,959	34,638	46,618
Subsidies		-	-	-	-	-	-
Total Asset Depreciation		- 2,983	- 2,983	- 2,983	- 2,983	- 2,983	- 2,983
Cash Flow							
+ Revenues and Avoided Costs		32,000	32,640	33,293	33,959	34,638	46,617.96
Operating costs + Labour		- *24,718*	- *25,212*	- *25,716*	- *26,231*	- *26,755*	- *36,008.98*
Operating Cash Flow	-	**7,282**	**7,428**	**7,577**	**7,728**	**7,883**	**10,609**
- Investments	- 62,267	-	-	-	-	-	-
- Loan annuity	-	-	-	- 6,993	- 6,993	- 6,993	-
Total Cash Flow	- **62,267**	**7,282**	**7,428**	**584**	**735**	**890**	**10,609**
Cumulative Cash Flow	- *62,267*	- *54,984*	- *47,556*	- *46,973*	- *46,238*	- *45,348*	*44,746*
Payback Year	-	-	-	-	-	-	-
CF shareholders	- 14,267	7,282	7,428	584	735	890	10,609
Cumulative Cash Flow	- *14,267*	- *6,984*	*444*	*1,027*	*1,762*	*2,652*	*92,746*
Payback Year	-	-	*Payback*	-	-	-	-
Project's impact on P&L	-	**4,299**	**4,445**	- **2,400**	- **2,248**	- **2,094**	**7,626**
CAPITAL STRUCTURE							
Equity private financing	- **14,267**	**22.91%**	of initial investment				
Grant	-	**0%**	of initial investment				
Concessional Loan	- **48,000**	**77.09%**	of initial investment				
Constant interest rate	**7.5%**						
Duration of loan (years)	10						
Grace period (year)	2						
Loan repayment plan	Constant installments						
Loan outstanding (BoP)	**48,000**	**48,000**	**48,000**	**48,000**	**44,607**	**40,960**	-
- Interests		-	-	3,600	3,346	3,072	-
- Capital repaid		-	-	3,393	3,647	3,921	-
Loan outstanding (EoP)	**48,000**	**48,000**	**48,000**	**44,607**	**40,960**	**37,039**	-
Project profitability							
NPV	$ (28,714)						
NPV to shareholders	$ 14,143						
Project IRR	**4.3%**						
IRR to shareholders	26.8%						
payback (years)	**16**						
Shareholders payback (years)	2						

Figure 31. Cost-Benefit Analysis of the 400-tonne Composting Plant

The 400-tonne plant has potential as a pilot or community-level facility, especially where farmers seek decentralized solutions. However, its small scale and relatively high share of fixed costs reduce its profitability under the current assumptions. For this option to become viable, a higher compost selling price, targeted subsidies, or some cost reductions—particularly in civil works—would be needed.

An important consideration is that, at a selling price of USD 0.20/kg, the plant would just about reach its annual break-even point if all the compost produced were sold. This means that yearly revenues would be sufficient to cover operating costs, but there would be no margin left to generate a profit for the operator. While this may appear acceptable in the short term, in the long run it is problematic: a project that only breaks even year after year does not create financial value. This explains why the Net Present Value remains negative, and the Internal Rate of Return is low, as the investment uses resources without producing consistent returns.

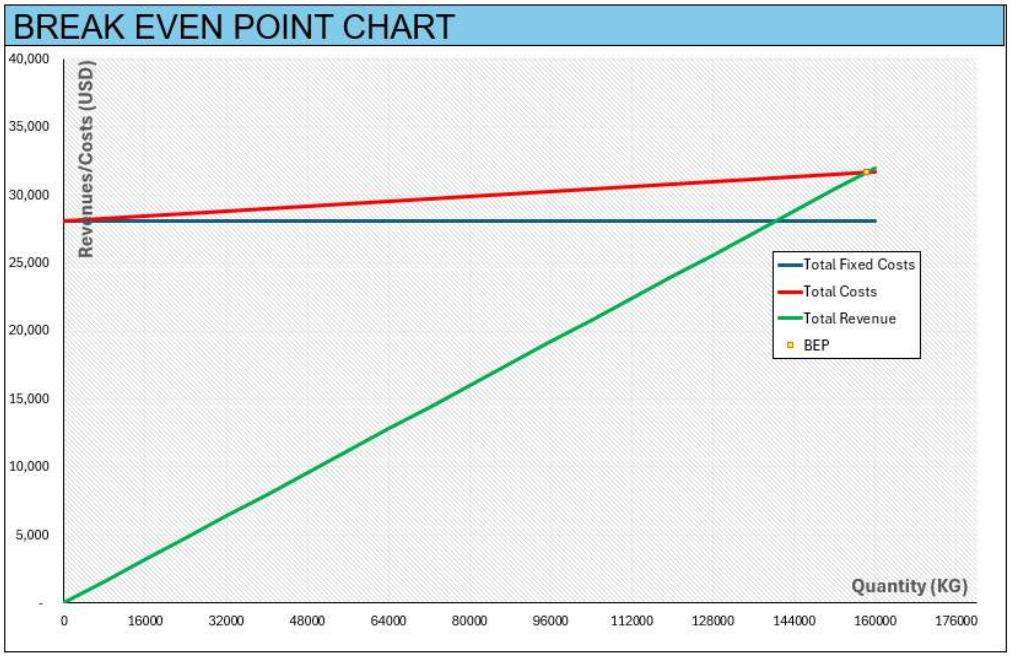


Figure 32. Break-even point for the 400-tonne plant, showing that annual revenues at USD 0.20/kg, even when assuming the full quantity produced is sold, only cover operating costs without generating profit.

At the same time, this configuration can still play a useful role. Small-scale units could help to reduce transport distances, which is a major challenge in Grenada due to narrow and mountainous roads. In this case, decentralized plants could complement a larger centralized facility, making it possible to capture waste streams from remote agricultural areas that would otherwise be too costly to deliver to the main site.

A 400-tonne pilot plant could also be valuable for building capacity and testing market acceptance of compost in specific farming communities. By showing the technical feasibility of composting and

gradually building farmer confidence in the product, such a unit could generate important co-benefits even if financial returns remain limited.

4.3.3 Case study: Commercial plant (6,500 tonnes of waste processed per year)

For the 6,500-tonne composting plant, which corresponds to the segregated organic waste delivered every year at the Perseverance landfill, three alternative configurations were developed.

In the first two configurations, the project assumes the direct involvement of the landfill owner as a primary investor. The Standard Configuration represents this basic setup, relying on grid electricity to power the machinery required for shredding, compacting, and bagging of the compost. The Energy Optimized Configuration introduces a photovoltaic system to reduce reliance on the grid and lower GHG emissions and operating costs. In both cases, it is assumed that the Grenada Solid Waste Management Authority, as the landfill owner, would act as one of the main investors in the project.

The third option, the Third-Parties Configuration, assumes that the facility is developed and operated by an external investor, fully independent from the GSWMA. In this case, the land would need to be leased from the landfill owner and a dedicated photovoltaic system installed to cover the plant's electricity needs. Since operations are still located within the landfill area, no additional transportation costs are incurred; however, the land lease and independent investment requirements make this configuration more capital-intensive compared to the other two alternatives.

In the Standard Configuration, the facility uses the existing infrastructure at the Perseverance landfill, including the shredder already present on site. This avoids extra investment in this machinery and reduces both capital and operating costs.

In this case, the selling price of compost was set at USD 0.20 per kilogram, based on the approach explained in section 4.3.1.

For this analysis, it is assumed that the entire quantity of compost produced (approximately 2,600 tonnes of compost from 6,500 tonnes of organic waste, as the composting process's efficiency is around 40%) will be sold. Based on this assumption and the chosen price, projected revenues amount to approximately USD 500,000 annually. Any potential reduction in sales volumes will be further explored through sensitivity analysis.

The cost structure of the 6,500-tonne/year of organic waste composting plant, already presented in detail in the previous chapter, can be summarized as follows. The largest component of the investment is represented by civil works (about USD 515,000), which include site preparation (excavation, levelling, compaction, drainage and access), the construction of a 3,000 m^2 concrete slab and shed coverage. Machinery accounts for around USD 114,000, covering the tractor unit, windrow turner, compactor, and bagging equipment. Additional items include initial working capital (USD 93,361), necessary to cover the first six months of operation when compost is still maturing and sales cannot yet be realized, as well as taxes and fees (USD 5,700) and shipping and customs (USD 20,000). In total, the CAPEX amounts to approximately USD 748,000.

On the operational side, the annual OPEX is estimated at USD 187,000. The most relevant cost item is electricity (USD 81,600), which represents more than 40% of total operating expenditure. Electricity consumption is mainly driven by the shredder and other machinery used for compost palletization and bagging. Packaging follows with around USD 59,400, necessary for the purchase of the bags, while labour accounts for USD 28,200. The remaining share is distributed across maintenance, diesel for the tractor, and other operating needs.

It is important to note that this configuration does not include the installation of a solar photovoltaic system with battery storage. As a result, the plant remains fully dependent on grid electricity, which results in comparatively high operating costs and represents one of the key challenges for the long-term financial sustainability of this option.

6500 T/Y Plant Cost Overview		
Category	**Cost Item**	**Estimated Cost**
CAPEX	**MACHINERY**	**114,000**
	Tractor Unit(USD)	*48,000*
	Windrow Turner	*50,000*
	Compost Compactor (USD)	*10,000*
	Bagging equipment (USD)	*6,000*
	Solar PV system (USD)	-
	Battery Storge (USD)	-
	CIVIL WORKS	**515,325**
	Other activities (Excav.,levell.,compac	*71,050*
	Concrete Slab (USD)	*160,550*
	Shed (coverage) (USD)	*283,725*
	INITIAL WORKING CAPITAL (6 MON	**93,361**
	TAX & FEES	**5,700**
	SHIPPING & CUSTOMS	**20,000**
	TOTAL	**748,386**
OPEX	Labour (USD)	28,200
	Electricity (USD)	81,600
	Machinery Maintenance (USD)	9,450
	Infrastructure Maintenance (USD)	4,443
	Diesel (USD)	3,630
	Packaging (Bags) (USD)	59,400
	TOTAL	**186,723**

Figure 33. Distribution of investment and operating costs for the 6,500 tonne/year plant inside the landfill.

Based on the revenues and costs described above, the financial analysis shows that the 6,500-tonne composting plant achieves a Net Present Value (NPV) of about USD 1.5 million and an Internal Rate of Return (IRR) of 41.2%, both well above the 12% discount rate applied.

Composting Plant GRENADA

Year	0	1	2	3	4	5	20
Waste/Compost production							
Organic Waste production		6,500	6,500	6,500	6,500	6,500	6,500.00
Compost production		2,600	2,600	2,600	2,600	2,600	2,600.00
CAPital EXpenditures							
Compost Facility	- 748,386						
- Asset Depreciation		27,914	27,914	27,914	27,914	27,914	27,913.75
Photovoltaic Solar Panel	-						
- Asset Depreciation		-	-	-	-	-	-
OPerational EXpenditures							
Equipment operations and Maintentance		- 13,893	- 14,171	- 14,454	- 14,743	- 15,038	-20,239.11
Diesel		- 3,630	- 3,703	- 3,777	- 3,852	- 3,929	-5,288.22
Electricity		- 81,600	- 83,232	- 84,897	- 86,595	- 88,326	-118,875.79
Labour		- 28,200	- 28,764	- 29,339	- 29,926	- 30,525	-41,082.08
Packaging (bags)		- 59,400	- 60,588	- 61,800	- 63,036	- 64,296	-86,534.58
Revenues							
Compost Revenues		520,000	530,400	541,008	551,828	562,865	757,542
Subsidies		-	-	-	-	-	-
Total Asset Depreciation		27,914	27,914	27,914	27,914	27,914	27,914
Cash Flow							
+ Revenues and Avoided Costs		520,000	530,400	541,008	551,828	562,865	757,541.81
Operating costs + Labour		- *186,723*	- *190,457*	- *194,266*	- *198,152*	- *202,115*	##########
Operating Cash Flow	-	**333,277**	**339,943**	**346,742**	**353,676**	**360,750**	**485,522**
- Investments	- 748,386	-	-	-	-	-	-
- Loan annuity	-	-	-	- 85,955	- 85,955	- 85,955	-
Total Cash Flow	- **748,386**	**333,277**	**339,943**	**260,787**	**267,722**	**274,795**	**485,522**
Cumulative Cash Flow	- *748,386*	- *415,109*	- *75,166*	*185,621*	*453,342*	*728,138*	*6,459,627*
Payback Year	-	-	-	*Payback*	-	-	-
CF shareholders	- 158,386	333,277	339,943	260,787	267,722	274,795	485,522
Cumulative Cash Flow	- *158,386*	*174,891*	*514,834*	*775,621*	*1,043,342*	*1,318,138*	*7,079,627*
Payback Year	-	Payback	-	-	-	-	-
Project's impact on P&L	-	**361,191**	**367,857**	**288,701**	**295,636**	**302,709**	**513,436**

CAPITAL STRUCTURE

Equity private financing	- **158,386**	**21.16%**	of initial investment
Grant	-	**0%**	of initial investment
Concessional Loan	- **590,000**	**78.84%**	of initial investment
Constant interest rate	**7.5%**		
Duration of loan (years)	10		
Grace period (year)	2		
Loan repayment plan	Constant installments		
Loan outstanding (BoP)	**590,000**	**590,000**	**590,000**	**590,000**	**548,295**	**503,463**	-
- Interests		-	-	44,250	41,122	37,760	-
- Capital repaid		-	-	41,705	44,833	48,195	-
Loan outstanding (EoP)	**590,000**	**590,000**	**590,000**	**548,295**	**503,463**	**455,268**	-

Project profitability		
NPV	$	1,503,417
NPV to shareholders	$	2,030,203
Project IRR		**41.2%**
IRR to shareholders		206.7%
payback (years)		**3**
Shareholders payback (years)		1

Figure 34. Cost-Benefit Analysis of the 6,500-tonne composting plant -Standard Configuration

The payback period is reached in approximately 3 years, meaning that the investment can be fully recovered rather early within the 20-year project horizon. This rapid recovery reflects the strong profitability of the 6,500-tonne configuration, as confirmed by the high NPV and IRR values. A decisive factor in achieving these results is the two-year grace period on debt repayment, which significantly eases the financial burden during the start-up phase. Such concessional financing has been confirmed in discussions with the Grenada Development Bank, which offers loan products with these conditions for climate-friendly investments.

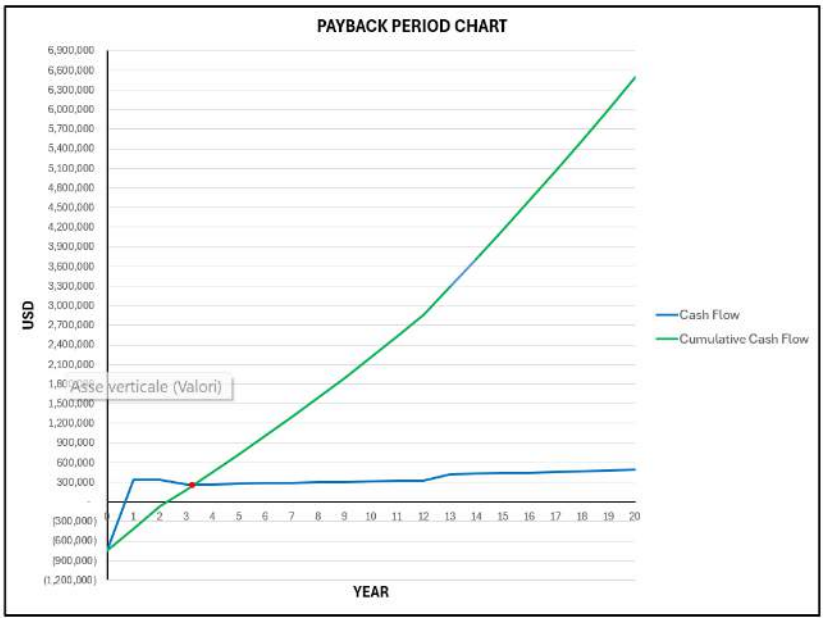


Figure 35. Payback Period of the 6,500-tonne composting -Standard Configuration

In the Energy Optimized Configuration, the revenues remain unchanged compared to the On-site – Grid Electricity option, since the same assumptions are applied regarding the selling price of compost (USD 0.20 per kilogram) and the full sale of the output (around 2,500 tonnes of compost per year).

On the cost side, the plant includes a 150-kW photovoltaic system, which substantially reduces dependence on the national grid. Nevertheless, it is assumed that around 20% of the electricity demand must still be supplied from the grid to ensure continuous operations. Compared to the on-site Grid Electricity option, this configuration results in higher upfront investment costs (CAPEX rises to about USD 958,000, mainly due to the PV system) but allows for significantly lower electricity expenditures (around USD 16,300 annually) while slightly increasing maintenance needs for both machinery and infrastructure. Overall, this configuration balances higher initial costs with long-term operational savings.

6500 T/Y Plant Cost Overview		
Catego	Cost Item	Estimated Cost
CAPEX	**MACHINERY**	**339,000**
	Tractor Unit(USD)	*48,000*
	Windrow Turner	*50,000*
	Compost Compactor (USD)	*10,000*
	Bagging equipment (USD)	*6,000*
	Solar PV system (150kW)	*225,000*
	CIVIL WORKS	**515,325**
	Other activities (Excav.,levell.,compact.,drain.,access) (USD)	*71,050*
	Concrete Slab (USD)	*160,550*
	Shed (coverage) (USD)	*283,725*
	INITIAL WORKING CAPITAL (6 MONTH)	**66,346**
	TAX & FEES	**16,950**
	SHIPPING & CUSTOMS	**20,000**
	TOTAL	**957,621**
OPEX	Labour (USD)	28,200
	Electricity (USD)	16,320
	Machinery Maintenance (USD)	20,700
	Infrastructure Maintenance (USD)	4,443
	Diesel (USD)	3,630
	Packaging (Bags) (USD)	59,400
	TOTAL	**132,693**

Figure 36. Cost structure – 6,500 t On-site – Energy Optimized Configuration

From a financial perspective, the project shows very solid results. The Net Present Value (NPV) is about USD 1.63 million, while the Internal Rate of Return (IRR) reaches 36.8%. The payback period is around 3 years, which means that the investment can be recovered quickly compared to the 20-year project lifetime and deliver increased environmental co-benefits to Grenada. These results confirm the strong financial performance of this configuration and highlight its potential as a viable and attractive option for implementation.

Project profitability		
NPV	$	1,630,953
NPV to shareholders	$	2,300,596
Project IRR		**36.8%**
IRR to shareholders		182.0%
payback (years)		**3**
Shareholders payback (years)		1

Figure 37. Financial indicators of the 6,500-tonne On-site – Solar PV Configuration

In the Third-Party Configuration, the revenues are assumed to remain the same as in the previous options, based on a compost selling price of USD 0.20 per kilogram and the full sale of the output.

On the cost side, this option requires a higher upfront investment (CAPEX about USD 1.04 million), since investors must purchase the shredder, install a 150-kW photovoltaic system capable of powering all the plant's equipment, and lease land for the plant. Annual operating costs (OPEX around USD 134,000) are slightly higher compared to the On-site options, mainly due to land lease expenses and additional maintenance requirements.

6500 T/Y Plant Cost Overview		
Category	**Cost Item**	**Estimated Cost**
CAPEX	**MACHINERY**	**414,000**
	Tractor Unit(USD)	*48,000*
	Windrow Turner	*50,000*
	Compost Compactor (USD)	*10,000*
	Bagging equipment (USD)	*6,000*
	Shredder (USD)	*75,000*
	Solar PV system (150kW)	*225,000*
	CIVIL WORKS	**515,325**
	Other activities (Excav.,levell.,compac	*71,050*
	Concrete Slab (USD)	*160,550*
	Shed (coverage) (USD)	*283,725*
	INITIAL WORKING CAPITAL (6 MON	**66,906**
	TAX & FEES	**20,700**
	SHIPPING & CUSTOMS	**20,000**
	TOTAL	**1,036,931**
OPEX	Labour (USD)	28,200
	Electricity (USD)	16,320
	Machinery Maintenance (USD)	20,700
	Infrastructure Maintenance (USD)	4,443
	Diesel (USD)	3,630
	Packaging (Bags) (USD)	59,400
	Land Lease	1,119
	TOTAL	**133,812**

Figure 38. Cost structure of the 6,500-tonne – Third Parties Configuration

From a financial perspective, the Off-site Configuration also performs strongly. The Net Present Value (NPV) amounts to USD 1.55 million, while the Internal Rate of Return (IRR) reaches 33.8%. The payback period is achieved in about three years, confirming that even with higher investment needs, this option remains financially attractive within the project's 20-year horizon.

Indicator	Standard Configuration	Energy Optimized Configuration	Third Parties Configuration
CAPEX (USD)	748,386	957,621	1,036,931
OPEX annual (USD)	186,723	132,693	133,812
Revenues (USD/year)	~500,000 (0.20/kg, full sales)	~500,000 (0.20/kg, full sales)	~500,000 (0.20/kg, full sales)
NPV (USD)	1,503,417	1,630,953	1,551,685
IRR (%)	41.2%	36.8%	33.8%
Payback (years)	3	3	3

Table 3. Financial comparison of the 3 configurations (6,500 t/y plant).

When comparing the three configurations in the commercial plant scenario, all of them demonstrate positive financial performance, with Net Present Values (NPV) well above zero and payback periods of around 3 years. These results are based on the assumption that the entire compost output of the plant is sold at USD 0.20/kg, which makes the business model financially attractive. In the sensitivity analysis, these indicators will be further tested by varying the quantities sold to assess how robust the project remains under less favorable – but more realistic – market conditions.

An interesting aspect of the comparison is that the Third Parties Configuration and the Energy Optimized Configuration option both show higher NPVs than the Standard Configuration. This is because, although they require a higher initial investment, they lead to more stable savings over time (lower electricity costs and, in the case of the Off-site option, a more diversified cost structure). These larger cumulative savings are spread over 20 years, which explains why the NPVs are higher.

On the other hand, the Standard Configuration records the highest IRR (41.2%). This is due to the comparatively lower initial investment, which in turn allows the first revenues to generate a proportionally higher return compared to the money invested.

Overall, the three configurations are all financially solid:

- Standard Configuration maximizes IRR thanks to lower upfront costs.
- Energy Optimized Configuration balances higher investment with long-term savings, boosting NPV.
- Third Parties Configuration remains financially attractive despite the additional shredder and land lease, confirming its viability.

4.3.4 Capital Structure Assessment

The capital structure is an important aspect to consider in any investment. In this project, however, its influence on overall profitability is rather limited, because the analysis was built on the most realistic, feasible, and financially attractive option. In all configurations, the financial structure assumes a concessional loan covering about 70–80% of the total investment. This loan, provided by the Grenada Development Bank, is offered at 7.5% interest, repayable over 10 years, with a two-year grace period. The analysis has shown the paramount importance of the grace period, which allows the project to withstand the start-up phase without repayment obligations, giving time for operations to stabilize and revenues to build up.

The remaining share—ranging from about 20% to a maximum of 30% depending on the project configuration—is provided as equity. On the one hand, this satisfies the equity requirement set by the Grenada Development Bank, and on the other hand, it ensures the full ownership and involvement of the private sector, which is a prerequisite for successful green economy projects. The contribution of equity is therefore essential to strengthen private sector participation and to increase the sense of local ownership around the project.

A financing scenario based on a commercial loan was not considered. From a financial point of view, the difference between the two options is very small: about 1.5 percentage points (7.5% concessional loan vs. 9% commercial loan), which would have only a small effect on NPV and IRR. From a broader perspective, it would also make little sense to give up the clear advantages of the concessional loan, especially the two-year grace period, which is crucial for the project's stability in the start-up phase. Since this option is available and can cover almost 80% of the total investment required for the largest scenario, replacing it with a commercial loan would represent an unnecessary risk.

Other loan products with even more favorable conditions—for instance, interest rates as low as 1%—are available from the Grenada Development Bank, but they apply only to small amounts (up to about USD 10,000), which are irrelevant compared to the investment cases tested in this assessment.

Having analyzed the main 6,500-tonne configuration composting plant, it is now important to highlight some additional considerations that apply exclusively to the smallholder (400-tonne) pilot plant. A further test scenario assessed the financial viability of the smallholder plant with the assumption that the investment costs (CAPEX) were covered by a grant (around USD 80,000). This configuration would reach financial parity, with a slightly negative NPV of about USD 590, and an IRR close to the 12% discount rate. This financial configuration would make an effective case for a pilot plant to be used for testing business models and calibrating the results of this feasibility assessment with real-world data.

The most relevant variable that affects the financial viability of a smallholder-led composting plant is the selling price of compost, as will be further shown in the Sensitivity Analysis. Increasing the sale price to USD 0.25/kg (20% increase compared to the estimated baseline retail price) would drastically affect the

results: at USD 0.25/kg, the NPV would rise to nearly USD 30,000, while the IRR would approach 20% even in the case of capex cost to be repaid through a concessional loan.

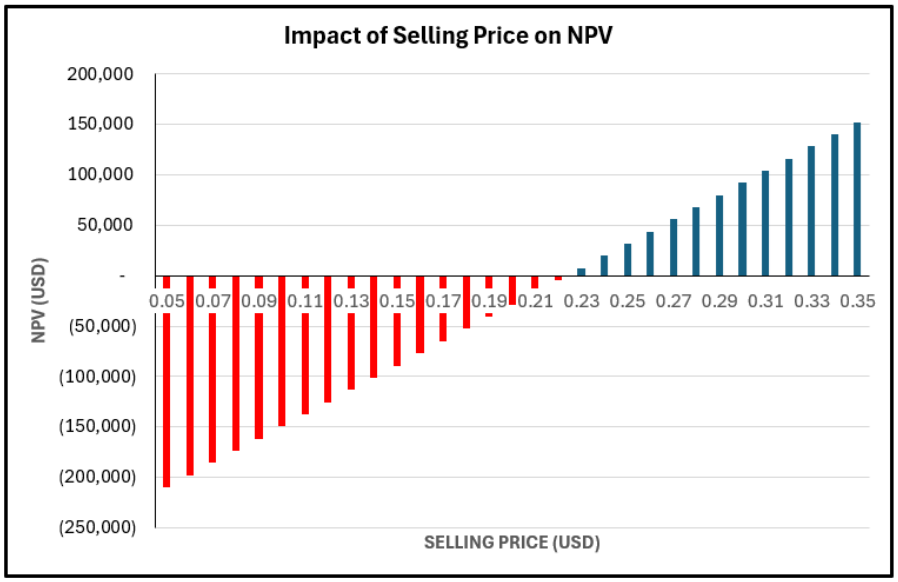


Figure 39. Impact of selling price on the Net Present Value (NPV) of the 400-tonne composting scenario

4.4 Sensitivity analysis

To assess the robustness of the results and the influence of key assumptions, a sensitivity analysis was conducted. The evaluation focused on four main parameters considered to be the most relevant in a compost production project: compost selling price, sales volume, investment costs, and operational costs. Each parameter was tested within realistic ranges to capture potential variations and their effect on project outcomes.

SELLING PRICE (USD/KG)

The selling price is a critical parameter, as the first reaction of many users is to compare the price of compost with that of chemical fertilizers. This comparison, however, is not fully appropriate: the two products have different properties and effects on the soil, and their value cannot be reduced to price alone. Nevertheless, the selling price remains a key factor for market adoption and for the economic performance of the project.

We analyzed a price range of USD 0.10 and 0.25 per kg of compost. In addition, a gradual price increase path from USD 0.15 to 0.20 per kg was tested: during the first five years of operation, the selling price was kept at USD 0.15/kg (without inflation-adjustments), and then it was assumed to gradually increase from USD 0.15/kg to USD 0.20/kg over the following 15 years, while taking inflation into account. This option was included to test the potential to increase market penetration of compost by reducing its initial price. USD 0.15/kg represents a reasonable entry price to penetrate the market, as most interviewed farmers estimated a minimum viable price for compost to be USD 0.20/kg, while the subsequent gradual increase towards USD 0.20/kg reflects the expectation that once compost sales are established, the market can absorb higher prices as demand will be consolidated. This price path was not applied to the smallholder scenario (400 tonnes/year of organic waste processed) because the financial analysis has clearly shown the minimal margin and breakeven point to be at USD 0.20/kg of final product. As a pilot, its role would mainly be to demonstrate the effectiveness of compost as an adjunct or partial substitute to chemical fertilizers, test the business model, build capacity, and learn how to improve compost production rather than generating profits.

The upper level (USD 0.25/kg) was identified as the minimum value at which the smallholder compost plant scenario (400 tonnes of waste per year) achieves a positive NPV and IRR. This value is slightly above the comparative average price for an equivalent nutrient content, set at USD 0.22/kg of compost. The reference price of USD 0.10/kg is not a benchmark, but it reflects the international wholesale price of about 0.05–0.06 USD/kg once import duties, taxes and other costs are added.

400 tonnes of waste processed per year (160 tonnes of compost produced per year): 400 t SCENARIO

In this scenario, the project remains structurally weak: results improve as the price increases, but profitability only becomes acceptable at high values (USD 0.25/kg). As this is a pilot facility, its primary role is not financial but demonstrative. It would therefore be plausible to secure a grant to test the quality

of the compost and demonstrate the sustainability of a future full-scale facility. Other options might include a national scheme where the compost is partially subsidized by diverting part of the existing subsidies to chemical fertilizers (USD 200 million/year) to compost.

6,500 tonnes of waste processed per year (2,600 tonnes of compost produced per year): 6,500 t SCENARIO

For the commercial-scale plant, the selling price is a key driver. At low price levels, the project is not viable, while from the mid-range (0.15–0.20 USD/kg) upwards it becomes solid, with IRRs well above the discount rate. All configurations achieve robust levels of profitability, with differences in NPV and IRR depending on their respective CAPEX and OPEX profiles.

	400 T SCENARIO		6,500 T – STANDARD		6,500 T – ENERGY OPTIMIZED		6,500 T – THIRD-PARTY	
SELLING PRICE (USD/kg)	NPV	IRR	NPV	IRR	NPV	IRR	NPV	IRR
0.10	- 149,565	n/a	- 460,411	1.5%	- 332,875	6.4%	- 412,142	5.4%
0.15	- 89,139	n/a	521,503	22.4%	649,039	22.1%	569,771	20.3%
0.20	*- 28,714*	*4.3%*	*1,503,417*	*41.2%*	*1,630,953*	*36.8%*	*1,551,685*	*33.8%*
0.25	31,711	19.7%	2,485,331	59.6%	2,612,867	51.3%	2,533,599	47.2%
Variation 0.15 → 0.20	-	-	**146,690**	**16.0%**	**274,226**	**15.1%**	**194,958**	**14.1%**

Figure 40. Selling price sensitivity analysis.

SALES VOLUME (%)

Sales volume is another key factor in a sensitivity analysis. Reaching full plant capacity takes time and depends on market acceptance and distribution channels. Sales levels from 40% to 100% of production capacity have been modeled considering a gradual S-curve path: starting at about 40% in the first years, as it is likely to happen when a relatively novel product enters the fertilizer market, then increasing its penetration gradually until reaching full plant capacity over time. This approach was not applied to the 400-t scenario, since even at 100% sales, the project shows negative results, making the calculation meaningless. Moreover, this facility is designed as a pilot, with the main goal of testing compost quality and market acceptance rather than achieving financial returns.

400 t SCENARIO

Even at full sales (100%), the project remains financially weak, and the situation worsens as volumes decline.

6,500 t SCENARIO

At full sales, all configurations generate strong returns, but profitability decreases when sales are lower than optimal. If sales are below 60% of plant capacity, the financial indicators deteriorate, and some configurations turn negative. The S-curve shows that the project can handle a slower start, but reaching full sales as soon as possible is crucial for long-term success.

	400 T SCENARIO		6,500 T – STANDARD		6,500 T – ENERGY OPTIMIZED		6,500 T – THIRD-PARTY	
SALES VOLUME (%)	NPV	IRR	NPV	IRR	NPV	IRR	NPV	IRR
100%	*-28,714*	*4.3%*	*1,503,417*	*41.2%*	*1,630,953*	*36.8%*	*1,551,685*	*33.8%*
80%	-77,054	n/a	717,886	26.2%	845,422	25.1%	766,154	23.0%
60%	-125,395	n/a	-67,645	10.6%	59,891	13.0%	-19,377	11.7%
40%	-173,735	n/a	-853,177	-13.4%	-725,640	-1.6%	-804,908	-2.2%
S-Curve 40% → 100%	**-**	**-**	**180.964**	**14.0%**	**308,500**	**15%**	**229,233**	**14.2%**

Figure 41. Sales volume sensitivity analysis

INVESTMENT COSTS (%)

Investment costs are particularly important because they represent the largest share of project expenditure and are subject to uncertainty (civil works, shipping, duties, contingencies). We tested a wide range, from –40% to +40% of the baseline.

400 tonne SCENARIOS

Even when investment costs are reduced, the project remains financially weak, with negative NPVs and very low IRRs. This confirms that a plant of this size can hardly be self-sustaining, but it's true value lies in demonstrating the technology and the quality of the compost.

6,500 tonne SCENARIOS

The industrial-scale plant shows strong resilience: even with a 40% increase in investment costs, NPVs remain positive, and IRRs are well above the 12% discount rate. When costs are reduced, profitability improves significantly, showing the robustness of the project and its capacity to absorb potential increases in capital expenditure.

	400 T SCENARIO		6,500 T – STANDARD		6,500 T – ENERGY OPTIMIZED		6,500 T – THIRD-PARTY	
INVESTMENT COSTS (%)	NPV	IRR	NPV	IRR	NPV	IRR	NPV	IRR
140%	-50,952	1.6%	1,236,136	29.3%	1,288,946	26.2%	1,181,353	24.1%
120%	-39,833	2.8%	1,369,776	34.2%	1,459,949	30.6%	1,366,519	28.2%
100%	*-28,714*	*4.3%*	*1,503,417*	*41.2%*	*1,630,953*	*36.8%*	*1,551,685*	*33.8%*
80%	-17,595	6.4%	1,637,057	51.7%	1,801,957	46.3%	1,736,852	42.5%
60%	-6,476	9.4%	1,770,698	69.8%	1,972,961	62.5%	1,922,018	57.3%

Figure 42. Investment costs sensitivity analysis

OPERATIONAL COSTS (%)

Operational costs were tested with a narrow variation of ±5%, since they are relatively smaller and more stable compared to capital costs.

400 t SCENARIO

Changes in operating costs only marginally affect the results, but the overall picture does not change: NPVs remain negative, and IRRs are below the discount rate. This confirms once again the non-commercial value of the pilot.

6,500 t SCENARIO

For the full-scale facility, the impact of operating costs is limited. Even with a 5% increase, NPVs remain strongly positive, and IRRs are comfortably above the discount rate. This shows that the project's financial performance is not highly sensitive to small changes in OPEX, especially in the Energy Optimized configuration, where electricity costs are already reduced.

	400 T SCENARIO		6,500 T – STANDARD		6,500 T – ENERGY OPTIMIZED		6,500 t – Third-Party	
OPERATIONAL COSTS (%)	NPV	IRR	NPV	IRR	NPV	IRR	NPV	IRR
95%	-19,379	7.0%	1,573,934	42.5%	1,681,066	37.6%	1,602,221	34.5%
100%	*-28,714*	*4.3%*	*1,503,417*	*41.2%*	*1,630,953*	*36.8%*	*1,551,685*	*33.8%*
105%	-38,049	1.5%	1,432,899	39.8%	1,580,841	36.1%	1,501,150	33.2%

Figure 43. Operational cost sensitivity analysis

4.5 Qualitative risk analysis

The qualitative risk analysis for the composting project in Grenada identifies key challenges across six categories: Legislative, Financial, Research, Teamwork, Market, and Training. Each risk is rated as Low, Medium, or High, according to its potential impact (Table 3).

Category	Risk Level	Main Issues Identified
Legislative	Medium	-Draft compost quality standards only -Final regulations may impose stricter requirements -Uncertainty concerning waste composition and availability
Financial	Medium	-High CAPEX and OPEX -Difficulty in raising equity
Research	Medium	-Limited local data on waste composition -Informal estimates may affect project design
Teamwork	Low	-Need for coordination between institutions and stakeholders
Market penetration	High	-Risk that buyers do not purchase compost because they do not know it or its benefits -Mixed waste collection -Narrow roads complicating transport
Training	Low	-Workers require specific skills -Limited existing training programs

Table 4. Risk category and level

As shown in Table 3, the most significant risks are related to local support, especially the possibility that buyers may not purchase compost due to lack of awareness of its benefits. Financial and legislative risks are also important, while research, teamwork, and training present moderate to low risks.

Category	Risk Description	Prevention and Mitigation Strategies
Legislative	Uncertain compost standards and regulations	- Keep production flexible to adapt to future rules - Engage with authorities to anticipate requirements - Carry out waste characterization campaigns and establish agreements with GSWMA for the supply of segregated organic waste
Financial	Difficulty in securing equity contributions	- Offer incentives to private investors - Explore grants and subsidies - Present clear and solid business plans
Research	Informal waste estimates; contamination risks	- Carry out waste audits and sampling - Collaborate with universities and research partners on composting practices and quality control
Teamwork	Limited coordination among institutions	- Set up a simple coordination group - Hold regular meetings with clear shared objectives
Market penetration	Buyers not aware of compost benefits; mixed waste collection; transport difficulties	- Run dissemination campaigns to explain compost and its advantages - Conduct demonstration trials to show results through Farmers Field Schools and other participatory approaches; - Choose suitable vehicles and plan efficient routes for compost distribution

Training	Lack of expertise for operations and end-users	- Provide practical training programs for workers and farmers - Invite experts for short courses - Support introduction of compost topics in local education programs

Table 5 Risk description and mitigation strategies

Table 4 outlines the main strategies to mitigate the identified risks. Market penetration requires priority action through awareness campaigns, efficient logistics, and above all, well-coordinated and participatory demonstration trials. These are key components to ensure that high-quality compost is recognized by farmers as a viable and effective alternative, and support plant nutrient management in addition to or in conjunction with chemical fertilizers. Financial risks can be reduced by attracting equity and external funding, while legislative risks call for flexible production processes and early engagement with regulators. Research, teamwork, and training risks can be managed with targeted actions.

5. CONCLUSION AND RECOMMENDATIONS

The approach used in this study provided market-based information on the feasibility of valorizing organic waste produced in Grenada through composting. It explored ways to implement composting methods through private investments that contribute to the sustainable development of the country. Private sector actors have been engaged during the research project, the potential mitigation benefits of compost production from organic waste and adaptation benefits of compost use in agriculture were assessed. The main conclusions of the study are presented below:

- Grenada is exposed to risks from climate change, including increased intensity of tropical storms, sea-level rise, prolonged droughts, and future forecasts foresee increased impacts with average temperatures rising, and precipitation patterns decreasing.
- Grenada's second NDC targets a 90% percent reduction in methane emissions from the waste sector, to mitigate the country's contribution to climate change. In terms of adaptation, the NAP places Climate Smart Agriculture, including composting and using organic fertilizers, as a key practice supporting the resilience of Grenada's agrifood systems.
- Composting is a mature and commercially available technology. Passive aeration systems, like windrow composting, are best suited to the conditions of Grenada.
- Composting can reduce emissions from organic waste by 98%, fully aligning with the country's NDC.
- The role of compost in improving the resilience of agrifood systems to the impacts of climate change is well known. It is highly relevant in Grenada as an enhancer of soil moisture and biodiversity. Additionally, it can support independence from chemical fertilizer imports, market shocks, and disruptions due to extreme climatic events.
- The segregated organic waste delivered at Perseverance landfill yearly (6,500 tonnes/year) could be processed into approximately 2,600 tonnes of high-quality compost each year in a commercial compost plant.
- A suitable location for the plant was found in the Perseverance landfill managed by GSWMA with the help of a photogrammetry assessment.
- Domestically produced compost can substitute about 16% of the chemical fertilizers used in Grenada.
- Private sector actors are actively involved in developing the necessary knowledge and skills to produce and market compost at various scales.
- The financial assessment tested several scenarios for the development of compost production and use.
- Small-scale decentralized plants with a capacity of less than 1,000 tonnes of waste per year require external financial support to be profitable and competitive with chemical fertilizers (e.g.

grants or subsidies) but are a key solution to enable local markets and develop profitable commercial scale market uptake.

- Assessment of a commercial-scale plant, such as the 6,500 tonnes of waste plant, shows strong financial performance and is a profitable investment option for the private sector.
- It is recommended that biomass and organic waste separation and segregation practices be introduced and expanded to ensure a constant supply of feedstock to compost plants and a high-quality product.
- A demonstration project that supports market penetration and awareness-raising campaigns are recommended to enhance the enabling environment for private sector investments in composting.
- Investor's interest was surveyed indirectly through discussions with the Grenada Investment Development Corporation (GIDC) and several consultations with private sector representatives.
- Investors have a clear appetite for any climate-friendly investment that demonstrates returns higher than the average discount rate (12%), which explains the selection of the acceptable ROI threshold in the Financial Assessment.
- Any configuration for a composting plant with a capacity of at least 6,500 tonnes of waste per year has an ROI of at least 14%, fully aligned with the propensity of stakeholders to invest in this technology.
- Composting projects face risks in terms of market penetration, as market acceptance of compost remains uncertain.
- Addressing this challenge requires a well-structured communication strategy coupled with a comprehensive demonstration campaign of compost benefits for organic farming in Grenada.
- Financial and legislative risks are medium but can be mitigated through structured financing mechanisms and proactive policy engagement, which already partially exist in the country.
- Overall, ensuring optimal market penetration and a high-quality product are key to ensuring the success of investments in commercial compost plants in Grenada.

ANNEX 1

Photogrammetric site survey

Photogrammetry is the process of authoring a digital asset using multiple photos of the original real-world object or area. This technique is gaining prominence due to its numerous advantages compared to traditional field surveys, including:

- Cost-Efficiency: Traditional surveying is labour-intensive and costly, especially for large-scale projects. Photogrammetry reduces expenses by minimizing the need for on-site personnel and equipment, and time spent taking measurements.
- Rapid Data Collection: Photogrammetry accelerates data acquisition. By utilizing drones or aircraft to capture aerial images, vast areas can be surveyed in a fraction of the time it would take using traditional methods.
- Safety: Surveyors often work in challenging or hazardous environments. Photogrammetry keeps personnel out of harm's way by allowing data collection from a safe distance.
- High Precision: Modern photogrammetry software can produce highly accurate results, often rivalling or surpassing traditional surveying in terms of precision.
- Versatility: Photogrammetry is suitable for a wide range of applications, from construction and environmental monitoring to archaeological site preservation.
- Preservation: Photogrammetry can be used to create detailed 3D models without causing any physical impact on objects and areas.

While both traditional surveying and photogrammetry have their merits, the advantages of photogrammetry are increasingly evident in today's fast-paced world. Its cost-efficiency, rapid data collection, and versatility make it an invaluable tool in a wide range of industries.

Photogrammetry was applied to surveying the area of the Perseverance landfill to prepare an accurate tri-dimensional (3D) model of the case study area, and the recreation of a true-to-scale replica of every existing feature and building on site, including the relative dimensions (height, length, width) and volumes of waste piles, structures, trees, and any other feature on the landscape.



Figure 44. Drone photogrammetry survey at Perseverance landfill

The workflow for photogrammetric surveys is divided into two major parts: Capture and processing. Capture is about taking photos of an object covering its entirety. The first step is to gather multiple photos of the object from various angles. It is also necessary to gather extra information for reference, scale metrics, and correctly exposing the photos. During the field survey in May 2025, an authorized drone pilot completed the photogrammetry capture survey by flying a GPS-equipped drone over Perseverance landfill with a pathway circling around the entire site, to collect a sufficient number of photographs to be fed into the processing software.

During the sortie, the drone captured 508 photographs of the Perseverance landfill from various angles and heights. Each photo overlapped for at least 30% with the next, a key requirement of the processing software for stitching all images and connecting them to one another. The drone camera was set on a manual shutter speed of 1/320 of a second to ensure the sharpness of each shot taken. The focal length and aperture are fixed on the drone camera model employed, at 24 mm and f 2.8, respectively. The drone was equipped with a Natural Density (ND) filter over its camera to ensure that the maximum dynamic range was captured by the sensor with the consistent settings described above. Moreover, the sortie took place between 11:50 am and 12:55 pm, to minimize the presence and appearance of shadows in each picture taken from different angles, relative to the position of the sun in the sky. These settings and precautions were chosen to ease the processing of images and enhance the results of the photogrammetry workflow.

Processing is about generating the mesh and texture data from the photos. First, the photos need to be calibrated (white balanced) and harmonized in terms of colour scheme and grading. This action is crucial to deliver the best images possible to the photogrammetry software to work with. The features

that make images apt to be used in photogrammetry are the low contrast and the absence of harsh shadows, crushed blacks, and highlights. The resulting image should therefore appear as having a “flat” colour profile which retains information without inducing chromatic aberrations. Colour-balanced photos are divided into groups characterized by main light conditions (e.g. top-down images, or backlit images, plain light images) and harmonized. In harmonization, colours are modified to resemble a midpoint in terms of saturation and vibrance, exposure, white balance, and once again contrast. When all groups are harmonized, the images are calibrated and ready for the reconstruction software. In the context of this project, colour calibration was carried out using the Adobe Lightroom Classic 2023® software. Each of the 508 images was colour balanced and harmonized to provide an even basis for the 3D editing software to work with.

The reconstruction application compares the shapes in the photos (Alignment) to generate a high-resolution 3D mesh. The colour contained in the pictures is then transferred to either the mesh’s vertex colours (Colorization) or to textures used on the surface of the mesh. Next, a low-resolution mesh for the baking process needs to be created: A medium to low resolution mesh is exported from the reconstruction software and modified in a 3D software tool to be used as the destination of the baking tools. Baking is a process through which colour textures are generated. The software used for this crucial step of the workflow is Reality Capture® Version 1.4.1.

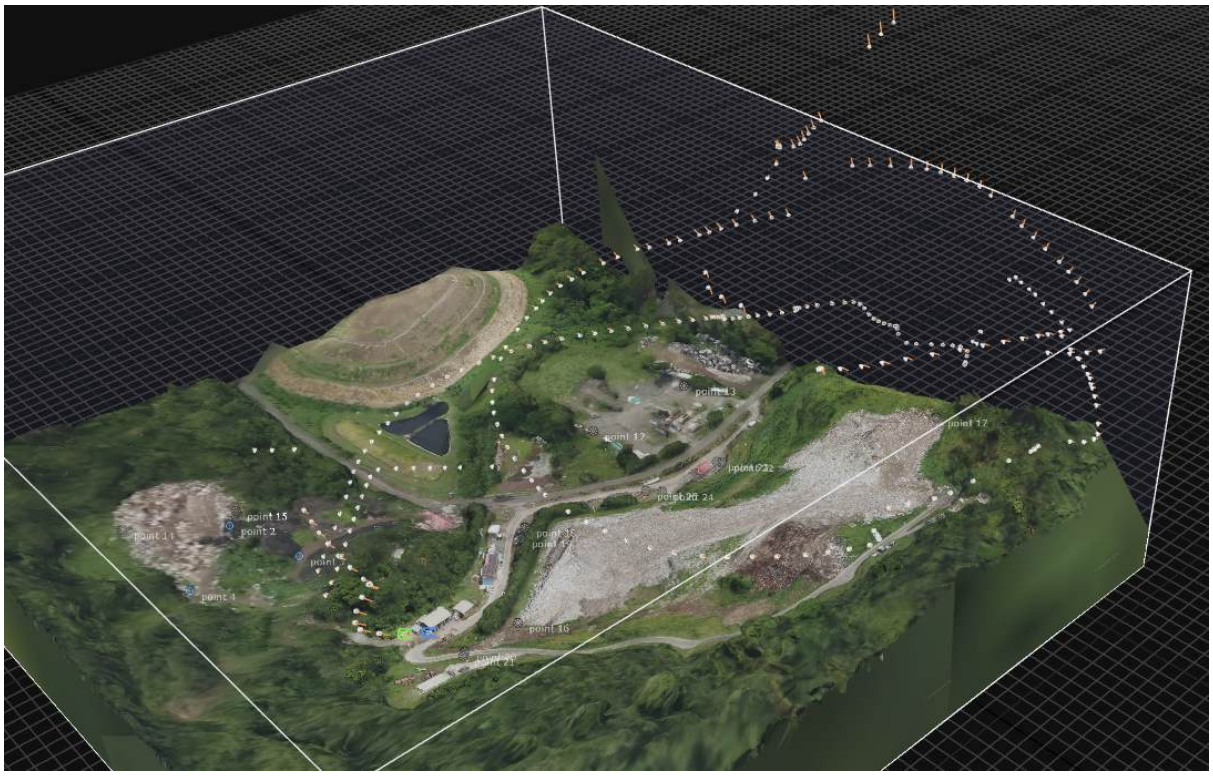


Figure 45. The aligned 508 images in Reality Capture create a point cloud of the 3D space

Each picture taken from the drone is aligned by the software to reconstruct the point cloud of the 3D space (Figure 43). A point cloud is a large collection of points that are placed on a three-dimensional

coordinate system. Point cloud files greatly speed up the design process by providing real-world context where the referenced objects can be re-created or additional models can be inserted, in a virtual reality environment. Each point in the point cloud exists in space as it is recognized by the software or the operator in at least three pictures taken in different positions. By triangulating recognizable points (pixels in the case of high-resolution digital images) the software can recreate a virtual three-dimensional (3D) space with effective relative distances and true-to-scale dimensions. The exact location of each picture taken is represented in space by the small thumbnails and orange residual lines (figure 43) tracking in this case the position of the camera. After the first point cloud is formed, the programme checks for unaligned images, and these require manual work from the operator to identify a common Control Point that needs to be placed in space by using at least three (better four or five) pictures where such point is visible. A sharp corner or high contrast area was used for this purpose. A total of 25 Control Points were manually placed and verified in at least 3 images each.

The software can also use control points to fix known distances and accurately reproportion the entire object to fit into a certain scale. With this operation, the processing software can build a solid 3D object (.obj of .fbx extensions) and provide exact measurements of every feature of the 3D model.

A 3D model is the result of the connection of triangles formed by the points detected in the point cloud. The 3D model of the Perseverance landfill is composed by 22 million triangles, each with its list of attributes such as distances, angles, and exact location in space. Even modern powerful software and computer hardware struggle to process several million triangles simultaneously and a useful action that allows swift visualization of the 3D model while retaining all attributes and parameters of the virtual object is a model simplification. Reducing the number of triangles by a factor of 10 (i.e. from 22 million down to 2.2 million triangles), reduces accuracy of the model only by 0.002%, while enabling swift visualization of the model also on less powerful computers or mobile devices. This step is also capable of enabling the transfer of the object to a local builder or construction company over the internet, thus reducing costs and increasing the availability of the product.

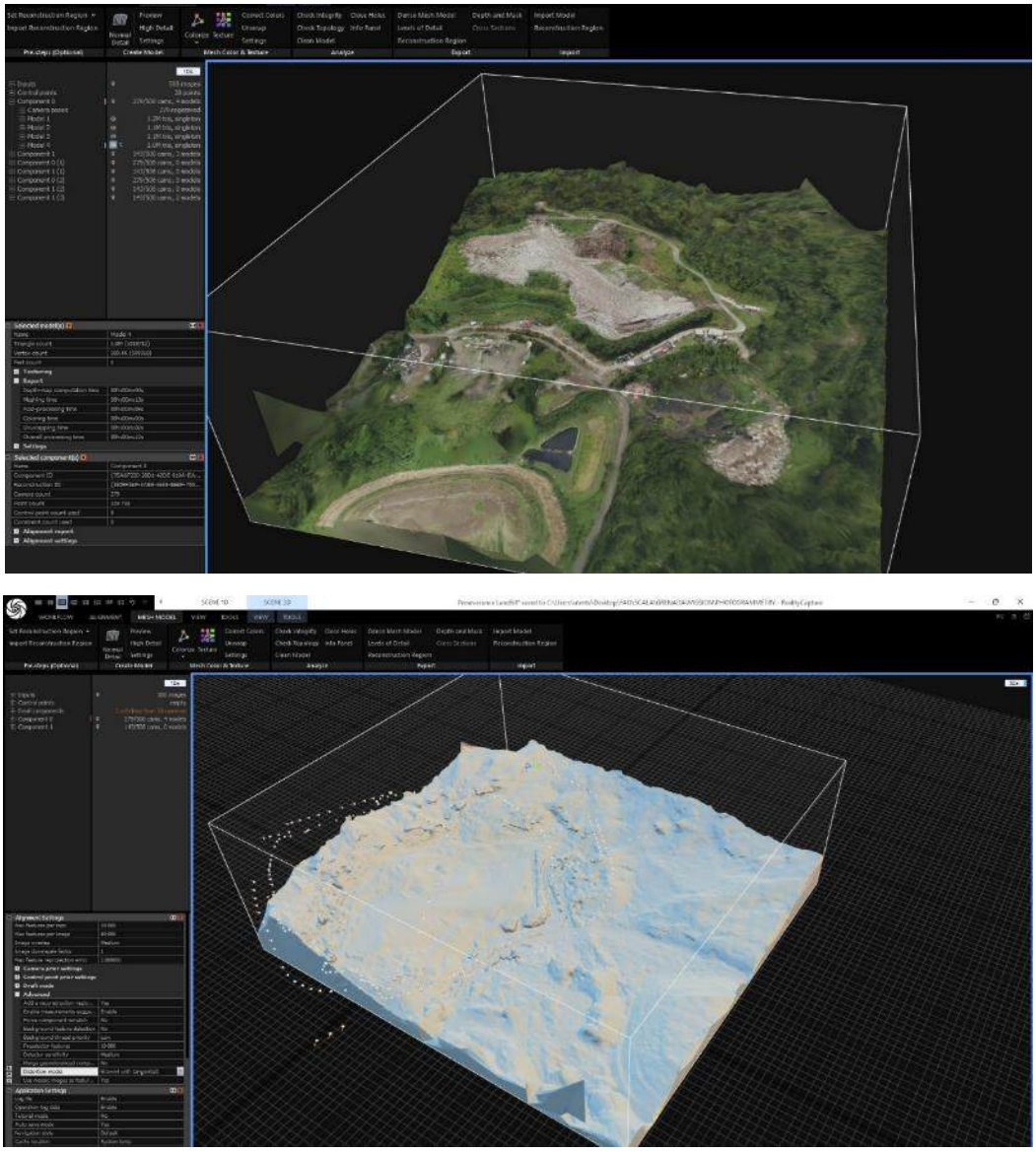


Figure 46. Above the Point Cloud with vertexes (above) is transformed into a solid 3D object (below) that has continuous surfaces instead of individual points in space.

Reality Capture displays the mesh as a point cloud, but internally it converts it to a mesh with vertices. The photo colour is transferred to the vertex colours. This requires only a .ply file (which handles vertex colour), which is easier to manipulate compared to an .obj file with big textures. The production of a dense model can benefit from the application of textures for visualization purposes and possible modifications once the 3D model is exported to another software (e.g. for architectural uses). Together with the solid 3D model, texturization is key to enabling a feature of photogrammetry that truly speeds up and enhances the production of engineering drawings in the true-to-scale environment: orthophotos. Through orthophotos, a CAD software can use a reference system based on real images that are non-perspective to represent and superimpose a model or engineering drawing to an existing feature.

From the texturized 3D model of the Perseverance, all sections and views can be extracted as orthophotos. With traditional surveys, this operation would require months and related costs for personnel and service providers.



Figure 47. Orthophoto from the top. The picture is now correctly oriented towards the magnetic north, and in non-perspective scale.

Orthophotos are the basis for any CAD software to take measurements as the starting point for drawing the biogas plant.

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SCALA responds to the urgent need for increased action to cope with climate change impacts in the agriculture and land use sectors. The twenty million euro programme will support at least twelve countries in Africa, Asia and Latin America to build adaptive capacity and to implement low emission priorities.

Country support includes strengthening policies, adopting innovative approaches to climate change adaptation and removing barriers related to information gaps, governance, finance, gender mainstreaming and integrated monitoring and reporting. To achieve this shift, the programme will engage the private sector and key national institutions.

SCALA supports countries to develop the capacity to own and lead the process to meet targets set out in their National Adaptation Plans and Nationally Determined Contributions under the Paris Agreement, and to achieve the Sustainable Development Goals. The SCALA initiative builds on another FAO-UNDP led programme, Integrating Agriculture in National Adaptation Plans (2015-2020) which is currently phasing out.





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