SRC WORKING PAPER

The Relationship Between Natural Disasters and Supply Chains in Small Island Developing States :

A Case Study on the Impact of Hurricane Ivan (2004) (and Hurricane Emily 2005) on Grenada's Nutmeg Supply Chain.

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ABSTRACT

As the frequency and intensity of natural disasters continue to increase in Small Island Developing States (SIDS), the risk of supply chain disruptions (SCDs) is inevitable. In the area of agriculture especially, there is limited understanding of the systemic or supply chain (SC) effects caused by natural disasters and their wider implications. The principal objective of the study was to conduct a case study examining the impact of hurricane Ivan (2004) (and hurricane Emily (2005)) on Grenada's nutmeg SC.

The findings of the case study revealed that hurricane Ivan (and Emily) negatively impacted the entire nutmeg SC with long-lasting consequences. Due to the interdependencies in the nutmeg SC, the hurricane's impact at the farm gate had a ripple effect along the SC. This resulted in a significant reduction in production and exports to date, a decrease in nutmeg revenue and employment in the industry, a loss in world market share and Grenada's position as one of the world's largest nutmeg suppliers.

Mitigative strategies undertaken prior to the hurricanes helped to reduce the severity of the impact. However, there were several pre-existing factors which served to increase the severity and longevity of the hurricane's consequences. These included: nutmeg crop characteristics, economic vulnerability, a lack of preparedness and risk transfer mechanisms such as market-based insurance for farmers, as well as several external factors.

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ABBREVIATIONS

CARDI	Caribbean Agricultural Research and Development Institute
CCCCC	Caribbean Community Climate Change Centre
EIC	Economic Intelligence Center
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GOG	Government of Grenada
GCNA	Grenada Cooperative Nutmeg Association
ICCAS	Integrated Climate Change Adaptation Strategies
IICA	Inter-America Institute for Cooperation on Agriculture
IMF	International Monetary Fund
ITC	International Trade Centre
MOA	Ministry of Agriculture & Lands
MOF	Ministry of Finance, Planning, Economic Development & Physical Development
NWS	National Weather Service
OECS	Organization of Eastern Caribbean States
PDNA	Post Disaster Needs Assessment
SC	Supply chain
SCD	Supply chain disruption
SCM	Supply chain management
SIDS	Small Island Developing States
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	The United Nations Educational, Scientific and Cultural Organization
VC	Value chains
WTO	World Trade Organization

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter provides an overview of the research background, problematique, rationale, objectives of the research, research questions, and the methodology.

1.1 Background of the Study

Supply chain disruptions (SCDs) have become one of the major risks of the 21st century (Craighead, Blackhurst, Rungtusanatham and Handfield 2007; United Nations Office for Disaster Risk Reduction 2013; Micheli, Mogre, and Perego, 2013, World Economic Forum 2018; WTO 2019). The importance of examining these disruptions has grown in line with the increased interconnectedness of the global economy, the increase in natural hazards such as hurricanes and extreme weather events, and more recently, the ongoing COVID 19 pandemic. Extreme weather events[1] and natural disasters especially, have been ranked in the World Economic Forum's Global Risk Report (2018) as the top SC risks most likely to occur in the next 10 years.

Although natural disasters such as hurricanes are not limited to Small Island Developing States (SIDS)[2] , they are particularly affected (UNESCO 2019). This fact is due to their location, small geographical areas and populations, high levels of debt, and undiversified economies that rely heavily on narrow export baskets and on the agriculture and tourism sectors (Ibid). Almost one-third of all disaster loss is accrued in the agricultural sectors, and each

[1] The World Economic Forum distinguishes between extreme weather events and natural disasters. Extreme weather events include heatwaves, heavy rain, floods, drought, storms, or other weather-related events that are rare for the place and time of year where it occurs.

[2] SIDS are defined by the UN, a group comprising 52 low-lying coastal countries sharing similar challenges to sustainable development, 38 are UN members and 14 are non-UN Members or Associate Members of the Regional Commissions(see UN-OHRLLS 2011 for more information).

subsector is affected differently based on the type of hazard (FAO 2018). Hurricane-related SCD's for example, can have devastating effects on agricultural SCs, having far reaching negative consequences beyond the short-term. The stages of an agricultural SC are highly interdependent. The impact of a hurricane can therefore spread quickly throughout the SC. The result being disruption to production, compromised food security and livelihoods, and stunted sectors (Ibid).

Grenada is a SIDS with a small open economy, and a population of 112,003 people as of 2019 (World Bank 2019).[3] In Grenada's history, the agricultural crop subsector has been one of the most important sectors. Nutmeg especially, has been an anchor industry, being a major contributor to GDP, foreign exchange, and employment, especially in the rural communities (ITC 2010; WTO 2019).

In 2003 for example, exports of nutmeg or mace represented over 65% of all agricultural exports which generated revenue of EC$39.5 million (Ministry of Agriculture, Grenada 2009). Additionally, Grenada was by far the largest cultivator and producer of nutmeg and mace in the world, only being surpassed internationally by Indonesia (ITC 2010). Grenada is also one of the only nations to have a nutmeg on its flag. The symbol alluded to the island's chief product and represents the importance of agriculture to Grenada's economy as well as a link to Grenada's former title; the "Isle of Spice" (GCNA n.d.).

In the space of 10 months however, hurricanes Ivan (2004) and Emily (2005), dealt significant damage to the nutmeg industry. Damage caused by hurricane Emily was not as extensive, however, it served to disrupt the critical path to recovery and to worsen the impact of hurricane Ivan (OECS 2005). Since then, Grenada's economy has further shifted from being

[3] Grenada is a tri-island state of Grenada consists of three main islands: Grenada, Carriacou and Petit Martinique. Grenada, the largest of three is the most southerly of the Windward Islands, with an estimated population of 112,628 in 2020 (United Nations, web reference)

"agriculture" dominant and into one that is more "services" dominant (Fries, Weiss, and White 2013). Grenada was rebranded in 2014 as "Pure Grenada" to better encapsulate the island's unique features such as eco-tourism, yachting and world-class diving (Grenada Informer 2014).

Nevertheless, the nutmeg SC in ways, has been resilient, still occupying a significant percent of agricultural exports. As of 2019 for example, nutmeg represented 24% of agricultural exports (Ministry of Finance, Grenada 2020). Nutmeg therefore remains one out of Grenada's three most important export commodities, nutmeg being grown for over 160 years and continuing (Fletcher 2020). A major factor however constraining the recovery and growth of the nutmeg industry is the risk of extreme weather events and natural disasters (ITC 2010). With the continuous increase in the severity and prevalence of hurricanes in SIDS, a research agenda on the impact of the hurricanes are fundamental steps in understanding the vulnerabilities of the industry in order to build resilience.

To concisely capture the impact of the hurricanes on the nutmeg SC, this research paper embodies the following structure:

1. **Chapter 2** presents the theoretical framework/orientation and the literature review.
2. **Chapter 3** presents the findings of the case study utilizing the methodology and theoretical framework.
3. **Chapter 4** concludes, and limitations of the study are highlighted as well as recommendations for future work.

1.2 Statement of the problem

While there is substantial literature documenting the macroeconomic impact of natural disasters on SIDS (IMF 2016; WTO 2019), limited information is available on its impact across agricultural SCs. This includes long-term consequences and consequences on closely linked, or interdependent sectors such as, the agro-industry (FAO 2015). For SIDS like Grenada, SCs like that of nutmeg, serve as a blood line for the agricultural sector . Similarly, however, there has been little in-depth analysis on hurricane Ivan's impact across the nutmeg SC, especially in the long-term. According to the FAO (2015), the lack of an understanding of the full ramifications of disasters across SCs, hinders efforts of countries to formulate strategic plans, mitigate costs, adopt risk reduction measures within sub-sectors, strengthen resilience and to protect development investments.

1.3 Rationale

The reasons for the focus of this case study on the impact of hurricane Ivan (and Emily) on Grenada's nutmeg SC in the context of this research paper are fourfold.

Firstly, while Grenada is not the only SIDS to suffer the effects of hurricanes, the impact of hurricane Ivan was especially catastrophic. It specifically underscored the potentially devastating impact of hurricanes on a SIDS with a vulnerable economy and a dependence on agricultural exports. Hurricane Ivan is an occurrence of the distant past; however, Grenada still remains uniquely vulnerable to such hazards, as such research in this area will always be important. Additionally, due to the time which has passed since the hurricane's occurrence (17 years), this case study allows for a unique opportunity to examine the long-term consequences and industry's resilience and recovery process. It also allows for an appropriate opportunity to test concepts of SCD and vulnerability from the angle of a SIDS.

Secondly, this study aims to contribute to the improvement of knowledge in the existing pool of literature. Examining the impact using a SC approach allows for in depth analysis of the impact, targeting SC participants. It also allows for visibility of the most vulnerable actors, or threats to the SC, which may not have been prevalent in an economy wide assessment.

Thirdly, from a SC management perspective, this study can be used as a starting point for governments as well as SC managers and stakeholders in the nutmeg industry to improve risk management strategies. Additionally, the methodological framework can be used to conduct further research in a diverse number of areas.

Finally, this study contributes to the achievement of the author's professional development and long-term career aspirations as an international trade policy analyst.

1.4 Objectives of the Study

The principal objective of the study is to examine the impact of hurricane Ivan (and hurricane Emily) on the nutmeg SC in Grenada.

The subsidiary objectives of the study were therefore to: -

- Map Grenada's nutmeg SC in order to understand the linkages amongst the main actors, and their contribution to the chain's performance.
- To examine the consequences or the impact of the hurricanes on each stage of the nutmeg SC (both immediate and long term) and the overall impact.
- To examine the factors which increased the severity and longevity of the hurricane's impact on the SC.

1.5 Research Questions

- What are the different steps in the nutmeg SC; who are the actors involved and what are their roles?
- How did the hurricanes affect the SC?
- Why did the hurricanes affect the SC to the extent that they did? :
- What are the main factors which influenced the intensity and longevity of the impact or the extent of the losses?
- What role did disaster management/recovery capacity play in mitigating the impact of the hurricanes?

1.6 Methodology

A case study approach is utilized to address the research problem. A case study approach allows for in depth-exploration of complex issues such as events or phenomenon of interest in their real-life context (Yin 2009). While case study research is usually qualitative, in order to develop a thorough understanding of the case, multiple sources of evidence will be collected through a mixed methods approach. The approach taken however is qualitatively dominant. The theoretical lens of SCD is used to gain deeper insights into the data and guide the data collection and analysis.

The qualitative methods include mostly content/document analysis.[4] The time which has lapsed since the occurrence of the hurricanes in 2004 & 2005 justifies this approach. This is supplemented with email interviews with senior officers in the Grenada Cooperative Nutmeg Association (GCNA). The interview questions are located at the end of this study as **Annex I**. Additionally, a sample of the interview consent form is attached as **Annex II**. Additionally, quantitative data is gathered, such as, statistical data to further test and validate qualitative findings. Using aforementioned sources of information makes it possible to cross-check and cross-reference information collected.

[4] The sources of data include: GCNA Reports, statistics from the Grenada's Central Statistical Office, Grenada's budget statements and other government documents, relevant documents, and data from the International Trade Centre (ITC), the OECS, World Bank, IICA etc. Information will also be collected from local newspapers and articles.

CHAPTER TWO

THEORETICAL ORIENTATION AND LITERATURE REVIEW

2.0 Theoretical Orientation and Literature Review

2.1 Theoretical framework

This research is conducted broadly within the supply chain disruption (SCD) domain. A SCD has been defined as "an unexpected event that stops or slows the normal flow of material (Craighead et al. 2007) with potentially negative consequences to SC participants (Chopra and Sodhi 2004; Blackhurst, Dunn, and Craighead 2011). The impact factor is therefore one the "most common attributes of the disruption" (Macdonald 2008). The theory of SCD provides a framework within which various related concepts/variables of this research can be connected. The theory of SCD also provides a base for the analysis and interpretation of the findings of the case study.

To date, significant research has been invested in "understanding, predicting, preventing, and managing disruptions" (Ivanov et al. 2017; Scheibe and Blackhurst, 2017). However, the field of SCD related research however is still nascent (J. Blackhurst et al. 2005; WTO 2019). As Macdonald (2008) and Ellis, Shockley, and Henry (2011) pointed out, across academic research there is a lack of consistency or a unifying framework in the application of the theory. Moreover, some papers in the field either omit to apply the theory as an integral part of their study or omit a theoretical underpinning altogether. Resultantly, research in this area requires the researcher to draw on principles close to the research context, or to outline a framework which connects the various concepts which can drive the research (Macdonald 2008).

According to Zingbagba (2019) more recently, research on SCD has covered four thematic areas namely: causes of SCD, supply chain (SC) vulnerability and resilience, and the management of SCDs. These key concepts have been examined in assessing the magnitude of natural disaster impact as well (Ponomarov, 2012; Ye, Linghe; Abe and Ye 2013; Andreoni and Miola 2015; National Academies of Sciences, Engineering, and Medicine 2020; and Ivanov and Wendler 2017).

- **SCD framework**

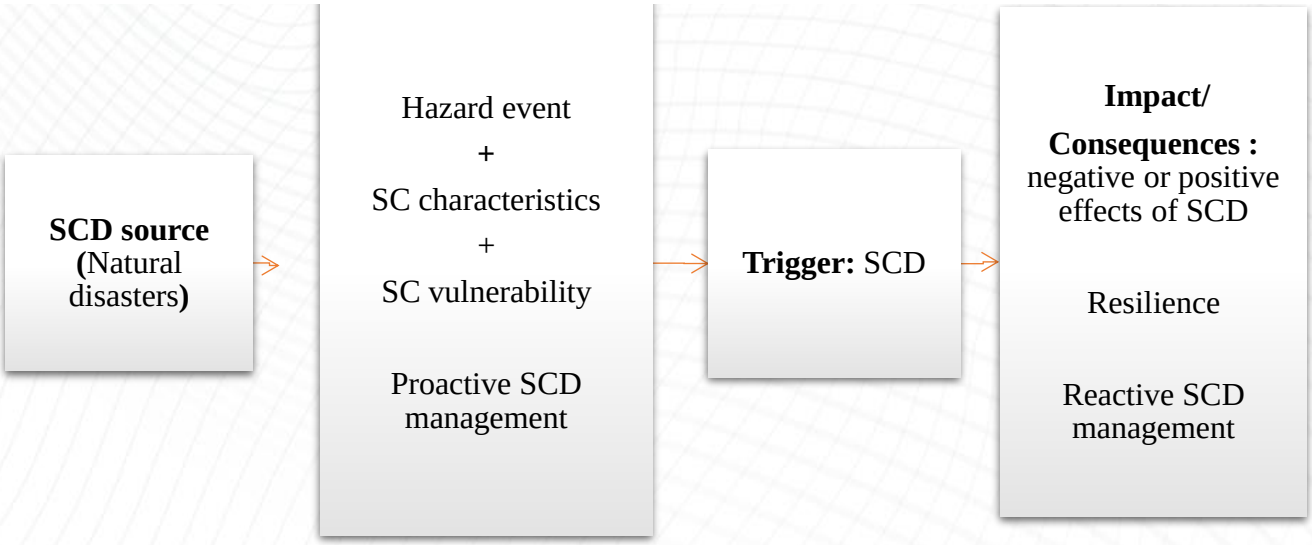
Monroe, Teets and Martin (2014) utilizes the logic of a chain of events or the cause and consequence approach using elements outlined by Wagner and Bode (2009); Wagner and Neshat (2010) ; to define SC risk in the context of SCDs. According to Monroe et al. (2014) SC risk consists of "SC characteristics which create vulnerability in the SC; a trigger in the form of a SCD; which will reveal the negative consequences that result from SC risk." Similarly, Gourc (2006) defined risk using similar elements (see **figure 1**).

Figure 1 *The risk vision.*

Source*: Elleuch et al. (2016) adapted from Gourc (2006)*

Similarly, the same logic of a chain of events or cause and consequence approach used in examining risk can be used as a framework connecting the elements in SCD related literature (see **figure 2**).

Figure 2 *SCD assessment framework based on elements in the SCD literature.*



Source: *Author's elaboration*

In summary a SCD therefore consists of:

1. The source/ cause of the disruption.
2. The pre- disruption state of the SC or SC characteristics which increase vulnerability or the severity of the disruption (this considers the hazard event, SC characteristics, vulnerability, resilience, and disruption management strategies).
3. A trigger in the form of a SCD; and
4. The resulting impact/ consequences.

2.2 Literature review

2.2.1 SC background

Mentzer et al. (2001) defines a SC as "a set of three or more entities (organizations or individuals) directly involved in the upstream[5] and downstream[6] flows of products, services, finances and information from a source to a customer." The terms "SC", "value chain" (VC), "commodity chain", and "agri-food system" are used interchangeably, with slight differences in meaning depending on the focus and context (Chen, Shepherd, and da Silva 2005). Certain studies, however, highlight that there are primary differences between the SC and VC approaches in the literature. SC approaches for example focus on production and supply while VC approaches focus on consumers and demand (Hobbs, Cooney, and Fulton 2000; CARDI, 2014, 19).

A simple SC involves participants in the following order: source supplier, manufacturer, distributer, retail, and customer (Crandall et al. 2014). These different entities are referred to as nodes/echelons that are directly linked. Each node, in theory, should play a "value added role" and each benefit economically (Craighead et al. 2007).

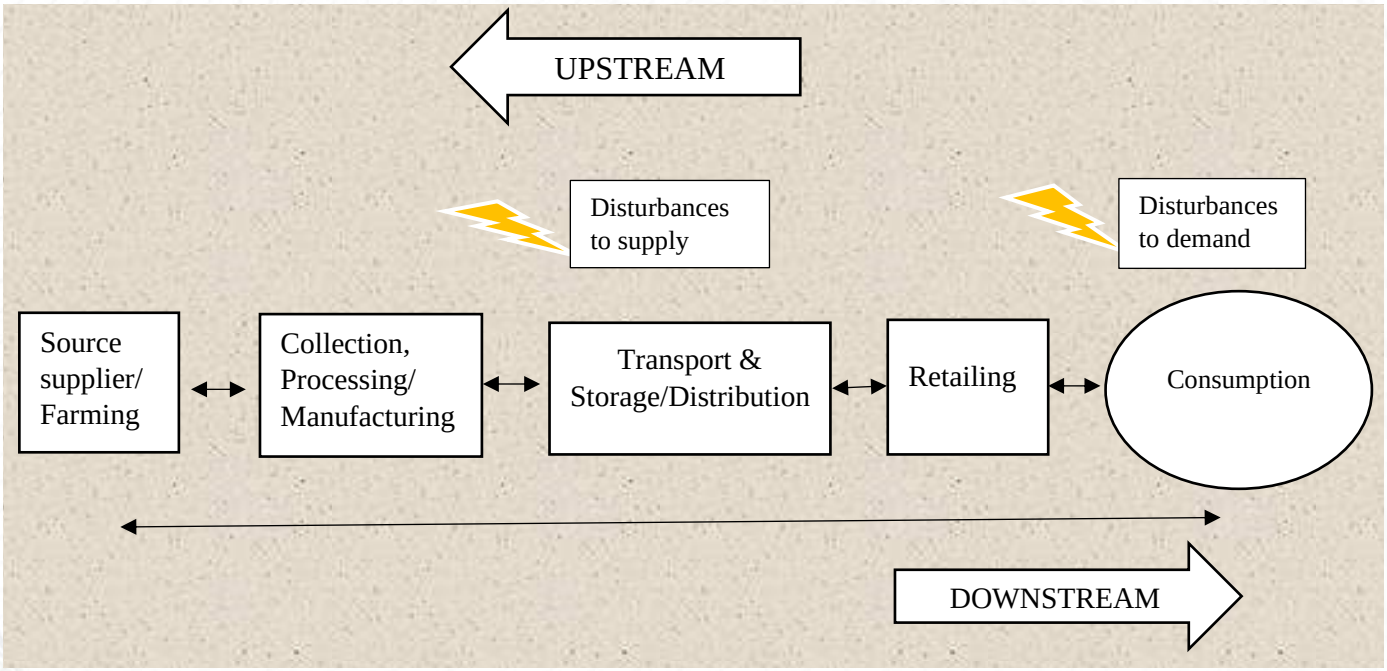
Agriculture involves a sequence of interlinked activities or transactions in a chain that starts from the supply of seeds and fertilizers and finishes in the mouth of the consumers (IFAD 2012). In agricultural SCs especially, farmers play a crucial role in the production and manufacturing stages especially in rural areas (Reddy, Singh and Anbumozhi 2016). Most agricultural products require further processing, storage, and transport. Processing may include simple tasks like cleaning or grading, or multiple steps and distribution. Distribution of products include local, regional, or global allocation/transportation, and certain distributors

[5] towards the origin of the raw material.
[6] towards the consumers.

may act as wholesalers as well. Retailers purchase products directly from producers, processors, or distributors, and act as the final players of the marketing system working directly with consumers. Infrastructure for storage, transportation, and water and energy supply services are also important components of SCs.

The linkages between a SC entities can be visualized through SC mapping (see **figure 3**). This could serve as a strong starting point for SC analysis and strategic planning processes (Stager, Perera, and Jayaratne 2012).

Figure 3 *SC map showing different stages of a SC.*



Source*: Adapted from Vroegindewey and Jennifer (2018)*

Research in the area incorporating the full scope of the SC is rare, and sometimes difficult to carry out (Macdonald 2008). Researchers may focus on the "basic SC ", an "extended SC ", or the "ultimate SC". A basic SC typically focuses on the linkages between a single organization and its immediate supplier/customer. The extended SC includes additional entities and multiple organizations, and an ultimate SC incorporates the complete scope, from securing raw materials to delivering products to final consumers (Brindley and Ritchie 2007).

2.2.2 Natural disaster related SCDs

Natural disasters such as hurricanes have been identified by researchers as "one of the major potential risks" in a SC (Blackhurst et al. 2005; Viswanadham and Gaonkar 2009). A natural disaster is "a serious disruption of the functioning of a community at any scale due to hazardous events [caused by nature**]** interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental loss and impacts" (UNISDR 2017).

With the increase in the frequency of natural disasters, more recently, academics have conducted varying research relating to SCDs triggered by natural disasters and climate related events. These natural disaster related SCDs have been examined by conducting a collection of case studies investigating the impact on local and global SCs in specific geographic locations, industries, subsectors, and firms (Altey and Ramirez 2010;Ye, and Abe 2012; Thorpe and Fennell 2012; Puzzello and Raschky 2014; Besedeš and Panini 2014; Barrot and Sauvagnat 2016; National Academies of Sciences, Engineering, and Medicine 2020).

2.2.3 SCD and agriculture

The agricultural sector has been recognized as being particularly vulnerable to natural disasters due to its reliance on weather, climate, land, and water to thrive (FAO 2018). Along with the risk of natural disasters, the agriculture sector faces additional risks due to market volatility, pests and diseases and extreme weather events. Cumulatively, these risks further intensify the impact of natural disasters, costing billions of damages in agricultural production (Ibid). Of all-natural disasters, floods, droughts, and tropical storms affect the agriculture sector the most (Ibid).

Research on the impact of natural disasters on agriculture and its sub-sectors, especially in SIDS, however, has been limited. According to the FAO (2018), in SIDS, data is "not

collected or recorded in a systematic way […] to allow for an in depth understanding of the long-term consequences as well as the mechanisms at play." (FAO 2018; Méheux, Dominey-Howes, and Lloyd 2006).

Additionally, in the field of agricultural SCDs there has been little research with storms or natural disasters as the cause of the disruption (Reardon and Zilberman 2018). This is despite the fact that SIDS are particularly vulnerable (FAO 2018). Over one-quarter of all disasters assessed through Post Disaster Needs Assessments (PDNAs) by the FAO (2018) for example, occurred in SIDS. Compared to only 8% loss and damage caused by a single disaster in agriculture in non-SIDS, SIDs experience 19%. Additionally, disasters affect a larger percent of the population of SIDS (18% in SIDS compared to 8% in non-SIDS countries) (Ibid). FAO (2018) however, attempted to address this information gap by taking a sub-sector-specific approach to analyzing the impact of natural disasters on agriculture with several case studies on SIDS.[7]

[7] The analysis covers 332 disasters in 87 developing countries across Africa, Latin America and the Caribbean, Asia and the Pacific Islands.

2.2.4 Impact/consequences of SCDs

According to Nakano (2011), impact refers to the positive or negative consequences generated by events. The SC impact of natural disasters are typically confined within the affected country as opposed to beyond national borders (WTO 2019). Within a country however, natural disasters affect all stages and sectors of the SC (Altay and Ramirez 2010; Zingbagba 2019). Despite this, the impact of SCDs has not been studied on a SC level but rather at isolated or limited points in the SC (Scheibe and Blackhurst 2017). It is important to note however that within the SC, disruptions rarely occur in isolation. SCDs can propagate throughout the network triggering a "ripple effect"(see **box 1**). The ripple effect occurs when rather than remaining contained to one SC part, the disruption cascades downstream impacting the performance of the SC (Ivanov et al. 2017). This occurs as a result of the connectivity and interdependency which is intrinsic between the entities (Pettit, Fiksel, and Croxton 2010; Scheibe and Blackhurst 2017). The resulting impact may include lower revenues, deliver delays, loss of market share and reputation and stock return decreases (Hendricks and Singhal 2009). Styger (2009) also pointed out that the impact of SCDs inevitably transfer to the real economy and markets of nations involved in the VC.

Box 1. Example of the ripple effect

SBC Economic Intelligence Center (EIC) (2017) used the example of the **disruption caused by the 2011 Japan earthquake** to the Xirallic SC to demonstrate the ripple effect. Xirallic , a metallic paint pigment used in automotive coatings, was only produced at one plant (Merck KGaA) worldwide at the time , in Onahama, Japan.

However, the plant was located in the quake zone of Japan. The resulting shortage of this essential raw material sent ripples throughout the automobile industry worldwide. Xirallic was used in about 20% of all automobile units sold. Automakers worldwide were therefore forced to stop making cars of certain colors. It took months before the plant restarted and deliveries resumed.

Source: SBC Economic Intelligence Center (EIC) (2017)

Disruptions not only spread throughout a SC but spirals, meaning that it continuously increases in severity as the disruption spreads as a result of circular linkages which exist between entities (Eisenberg and Noe 2001; Blackhurst et al. 2011). For example, disruption at the production stage can result in a shortage of inventory. A shortage of inventory means that there would be a shortage of supply and sales. A shortage of sales means that there is less physical capital to invest in inventory.

Andreoni and Miola (2015) summarizes some of them main impacts that climate related events could generate on SC and an economy. These include physical damage to infrastructure, agricultural land, raw materials, products in stock etc., loss of production, costs for recovery, market disturbances, decreased competitiveness in the short term, increased productivity in the long term, increasing poverty, to name a few.

- **Natural disaster impact on the agricultural sector**

A comparative analysis of PDNAs across sectors show that the largest relative share of damages in the agricultural sector is absorbed by the crops sector (over half of the damages and loss). These losses are driven mostly by floods and tropical storms. Crop loss is caused by either sudden shocks or slow-onset events cause by storms, floods, and drought, which reduce annual and perennial crop yields. Longer-term production loss is also common, stemming from fully destroyed perennial crop fields (e.g., fruit trees).

According to the FAO (2018), one of the most direct ways in which natural disasters affect the crop sub-sector is through reduced production. This results in direct economic loss to farmers, which can cascade along the entire value chain, affecting agricultural growth and rural livelihoods." Reduced production is also a strong indication of the scope or scale of an impact. Similarly, Reddy, Singh and Anbumozhi (2016) noted that while a natural disaster related SCD can cause a breakdown at any stage of the flow of products, the most significant

impact occurs where the disruption is at the production level. Apart from reduced production however, there are a number of cascading impacts (see **table 1**). The extent of the consequences however may vary based on the sub-sector and pre-existing factors (see **table 2**). According to the FAO (2018) in the formulation of policies these differences must be understood.

Table 1 *The cascading consequences of natural disasters on the agricultural sector*

Direct physical damage	▪ Damage to crops, seed stocks etc. ▪ Damage to agricultural infrastructure (irrigation, storage facilities, , etc.) ▪ Damage to suppliers of agricultural inputs to financial and business services. ▪ Damage to transport and communication such as farm access road. ▪ Damage to forests and other natural resources that support agriculture.
Losses across the food value chain (backward-forward linkages)	▪ Losses in production ▪ Losses to suppliers of inputs, and lower sales /supply of agricultural inputs(seeds fertilizers, feed, tools, etc.) ▪ Disruption of financial and business services to agriculture (credit, farm schools, etc.) ▪ Lower supply of food and agricultural commodities to processors, traders, markets, wholesalers, and retailers
Losses to manufacturing (agro-industries)	▪ Particularly food and non-food agro-industries, such as food processing and textiles.
The macro-economic impact	▪ Deterioration of country's balance of payments, and increased borrowing ▪ Increased imports and lower exports and lower export earnings ▪ Reduced GDP % ▪ Drop in national GDP ▪ Reduced sector growth in agriculture and manufacturing
Impact on livelihoods, food security and nutrition	▪ Erosion of livelihoods, increased food insecurity and malnutrition
The effect on sustainable development	▪ Compromises the capacity to meet global commitments

Source*: FAO (2015)*

It appears that most evaluations of hurricane or natural disaster impact focus on short term implications in the years directly after the disasters, as opposed to long-term consequences and recovery. Coffman, Makena & Noy, Ilan (2012) for example, describes the long-term impact of disasters as being "hidden", as proving that the impact is caused by a single event becomes more difficult over time. While Coffman et al., (2012)'s case study on hurricane Iniki's impact on the Hawaiian island of Kauai 17 years later, sought to capture the long-term impact, the analysis focused on the macro-economy as opposed to a subsector or SC.

2.2.5 Factors increasing SCD risk, impact, and vulnerability

Lastly, here have been several SC factors which have been considered when examining the impact of SCDs. These factors inevitably increase the severity of the impact of a disruption. Depending on the SC network therefore, the magnitude of the damage may differ, based on specific SC and hazard characteristics (Mentzer et al. 2001; Manuj and Mentzer 2008). **Table 1** below outlines a number of factors considered in the literature, which may increase the impact or vulnerability of a SC to disruptions.

Table 2 Factors considered in the literature which can increase the magnitude of the impact of a SCD.

CATEGORIES	SC Factors	Authors	
Hazard characteristics		WTO (2019), FAO (2015)	▪ Although natural disasters can affect all stages of the SC, the intensity of the impact is dependent on the type of disaster. An earthquake for example might have different effects on the SC than that of a hurricane. Different categories of hurricanes may cause different levels of damage.
SC structure Characteristics	**SC density** (The geographic spacing of entities in a SC.)	**Craighead et al. (2007)**; Falasca, Zobel, and Cook (2008); Reddy, Singh, and Anbumozhi (2016)	▪ Where entities in a SC are clustered within a geographical region, the overall impact of an event on the SC would be significantly increased in these areas.
	SC complexity (Number of entities and flows and their dependence on each other)	Perrow (1999)**; Craighead et al. (2007);** Speier et al. (2011**)** Falasca, Zobel, and Cook (2008)	▪ A less complex SC would have few entities depending on each other and as such the likelihood of the disruption spreading and increasing in severity is lessened. A more complex SC, however, may most likely have more entities and flows affected. Where entities are highly dependent on each other, a disruption will potentially spread faster.
		Falasca, Zobel and Cook (2008)	▪ Highlighted the usefulness of Craighead et al. (2007)'s research. However, the authors noted that whereas lower SC complexity implies that fewer entities might be affected, the relative importance of each entity would be greater thus lowering resilience. ▪ Similarly, whereas a higher degree of SC complexity implies that there would possibly be more disruptions, it also implies additional sources of supply which may increase the overall resilience of the SC.
	SC Node criticality (Importance of each entity)	**Craighead et al. (2007);** Falasha, Zobel, and Cook (2008)	▪ An unplanned event disrupting a SC with many important entities is likely to be more severe than a SC with fewer critical entities. For example, A SC with a sole supplier can lead to more severe disruptions for the SC.
SC Vulnerability	**Industry/Product/process characteristics**	Macdonald (2008)	▪ Product characteristics include for example, the life cycle of the product, perishability, manufacturing costs and sustainability of the product. These factors can influence resilience and the intensity of a shock.
		Reardon and Zilberman (2018)	▪ The greater the perishability of the product, (the need for fast delivery and/or cold storage), the greater the vulnerability to climate shock.

	Physical capital	Reardon and Zilberman (2018)	▪ Access to physical capital is a key element in the vulnerability of SCs to climate shocks. It enables SC managers and participant to "off-set climate-imposed costs with economies of scale". Economies of scale refers to the cost reduction which occurs when companies increase production.
	Location specificity (the interchangeability of places to produce or handle a crop)	Reardon and Zilberman (2018)	▪ Where a product is location specific, buyers in the SC are usually "held hostage" to sourcing from a farm zone or point due to specialized resources. Similarly, farmers may also be dependent on specific buyers. Both parties are therefore forced to undergo shock resulting from the disruptive event. ▪ Menz and Knioscheer (2003) highlights that farming systems are usually location specific in that, they cannot be efficiently implemented over geographical areas without adjustment to local needs and conditions.
	Input specificity (the extent to which companies can find substitutable inputs from alternative sources)	WTO (2019); Barrot and Sauvagnat (2016)	▪ The level of input specificity in a SC can increase the extent to which natural disaster impacts a SC. Where inputs are not easily substitutable the effects along the SC spreads quickly affecting more entities.
SCD management	**Response/mitigation**	Andreoni and Miola (2015)	▪ Effective disaster responses can influence both the magnitude of costs and the propagation of the negative effects. ▪ The role of effective leadership, international agreement and collaboration are important. The ability and power of leaders to make timely decisions and to plan and implement effective strategies can reduce the magnitude and costs of hazard events.
	Recovery capability and warning	Craighead et al. (2007)	▪ An unplanned event that disrupts a SC which has the ability to respond quickly and effectively (whether proactively or reactively) is less likely to be as severe as that of a SC with little or no capability to recover. ▪ The availability of resources in and of itself is insufficient, effective responses require "coordination", "cooperation" and "communication" amongst the different entities in the SC. ▪ Also, the quicker that a SCD is identified and is communicated to SC participants the less severe it may be.

	Prevention and preparation	Craighead et al. (2007)	▪ Planning also has a role to play in recovery capacity. Ideally recovery capacity should be by nature proactive. This means that actions which should be triggered after a potential disruption should be defined or mapped out to allow for a quicker response and hence lessen on the severity of the SCD. ▪ A few examples of proactive strategies include having strategically placed excess transport within the SC or having SC managers trained in SCD management.
		Andreoni and Miola (2015)	▪ Suggests that creating a culture of awareness, gaining international support and planning adaptation strategies are element to increase resilience and to prepare. ▪ Additionally, scientific knowledge and research can be useful to identify sensitive geographical areas and to forecast certain types of events.
SC resilience	**Redundancy**	Ivanov and Wendler (2017); Reddy, Singh and Anbumozhi (2016) ;National Academies of Sciences, Engineering, and Medicine (2020)	▪ A main characteristic of resilient SCs is redundancy, that is, the availability of additional inventory, manufacturing and transport capacity, infrastructure, storage and handling facilities. ▪ Regular inventory and buffer stocks for certain food products help to reduce the impact of disruptions
`	**Flexibility**	Ivanov and Wendler (2017)	▪ Another characteristic is flexibility refers to various strategies in place to ensure, "quick adaptation of production lines, transportation modes, as well as polyvalent workforce."
		Andreoni and Miola (2015)	▪ Having different suppliers for the same commodity is an important in increasing the flexibility of the SC this increasing resilience following an unexpected event.
	Adaptive capacity	Andreoni and Miola (2015)	▪ Differentiates between resilience and adaptive capacity. ▪ Whereas resilience refers to the short-medium term ability to recover, adaptive capacity refers to "long term or planned strategies including all the structural changes that have to be adopted to overcome adversities". ▪ These include crop substitution, land allocation, inventories, substitution possibilities, transport and infrastructure resilience or flexible managements which could minimize impact generated (Reidsma et al., 2010; Smith and Olesen, 2010)
	Market based insurance	WTO (2019)	▪ Empirical studies from previous disasters show that countries with more mature insurance markets recovered faster and even realized economic benefits following a disaster. Mostly the uninsured part of catastrophe-related losses that drove the following macroeconomic losses.

CHAPTER THREE

RESULTS AND DISCUSSION

3.0 Results and Discussion

This Chapter discusses the results of the case study utilizing the methodology and the theoretical framework of supply chain disruption (SCD). This theoretical framework was used to guide the data collection and analysis. It requires mapping of Grenada's nutmeg supply chain (SC); an examination of the source of the disruption and the pre-existing factors which may have influenced the extent of the impact; as well as the consequences generated.

3.1 Mapping Grenada's nutmeg SC

The first objective of this research is to map Grenada's nutmeg SC, in order to identify the main participants involved, their linkages and contributions. This is an effective starting point in examining the sensitivities and the areas most impacted due to the hurricane disruptions (Styger, Perera, and Jayaratne 2012).

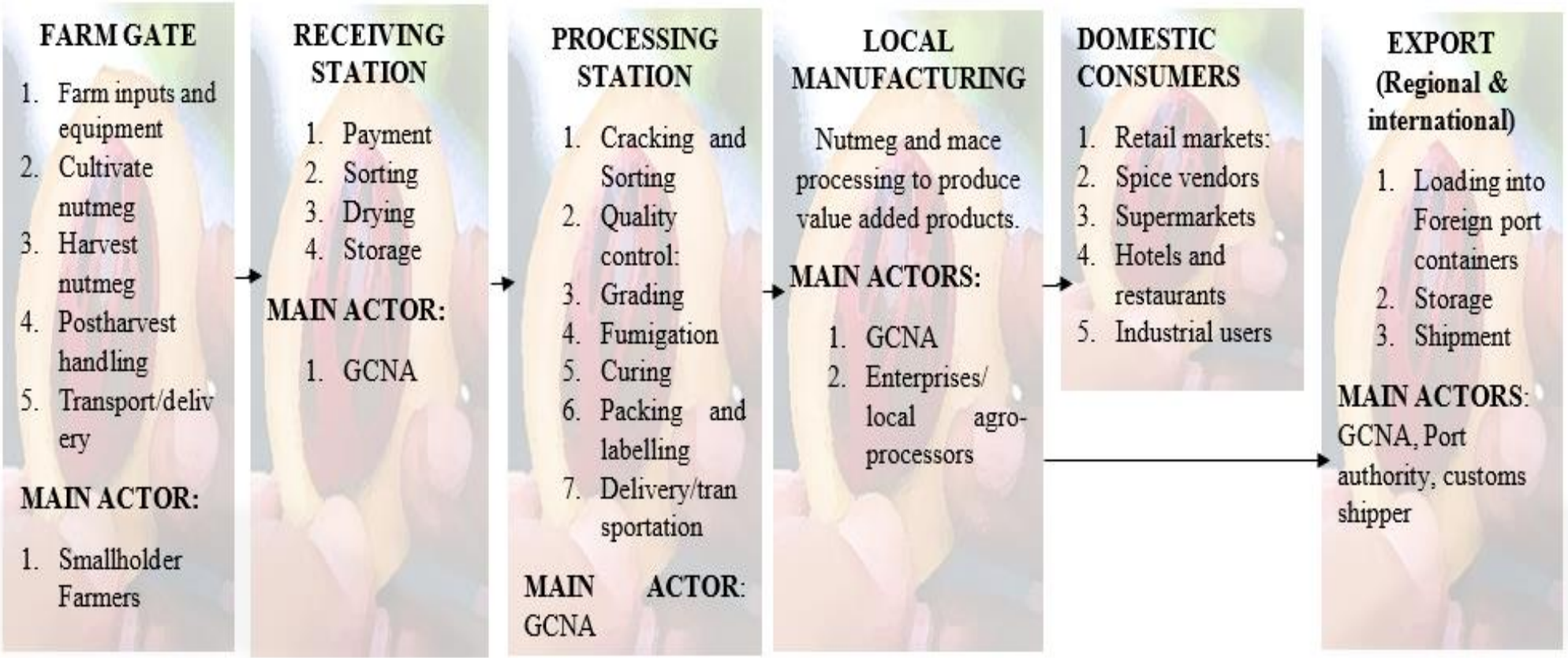
According to Fries et al. (2013), the success of Grenada's nutmeg industry depends on the entire SC. This includes not only farmers, but suppliers of farm input and equipment, processors, exporters, truckers, shipping companies, port authorities, spice vendors, supermarkets, hotels and restaurants and industrial users, to name a few (Ibid). The different entities along the nutmeg SC play in some way, a value- added role in the supply of nutmeg and nutmeg products locally, regionally, and internationally. **Figure 4** below illustrates Grenada's nutmeg SC, mapping the flow from the suppliers to the consumers.

This study focuses mainly on the impact of the hurricanes on the GCNA (Grenada Cooperative Nutmeg Association) and its immediate suppliers, the farmers. The market structure for nutmeg in Grenada is such that there is one principal exporter, GCNA. The

GCNA, a public entity, is a cooperative of nutmeg farmers[8], developed and protected by law[9], for the purposes of buying, processing, manufacturing, distributing, and exporting nutmegs (MOA, Grenada 2009).

[8] The GCNA's Board of Directors has six farmer representatives and three government appointed representatives.
[9] Cap 25 of the Nutmeg Industry Ordinance, No. 8 of 1946, as amended by Ordinance Nos. 8 and 29 of 1947 and 10 of 1949 (Cap. 215 1990 Revised Laws of Grenada)

Figure 4 *SC map of Grenada's nutmeg industry.*



Source: *Author's elaboration adapted from Marcelle (1995); Singh, Mujaffar, and Sankat (2003); Fries et al. (2013) and Fletcher (2016)*

Farm gate to the Receiving Station

The first stage of the SC involves farmers who plant, harvest (collect, wash and de-mace)[10] and transports fresh, green, wet, partially dry, or dry nutmeg to a GCNA nutmeg receiving station. The frequency with which nutmegs are harvested are dependent on a number of factors. These include, "the availability of labour, location of the field , the level of production, and the price offered to farmers" (Marcelle 1995; MOA, Grenada 2009; ITC 2010).

At the receiving station, the nutmeg is emptied into sorting trays and inspected in order to weed out broken, discolored, or rotten seeds. The unwanted seeds are returned to the delivering farmer. The remaining seeds are placed into a receiving bag. It is then weighed and recorded in the farmer and station notebooks. The farmer is then given a bill and is paid a rate per pound. This is entered in the reweighed book at the station.

Subsequently, nutmegs are dried on drying beds/trays for a period of approximately 4-8 weeks (depending on the season) and are stirred manually. The energy used for this process comes from the sun and the warm circulating air. After 6 weeks, the nutmeg is inspected for moisture. If the inspection is satisfactory, the seeds are scooped into bags and dried nutmeg in shells are stored until an order is received (Marcelle 1995; Singh et al. 2003; Fries et al. 2013; Fletcher 2016).

Processing station

Upon receipt of an order, the nutmeg is brought to a processing station for further drying, cracking, sorting, and bagging. The cracking is mostly done by a cracking machine. Sorting is done manually with workers most of which are women. The workers sort, shell and compartmentalize the nutmeg into four products consisting of: whole kernels, cracked kernels

[10] De-mace means to remove the mace from the nutmeg.

or pieces, seeds with unbroken testa and shells. After careful quality control, nutmegs are packed into jute bags. These bags are transported to the port by GCNA trucks for loading into containers. The mace is bagged and separated into grades (grade 1,2 &3 based on quality) and after three months curing, the mace is bagged accordingly, fumigated, and ready for export (Marcelle 1995; Singh et al. 2003; Fries et al. 2013; Fletcher 2016).

Manufacturing & local distribution

GCNA is the principal player in manufacturing nutmeg and mace products. In addition to selling the raw nutmeg, nutmeg is converted into commercially viable marketable products in processing and distillation plants. These products include nutmeg and mace oil along with other secondary and tertiary products such as: jams, jellies, and ground nutmegs under the brand "Island Spice" (Singh et al. 2003).

Prior to 2004, production was derived mainly from four companies namely: Grenada Co-operative Nutmeg Association (GCNA), W&W Spices, Noelville Ltd.[11] and De La Grenada Industries (Ibid). These products are distributed and sold locally and internationally. Locally, there is a small retail market for packaged ground nutmeg, spice mixes, processed products, and food preparations. Local retailers include spice vendors, local supermarkets, hotels, restaurants, and industrial users (Rodriquez 2003).

Export

This stage of the SC involves a chain of actors including the GCNA, Port Authority, Customs Shipper, to name a few (Fries et al. 2013). Both nutmeg and mace are traded regionally and extra-regionally. Exports are done through a few intermediaries/agents or brokers. These agents finalize the transaction and as such sales to importers are not direct (George 2011). Brokers trade

[11] Producers of Nut-Med Instant Pain-Relieving Spray (NUT-MED™)

in whole nutmegs and mace and are also involved in further processing – grinding, packaging and distribution. Some are also involved in the distillation of nutmeg oils (Singh et al. 2003).

Once the products are packaged, shipments of nutmeg are transported on flat-bed trucks to the port, where they are then loaded into containers by port authority employees. Containers are fumigated and bags are packed between layers of craft paper to absorb humidity and minimize potential damage from condensation and mold. Facilities are open-air for nutmeg, which may be stored for up to 15 weeks prior to loading and shipment (Fries et al. 2013).

When nutmeg products arrive at the port, they are loaded by port workers directly into containers for maritime shipment by shipping companies. Shippers must abide by temperature and humidity parameters in order to mitigate mold buildup or moisture damage (Ibid).

3.2 Overview of the SCD source: hurricanes Ivan (2004) and Emily (2005)

Grenada, like most SIDS, is prone to experiencing tropical cyclones, storms or depressions between June 1st and November 30th each year (Caribbean Community Climate Change Centre 2015). Between the years 1950 to 2020 Grenada was impacted by 3 hurricanes that passed within 50 Km of its capital city, St. Georges. Since Janet in 1955 Grenada went approximately 50 years without having been impacted, until hurricanes Ivan and Emily (Ibid). **Table 3** provides a broad overview of the hurricanes.

The agriculture sector especially was devastated, the majority of the damage being attributable to crops and farm roads (Roberts and Shears 2008).[12] The nutmeg crop subsector in Grenada, therefore, has faced several challenges relating to three main devastating hurricane hazards (Roberts and Shears 2008). In 1955, hurricane Janet destroyed about 80%-90% of nutmeg plantations devastating Grenada's economy (Crask 2009). Pre-Janet levels of nutmeg production were only regained 20 years later around the mid 1970's (Ibid). Like hurricane Janet, hurricane Ivan destroyed approximately 90% of the nutmeg crop (OECS 2004).[13] After hurricane Ivan, while mitigation efforts were in progress, hurricane Emily passed, inflicting further damage to "an already weakened and vulnerable nutmeg sector." (OECS 2005).

[12] Costs after hurricane Ivan in 2004 for example, amounted to EC$ 101 million in direct and indirect damages by hurricane Ivan (OECS 2004). Hurricane Emily in 2005 amounted to an additional EC$35.51 million damages (OECS 2005).

[13] This figure was modified to 70 % by the OECS team during the assessment of damages resulting from Hurricane Emily (OECS, 2005).

Table 3 Overview of hurricanes Ivan (2004) and hurricane Emily (2005).

HAZARD	HURRICANE IVAN	HURRICANE EMILY
Time	Monday, September 7th, 2004; twenty-eight or twenty-nine deaths (OECS 2004; Boatswain 2005: 3)	Thursday, July 14th, 2005 (10 months after hurricane Ivan); One death (OECS 2004)
Magnitude	The hurricane hit directly, across the middle of the main island as a category 3 hurricane with severe winds of 115mph and rains passing directly for over twelve hours. At their peak, wind speeds measured 193 km/h with gusts of over 233 km/h. 133 mm of rainfall was recorded in Grenada during Ivan which was roughly 70% of the total rain that fell during the entire month.	Hurricane Emily hit Grenada as a very strong category 1 system. It packed sustained winds of 90 mph (150 kmh/hr) and headed west of Grenada at about 18 mph (30 kph). Unlike hurricane Ivan there was a total amount of 73.1 mm during that ten-hour period. (Very little rain fell during this time).
Location & most affected areas	Whereas mainland Grenada and all its dependencies were struck; the most affected area was the south-east of the main- land and the least affect area was the northern half of Carriacou. The damage was most intense in the parish of St. Andrew (60 % of total damage), St. David (20%), St. Johns (10%), St. Georges (5%) with St. Mark, and St. Patrick (5%). These parishes consist of 80% of the total population. The coastal areas were also inundated by the storm surge (OECS 2004).	Unlike in 2004 where hurricane Ivan Emily struck hard on the northern sphere of the island. Out the seven parishes which were impacted therefore, St. Andrew, St. Patrick, and Carriacou and Petit Martinique were most severely affected. These parishes cumulatively contained 40 % of the total population.
General impact	Hurricane Ivan affected every sector of Grenada's economy and devastated the island's limited productive capacity and resource base. A damage assessment estimated damage over US$800 million or twice Grenada's Gross Domestic Product (GDP) (World Bank 2005) Millennium Development Goals (MDGS), noted that Hurricane Ivan had likely set back the country's development by ten (10) years.	While damage caused was not as widespread as Ivan, hurricane Emily affected mostly the agricultural productive sector disrupting its path of recovery (OECS 2005). The total damage (direct and indirect) caused by hurricane Emily is estimated to be about EC$ 140.0 million, that is about 12.9% of the current value of GDP. The bulk is concentrated in direct damages. These account for 87% of the damage or 11.2% of GDP (OECS 2005).

3.3 Impact to and characteristics of nutmeg crops

The nature of the nutmeg SC is such that there is a high level of input specificity.[14] This means that the SC network is dependent on the input of a special species of "West Indian" nutmeg, grown in Grenada (Singh et al. 2013). It is therefore important to examine the nutmeg crop's characteristics and vulnerabilities, as this has relevance in explaining the intensity of the hurricane's impact and the resilience of the SC (Macdonald 2008).

3.3.1 Nutmeg crop characteristics driving vulnerability

Figure 5 *Annotated diagram of nutmeg fruit*

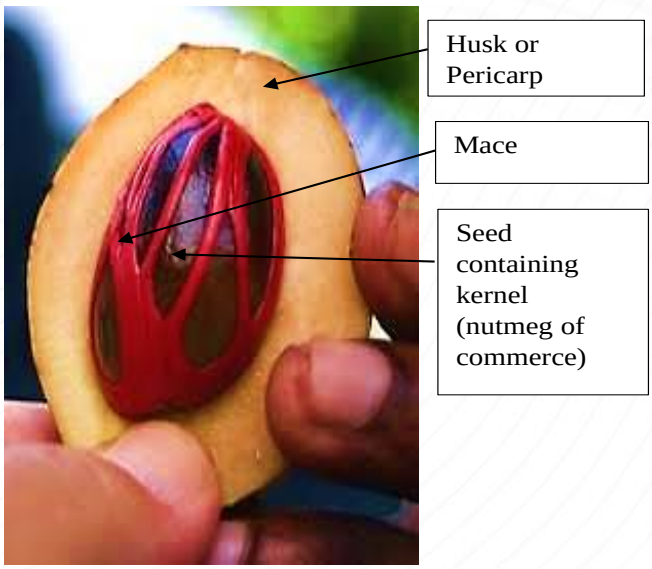


Photo by Mila Kinkova, ***Source:*** *Grygus, Andrew (n.d)*

Nutmeg (Myristica fragrans) is an aromatic perennial evergreen spice tree, which produces the nutmeg fruit. The nutmeg fruit is a drupe which when mature, splits its yellow fleshy outer covering in two halves, exposing the kernel. The kernel is enclosed in a deep brown shell. Surrounding the shell is a crimson-colored aril called the mace, which grows from the base of the seed (see **figure 5**). From the fruit, two separate spices are obtained, nutmeg (the seed in the pericarp) and mace (colored aril). Being a perennial crop, nutmeg has been referred to as the "spice tree most at risk or vulnerable to adverse impacts of climate change and extreme weather events" (ICCAS 2017).

[14] Recent studies such as Barrot, J. N., & Sauvagnat, J. (2016), Calvarlho et al. (2016) and Kashiwagi et al. (2018) have shown that the extent to which natural disaster shocks are amplified in a supply chain network depends on the level of input specificity.

Life cycle of the nutmeg crop

Due to the unique lifecycle or lengthy gestation period for nutmegs, damage as a result of the hurricane was particularly debilitating(UNDP and OECS. 2007). The nature and the growth cycle of nutmeg crop were factors which influenced the resilience or adaptive capacity of the nutmeg SC. Nutmeg is a perennial crop. Perennial crops are typically considered as those that are permanent requiring decades of growth cycles before fruit is produced. Moreover, perennial crops are valued for their total production and the quality of the harvested product (Hatfield and Walthall 2014). However, since by nature crop production is long-term, after establishment, production is tethered to a specific geographic area. Additionally, perennial crops such as nutmeg require specific growing conditions. In Grenada, cultivation is in the lowland tropical rainforest and in mountainous areas which cater for the conditions for nutmeg cultivation (Singh et al. 2003). The nature of perennial crops such as nutmeg, reduces flexibility for cultivation and makes these crops less resilient and more vulnerable to climate related events.

Nutmeg is a year-round crop with peak harvesting periods from April/June to September/October in Grenada (Renwick Nd; Fletcher 2016). This coincides with the hurricane season which is between June 1 and November 30th each year (CCCCC 2015). A typical nutmeg tree takes 7 – 10 years (Singh et al. 2003) or more recently quoted 4-6 years (ICCAS 2017) to produce its first fruit. Commercial production commences at about the 7th – 8th year and by age 15 – 20 years the tree will reach its maximum productivity (2,000 pounds nutmegs/year) and attain a height of 40-50 feet. Fruiting continues for another 40 to 80 years (Singh et al. 2003). Therefore, the nutmeg crop is characterized by a long gestation period between "the initial inputs and first output, followed by an extended output flowing from the

initial investment, and finally gradual deterioration of the productive capacity after 70 years of age". (French and Matthews 1971; Marcelle 1995; Zeweldi 2010).

Furthermore, the nutmeg plant is dioecious, this means that there are separate male and female plants and biologically, only female plants can produce fruits. Traditionally therefore, farmers must wait till plants are five to seven years old, at the time of flowering in order to find out the sex of the plant. Approximately 50% of plants are usually male and the males are then thinned out, leaving one male for every ten females (New Argiculturist On-line n.d.). The reproductive requirements of the plants further hindered efforts to grow nutmegs at pre-hurricane levels. This is as many farmers have waited to find out the sex of the tree only to then discover the tree is male, resulting in a total loss of their investment. After the hurricanes for example, unintentionally too many male trees were replanted (ITC 2010).

Quality and vulnerability to weather conditions

Grenada's nutmeg has a competitive advantage due to its low aflotoxin and safrole levels and the unique quality of the product (ITC 2010). Additionally, in the international market, suppliers must adhere to international quality standards to ensure that there is consistency in high quality production (MOA, Grenada 2009). A factor influencing the intensity of the hurricanes impact on the nutmeg crop has been its sensitivity to changing weather patterns and high moisture levels.

Nutmeg is not a highly perishable crop as compared to other agricultural crops such as bananas and soursop. However, it is less resilient and is sensitive to climate related factors such as air temperature and humidity. In order to maintain the grade one nutmeg driving the industry's competitive advantage and to maintain high volumes of nutmeg production, nutmeg must be kept in relatively tropical conditions. Furthermore, the nutmeg tree has very shallow

roots which allows them to be easily uprooted by strong winds and rainfall making it vulnerable to wind damage (ICCAS 2017).

No. 1 mace quality particularly, depends solely on the speed of collection and delivery to the Receiving Stations (ITC 2010). Exposure to high moisture levels can reduce the viability of the nutmeg or mace contributing to reduced production (MOF, Grenada 2018). To maintain quality, farmers use a bamboo to pick the fruit from the tree as opposed to allowing it to fall to the ground where there is a risk of mold infection (Ibid). In doing so, the mace would be "firmer, free of mildew (black, white or grey) and mold and able to sustain more handling" (Fletcher 2016). However, after the hurricanes, farmers were unable to access farms to collect nutmeg leaving nutmeg exposed to risk of mold. Additionally, 40 % of the GCNA's nutmeg reserves were affected by water damage and thusly downgraded (World Bank 2005).

Susceptibility to "Wilt Disease"

Along with the existing vulnerabilities of the nutmeg crop, the subsector has been susceptible to another crippling challenge, the nutmeg wilt disease (MOA, Grenada 2009). This disease has threatened the resilience of nutmeg cultivation, further exacerbating the damage inflicted by the hurricanes. Nutmeg wilt disease has been one of the highest profiled diseases in nutmeg locally since the 1970's (FAO 1995).The effect of nutmeg wilt disease is the gradual wilting of a plant and dieback of the roots. According to MOA, Grenada (2011), after hurricane Ivan, remaining fields especially in the northern areas were attacked by the nutmeg wilt disease destroying productive trees. In 2008, the disease caused an average loss of 30 % of nutmeg trees (MOA, Grenada 2009). As the nutmeg sub-sector struggles to increase production, the nutmeg wild disease continues to have an adverse impact on recovery.

3.3.2 Impact to nutmeg crop

Taking into consideration the pre-disruption vulnerabilities of the nutmeg crop, the damage to the subsector has been a major source of losses for the nutmeg SC in the short and long-term. Damage to nutmeg sub-sector amounted to US$11.2 million (MOA, Grenada). Hurricane Ivan reduced 90% of Grenada's nutmeg supply capacity, 10% of the total estimated 555,000 nutmeg trees not being damaged (OECS 2004; James 2015). This was as a result of extensive damage to the nutmeg tree stock. 30% of the nutmeg trees were completely uprooted, about 30% partially uprooted while 30% remained upright but lost branches and leaves (James 2015).

An OECS reassessment of the damage to the industry in 2005 however, revealed that there was a 70% loss contrary to the 90% previously estimated. The remaining 30%, (3,600 acres) were expected to produce 2,880,000 lbs. of green nutmeg in 2005 (OECS 2005). World Bank (2005) estimates differ slight stating that up to 85 % of the nutmeg crop was damaged, with 60 % of the trees completely destroyed.

While efforts were being made to mitigate the impact on the nutmeg crop from hurricane Ivan, hurricane Emily inflicted further damage resulting in damage to 11.6 acres of the remaining post-Ivan acreage (OECS 2005). Evidently, the damage caused by hurricane Emily was not as widespread and devastating as hurricane Ivan. The scope of damage was due to the toppling of trees and the loss of set blossoms and mature nutmeg (Ibid).

The 2012 Grenada Agriculture Census (GAC 2012) show that at census date there were 198,798 bearing nutmeg trees, the equivalent of 2,557 acres. This was 36% pre hurricanes levels. Given the perennial nature of the nutmeg crop, cultivation has not been rehabilitated to pre-hurricane production levels as of 2020. This is in line with observations from the aftermath of hurricane Janet in 1955, in which it took approximately 25 years to rehabilitate the nutmeg industry to pre-hurricane production levels (Zeweldi 2010).

3.4 Impact at the farm gate and characteristics driving vulnerability

Grenada's nutmeg SC is a less complex SC network. Falasca et al. (2008) noted that while Craighead et al. (2007)'s premise that a SC with a less complex SC would lessen the severity of a disruption, the relative importance of each node would be greater thus lowering resilience. Similarly, whereas Grenada's nutmeg SC is a less complex network with few nodes, the relative importance, and interdependencies of each node in the nutmeg SC are high. The impact of the hurricanes on the farmers or supplier of nutmeg therefore affected the entire chain.

The first macro area of impact which will be examined therefore, is the impact on the suppliers in the chain. To reiterate, the market or governance structure of the nutmeg SC is such that there is only one principal exporter for the nutmeg product. As such, all nutmeg producers are required to be registered members of the GCNA (James 2015). Nutmeg farmers are therefore dependent on the GCNA to purchase unprocessed nutmeg. Likewise, the GCNA is dependent on sourcing nutmeg from the farmers for manufacturing and export. According to Reardon and Zilberman (2017), location specific products where buyers are "held hostage" to sourcing materials from a specific supplier or zone, increases the vulnerability of a SC to shocks. This is as both parties are "forced to undergo shock from the disruptive event". Similarly, the farmers as well as the GCNA were forced to undergo the shock from the hurricanes.

Economic vulnerability of nutmeg farmers

According to Reardon et al. (2018), the robustness of physical capital is a key element in the resilience of SCs to climate shocks. This is as it enables SC actors to off-set imposed costs with economies of scale. In the nutmeg SC, farmers require finance for inputs such as seeds and fertilizers; for labor to harvest nutmeg, and for infrastructure such as rural transport systems .

The economic vulnerability of nutmeg farmers, therefore, has been a factor which has impaired the ability of farmers to recover from the disruption.

Nutmeg farming in the SC has been characterized by many growers, the majority of whom are small, low resource producers (ITC 2010). For many farmers, the proceeds from the harvest of nutmeg were their only source of revenue, providing "continuous income throughout the year" and a source of retirement income (World Bank 2005; ITC 2010). The nutmeg tree as such, has been referred to as the "retirement tree" as it was at one time a better option than most pension funds(New Argiculturist On-line n.d.). Many of these farmers were from the rural areas where the nutmeg crop was concentrated (north eastern parishes of St. Andrew and St. Patrick). The total populations of these parishes made up 24% and 10.4% of the poor in Grenada (OECS 2005).

The need for market-based insurance for production loss linked to the hurricanes and access to finance became apparent. Nutmeg farmers had no insurance to cover the damages and future earnings they might have received. This is as there was no farmers' crop insurance scheme at the time and still at present (Antoine, Martin[15], E-mail interview by author, November 4, 2020).[16] The lending environment for agriculture has suffered and continues to suffer from a reluctance of agencies and financial institutions to inject capital (IFAD 2009; Ruete 2015). This has been due to the risk factors inherent in agriculture such as, production risks linked to natural hazards as well as the inability of farmers to provide collateral or their lack of financial freedom (IFAD 2009). According to FAO and Government of Grenada (2011), factors affecting the environment for agricultural lending in Grenada include the failure of farmers to demonstrate their historical farm income, both because of the absence of farm

[15] Mr. Martin Antoine is the Operations Officer at the GCNA.
[16] Notably, recently in 2020, the Government of Grenada has highlighted its plan to develop and pilot an agricultural risk insurance product for nutmeg production for the 2020 hurricane season (Government of Grenada 2019).

records and the limited use of bank accounts by farmers; high costs, poor availability, and low productivity of labour; incomplete land registration, a lack of land titles, and illegal land tenure and disputes over ownership.

Consequentially, farmers lacked the financial support to replant crops and restart cultivation (World Bank 2005). Additionally, several farmers were unable to maintain their loan payments from the commercial banks and the Grenada Development Bank (GDB), the main source of loan financing for farmers. As such, they were in default (Lord, Interview with Fletcher 2017, March 19, 2015).

Age

The nutmeg industry is traditionally a family-oriented business. Many of these farmers are older generation farmers, the majority being in their 60's (ITC 2010). In fact, according to an IFAD (2009) assessment of the farming population in Grenada, Grenadian farmers tended to be above the average age of many other countries. The demographic profile of the sector, therefore, has been deemed as a critical social vulnerability factor for the nutmeg industry in Grenada (Simpson et al. 2012). This influenced the recovery capacity of farmers.

The advanced age of the farmers meant that many were unable to clear and replant their fields as compared to the young farmer who were able to respond quicker (Antoine. E-mail interview by author, 2020). Additionally, many farmers felt demotivated to remain with nutmeg production after the hurricanes. "Older farmers especially were reluctant to reinvest in nutmeg tree crops which would not yield a full crop in less than 5-7 years" (FAO 2011).With the reluctance of youths to pursue farming, many farms were abandoned, nutmeg was left uncollected in the fields and many nutmeg trees were left to die (World Bank 2005; ITC 2010).

SC Geography - Concentration/location of farmers

According to Craighead et al. (2007), where many participants in a SC are clustered within a geographical region, the net impact of an event on the SC would be significantly increased in these areas. Similarly, in the Grenada's nutmeg SC, farmland for the nutmeg and farmers is concentrated in the north eastern parishes of St. Andrew and St. Patrick, where the rich volcanic soil and rainforest areas are located. Coincidentally, hurricane Ivan's damage was most intense in the parish of St. Andrew (60 % of total damage). These areas accounted for approximately 64% of production (MOA, Grenada 2008). As such, the net impact of the hurricanes was significantly increased in these areas, destroying most of the nutmeg plants, and increasing the severity of the disruption.

Figure 6 *Map of Grenada*

Source: Mapsopensource.com n.d)

3.4.1 Impact at the farm gate

The hurricanes had an immense negative impact on the farming community both in the short and long term. Along with the estimated 65% to 85 % minimum and maximum losses incurred by the farmers, due to nutmeg trees damage (Zeweldi 2010), there was damage to: farm inputs, farmland, farm roads and a decrease in the overall number of actual supplying farmers in the long run.

Damage/ disruption to propagation Stations

Following the passage of the hurricanes, tree crop nurseries and government-owned plant propagating stations for nutmeg seedlings and plantlets were left uncultivated or semi-abandoned due to the shortage of planting materials. More specifically, two of the three main propagating stations were neglected. Consequently, there was a lack of planting materials for farmers to begin replanting crops (IICA 2009).

Damage to farmland/forestry

Most nutmeg farmers had less than in average 5 to 7 acres of land and no more than 300 to 500 farmers had holdings larger than 10 acres (ITC 2010). Few farm locations had pure nutmeg trees as most farms were heavily intercropped with traditional crops such as cocoa and banana (Lazare, Antoine, and Samuel 2001). The aftermath of the hurricanes was such that there was extensive damage to farmlands and forestry needed to cultivate nutmeg. (OECS 2005).

Rains which accompanied hurricane Emily reduced the productive capacity of soils through excessive erosion and loss of topsoil (OECS 2005; World Bank). Runoff as a result of rainfall during Hurricane Emily, has been listed as " one of the most significant effects of hurricane Emily on the Ivan attenuated agriculture sector, in terms of both its short and long run implications" (OECS 2005). Additionally, heavy layers of silt and undesirable materials were deposited on lands. This made farmlands inaccessible to farmers, impeding efforts to collect and replant nutmeg crops and cultivate nutmeg for the GCNA and extending the rehabilitation process (Antoine. E-mail interview by author, 2020). Farmers as such endured major losses due to the harvesting delays (ITC 2010).

Damage to farm roads

Farms roads as well as roads connecting rural areas and urban areas are especially important, as it provides access to farms for the cultivation of nutmegs and to stations for delivery. Nutmeg cultivation occurred predominantly in rural areas where roads were of poor quality. These roads became inaccessible when the hurricanes occurred. During hurricane Ivan, 150 miles of farm roads were damaged. The damage resulted from fallen trees, clogged drains and culverts, destruction of the road base and surface, the estimated value of reconstruction being EC$28,633,610 (OECS, 2004).

Decrease in the number of suppliers

Prior to the hurricanes the number of nutmeg farmers were already in decline. However, there were approximately 7000 active nutmeg farmers (ITC 2010; GCNA data). In addition to the aforementioned vulnerabilities of farmers, farmers faced a number of challenges such as: inadequate financing and support for the clearance of land and farm inputs, high labour costs, a scarcity of planting materials and nutmeg wilt disease (MOA, Grenada 2009). After the hurricanes, according to a land utilization survey conducted after the hurricanes, four out of every ten farmers intended to reinvest in nutmeg production (Shemer 2012). Following this many farms were actually abandoned and employment in the sector declined. From 2005 - 2010, the number of active nutmeg farmers amounted to 2,500 as compared to the 6,577 farmers prior to 2004 (Antoine. E-mail interview by author, 2020). As of 2019, the number amounts to 3,094 farmers, which is less than half the number of active nutmeg suppliers (Antoine. E-mail interview by author, 2020).

3.4.2 Disaster/Disruption management

According to Craighead et al. (2007), an unplanned event that disrupts a SC which has the ability to respond quickly and effectively (whether proactively or reactively) is less likely to be as severe as that of a SC with little or no capability to recover. Ideally however, planning should be proactive in order to lessen on the severity of the SCD (Ibid).

In Grenada's nutmeg SC, the majority of nutmeg farmers did not have a properly developed contingency plan to deal with the aftermath, and as such planning was reactive. Historically in the region, hurricanes were infrequent, as such, there was not a culture of awareness or preparation (World Bank 2018). Due to the lack of physical capital and market-based insurance and the age of many farmers, their recovery capacity was weak. Additionally, many farmers had to prioritize the renovation of their homes and properties (George 2011). Many farmers therefore immediately after the hurricanes, looked to the GCNA and the MOA for assistance to rehabilitate their fields (Antoine. E-mail interview by author, 2020).

The role of effective leadership and response

The role of effective leadership by the government of Grenada and the GCNA, which is the governing body for the SC, international aid and collaboration, therefore, was important. According to Andreoni and Miola (2015), the ability and power of leaders to make timely decisions and to plan and implement effective strategies, can reduce the magnitude and costs of a hazard.

While a number of initiatives were undertaken immediately after the hurricanes, with regards to the nutmeg sector, according to IICA (2009) a planned approach to the revitalization of the nutmeg industry was lacking until the later part of 2008. In 2008, a strategic planning workshop was held to develop a Strategic Development Plan for 2008 to 2012. By 2010, with the technical support of the ITC, FAO, UNCTAD, the World Bank and

other international donors, a comprehensive "Nutmeg Sector Development Strategy" was developed. It aimed to assist with the revitalization of the subsector, using the VC approach (MOA, Grenada 2009).

Mitigation efforts undertaken after the hurricanes

Nevertheless, several strategies were undertaken prior to the hurricanes which served the lessen the impact. According to the UNDP and O.E.C.S. (2007), as quickly as possible after hurricane Ivan in 2004, farmers were given help to clear debris from nutmeg trees and to prepare the land for replanting. This was coordinated by the GCNA under a project named "Operation Salvage" (Antoine. E-mail interview by author, 2020). The UNDP and OECS (2007) stated that if not for these early measures, the hurricane's impact on the nutmeg trees would have been greater. This is as the early clearing of debris from nutmeg trees helped to save some of these trees from further damage so that they remained productive. Additionally, Laborer's were assigned to assist farmers in their clearing and recovery efforts through a 'cash for work' programme, in which profits from the sale was to be shared among both parties (Antoine. E-mail interview by author, 2020).

In 2005 however, hurricane Emily disrupted the recovery process. Immediately after, nutmeg was salvaged from the fields. However, efforts to revitalize the sector was not done in an "organized manner". According to Government of Grenada Prospectus (2007) and the Ministry of Finance (MOF), Grenada (2006) in 2006, the Ministry intensified its effort to revitalize the sector in a more "organized manner". The Agricultural Enterprise Development Programme provided soft loans to over 430 farmers involved in the rehabilitation of nutmeg. In addition to this the programme provided monetary support for drainage; for the purchase of fertilizer which was distributed to farmers; for purchasing irrigation equipment and supplies and for training (Government of Grenada Prospectus 2007).

By 2008 however, many estates were still not properly cleared (only 40% was cleared in 2009) (IIAC 2009). As such, many farms remained inaccessible. Farms that were cleared with the help of the government remained unproductive and there was a lack of farm inputs and aid for farm workers.

In 2008 and 2009 however, the GCNA with the assistance of the government and international aid implemented several activities to revitalize the nutmeg industry (MOA, Grenada 2009). Firstly, in collaboration with Grenada's Ministry of Agriculture (MOA), a number of high-quality nutmeg plantlets (of which 90% were female plants) plantlets were propagated and distributed to farmers at a highly subsidized price. Propagation stations and tree crop nurseries were refurbished by the government in the latter part of 2008 for the production of adequate quantities of planting materials (IIAC 2009). Secondly, a land clearing and harvesting programme was implemented. Through this programme, a number of farms were cleared, and nutmeg was collected in abandoned fields. Thirdly, under "Nutmeg Tree Clearing Loan Programme" a number of farmers were assisted under a soft loan scheme under the MOA. Other revitalization efforts included Epicotyl Grafting Projects aimed to increase the production of planting material. The cumulative effect of these programmes along with nutmeg farmer's own initiatives contributed to at least a slight increase in nutmeg production in the years after the hurricanes .[17] It also attracted the entrance of a few new farmers in 2009 (MOA 2009).

Due to financial constraints of the GCNA and reduced government intervention in the form of subsidies, even with outside assistance, the GCNA was unable to unable to increase its assistance to all nutmeg producers (MOA, Grenada 2009; Antoine. E-mail interview by author, 2020). Up to six years after the hurricane in 2011, many farms were still

[17] For example, in 2008, 30% of nutmeg sales from fields cleared were retrieved for loan repayments, whilst the Association also held 30% of the revenue from sales of nutmegs on abandoned fields (MOA, Grenada, 2009).

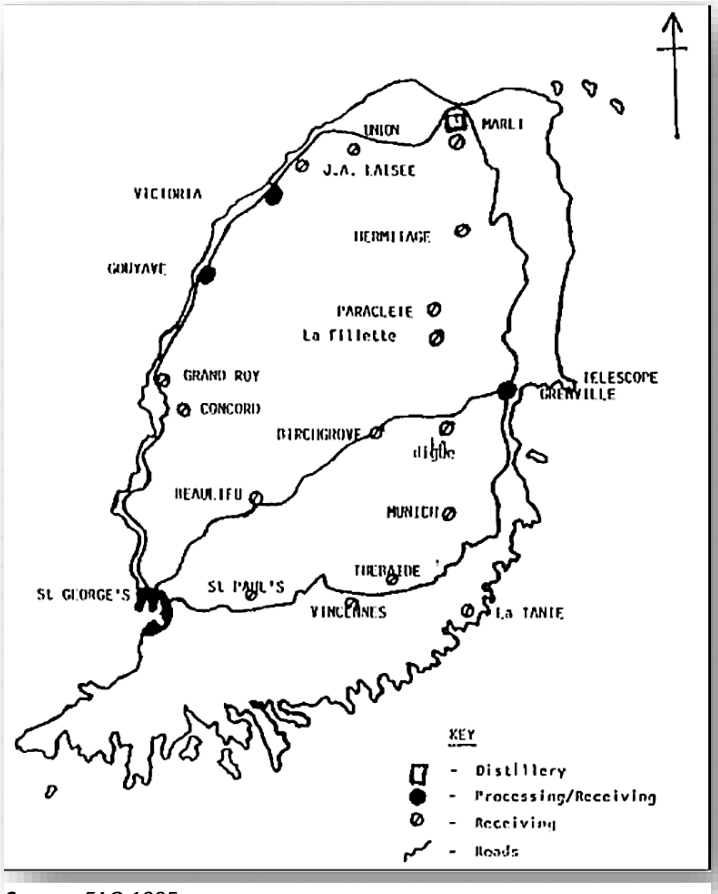
unapproachable to collect nutmeg fruits as thick bush developed due to continued neglect (George 2011) . Farmers who replanted only covered 25-30% of the areas. As such, 75% of the land was still left for replanting (Ibid).

According to Craighead et al. (2007) effective disaster responses include not only the availability of resources , as this in and of itself is not sufficient. Effective responses require "coordination", "cooperation" and "communication" amongst the different nodes in the SC. In line with this, the ITC (2010) opined that "the ineptness in organizing re-planting efforts and increasing collection amongst the farmers in the years after the disasters, points to the weak relationship between GCNA, extension officers and farmers in areas of production and post harvesting."

3.5 Impact at the receiving/processing stage

Prior to hurricane Ivan, there were around 16 GCNA receiving stations/pools well distributed around the island as shown in **figure 7**. There were 3 processing stations at Grenville, Gouyave and Victoria. These 3 also carried out receiving stations activities (Karp Rodriguez 2003; ITC 2010; Antoine. E-mail interview by author, 2020). According to George (2011), these pools functioned in well-constructed buildings. It allowed farmer and buyers easy access and reduced costs of travel (Fletcher 2020). There was also one distillation plant, north west of the island, an organic plant, and a reconditioning plant.

Figure 7 *Location of key nutmeg processing and manufacturing infrastructure and linkages pre-2004.*



Source*: FAO 1995*

Damage to infrastructure

While Stations were distributed around the island, damage to infrastructure vital for processing and distillation of nutmeg was widespread. According to OECS (2004) damage to infrastructure was as follows:

- Eleven on the nineteen stations sustained considerable damage at an estimated cost of EC $5.7 million.
- The distillation plant (nutmeg oil plant) at Marli, suffered significant damages and required approximately EC$150,000 to secure and repair the factory shell and another EC$500,000 to return the plant to a desired level of operation.
- The reconditioning plant also suffered damages which required repairs costing EC$100,000.
- The organic plant, because of the extensive damages had to be replaced. The replacement cost was estimated to be EC$750,000.
- Inclusive of the damages several tools, equipment's and machinery were damaged especially in the distillation plant and the organic nutmeg plants (GCNA data).

- **Decrease in employment**

Prior to the hurricanes the GCNA employed over 500-600 workers with over 80% of them being unskilled (Charles 2007). After the hurricanes, a number of nutmeg facilities and several receiving stations around the island were closed. Consequently, the GCNA had to sever a number of workers. According to MOF, Grenada (2006) these workers remained without employment and a source of income for months to support their families. Additionally, the livelihoods of the staff members were disrupted as 89% of the housing stock was damaged or destroyed. For staff with children, 85% of schools were damaged or destroyed and basic supplies such as water and electricity were disrupted for an extended period, especially in the rural areas. (MOF, Grenada 2005; Shemer 2012). The Grenville nutmeg Station alone for example, employed around 140 people for the receiving and processing stage, prior to the hurricanes. By 2009, employees only amounted to 10 persons (Crask 2009). Similarly, by

2009, the GCNA only provided a direct source of labour for 150 staff members distributed throughout the eight (8) operating nutmeg stations (MOA, Grenada 2011). Currently, the GCNA employs around 138 persons (Antoine. E-mail interview by author, 2020).

- **Decrease in operation capacity**

Prior to 2004, the G.C.N.A. had invested in an organic processing station. After the hurricanes, it was not being utilized because of the low volumes of production (ITC 2010; Compete Caribbean 2015). Up to 2010, as a result of a decrease in production there were just two main operating stations, the processing station in the town of Gouyave and the receiving station in the town of Grenville (ITC 2010). Presently, the GCNA has one processing station and seven receiving Stations in full operation, for want of adequate nutmeg arrivals (Fletcher, 2017; Antoine. E-mail interview by author, 2020). These stations took approximately 1 year to be renovated and to revert to full functionality, while the nutmeg oil distillery took around 2 years (Ibid).

- **Storage/Warehousing**

The tangible assets of the GCNA includes two storage stations (Charles 2007). Prior to Ivan, large stocks of nutmeg were accumulated by the GCNA and placed in storage, as a reaction to the low world prices. Hurricane Ivan destroyed around EC$11 million of nutmeg that were sitting in stock, including the infrastructure (Crask 2012).

3.5.1 Disaster/Disruption management

"GCNA was not prepared for the impact of hurricane Ivan in particular, hence the widespread damages caused" (Antoine. E-mail interview by author, 2020). All GCNA facilities were insured however, access to finance from stakeholders was poor, and many facilities including storage facilities did not meet the applicable building codes and requirements.

After Hurricane Ivan however, the GCNA started implementing mitigative strategies to prevent widespread damages. These include improving access to finance from stakeholders to facilitate sector operations to manage risks; meeting applicable building codes; and upgrading storage facilities to fire/flood proof storage to keep all needed products. Additionally, Customer Based Software was implemented to protect electronic information (Antoine. E-mail interview by author, 2020).

Measures in place currently still seem reactive. Recovery strategies in the case of another natural disaster include mainly plans to offer " farm assistance clearance programmes to facilitate farmers" (Ibid).

3.6 Impact to manufacturers/suppliers of value added

The majority of GCNA's revenue came from its sale of raw/processed nutmegs to customers. As such, the GCNA's income source has been undiversified. Prior to the hurricanes, processed nutmeg products however were showing an increase from US$2.5 million in 2000 to US$4 million in 2003 (MOF, Grenada 2006). Inclusive of the GCNA there were many small-scale enterprises involved in agro-processing in the nutmeg industry. These products were exported in relatively small levels or by mail order (Ibid).

For the GCNA especially, the advantage comes from using local nutmeg to manufacture value added products. Damage to manufacturing infrastructure as well as the decline in nutmeg production, therefore, resulted in the unavailability of nutmeg for manufacturing for products such as nutmeg oil within the GCNA. In addition to the lack of production capacity, factors such as: inadequate transportation, lack of export aggressiveness, and appropriate export financing, have also contributed to the low exports of value- added products (MOF, Grenada 2006).

Additionally, the effect of the decrease in production capacity also spread to other main manufacturing companies. According to IICA (2009), for example, due to the rapidly diminishing supply of nutmeg there was an unavailability of nutmeg oil, which was the main ingredient in the manufacturing of "Nutmed", a locally produced but internationally used pain-relieving spray. The main producer of Nutmed the late Grenadian Stalwart, Denis Noel, at the time indicated the likelihood of having to import nutmeg oil when his current stock was exhausted (Ibid).

3.6.1 Disaster/Disruption management

While there were serious supply constraints for the manufacturing of nutmeg products, early on, the recommended strategy to revitalize the nutmeg industry was through the diversification of nutmeg exports (MOF, Grenada 2006). This required a shift from the sale of raw nutmeg to local processing of high value-added products and increased agro-processing (ARD 2007b; Shemer 2012). This would allow for effective utilization of the limited quantity of nutmeg, which was being produced, until production increased. A complete study was carried out identifying new value-added product. This highlighted opportunities in the area of essential oil and oleoresins for nutmeg. Grenada's nutmeg product "Nutmed" for example was highlighted as a 'Best Practice' in value addition in the nutmeg industry. Also, it was recommended for developing countries to follow to achieve maximum benefits from agriculture (MOF, Grenada 2006).

Factors hindering the progress in the production of value-added nutmeg products however included: high production costs, lack of appropriate technology, and the competencies needed to address the competitiveness of firms (MOF, Grenada 2006). Additionally, given the existing monopoly by GCNA in the nutmeg SC, in the past, according to Charles (2007), the GCNA has been unwelcoming to the introduction of local competition in the market.

Nevertheless, The GCNA has over the years attempted to diversify its income and shift from full dependence from sales of raw nutmeg and mace. After the hurricanes, for example the GCNA constructed a new complex aimed at leasing commercial spaces in 2008. The move was highly criticized as a waste of resources, and the association faced several financial obstacles in executing the project (Grenada Today, Nov. 30, 2007; Shemer 2012).

Nevertheless, the GCNA complex now raises in excess of $1.3 million annually from its rental income (Campbell and NOW Grenada 2018). Additionally, a number of new innovative value- added products have been added to the GCNA's portfolio to generate revenue. These include: "Nutmeg Shell Potting Mix (used to germinate nutmeg seeds), Nutmeg Pickle, Nutmeg Hot Sauce, Nutmeg Seasoning, Nutmoss, Nutmeg Cooler". These products are sold locally. However, the goal is to have them approved by the Grenada Bureau of Standards for sale regionally and internationally (Grenada Broadcasting Network 2019).

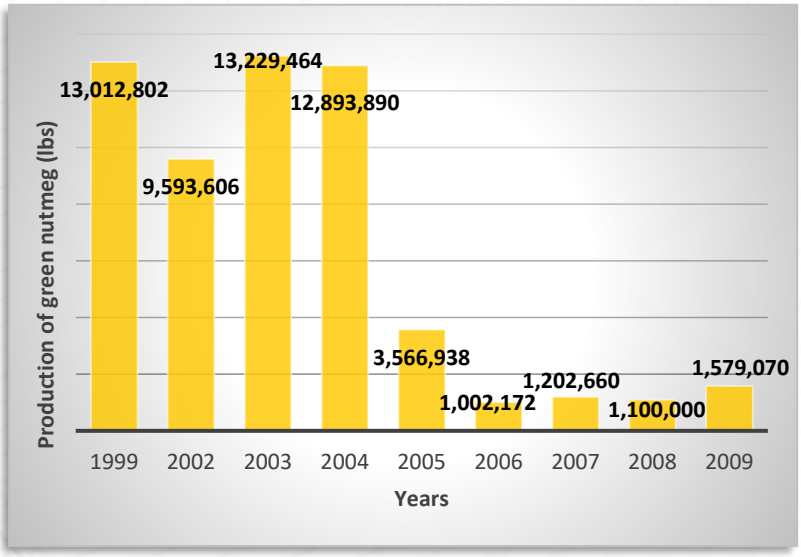
3.7 Resulting SC impact – Production, exports, revenue, market share and reputation

The disruption caused by the hurricanes to the suppliers, processors and manufacturers in the nutmeg SC had a negative cascading effect. It resulted in a reduction in the supply, and thus export and sale of nutmeg and nutmeg products in the short and long term. This led to a decrease in competitiveness, market share and foreign exchange from Grenada's nutmeg industry. The following subsections examines the resulting/ macroeconomic impact and the factors which have increased the extent of the impact.

Decrease in production

According to the FAO (2017), reduced production is a strong indication of the scope or scale of an impact, and one of the most direct ways in which disasters can affect a sector in the agricultural industry. Similarly, one of the most direct ways through which the hurricanes have affected the nutmeg SC has been through decreased production over the years (see **figures 8** and **9**). Compared to the 2,000 pounds of nutmeg produced by more than half of all supplying farmers prior to the hurricanes, only one in ten farmers harvested on average 100 pounds of nutmeg in 2005 (Agency for Reconstruction and Development 2005; Shemer 2012). By 2009, along with the prevalence of several bouts of "Nutmeg Wilt Disease", and the decreased production capacity of farmers and providers of

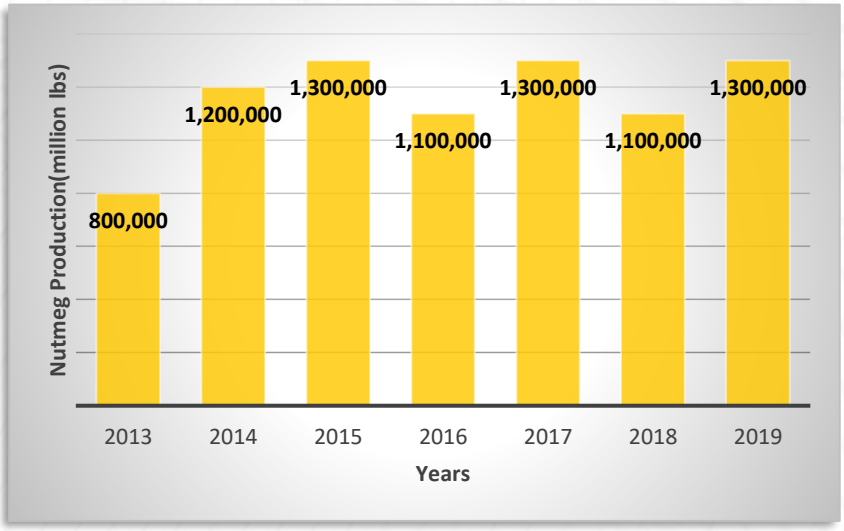
Figure 8 *Grenada's green nutmeg production from 1999-2009 in lbs.*



Source *:ITC 2010*

farm input, nutmeg production reduced from approximately 13,229,464 lbs. of green nutmeg in 2003 to 1,579,070 lbs. in 2009 (ITC 2010). By 2011, according to George (2011) nutmeg and mace arrivals at the pools were not even 15% of the production of 2003, pre-Ivan. By 2014, nutmeg seeds and trees which were planted in the aftermath of hurricane Ivan, matured. This coupled with the direct incentives provided to local nutmeg farmers, increased production by 50.7 percent (MOF, Grenada 2015) . However, the following years, due to unusual weather patterns nutmeg production declined.

Figure 9 *Quantity of nutmeg production in Grenada from 2013-2019 in lbs.*



Source *:MOF, Grenada 2019*

Presently, G.C.N.A only produces around 1,000,000 to 1,300,000 lbs. of nutmeg annually, the same as 454 to 590 metric tons (GCNA data). In 2019 for example, GCNA purchased 1.3 million lbs. of nutmeg from farmers for the creation of value-added products and export (Ewing-Chow 2020).

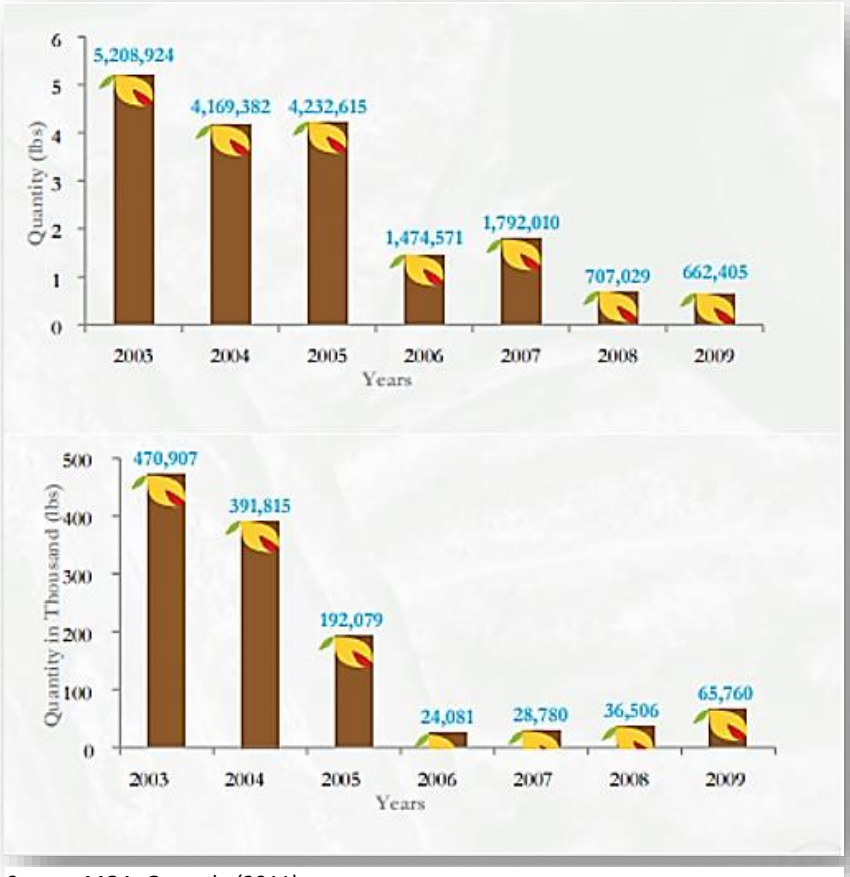
A characteristic of a resilient SC which has been highlighted is flexibility (Ivanov and Wendler , 2017). This includes various strategies to ensure quick adaptation of production lines. However, with the disruption to nutmeg cultivation in Grenada, harvesting and production could not be easily adapted to respond to changing market conditions (Fletcher 2020) . Adaptability in this case was dependent on the long recovery/ gestation period for the nutmeg crops as well as input of the farmers (Fletcher 2020). The inconsistency of delivery by nutmeg producers has also been a major concern and has reduced the flexibility of the SC (ITC 2010).

Additionally, with the globalization of trade, new SC management strategies have been developed such as "just-in-time" practice and lean SC management. These require frequent deliveries of supplies. For SCs such as nutmeg with inflexible productions lines, the occurrence of disruptions is increased (Abe and Ye 2013).

Decrease in the volume of exports

Since the occurrence of the hurricanes, production has not returned to its pre-hurricanes level and there has been a significant decrease in the volume of exports (see **figure 10**). In 2003, quantity of exports of nutmeg and mace amounted to 5,679,831 lbs. After the hurricanes, the GCNA was able to operate on stocks that had been bought from farmers (ITC 2010). Therefore, the decline in the volume of exports did not reflect the full impact of the hurricanes. In 2004 and 2005 nutmeg/mace exports were 4,560,197 and 4,561,197 lbs. respectively. The role or importance of storage/buffer stocks therefore became apparent in the aftermath of the hurricanes. Prior to Ivan, large stocks of nutmeg were accumulated by the GCNA and placed in storage, as a reaction to the low world prices (World

Figure 10 *4 Quantity of Grenada's nutmeg(Graph 1) and mace (Graph 2) exports 2003-2009 in lbs.*



Source: MOA, Grenada (2011)

Bank 2005). These stocks amounted to approximately 6 million lbs (equal to three million lbs of processed spice). While 40% of the reserves were affected by water damage, the remaining 60% could be sold at premium prices(Ibid). Similarly, redundancy or the availability of additional storage and handling facilities has been highlighted as a main characteristic of a resilient SC in the literature (Ivanov and Wendler 2017).

By 2006-2007, the quantity of exports further decreased to 1,498,652 lbs and 1,820,790 lbs respectively, reflecting the impact of the hurricanes. In 2008-2009 however, when nutmeg reserves were used up, the quantity of exports significantly decreased to 743,535 lbs (2008) and 733,165 (2009). Compared to pre-Ivan levels (2003), this represents an 86% decrease in nutmeg exports in 2008 and a 61% decrease compared to that of 2007 (MOA, Grenada 2009). Presently, the annual quantity of nutmeg exported is on average 500 metric tons (1,102,311 lbs), which is 20% of the period before Hurricane Ivan (GCNA data).

Decrease in sales or export revenue

International commodity prices for nutmeg are highly volatile. Unanticipated changes in demand or supply can lead to strong price fluctuations and thus swift changes in market dynamics and opportunities (CBI 2018). Furthermore, nutmeg is an intermediate commodity and as such demand is driven by the demand for the final products which are influenced by a number of factors other than price, quantity, and availability (Fletcher 2020).

In the 1980's, Grenada along with Indonesia had sufficient international market power to influence the world nutmeg supply and price (Fletcher 2016). With Grenada and Indonesia providing 98% of the world supply of nutmegs, prices remained high. Coincidentally however, in the year 2004, along with the hurricane which hit Grenada, Indonesia was hit by a tsunami which reduced the number of nutmeg crops. This opened the nutmeg trade to opportunities for

new entrants. Cost competitiveness therefore increased due to the increase in number of nutmeg suppliers while local competition remained low (Catholic Relief Services 2014).

With the decline in the world share over time, Grenada/GCNA has been unable to increase its capacity to respond to international market demands and are price takers in the market (Fletcher 2020). Despite the quality of Grenada's exports which fetch premium prices in the market, as a small open economy Grenada is susceptible to international price fluctuations, lacking the scale or negotiating power to influence buyers (Ibid).

In some cases, after the hurricanes, while there was a drastic decrease in the volume of production , the increase in the market price of nutmeg was able to somewhat offset the drop in the volume of production. In other cases, however, falling prices have posed as a challenge. For example, while there was a marginal increase in production in 2008 as compared to 2007, earnings from 2007 amounted to EC$9.5 million compared to the EC$6.5 million in 2008 (MOA, Grenada 2011). This is as the growth in 2007 was driven principally by the increased market price.

The decrease in the volumes of nutmeg supplied, paired with the price volatility in the nutmeg market impacted Grenada's foreign exchange earnings and GDP; the income of the GCNA; and the incomes of individual nutmeg farmers. Consequentially, this has decreased the recovery capacity of the nutmeg SC. In 2003, nutmeg exports generated revenue of EC$39.5 million (Central Statistics Office 2008; Panels Kerr Foster 2008; MOA, Grenada, 2011).

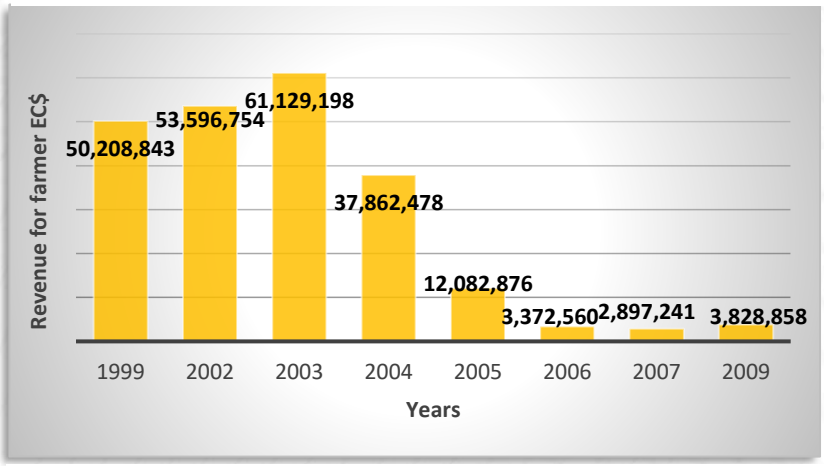
Figure 11 *The value of Grenada's nutmeg exports from 2003-2009 in EC.*

Source: *MOA, Grenada (2011)*

Since then, revenue from nutmeg has reduced significantly and has varied significantly over the years (see **figure 11**). The uncertainty of international market prices has complicated financial and long-term planning, increased commodity dependence and has made it increasingly expensive to invest in technology.

Furthermore, the decrease in export revenue has affected the income of the nutmeg farmers. Before the hurricanes, revenue for farmers amounted to EC$61,129,198 million. After the hurricanes however revenue decreased significantly (See **Figure 12**). In order for farmers to maximize harvesting or to meet the expenses for nutmeg harvesting and land clearing, it is necessary they receive prices of $3 per lbs. or more(MOA, Grenada, 2009). When there is a stable market for nutmeg and mace, the GCNA is able to offer the farmers high prices needed to meet required supply levels. However, where international prices fall, the GCNA reduces the price paid to local farmers (MOF, Grenada 2018). In some cases, after the hurricanes, due to the low volumes of nutmeg processed and exported, the GCNA faced economic constraints impairing its ability to pay the expected prices of nutmeg farmers (MOA, Grenada, 2009). According to Fletcher (2016) in 2008, 2009 and 2010, farmers did not receive any bonus payments because of low sales. This is an example of the feedback effect which can manifest in a SC (Eisenberg and Noe 2001; Blackhurst et al. 2011). In Grenada's nutmeg SC, decreased harvesting and production at the farmgate affected the GCNA's output and income. As a result of GCNA's reduced income, revenue needed for farmers to increase

Figure 12 *Grenadian nutmeg farmers' revenue from 1999- 2009 in EC.*



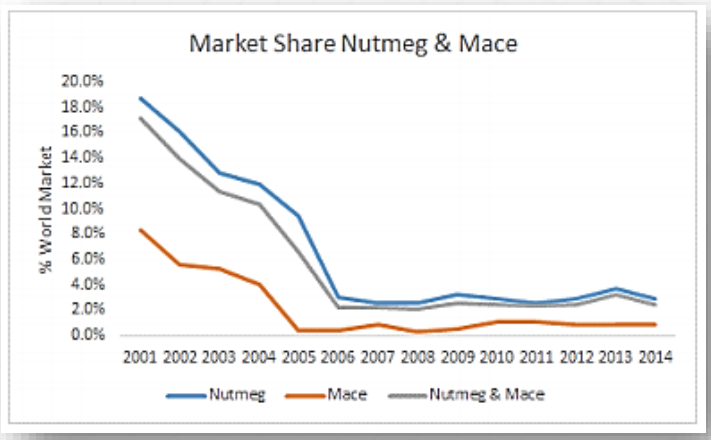
Source*: ITC (2010) ; GCNA Data*

production was also affected. The uncertainty of export income and farmer revenue continues to be a factor affecting the resilience of the nutmeg SC.

Loss of market share

During the period 1986-1990 Grenada, in concert with Indonesia, enjoyed an oligopoly arrangement with regard to international trade in nutmeg (Catholic Relief Services 2014). This kept the nutmeg prices high. However, the nutmeg trade agreement collapsed in 1998 (Fletcher 2016). Consequently, even before the hurricanes Grenada experienced a decline in its world share, losing its position as the second largest exporter of nutmeg in 2001 becoming the 9th largest exporter by 2009 (CARICOM 2011). Between 2004 and 2014, due to the disruption in production, and the entrance of a number of producing countries into the nutmeg market, Grenada's market share declined with a percentage share above 1% (see **Figure 13**) (James 2015)[18]. As of 2019, Grenada has a 0.5 share in world exports of Nutmeg and mace ranking at number 13 (ITC 2019; OEC n.d).

Figure 13 *Grenada's world market share for nutmeg & Mace from 2001-2014.*



Source*: James (2015)*

[18] By 2008, Grenada supplied less than 2% of world export volumes (ITC 2010)

CHAPTER 4

CONCLUSION

4.0 Conclusion

As hurricane disasters continue to pose a threat to SIDS, it is important to understand their full implications across SCs, especially in the agricultural sector. This case study examining the impact of hurricane Ivan (2004) (and Emily, 2005) on Grenada's nutmeg SC, echoes numerous studies and reports which indicate that natural disasters have important disruptive effects, which spread along SCs, with far reaching consequences (SBC EIC 2017; Altey and Ramirez 2010; Abe and Ye 2013; Scheibe and Blackhurst. 2017, FAO 2018; WTO 2019 etc.).

While the end consumer may only see the final product, mapping of the SC revealed the numerous steps and resources which are involved in the supply of nutmeg and nutmeg products. It also revealed the strong interdependencies between the entities in the SC, showing that the effective functioning of each stage is crucial to the success of the industry. This was an important building block in identifying and evaluating impact as a result of the hurricanes.

Generally, the findings reveal that the SCD triggered by the hurricanes negatively impacted the entire nutmeg SC in the immediate and long term. In line with the FAO (2018), the most prominent impact was reduced production which resulted in economic losses which spread along the SC with wider national consequences. To date, 17 years after the hurricanes, production levels have not recovered, the annual quantity of nutmeg being only 20% of the period before the hurricanes.

The hurricane impact at the farm gate crippled the production capacity of the farmers, which is critical to the functioning of the SC. This resulted from damage to farm inputs and tools, the nutmeg crop, farmland, and farm roads. In the long run there was a drastic decrease

in the number of nutmeg suppliers. The disruption to production in turn had a ripple effect along rest of the SC. As a result of the disruption to production, coupled with the damage to infrastructure, the processing and manufacturing stages of the SC were also affected. This in turn negatively impacted the eventual sale and export of nutmeg and nutmeg products.

Resultantly, there was a significant reduction in the GCNA's income and foreign revenue for Grenada. This had a feedback effect on the SC, resulting from a decrease in farmer revenue needed to increase production, a decrease in GCNA's financial capacity to develop infrastructure, and a loss of employment due to the decrease in operating plants. As a result of the decrease in exports and the increase in the number of nutmeg suppliers in the international market, Grenada's nutmeg world market share was significantly reduced to date. Currently, Grenada ranks at number 13 in world exports, with a 0.5% share.

The findings also indicate that there were several factors which increased the severity of the hurricane's consequences. These included factors which were beyond the control of SC managers and participants such as: the location specific nature and vulnerability of the nutmeg crop, and the volatility of the international market for nutmeg. Understanding these factors however can have important policy implications for effective resource allocation and for long-term strategy planning. For example, due to the characteristics of the nutmeg crop, it follows that focus should be placed on climate smart agricultural practices.

Economic vulnerability and the absence of risk transfer mechanisms and solutions such as market-based insurance were major factors affecting resilience of farmers especially. These findings may therefore stimulate the policymakers in Grenada and in SIDS to explore the efficacy of viable ex-ante disaster risk financing tools (such as crop insurance) and to increase access to finance for farmers. This can serve to increase the number of supplying nutmeg

farmers which can in the long-term help cushion the economic fall out in the face of another disruption.

Secondly, for all Members of the SC, the nutmeg farmers especially, the lesson is clear that although the SC's vulnerability to natural disasters is inevitable, SC participants can play a role in reducing these disasters by changing the system's resilience and recovery capacity.

Lack of preparedness and planning was another major factor influencing the impact of the hurricanes. Strategies undertaken were mainly reactive being criticized as having lacked the coordination needed for effective SCD management. After the hurricanes, several measures undertaken helped to reduce the impact and to prevent further damage and losses. Mitigative measures such as having buffer stocks also served to reduce the impact in the years after the hurricanes. Best practices in response to the extensive damage to the nutmeg crop included: the diversification of nutmeg exports, with focus on value added products, and GCNA income sources. Ideally, however SC managers should aim to map out continuity plans as this would allow for a quicker response, thus lessening on the severity of the SCD.

Building upon the findings of this research, this case study provides important analysis which can aid in formulating a nutmeg SC risk management plan for future hurricane disruptions. It can be argued that a positive consequence of the hurricanes' occurrence is the now heightened awareness of the importance of risk management. Since the hurricanes, for example, Grenada has created a new "Ministry of Climate Resilience, Environment, Fisheries, Forestry and Disaster Management" and has been working on plans to develop an agricultural risk insurance product for nutmeg production for the upcoming hurricane seasons.

4.1 Limitations of the study and recommendations for future work

Firstly, there appears to be a dearth of studies incorporating the SCD stream of research in natural disaster impact assessment for SIDS. This may be due to the fact that SCD research is still in the incipient stages of development. This limitation highlights an important opportunity or need for further research on the systemic or cascading effects of natural disasters on SCs in SIDS.

Secondly, the findings of this study are only limited to the selected case and, consequently, may not be fully applicable in other related scenarios. While SIDS all share similar geographic features or vulnerabilities which may affect the extent of a hurricane impact or recovery, all-natural disasters have unique fingerprints. Natural disasters therefore can produce different outcomes in different SIDS, indicating variation in vulnerabilities. Similarly, natural disasters do not affect all sectors, industries or SCs to the same extent, as such, the policy implications of such studies may differ. Future research could therefore focus on conducting comparative case studies across SIDS and SCs which might improve generalizability. This would allow for the identification of best practices and creation of context specific SCD management strategies which can benefit SIDS.

Lastly, there was a lack of comprehensive data on the subject which required the researcher to limit the scope of the analysis. Data was gathered from diverse sources with different aims. This meant that the research depended on the interpretation of data from the various sources to the research context.

4.2 Annexes

ANNEX I

Questions for the GCNA

1. What is your name and position at the GCNA?

Infrastructure

2. How many receiving/processing/distillation nutmeg stations are there now as compared to before the hurricanes? How many persons were employed back then as compared to now?
3. Was there any machinery etc. that was damaged as a result of the hurricanes?
4. How long did it take for the stations to be renovated and back to full functioning?
5. What were the measures taken immediately after a disaster to ensure quick restoration of services, reconstruction of infrastructure and to minimize the disaster hazard?
6. Was the infrastructure at the processing and manufacturing stages insured and are they insured now?

The GCNA

7. Was the GCNA prepared for the risk of hurricane impact prior to the hurricanes? Since the hurricanes what measures were put in place to increase the resilience of the nutmeg SC against hurricane risk?
8. What factors affected the GCNA's ability to recovery quickly/ what factors lent to its vulnerability to the hurricane?
9. How many farmers/what percentage had insurance for their nutmeg crop prior to the hurricanes? Are farmers required to pay NIS? Is there market- based insurance for the nutmeg crop?
10. What measures were put in place since the hurricanes to protect the nutmeg crops from future hurricane damage?
11. If possible, can you provide statistics showing nutmeg exports and income over the years>

Farmers

12. How did the farmers respond after the hurricanes or what difficulties did they face?
13. What were the reasons for the significant decrease in the number of nutmeg farmers over the years that are connected to the hurricanes?
14. How many supplying farmers were there prior to the hurricanes as compared to present or the years after the hurricanes?
15. What were the reasons for the significant decrease in the number of nutmeg farmers over the years that are connected to the hurricanes?

ANNEX II

The Relationship between Natural Disasters and Supply Chains in Small Island Developing States :**A Case Study on the Impact of Hurricane Ivan (2004) (and Hurricane Emily 2005) on Grenada's Nutmeg Supply Chain**.

Consent Form

Please confirm your participation by signing the consent form at the end of this document.

i. I confirm that I have read the attached information sheet on the above project and have had the opportunity to consider the information, ask questions and had these answered satisfactorily.

ii. I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason.

iii. I also understand that my words may be quoted directly, and my name published in the research paper.

Name of participant	Date Signature
……. ……	……
Name of Interviewer	Date Signature
…… …….	…….

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