"Integrating lean concepts in smallholder farming to catalyze sustainable agriculture for food security in Trinidad, WI."

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Abstract: "Sustainable Agriculture and Food Security"

The roadmap for developing sustainable smallholder farms is not always clear and replicable. Mainstream agricultural development still concentrates on productivity with a minimum focus on lean management and sustainability. It currently requires a 70% increase in production while ignoring the complementary factor of reducing food loss and waste as a sustainable strategy of achieving food security and nutrition. This paper examines the integration of lean concepts in smallholder farming to catalyze sustainable agriculture for food security.

Several sources indicate that approximately 500 million smallholder farms worldwide cultivate on farm size less than 2 hectares under traditional or informal tenure. These farms are located mostly in marginal or risk-prone environments, reducing their resilience to climate change and sustainable production. Although smallholders account for 84% of all farms that produce approximately 30% of food globally, these farmers constitute approximately 75% of the world's underprivileged, hungry, and undernourished people. The situation is exacerbated by smallholder farms experiencing more postharvest loss due to inadequate market facilities and access to cold storage. Additionally, smallholder farmers have limited adaptive capacity to climate change based on a lack of knowledge and experience, low income, small farm size, and inadequate access to technical assistance and markets. Although smallholder farms experience these challenges', they are touted as the potential backbone to implement the UN Sustainable Development Goal #2 to achieve Zero Hunger by 2030.

Ro-Crops Agrotec, a (1.5-ha) family farm in central Trinidad, is presented as a case study with over 26 years of integrating lean concepts and continuous improvement strategies. Ro-Crops demonstrates that sustainable agriculture and food security are achievable through strategic planning, farm management, and applying innovative waste removal measures without it becoming an obsession.

While lean is initially associated with the manufacturing industries, it is equally essential in agriculture, which experiences losses in the supply chain at production, postharvest operations, and processing. At the retail and consumer stages, the "losses" are due to "food wastage," consisting of approximately a third of consumer food globally and estimated at over 1.3 billion tons annually. The lean concept is to reduce waste, maximize efficiency, and increase economic value due to productivity, quality, and flexibility as the primary indicators of performance. It helps organisations effectively reduce all kinds of waste, develop and maintain standardised processes, and continuously improve the processes.

Keywords: Lean management; Food wastage; Smallholder farmers; Sustainable agriculture; Food security; Strategic planning; Farm management

Introduction

This chapter critically examines integrating lean concepts in smallholder farming to catalyze sustainable agriculture and food security in Trinidad, WI. There is great emphasis on increased production with limited focus on sustainability (Rockström, 2017) while ignoring the complementary factor of reducing food loss and waste as a sustainable strategy to achieve food security and nutrition (Hodges et al., 2011). There are "losses" in the food industry along the supply chain at the level of production, postharvest operations, and processing (Parfitt et al., 2010). The majority of waste and loss in developing countries occur in the food supply chain (FSC) at the early stages of production and harvesting (Gustavsson et al., 2011). These losses are due to inadequate harvesting technologies, lack of timely transport, and improper storage facilities (Papargyropoulou et al., 2014). Smallholder farms experience a considerable amount of postharvest loss due to inadequate market facilities and access to cold storage (Hodges et al., 2011; Tefera, 2012). According to Dobermann and Nelson (2013:2), the food systems and agricultural production worldwide must become more productive, resource-efficient, resilient, and 'less wasteful.'

Dora et al. (2015) argue that there are little literature and understanding of lean in agriculture and farming so far, and its introduction is necessary given the magnitude of waste and losses generated at different levels of production. However, its penetration into the agricultural industry is slow due to the perishability of a wide range of food products, the complexity of the supply chain in agriculture and, a dynamic preference of consumers (Dora et al., 2016). The perishable agricultural products require effort to reduce lead times (Mahalik and Nambiar, 2010) to avoid wastage of unmarketable products due to their early expiry shelf life (Pauls-Worm et al., 2014).

Several studies indicate that lean practices can help the agricultural sector become more productive, such as trying lean in a 'Northumbrian Farm case' (Colgan et al., 2013) and lean in the UK's food supply chains UK pork sector (Taylor, 2006). According to Krafcik (1988), the lean concept of production is a desire to reduce waste, maximize efficiency, and increase its economic value due to productivity, quality, and flexibility as the primary indicators of performance. The intention is to reduce waste in human efforts, the number of inventories, the manufacturing space, and the time it takes to respond to the customers' demand for quality products (Womack et al., 1990).

Lean management helps organizations maintain a standardized process and continuously improve the processes to effectively reduce all types of waste (Cudney and Elrod, 2011). However, it faces more implementation issues such as culture change and a lack of employee involvement and empowerment (Bhatia and Drew, 2006). Therefore, leadership in lean organizations must ensure that all employees are fully engaged and involved in daily improvement activities (Dombrowski and Mielke, 2013). On the other hand, lean initiatives often fail when leaders cannot grasp and convey the need for systemic change (Al-Balushi et al., 2014) or manage by a process rather than outcome (Toussaint, 2015). Therefore, it requires a cultural change in empowering and encouraging employees to adopt lean thinking in making improvements (Drotz and Poksinska, 2014).

However, there should be a thoughtful process in applying lean principles to avoid them becoming emaciated and uncompetitive (Browning and Sanders, 2012). Implementing lean should be in keeping with the realities of the current environment (Corbett, 2007) by considering the methods and reason for the implementation (Handfield and Melnyk, 1998). The constant focus on improvement and waste removal can become an obsession resulting in significant work-related stress (Nayab, 2011). Therefore, the emphasis is now on using lean concepts scientifically (Spear and Bowen, 1999), emphasizing learning as a central component of the process (Holweg, 2007).

Ohno (1988) identified seven categories of waste as overproducing; waste in processing; while transporting; non-work time-waiting waste; high/low inventory; people moving unnecessarily; corrective waste, and defective production (Figure 1). Womack and Jones (2003) added an eight-type waste, such as designing goods and services that do not meet or satisfy the user/customer's needs.

Figure 1:7 Forms of Waste (Ohno, 1988) Google: Free access

This paper presents a study of the trends in smallholder farming towards sustainable agriculture and food security in Trinidad. It examines the Government's policy in state land distribution for smallholder farmers, the National Agricultural Marketing and Development Corporation (NAMDEVCO) and the Agricultural Development Bank. The paper also presents Ro-Crops Agrotec, an agroecology 1.5-hectare family farm in Central Trinidad, as a case study and change agent.

Methodology

The research consisted of a literature review based on a mixed-method (qualitative and quantitative) (Bettany-Saltikov, 2012) from credible sources in the English language such as Web of Science, Scopus, AgEcon, and Google scholar databases. Such review aims to minimise researcher bias (Petticrew and Roberts, 2006). It examined the trends of smallholder farming in Trinidad and reviewed research papers on sustainable agriculture by the Ministry of Agriculture and the Government's land policy documents. It also investigated NAMDEVCO's Farm Certification protocols with its Chief Executive Officer and facilities managers on its Good Agricultural Practices (GAP). The research examined postharvest management at its Wholesale markets and Packing House facilities regarding implementing lean management concepts. NAMDEVCO's CEO approved undertaking the case study and utilise the information gathered only for the research. It also researched the financial support which the national Agricultural Development Bank (ADB) provides to the agricultural sector.

The researchers focused on a retrospective analysis of the development of Ro-Crops as a model farm. It used a single-case descriptive case study with chronologic key-turning points in the farm's development identified through document analysis (content and theme) following procedures outlined by O' Leary (2014) and Bowen (2009). The researchers used a deviant purposive case sampling method (Kuzel, 1999) since they actively participated in the farm development or were aware of its history and repute through publication, specifically related to addressing the challenges of ameliorating and managing the farm's heavy clay, low fertility-acid soils. It directly integrated participant's data into the analysis as themed-narratives and commentaries (Bowen, 2009) from the farmer who is the lead author of this study. The researchers valued the farmer's commentaries as supplementary or complementary, mainly when the details of farm records seemed confidential or data not recorded systematically for metric analysis. The farmer's narratives were useful in gaining insight into strategic business management processes and decisions, which could not necessarily be captured or traced using metric data. The researchers used the farmer's field observations to meter interpretation of metric data (on-farm trials) for congruency using practices described by Robinson et al. (2007). It used the document and archival data to construct and validate the farm's history, achievements, processes, financial health, and relationships with collaborating partners and communities.

Literature review

A Global perspective

As the world population expects to reach 9.6 billion by 2050 (UN, 2019) and the prospect of attaining 11 billion by the end of the century (Gerland et al. 2014), it requires a 60 and 110% (70%)

increase in food production (Dobermann and Nelson, 2013; UN, 2013; Pardey et al. 2014) to be grown in adverse conditions due to climate change (Hanjra et al., 2013; Wheeler and von Braun, 2013). These challenges constitute a social-ecological framework for sustainable intensification of world agriculture (Jackson et al., 2012). This immediate solution of increasing agricultural production competes for scarce natural resources such as land, water, protected areas, and forest necessary for a healthy environment and biodiversity (Godfray et al., 2010; Phalan et al., 2011).

While over 870 million chronically undernourished people exist, approximately a third of consumer food is wasted or lost globally along the supply chain, estimated to be over 1.3 billion tons annually (Kojima and Ishikawa, 2013). At least 2 billion people are micronutrient deficient, of which a large proportion are smallholder farmers who are dependent on agriculture as a source of food and income (FAO, 2019). At the retail and consumer stages, the "losses" are due to "food wastage" consisting of any discarded raw or cooked food (Parfitt et al., 2010; Gustavsson et al., 2011; Miller and Welch, 2013). These postharvest losses (PHL) contribute to food insecurity due to environmental degradation, waste of natural resources, human labour, non-renewable resources such as fertilizer and energy in production, storage, and transportation (Bai and Dent, 2006).

Postharvest handling in perishable products such as vegetables and fruits suffer more loss and waste than staple foods (Yu and Nagurney, 2013). This loss and wastage negatively affect food accessibility to poor people (Murthy et al., 2009). According to Munesue et al. (2015), a 50% reduction in waste along the postharvest supply chain can potentially provide the nutritional requirements of approximately 63 million undernourished people worldwide.

Smallholders farmers

Several sources indicate that approximately 500 million smallholder farms worldwide cultivate on farm size less than 2 hectares (Hazell et al., 2010; HLPE, 2013). Smallholder farms in many regions occupy lands held under traditional or informal tenure, mostly in marginal or risk-prone environments, which further reduces their resilience to climate change and sustainable production (Bautista-Solı's et al., 2014; Locatelli, 2016). Over two billion rural people occupy these farms (FAO, 2019), which account for 84% of all farms that produce approximately 30% of food globally (Lowder et al., 2019). Moreover, these farmers constitute approximately 75% of the world's underprivileged, hungry, and undernourished people (Wiggins and Keats, 2013). They generally avoid monocultures and benefit from their independence in cultivating and marketing crops with a high degree of biodiversity, making them more resilient to an economic crisis and a potential backbone for implementing Sustainable Development Goal 2 (Terlau et al., 2018). Smallholder farmers have a large role in developing sustainable food systems of the future (SDSN, 2013; Hong, 2015) because industrial agriculture is highly dependent on off-farm inputs which, make them extremely vulnerable to insect pests, diseases and climate change (Altieri et al. 2015).

Despite the contribution to food security, smallholder farmers are most vulnerable to climatic impacts, which result in significant yield gaps (Lindoso et al., 2012; Tittonell and Giller, 2013). Additionally, smallholder farmers have limited adaptive capacity to climate change based on a lack of knowledge and experience, low income, small farm size, and inadequate access to technical assistance and markets (Tran and Brown, 2019). Smallholder farmers are generally characterised

by marginalization in varying degrees regarding accessibility to resources, information, technology, capital, and assets (Murphy, 2010). From a globalisation perspective, smallholders appear inadequate to cope with challenges of production due to economies of scale, investment capacity, and a lack of technical knowledge, which will likely contribute to their decline over time (Collier, 2008).

Challenges to implementing lean

There are several constraints and challenges which smallholder farmers encounter in achieving sustainable agricultural development, including land tenure and succession, accessing capital, production challenges, postharvest management, social and environmental constraints.

Land tenure and succession

According to Hicks et al. (2012), succession planning is one key mechanism to achieving the necessary food production at a sufficient and sustainable level to attain food security. There exists a lack of comprehensive land policy for many farmers, and mostly women farmers have no rights to the land they farm (Dioula et al., 2013). Secured land rights ensuring permanent farmland retention incentivises and encourages farmers to invest in sustainable development for long-term benefits to increase their output (Ali et al., 2012). The ability to access capital for investment enables farmers to become resilient and sustainable (Thulstrup, 2015). Additionally, land ownership facilitates succession planning, which also acts as a stimulus for on-farm and business investment by farmers' current generation (Cassidy et al., 2019). According to Cassidy et al. (2019), succession also facilitates the transfer of traditional knowledge and skills, providing sustainable changes in farming styles and practices.

Research shows that land transfer from one generation to the next increases farm diversification by up to 10 percent (Barbieri et al., 2008). According to Mann et al. (2013), where a successor is appointed, it provides an incentive for the older generation to invest in the farm and its activities while the younger farmer (successor) is motivated to increase the outputs of the farm through involvement in other farming activities and to increase the size of their holding.

On the other hand, many farmers with unsecured land rights are more interested in gaining short-term benefits from their investment (Akram et al., 2019). As a result, they tend to spend on supplements, which help increase productivity but gradually diminish soil fertility and sustainability (Ali et al., 2012; Kumari and Nakano, 2015). Unsecured land tenure or leases deter farmers from investing in sustainable soil conservation technologies because of the uncertain expectation of a future return on investment is (Gavian and Ehui, 2002). When these farms become unviable, many farmers seek another type of employment or migrate to the city or abroad (de Schutter, 2011), which seriously threatens food self-sufficiency and food sovereignty (IFAD and UNEP, 2013). With an aging population of farmers not having a successor, there are questions on the future of smallholder farming (Cassidy et al., 2019). An aspect of the problem is youth's apparent aversion to farming as a future (Cuervo and Wyn 2012; Proctor and Lucchesi, 2012; White, 2012) and parents actively discouraging their children from a farming career (Ball and Wiley, 2005).

Education and sustainability

Schumacher (1973, p.64) described education as the "greatest resource" to achieve a just and ecological society as an essential tool in achieving sustainability (Hopkins and McKeown (2002). According to Hopkins and McKeown (2002), the basic education level is too low in many countries, which tends to hinder the national plans for sustainable development. A 'meta-entry' on education by Roser and Ortiz-Espina (2016) states that while there is a global improvement in education, many countries, especially in sub-Saharan Africa, have youths with literacy rates below 50%.

However, a country's shift to information or a knowledge-based economy requires a subtle combination of higher education, research, and life-long learning (UNESCO-ACEID, 1997). Agriculture requires a minimum of four to six years of education as the threshold for increasing agricultural productivity (Phillips, 1994). An additional year of studies and training can significantly increase agricultural productivity (Ndour, 2017). Literacy and numeracy are necessary for farmers to adapt to new methods, cope with risk, and respond to market signals (Hopkins and McKeown, 2002). The ability to prevent risks depends on access to knowledge and information (Beck, 1992). Households with a higher education level can improve risk perception, reduce poverty and promote access to information and resources (Muttarak and Lutz, 2014).

Human capital development

The human capital theory considers it a life-long process of acquiring knowledge and skill at any age in shaping peoples' lives and making it meaningful (Steve et al., 2014). According to Schultz (1961), capital acquired in pursuing vocational and technical education is a product of well-considered investments to generate income. Babalola (2003) argues that it is the human resources of a nation and not its natural capital or material resources that ultimately determine its economic and social development.

Human capital impact on agricultural productivity shows that workers' education and training results in increased productivity and income (Schultz, 1961). According to Welch (1970), by developing the human capital through education and training, the farmer can significantly improve his/her work quality, use the available resources more efficiently to reduce waste, and seek channels to apply the acquired education and experiences for sustainable production (Klasen and Remeirs, 2011). The development in agriculture involves several innovations and adjustments to complex scientific changes, which require a more sophisticated and overall better-educated farmer to achieve sustainable agricultural production (Steve et al., 2014). Djomo (2012) states that an additional year of study and experience significantly increases agricultural productivity.

Trends in Trinidad

Land distribution

Through an official agricultural land distribution programme in Trinidad and Tobago during the past 50 years, the State allocated more than 30,000 hectares of lands with tenure for smallholder (1-4 ha) production of crops and livestock (Persad et al., 2007). Additionally, in 2003, the State allocated 12,158 hectares of former sugar cane lands of Caroni (1975) Limited for diversified

agricultural production after restructuring the sugar industry (Wilson 2006). Seven thousand eight hundred former employees of the sugar industry received 2-acre (0.8 ha) parcels under standard agricultural leases of 25 years to engage in a range of small-scale agricultural projects, with support in necessary infrastructure, marketing, and training (Persad 2004). These land assignment's objectives included enhancing food production, generating agricultural activity, and promoting national food security (Inter-Agency GOTT, 2004).

However, these agricultural programmes are distributed on poor soils (mainly heavy clay), challenging terrain, and generally classified as class V – VIII, which encountered many technical and economic challenges resulting in limited success (Persad et al., 2007). According to Persad et al. (2007), inadequate agricultural practices further exacerbate the challenges, with < 20% of lands cultivated and < 50% cultivatable indicating that small farm holdings generally lack the technical and financial resources to achieve sustainable soil management and amelioration practices.

Further, a Joint Select Committee on Land and Physical Infrastructure (2017) reported that the sector still operates under the 19th-century farming methods resulting in widespread under-utilization of State lands. Several reasons account for the under-utilization of agricultural State lands, including lack of tenancy by most occupants, land management and administration system inefficiency, and an inefficient mechanism of removing State lands' squatters. The report also indicated that the challenges of developing the agricultural sector included an aging population without the willingness to embrace new methods and technology and an uninterested youth population in agriculture.

Based on these findings, the committee recommended providing the necessary infrastructure, maximizing willing farmers' innovations with additional training, and engaging youth for the agricultural sector's succession and continuity. It also incorporated SDG 2 as part of the National Action Plan to promote sustainable agriculture by engaging all stakeholders to participate in the programme. It also recommended the establishment of public/private partnerships as a strategy for sustainable development.

Marketing support (NAMDEVCO)

Trinidad and Tobago Government established the National Agricultural Marketing and Development Corporation (NAMDEVCO) as a Statutory Body by the Act of Parliament No. 16 of 1991 (NAMDEVCO, 1991). The role of NAMDEVCO is to foster the development of a sustainable, competitive sector by establishing programmes that aim to provide safe, healthy foods to the local and international markets, build the productive capacity of farmers, and provide market information for timely decisions making and marketing services.

NAMDEVCO's mandate includes developing and maintaining an environment conducive to the efficient production and marketing of fresh and value-added agricultural commodities. NAMDEVCO provides marketing services and investment opportunities to stimulate agricultural business development in Trinidad and Tobago to achieve this mandate (NAMDEVCO, 2015b). It has a Quality Assurance (QA) Department, which provides a "Farm Certification and Monitoring Programme" to advise farmers on adopting Good Agricultural Practices (GAP) to reduce wastage along the production stages (NAMDEVCO, 2015a). The aim is to provide a system that enables the application and verification of controlled measures intended to assure the safety and quality of

agricultural products. GAP constitutes several farming practices, resulting in safe and healthy food while considering economic, social, and environmental sustainability (Dookie, 2018). The farm certification programme consists of approximately 2186 registered participating farmers located in 6 counties in Trinidad and serviced by 11 Field Officers (Table 1) (NAMDEVCO, 2018b).

Table 1: Listing of registered farmers

County	Allocation of farmers
Caroni	617
Mayaro/Nariva	98
Saint Andrew/ Saint David	460
Saint George	493
Saint Patrick	301
Victoria	217
Total	2186

Wholesale and farmers' markets

NAMDEVCO has several wholesale and farmers' marketing facility outlets located throughout the country (NAMDEVCO, 2015c), as shown in Figure 2. The location of its head office is on the compound of the Penal wholesale and retail market on the southern side of the country. Postharvest and waste management at these markets include facilities to receive and safely dispose wastes.

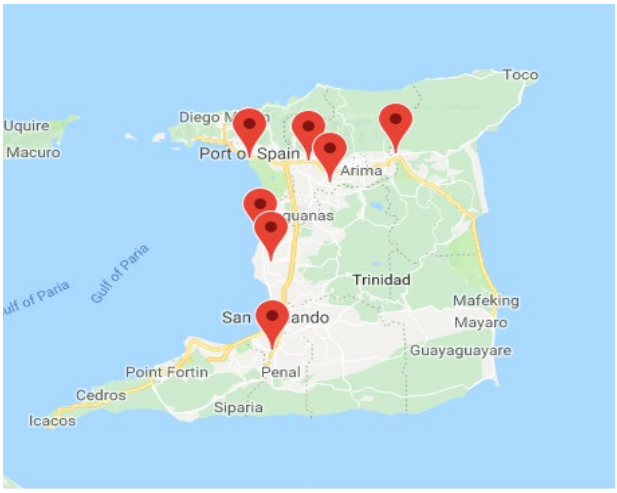

Figure 2: NAMDEVCO's market locations (NAMDEVCO, 2015c)

NAMDEVCO's Packinghouse

NAMDEVCO has a fresh produce Packinghouse facility strategically located almost 2 km from the International Airport at Piarco to facilitate easy air transport to maintain the export market's quality requirements (NAMDEVCO, 2015c). The Packinghouse provides facilities for a one-stop postharvest operation for packers and exporters of fresh produce for local and foreign markets (NAMDEVCO, 2015c). On average, the Packinghouse generates 2,164 kgs of waste per month. This figure comprises rejects, trimmings, peelings, and spoilage collected by livestock farmers daily for substitute animal feed.

GreenVine bulletin

The GreenVine is NAMDEVCO's monthly bulletin that provides information to strengthen agribusiness stakeholders' managerial and technical capacity (NAMDEVCO, 2015c). It delivers timely market intelligence on the status and outlook for the development of a sustainable Agri-Food sector.

Financial support (ADB)

The Ministry of Agriculture, Land and Fisheries established the Agricultural Development Bank (ADB) in 1968 to provide a significant funding source for developing the agricultural and agro-business sectors in Trinidad and Tobago (ADB, 2020). The ADB provides the agricultural sector with several financing options, strategic linkages for customer support, and flexible payment terms. The bank offers competitive developmental interest rates as the lowest amortized rates in the local financial sector. In response to customer and sector needs, the bank developed various loan products and services to introduce savings and investment options.

Ro-Crops model farm

Background

Ro-Crops is a smallholder family farm with tenancy since 1960 for 1.5 hectares of State land located at plot # 23 Uquire Road, Carlsen Field, Trinidad. The farm forms part of 686 hectares of State lands agricultural project and is within a 100- acre block allocated to 30 smallholder farms averaging 1.5 ha. The farming area is located on the former United States Army Air Forces (USAAF) airbase during World War II (WWII), from 1941 to 1949 (Wikipedia, 2021). Figure 3 shows the site location. Development of the airbase resulted in removing much of the land's natural vegetation and topsoil for constructing the paved runways, hangars, access roads, and buildings. The physical infrastructure and utilities, including access roads, potable water, electricity, and telephone services left-over from the old war base, became part of the farming community.

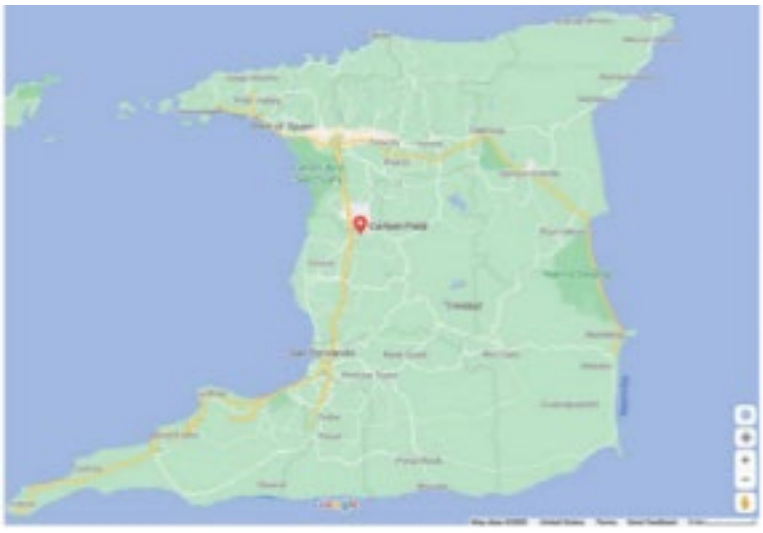

Figure 3: Shows Carlsen Field on Map of Trinidad (Google Map Data, 2020)

Land tenure and succession

Ro-Crops has land tenure and a succession strategy through a 30-year State Land Standard Agricultural lease until 2045 with a renewal option at each expiratory date for agricultural and residential purposes. The farm family now constitute the 73- and 75-years old parents with a 40-year-old son and daughter-in-law plus a 5-year old grandson as the successors. The farmstead is the family's home for the past 36 years, providing the principal income source.

Ro-Crops core business

Although development work started in 1985, Ro-Crops was registered as a Partnership Business in 1996 as 'Ro-Crops Agrotec.' It is certified by The National Agricultural Marketing and Development Corporation (NAMDEVCO) on its Farm Certification programme as implementing Good Agricultural Practices (GAP) for sustainable production (NAMDEVCO, 2010). Its core business is producing and marketing tropical vegetable crops and selected fruits, utilizing innovative agricultural technology in micro-irrigation and integrated sustainable management systems. It provides the well-known 'Ro-Crops' brand of quality fresh fruits and vegetables with traceability to the source of production. Ro-Crops supplies fresh limes with attractive packing to leading supermarkets in Trinidad (Figure 4).

Figure 4: Ro-Crops lime and labels

Ro-Crops accomplishments

Internationally, Ro-Crops farm is on the FAO's Agroecology Knowledge Hub as one of "52 Profiles on Agroecology (FAO, 2016); it is a Global Water Partnership – Caribbean partner seeking a water-secure world (GWP- C, 2011), and an advocate for Climate-Proof Farming in building resilience to climate change (Fraser, 2013).

Regionally, Ro-Crops is one of three family farms in Trinidad and Tobago, which The Inter-American Institute for Cooperation on Agriculture (IICA) honoured in 2013 for contributing to agricultural innovation (Guardian, 2013). All participants took part in the Regional Fund for Agricultural Technology (Fontagro) contest on family farming entitled "Competition of Success cases of Innovation for family agriculture 2012". The Fontagro fund is an alliance of the Latin American and Caribbean countries that support research and innovation in agriculture to reduce poverty, promote competitiveness, and sustain natural resources. Ro-Crops presented the case on "Integrated system to rehabilitate degraded heavy clay acidic soils for horticultural production

based on the management of pests, diseases, soil and water with minimum external inputs that are economically sound and environmentally friendly."

At the National Agricultural Awards 2001 in Trinidad, Ro-Crops won 1st Place in Integrated Agriculture and the Agricultural Entrepreneur of the Year Award, 2001 (Stan, 2002).

Ro-Crops development

Pre-lean implementation (1985-1994)

The early farming practices from 1985-1994 consisted of sugarcane cultivation and subsistence cropping under rain-fed conditions resulting in losses due to uneconomical yields and low productivity. The soil type is heavy clay (pH 3.5) consisting of degraded sugarcane lands (Persad and Wilson, 1998). According to Virmani et al. (1982), heavy clay soil consists of poor internal drainage, low hydraulic conductivity, and infiltration, but high field capacity, leading to waterlogging and wet season flooding. Bai and Dent (2006) state that farming under these conditions often resulted in low production, uneconomical yields, with a waste of natural, non-renewable, and human resources, which contribute to environmental degradation. Figure 5 shows Ro-Crops initial farm layout for subdivision into eight (8) farming blocks.

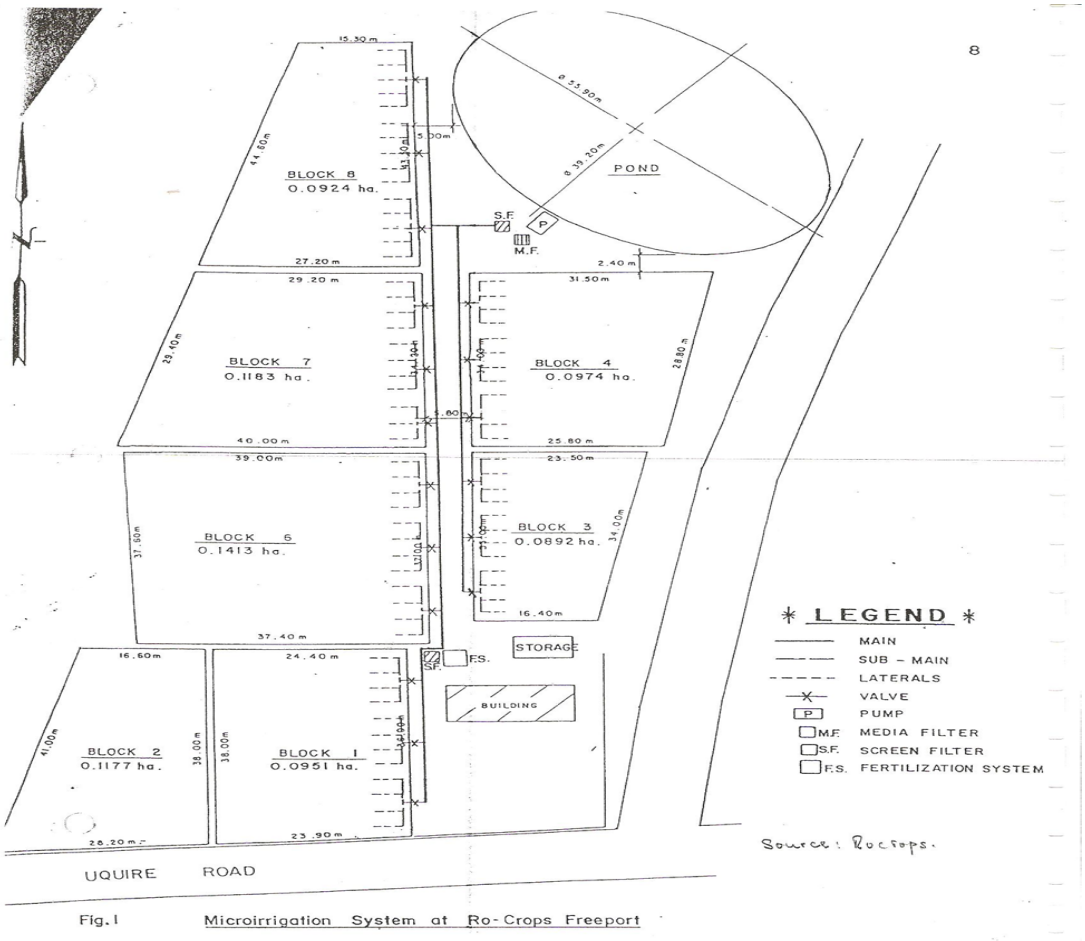

Figure 5: Initial farm layout

Implementing lean (1994-1997)

With a desire to reduce waste, maximize efficiency and increase production, this period focused on establishing an alliance with the Ministry of Agriculture to conduct on-farm research and data generation. The aim is to transform the existing farm from subsistence cropping into an efficient and environmentally friendly sustainable unit. The Rocrops family had the educational background and prerequisite requirements to access the Agricultural Development Bank (ADB) funding to undertake the project.

During the period 1994-1997, the soil scientist and fellow researchers of the Ministry of Agriculture conducted on-farm research on soil and water management. Two research papers documented soil management of heavy clay soils on a vegetable farm in Central Trinidad (Persad and Wilson, 1998) and Evaluated a micro-irrigation system for vegetable production on heavy clay soils in Central Trinidad (Persad and Roop, 1998).

Lean concepts in soil and water management

Soil management

As a lean strategy, the project demonstrated that implementing low input soil management techniques could ameliorate heavy clay soils for intensive vegetable production in Trinidad. Data from soil management the research (Persad and Wilson, 1998) shows the land reformation consisted of soil amelioration initiatives using low cost quarry overburden limestone, subsoiling, and tillage to improve the soil's physical conditions, including surface and subsurface drainage. As result of these measures, the soil pH increased within one year from 3.98 to 6.38. The pH values were maintained at levels near 6.50 by frequent soil testing and corrections. A pH value of 6.5 is preferred for a wide range of vegetable crops grown on small farms to reduce wastage of agricultural inputs and increase productivity. The results also showed a marked improvement in key soil fertility parameters with increases in available phosphate, potassium, calcium and magnesium which increases fertilizer efficiency and reduce wastage.

Water management

Data from the water management research (Persad and Roop, 1998) also shows that the application of micro-irrigation systems improved crop yields and quality, especially in heavy clay soils, with water use saving and efficiency. A critical aspect of micro-irrigation is the potential to produce high-value crops with control over the production cycle, land-use efficiency, increase yield, productivity, profitability, and fertilize crops more effectively. The use of the micro-irrigation and fertigation system at Ro-Crops in the dry season reduced water wastage, resulting in an approximately 80% increase in marketable vegetables.

Establishing the irrigation system included redesigning the farm layout in compliance with the lean concepts by constructing internal access roads, establishing a by-pass irrigation pond (56m x 39m x 5m) with a holding capacity of 10,000 m^3 of water and an independent fertilization station. The field layout design included subdivision of the 1.5-hectare holding into eight (8) irrigation blocks (7 for cultivation), with the farm pond as block 5. Construction of the access roads facilitated the drainage and water harvesting, reducing wastage by recycling field water into the irrigation pond. The internal access roads allow easy movement of farm vehicles for field maintenance and harvesting to reduce postharvest losses and wastage. The complementary irrigation and fertility practices and cropping patterns formed part of the integrated strategies to

increase overall farm production, productivity, and profitability by reducing waste at the production stage.

Further farm development included constructing a permanent steel and concrete two-story family dwelling house (55ft x 45ft), storage and postharvest buildings, and upgrading the water storage pond, micro-irrigation system, access roads, and peripheral fencing. The new farm layout consists of lean implementing measures of ‘flow and coverage' of farm activities to reduce movement on the farm as part of the lean strategy (Figure 6). Figures 7, 8, & 9 show the Farm pond and filtration; Micro-irrigation system; Access road.

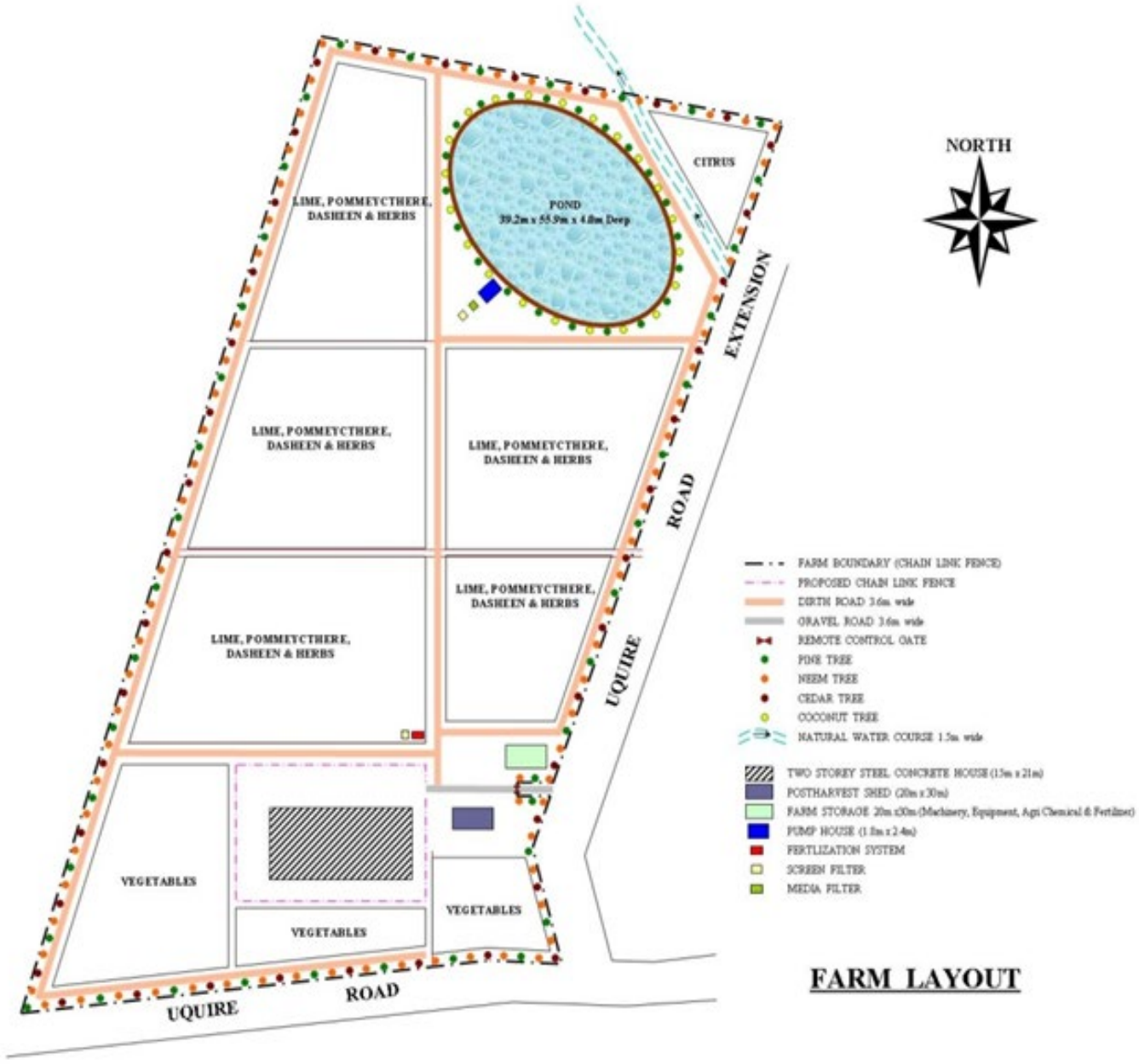

Figure 6: New lean farm layout

Figure 7: Farm pond and filtration

Figure 8: Micro-irrigation system

Figure 9: Access road

Lean in sustainable development (1997 to 2021)

The post-1997 to 2021 period focused on strategic business management processes and sustainable development to achieve food and nutrition security. The business management focused internally on entrepreneurship, including management planning, business registration, land tenure, succession planning, and human capital development. External connections include participation in farmers' organisations and strategic alliances with local, regional, and international organisations. The crop production strategies involved changing the mono-cropping from vegetables to integrated tree crops with low-input production, agroecological and conservation farming, and Integrated Crop and Pest Management (ICPM). These measures resulted in producing high-quality pesticide-free agricultural products throughout the year. The harvesting method included collecting the limes in a back-sack and stored in a ventilated vehicle to minimise post-harvest losses, as shown in Figure 10.

Figure 10: Harvesting limes in a sack to reduce postharvest damage and losses.

Integrating lean with agroecology

In consultation with the Ministry of Agriculture researchers, the farm management adopted a diversified farming system that includes functional biodiversity through traditional and agroecological scientific knowledge. This system included integrated cropping of vegetables, herbs, spices, lemongrass, tropical fruits, with limes as the commercial crop. It also incorporated non-cropping trees around the borders as live fencing and hedgerows. These trees are planted as windbreaks to create a microclimate less conducive to pest and disease proliferation and provide shade for the vegetable crops. The selected trees included Caribbean pine (*Pinus caribaea*), Colombian cedar (*Cedrela odorata*), bougainvillea (*Bougainvillea glabra*), variegated (decorative) bamboo (*Bambuseae multiplex*), and neem (*Azadirachta indica*). The nitrogen-fixing "fertilizer trees" complemented and enhanced mineral fertilizer to increase crop yields and improve rain-use efficiency (Sileshi et al., 2012). Figure 11 shows trees along the access road and fence.

The Integrated Crop and Pest Management (ICPM) practices on the farm included applying organic manure and mulch to protect the soil structure and stability. These measures contribute to improved water retention and increase fertilizer efficiency in the dry season. Controlling weeds before they flower using hand-held motorized brush cutters and hand weeding with the cuttings left as a mulch to retain moisture, especially during extended dry periods. Field sanitation and exceptional attention to postharvest handling techniques became strategies for integrating lean management in the farming system.

Figure 11: Caribbean pine and variegated bamboo along the access road

Lean in strategic alliances

The UN Sustainable Development Goals (UN, 2015) called for multi-stakeholder partnerships, including farmers, companies, governments, and civil society, in achieving sustainable agricultural development.

Ro-Crops has demonstrated that its sustained and equally rewarding technical relationship in 1994-1997 with the Ministry of Agriculture, Land and Marine Resources has contributed to its sustainable development. During the past 26 years, it has also formed relationships with other local, regional, and international organizations and businesses. Its interaction with farmers' groups and the universities of The West Indies (UWI) and the University of Trinidad and Tobago (UTT) provides on-farm training and demonstration for farmers, Extension Officers, environmental and agricultural secondary school students, Figure 12. The understory of the family dwelling house serves as an agricultural training centre. These training sessions demonstrate hands-on experience on various best management practices where the emphasis is now on using lean concepts scientifically (Spear and Bowen, 1999), emphasizing learning as a central component of the process (Holweg, 2007).

Figure 12: Training sessions for extension officers and environmental students

Human capital development

Ro-Crops family understands the importance of education, life-long learning, and human capital development with the three children (sons) and their wives attaining tertiary education. The farmer's wife received secondary level education with extensive training in agriculture and agribusiness. The household head advocated the importance of lifelong learning and demonstrated that it is Never Too Old to Learn by acquiring two master's degrees in Business with distinctions at 69 and 71 years (Gates, 2017; GWP-C, 2019). He desires to share this knowledge to achieve the Sustainable Development Goals of sustainable agriculture and food security. Additionally, in 2020, he contributed a chapter on climate change as the lead author for Springer's Handbook on Climate Change Management: Research, Leadership, Transformation (Roop and St. Martin, 2020). As an advocate for lifelong learning, it influences developing the human capital beyond the farmer, family, and workers.

Conclusions

The research demonstrates that while there are little literature and understanding of lean in agriculture and farming so far, its introduction is necessary given the magnitude of waste and losses generated at different production levels (Dora et al., 2015). There is great emphasis on increased production with limited focus on sustainability (Rockström, 2017). However, often ignored is the complementary factor of reducing food loss and waste as a sustainable strategy to achieve food security and nutrition (Hodges et al., 2011). There are "losses" in the food industry along the supply chain at the level of production, postharvest operations, and processing (Parfitt et al., 2010). These losses are due to inadequate harvesting technologies, lack of timely transport, and improper storage facilities (Papargyropoulou et al., 2014). Smallholder farms experience a considerable amount of postharvest loss due to inadequate market facilities and access to cold storage (Hodges et al., 2011; Tefera, 2012). According to Dobermann and Nelson (2013:2), the food systems and agricultural production worldwide must become more productive, resource-efficient, resilient, and 'less wasteful.' According to Krafcik (1988), the lean concept of production is a desire to reduce waste, maximize efficiency, and increase its economic value due to productivity, quality, and flexibility as the primary indicators of performance. Therefore, this paper examined integrating lean concepts in smallholder farming to catalyze sustainable agriculture and food security.

The paper also examined trends in Trinidad, which show that the distribution of agricultural lands is also on poor soils (mainly heavy clay), challenging terrain, and generally classified as class V – VIII, which encountered many technical and economic challenges resulting in limited success (Persad et al., 2007). According to Persad et al. (2007), inadequate agricultural practices further exacerbate the challenges, with < 20% of these lands cultivated and < 50% cultivatable indicating that small farm holdings generally lack the technical and financial resources to achieve sustainable soil management and amelioration practices. Further, a Joint Select Committee on Land and Physical Infrastructure (2017) reported that the sector still operates under the 19th-century farming methods resulting in widespread under-utilization of State lands.

The research shows that The National Agricultural Marketing and Development Corporation (NAMDEVCO) (NAMDEVCO, 1991) fosters a sustainable, competitive agricultural sector. It established programmes that will provide safe, healthy foods to the local and international markets, build the capacity of farmers, and provide market information for timely decisions making and marketing services.

Additionally, the Agricultural Development Bank (ADB) provides a significant funding source for developing the agricultural and agro-business sectors in Trinidad and Tobago (ADB, 2020). It provides several financing options, strategic linkages for customer support, and flexible payment terms. According to Thulstrup (2015), the ability to access capital for investment enables farmers to become resilient and sustainable.

The literature indicated several constraints and challenges which smallholder farmers encounter in achieving sustainable agricultural development. These include land tenure and succession, accessing capital, production challenges, postharvest management, social and environmental constraints. Hicks et al. (2012) identified succession planning as one key mechanism to achieve sustainable agriculture and food security. On the other hand, Schumacher (1973, p.64) described education as the "greatest resource" to achieve a just and ecological society. According (Hopkins and McKeown (2002), education is an essential tool in achieving sustainability.

The case study of Ro-Crops shows that land tenure, succession planning, building strategic alliances, and human capital are essential prerequisites for implementing lean concepts to achieve sustainable agriculture and food security.

Recommendations

Developing the agricultural sector in Trinidad incorporates the Joint Select Committee's findings, which recommended providing the necessary infrastructure, maximizing willing farmers' innovations with additional training, and engaging youth for the agricultural sector's succession and continuity. It incorporated SDG 2 as part of the National Action Plan to promote sustainable agriculture by engaging all stakeholders to participate in the programme. It also recommended establishing public/private partnerships to explore modern farming techniques to enhance the level of training provided for farmers. The case study of Ro-Crops is an example of a willing private partner, which demonstrates that integrating lean concepts in smallholder farming is a catalyst for sustainable agriculture and food security in Trinidad. The management of Ro-Crops demonstrates that sustainable agriculture and food security are achievable through strategic and succession planning, farm management, and applying innovative waste removal measures without the process of it becoming an obsession.

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