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SCIENTIFIC CORRESPONDENCE

Mechanization of sugarcane cultivation in Fiji – status and way forward

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Abstract
Sugarcane is Fiji's most important commercial crop, with the sugar industry being the largest enterprise in the country. The industry employs close to 48,000 individuals, with a quarter of the country's population depending directly and indirectly on the industry for their livelihoods, despite the subsiding sugar industry and declining yields observed in the past two decades. Therefore, to increase yield per hectare and solve the labour storage problem, there has been an immense focus on the mechanisation of the sugar industry.There is very little documentation regarding the mechanisation of sugarcane farming in Fiji, hence, the present study was undertaken to determine the status of farm mechanisation in sugarcane production, using the Nadogo district of Vanua Levu, Fiji, as a case study site. The study revealed that to increase the productivity of the farm and reduce the cost of cultivation, farmers in the Nadogo district were attempting to adopt various mechanisation strategies related to land preparation, planting of sugarcane crops, intercultural operations, weedicide application, harvesting, ratoon management, and transportation of the harvests. In the study, we also focus on the advantages and disadvantages related to the mechanisation of the sugarcane farms. The study revealed advantages such as saving time and labour for the growers, minimizing drudgery, improving work quality, lowering operating costs, and ensuring optimal resource utilisation related to farm mechanisation. The disadvantages were high maintenance costs due to wear and tear, the high cost of fuel to use some of the machinery, increased carbon footprints, and pollution. Most of these machines were also causing soil compaction during rainy seasons and delaying the cultivation process when machine breakdowns occurred and parts were not available.

Keywords: Mechanisation; Sugarcane production; Fiji Islands; Labour shortage

Introduction

Sugarcane cultivation plays a vital role in Fiji's agricultural sector, not only as one of the most important links in the agricultural production cycle in the country but also because it provides livelihoods for many households in the sugarcane belts of Fiji (Narayan and Prasad, 2006). In 2018, the sugar industry contributed about 1.2% of GDP to the national economy, generating about 4.3% of total exports (Fiji Sugar Cooperation (FSC) – Annual Report 2019). The production of sugarcane in Fiji, however, started in 1879 with labourers sourced from British India under the indenture system. At the very beginning, the indentured labourers worked on plantations owned and managed by the Australian Colonial Sugar Refinery Company (Dean, 2019).

After serving their indentures, some of these labourers chose to stay back in Fiji, and together with their descendants, they lived on to become the economic strength of the sugar industry and the country. Later, the sugarcane growers were given approximately 4.5 hectares of land to begin their farming operations as smallholder farming systems.While the system favoured growers by granting them increased control over their farms, the sugarcane production has experienced substantial fluctuations in recent years, ultimately declining from 1972 to 2021 to reach a final output of 1.42 million tonnes in 2021. Despite this

decline, Fiji still has a thriving sugarcane industry, with a total cultivated area of 37,105 hectares and over 16,754 farmers relying on sugarcane farming as their source of income (Singh, 2020).

Fijian agriculture mainly comprises small, scattered holdings, and sugarcane production is no exception (Hone et al., 2006). The sugarcane crop remains in the sugarcane fields for almost a year and throughout the crop cycle (land preparation, planting, management practices, harvesting, and delivery to the mill). These operations in other parts of the world have often required outsourced labour and machinery (Singh et al., 2011). However, in Fiji, traditionally the sugarcane crop production has seen little to no mechanisation, with all farm operations majorly relying on manual labour, from the initial process of planting the sugarcane setts to harvesting the fully grown, matured produce. In a technical sense, if we look at the current level of mechanisation in sugarcane production in Fiji, it is limited to tractors mainly, and the utilisation of land preparation equipment, is confined to cultivators and harrows only.

While it was observed that farmers relied mostly on traditional farming implements in the Nadogo district, we also found that some of the growers have started to adopt other forms of mechanisation strategies for easing tasks related to sugarcane production as well as increasing yields. However, there is little information available in the literature on the types of mechanised farming implements used in the sugarcane fields of Fiji and their advantages and disadvantages. Therefore, this study aims to fill this gap by focusing on the sugarcane production processes, the sugarcane growers, and the use of farming implements in the sugarcane fields of Nadogo district in Labasa, Fiji.

Materials and Methods

This study was conducted in the Nadogo district in Labasa, Fiji, during the 2020-2021 cropping season to investigate the status of sugarcane mechanisation in Fiji and the advantages and disadvantages related to the adoption and utilisation of the mechanising implements. This study is the first of its kind to be conducted in the Nadogo district, which is located approximately 42 kilometres away from Labasa Town (Vanua Levu) (Fig. 1). The district lies in the dry zone and receives comparatively less rainfall (1500-2500mm) than other parts of the country (Robertson, 1931; Gunathilake et al., 2020).

The Nadogo district has two sugarcane-producing sectors: Wainkoro and Daku, respectively. The Nadogo district is made up of ten sugarcane farming settlements - Nubu, Vunivutu, Nasasa, Karewa, Naqili, Kurukuru, Lagalaga, Natabe, Navukebuli, and Kilikoso. Out of these ten settlements, only five: Nubu, Natabe, Lagalaga, Kilikoso, and Kurukuru - were purposefully selected for this study because of their high sugarcane yield outputs in comparison to the other settlements. In addition, the following parameters were also considered when choosing a settlement: the researchers can easily access the settlements (Prasad et al., 2021), the settlements (Table 1) should have relatively good road access, and farmers in the settlements were working together and were willing to share their experiences and observations related to sugarcane farm mechanisation (Kumar et al., 2017).

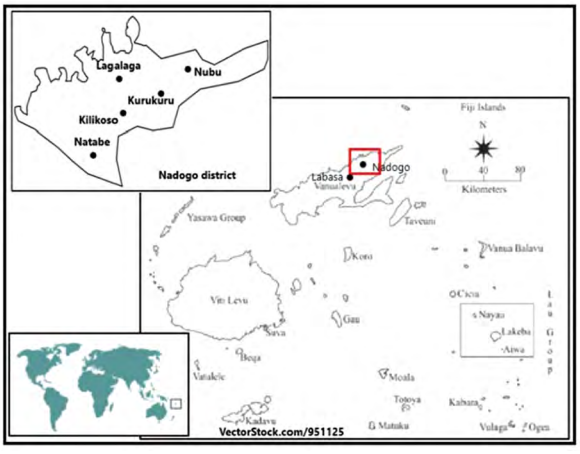

Figure 1. Map of the study area

Research design

The main aim behind the research design of this study was to enable the researchers to collect data for this study in the most legitimate, objective, accurate, and cost-effective way feasible. Therefore, we adopted an ex-post-facto method because it was a systematic investigation in which the researchers did not have direct control over the independent variables because they had already manifested themselves or because they were fundamentally unmanageable (Bunyatta et al., 2006), focusing instead the primary goal of determining the farmer's knowledge, observation, and experience of using agricultural implements and machines in sugarcane farming.

Data collection

We adopted the data collection method utilised by Bunyatta & Mureithi (2010). We utilised pre-designed and pre-tested questionnaires and semi-structured interview questions for collecting data for this study. We also incorporated the approach and research method of informal conversation adopted by Dean (2019) to build trust with the farmers and to access maximum information regarding sugarcane mechanisation in the Nadogo district. In addition, we also utilised phone interviews for member checking and re-validating the collected data because of the ongoing COVID-19 virus surges and restricted movements and containment zones enacted by the government to prevent community transmission of the virus. In addition, the phone interview technique proved to be a feasible alternative for contacting sugarcane farmers for data accuracy and obtaining other crucial information that could not be obtained during the actual field visits when movements were still allowed in the country and the nation was COVID-19 virus- contained.

The structure of the questionnaire for a study on the mechanization of sugarcane production aimed to gather comprehensive information about various aspects of the subject. The questionnaire included demographic information such as the respondent's age, gender, education level, and experience in sugarcane farming. Additionally, it inquired about the current farming practices, including the use of machinery, attitudes towards mechanization, financial considerations, barriers to adoption, and future intentions. The questionnaire also sought information on the types of machinery in use, their frequency of use, and the advantages and disadvantages of using machinery. Financial considerations such as the cost of acquiring and maintaining machinery, the impact on profitability, and access to financing were also explored. Finally, the questionnaire identified any obstacles that may have prevented farmers from adopting machinery in their operations, such as lack of knowledge or access to financing. It was crucial to ensure that the questions were clear, concise, and easy to understand, and that the questionnaire was designed in a way that minimized response bias.A 20% sampling of the total number of the household (sugarcane farmers) in the five villages of the Nadogo district was surveyed using the household questionnaire. This sampling technique is similar to the method used by Rasmussen et al., (2009).

Table 1: Sampling size of household survey

Village	Total number of sugarcane farmers	20% of the household
Nubu	30	6
Natabe	22	5
Kurukuru	37	7
Lagalaga	60	10
Kilikoso	28	6
Total	177	34

Data analysis

Data gathered from 34 household questionnaire was analysed and tabulated on MS Excel with statistical analysis done using the SPSS software

and the analysed data was grouped into the following: frequencies, percentages, and averages. The data was represented in summary graphs and tables for ease of interpretation and explanation. The data collected through semi-structured interviews, informal farmer conversations, and phone interviews from34 farmers were transcribed (a process of converting data from an audio or video format into written document format) and translated (a process of creating a written document from a transcript or a digital or video recording from one language to another), using Appau et al.'s (2019) method.

Results and Discussion

Mechanisation of sugarcane production refers to the use and application of mechanical equipment in soil preparation, furrowing, planting, cultivation, fertiliser application, plant protection, harvesting, loading, and transportation in the overall sugar production system (Yinggang et al., 2013). The decision to mechanise sugarcane production in the Nadogo district in Labasa, Fiji,is unavoidable because mechanisation saves time, assures operational timeliness, eliminates drudgery, improves work quality, lowers operating costs, and ensures effective resource utilisation,which to that effect also assists in increasing sugarcane yield. In the following section, we present information on biographical information of the farmers and mechanical implements adopted by the sugarcane growers in land preparation, planting, intercultural communication, chemical application, harvesting, transportation, and ratoon control procedures, together with their advantages and disadvantages.

Profile of sugarcane farmers

Age

The study reveals that most of the sugarcane farmers (52.9%) were categorized as "old age (50-65)", followed by 41.2% of the sugarcane farmers in "middle age (35-50)" and 5.9% sugarcane farmers in the "young age (50-65)". (Table 2) The majority of the sugarcane farmers were between middle age and old age in the Nadogo district. These farmers had broad experience of 15-35 years in sugarcane husbandry.

Gender

Sugarcane farming is a 100% male-dominated industry. However, females within the household actively participate in the sugarcane value chain such as planting, weeding, applying of fertilizer, and harvesting. All the farmers in the study are male and are also head of their households (Table 3).

Table 2: Personal information of the respondents on age

Parameters	Options	Frequency	Percentage (%)
Age	Young age (20-35)	2	5.9
	Middle age (35-50)	14	41.2
	Old age (50-65)	18	52.9
	Total	34	100

Table 3: Personal information of the respondents on gender

Parameters	Options	Frequency	Percentage (%)
Gender	Male	34	100
	Female	0	0
	Total	34	100

Table 4: Personal information of respondents' education level

Parameters	Options	Frequency	Percentage (%)
Education level	Primary School	26	76.5
	Secondary School	8	23.5
	Tertiary institution	0	0
	Total	34	100

Table 5: Type of land ownership and farm size

Land type	Total farm size (ha)	No. of farmers	Percentage (%)
Native Land	0-5	5	14.7
	5-10	20	58.8
	10-15	5	14.7
	15-20	4	11.8
	Total	34	100

Education

The analysis of this study shows a low level of education amongst the sugarcane farmers because the majority (76.5%) of the farmers had primary education while 23.5% of the farmers had secondary education. And none of the studied farmers had tertiary education (Table 4).

Land ownership and farm size

The land type of sugarcane farmers in the Nadogo district is Native land, leased to the sugarcane farmers by the iTaukei Land Trust Board under Agricultural Leasing Act. The majority (58.8%) of the studied sugarcane farmers land size range between 5-10 hectares, while 14.7% of the farmers had a land size that ranges from 0-5 hectares and 10-15 hectares. Only 11.8% of the farmers had a land size between 15-20 hectares. The biggest land size leased found in this study is 20 hectares while the smallest land size leased is 3 hectares (Table 5).

Table 6: Common tractor driven implements/machine used in sugarcane production

Implements or machines	No. of farmers	Percentage (%)
Disc plough Disc harrow Spike harrow Scarifier Spring tine cultivator Rotovator Furrow opener Whole stalk cane planter machine Cane Harvester	30	88.2

Table 7: Common animal driven implements used in sugarcane production

Implements or machines	No. of farmers	Percentage (%)
Mouldboard plough Diamond harrow Furrow opener	4	11.8

Use of agricultural machinery in sugarcane cultivation

Sugarcane cultivation requires a high demand for labour and machinery, from land preparation to harvesting. Although machines' utilization in sugarcane farming has increased, most of the cultivation operations mainly depend on labour (Singh et al., 2017). However, the farmers in the Nadogo district depend more on tractor or machine driven implements than on bulk-driven implements or labourers.

Land preparation

A well-prepared plot of land is essential for high sugarcane production. The primary reason for ensuring adequate land preparation is to create desirable soil texture, provide favourable environmental conditions for cane growth, allow rapid infiltration and retention of water (rainfall), provide enough air exchange in the soil, and ease root penetration by the sugarcane plants in the soils (Kishore et al., 2017). We discovered that sugarcane farmers in Labasa's Nadogo district of Labasa traditionally used an animal-drawn mould board plough and diamond harrow (Fig. 2). The mould board plough consists of a double handle, steel beam, and plough bottom, which has a share and chisel for cutting the soil, the mould board to turn the soil and land slide for guiding the plough, and the diamond harrow for pulverising the soil after the land has been ploughed. The harrow consists of a diamond-shaped steel frame that has spikes that break the soil clods into smaller pieces and collect debris. While this implement continues to be utilised by some of the sugarcane growers, its relative importance has decreased. Farmers indicated that land preparation with animal-drawn implements consumed more energy and time, and therefore many of the farmers have ventured into the adoption of mechanised farming systems, starting with tractorisation.

Figure 2. Mouldboard plough (Top) and a diamond harrow (Bottom)

With the introduction of tractors, most animal-drawn or animal-powered farming implements have been replaced. The tractors were observed to be playing an important role in sugarcane farming and in the cultivation of other crops planted by the farmers. The most common types of tractor-drawn implements used by sugarcane farmers were disc ploughs, disc harrows, spike harrows and

rotovators. Unlike the animal-driven implements, the tractor-driven disc plough and harrow, spike harrow, and rotovators have an additional part known as the three-point hitch that connects the implement to the tractor in such a way that the implement's orientation is fixed in relation to the tractor and hitch's arm position (Fig. 3). The main parts of a disc plough consist of the disc (which cuts and turns soil), beam (holds the disc), and furrow wheel (keeps the plough steady), while the parts of a disc harrow consist of a frame that holds the discs, as well as the scalloped disc that breaks soil clods and mixes debris in the soil. Unlike the disc harrow, the spike harrow consists of a square frame that holds the spike used to break soil clods and collects the debris.

Figure 3. A disc plough (left top), a spike harrow (left bottom) and a disc harrow(top)

In the past, sugarcane farmers in the Nadogo district did not use rotovators for land preparation of sugarcane fields, but at present the adoption of rotovators in land preparation has increased (Fig. 4). The rotovator is a powerful implement that consists of a frame that holds rotating blades for breaking the soil into smaller particles. Although the sugarcane farmers used both traditional and

Figure 4. A rotovator (top) and a furrow opener (bottom)

mechanised land preparation, tractors and tractor-drawn implements were found to be more effective and time-saving than animal-drawn implements. After ploughing and harrowing the sugarcane fields, farmers used a furrow opener to open furrows, which is a crucial step in the sugarcane seedling planting process. In the past, sugarcane farmers used a mouldboard plough to make furrows in the fields, but now most of the farmers are using a type of furrow opener, also known as a Arakasi in Fiji, to perform this activity. A three-point hitch connects the implement to the tractor, and a frame holds the plough bottom, which has a shovel and chisel for cutting the soil, two mould boards on each side to turn the soil on both sides of the furrow, and a land slide for guiding the plough.

Planting of sugarcane

After the preparation of land, sugarcane planting is the next step in the production process.Over many years, tractor-drawn sugarcane planters have been created, tested, and shown to sugarcane farmers by stakeholders in the sugar industrysuch as the Fiji Sugar Corporation (FSC) and the Sugar Research Institute of Fiji (SRIF) for the planting of sugarcane seedlings or setts. However, most sugarcane farmers were found to be continuing to rely heavily on manual planting, while very few farmers did utilise sugarcane planting machines such as the whole stalk cane planter (Fig. 5). For the growers, manual planting consisted of the whole operation process, such as furrow opening, de-trashing of cane stalk, cutting cane stalk into setts using a cane knife after placing the setts in the furrows, setting and planting the cane setts, and then covering the setts with loose soil using a hoe. Specifically, sugarcane farmers highlighted that a sett should be planted at a depth of 10 to 15 cm in the soil, with the eye buds on the setts placed on the side for easy germination. These findings were found to be similar to those of Dean's (2019) study.

Figure 5. Placing of cane stalk in the furrow (top) and cane setts (bottom)

On the other hand, planting sugarcane seedlings or setts by machines has become a realistic option since the introduction of mechanised sugarcane planters, which allow automatic slicing of whole cane into setts (Singh et al., 2011) (Fig. 6). A tractor-driven whole stalk cane planter that is used by farmers in Nadogo does a combination of processes independently, such as preparing drills, cutting cane into pieces, applying fertilisers or

Figure 6. Whole stalk cane planter machine

fungicides, and providing soil cover over the setts by compacting the soil. However, it was revealed that the machine still requires continuous manual feeding of sugarcane stalks into the planter.

Intercultural operations

Sugarcane stem dressing, commonly known as tillering, has been one of the most important approaches for reducing weeds, allowing moisture conservation in the soil, and establishing a better environment for overall cane growth (Kishore et al., 2017). Sugarcane farmers in Nadogo district were found to be using hoes, knives, and spades for side dressing, weeding and tillering purposes. The utilisation of this equipment remained unchanged even when the option of, for example, mechanical weeders such as animals (mould board plough) and tractor-driven scarifiers, also known as cultivators (implement), were available (Fig. 7). The parts of this mechanical weeder equipment consist of a three-point hitch that connects the implement to the tractor and a frame that holds the spring tines for inter-row cultivation and for removing or uprooting the weeds. However, many of the farmers told us that they preferred manual weeding in the sugarcane field with traditional tools and implements like knives, hoes, spades, and scarifiers as soon as sugarcane shoots appeared.

Figure 7. Traditional tools (top) and a *scarifier* (bottom)

Fertilizer and weedicide application

Around the globe, there are various types of tractor-mounted fertiliser distributors that are utilised for fertiliser applications in the sugarcane fields (Kishore et al., 2017). Also, around the globe, other types of fertiliser sprayers exist, such as power sprayers, hydraulic sprayers, knapsack sprayers, bucket sprayers, hand compression sprayer, rocker sprayer, and foot-operated sprayers (Kishore et al., 2017). However, in Nadogo, there are no mechanised forms of fertiliser distributors that can be adopted by the sugarcane farmers to assist them in fertiliser applications. The farmers were found to be solely relying on a knapsack sprayer (hand-operated) for weedicide applications (Fig. 8). The knapsack sprayer gets its name from the way the operator carries the sprayer on his back. The knapsack sprayer is made from brass or PVC material. It has a flat or bean-shaped tank with a capacity of 10-15 litres, a hydraulic pump that is installed inside the tank, a pump handle, an agitator, a filter, delivery hose, and a spray cannon

Figure 8. Hand operated knapsack sprayer

with a nozzle and a flow control lever. When the chemical solution is poured into the tank, the pump suctions the fluid through the suction hole and sends it to the spray cannon when it is turned on. When the cut-off lever is pressed, a fine droplet is automatically sprayed out through the nozzle.

Sugarcane harvesting

Once the sugarcane crop has matured, the most crucial operation thereafter is harvesting the produce to obtain the crop's profit in the form of cash (Kumar et al., 2018). For Nadogo, farmers and other cane cutters primarily utilised knives for carrying out the harvesting manually. The cane stem is cut at the bottom, and the cane top is sliced off after the de-trashing of the stalks. All over the globe, different types of cane-cutting knives coming in a variety of shapes and sizes have been adopted (Dharmawardene, 2006). In Latin America, for example, cane cutters use a machete; the Australians use a 135-degree curved blade knife; and in South Africa, they use short- and long-handled cane knives (Irvin, 1993). In Nadogo, cane cutters are using a long-handled straight-bladed sugarcane knife to harvest sugarcane because it is more comfortable to use when compared to other types of knives (Fig. 9).

However, effective and efficient on-time harvesting and delivery of the produce, including the costs associated with just the harvesting, is gradually becoming difficult for the Nadogo farmers. The compensation paid to the hired cane cutters and the costs associated with transporting the produce to the mills for processing are taking a toll on the farmers. For example, in addition to wages, farmers must provide these hired laborers with food, lodging, and other types of necessities (Dean, 2019). In addition, delayed harvesting because of various reasons, such as the weather and the lack of available harvesting laborers, often affects the quality and of sugar recovered in sugar mills. Considering such challenges, the sugar industry in Fiji introduced cane harvesters to help the farmers with timely harvests of the mature sugarcane (Fig. 10). The cane harvester machine performs basal cutting, promotes cane cleaning with fans and/or blowers, and chops stalk into 15- to 20-cm-long billets before discharging them into a transport unit (a truck or tractor bin) that transports the harvested cane to the sugar mill. The sugarcane passes through numerous steps inside the machine from basal cutting to loading the harvested sugarcanes into the lorry.

Figure 9. Long-handled straight-bladed knife

During the harvesting process, the harvester is positioned in the cane row, where the crop topper cuts the sugarcane top. The power supply system, consisting of crop dividers, knockdowns, and feeding rollers, directs the sugarcane bundle to the base cutter, which is made up of two revolving disc blades. An elevator roller is responsible for gathering and elevating the sugarcane bundle. The feeding rollers carry the sugarcane bundle horizontally and distribute it for slicing into billets bythe chopper rollers. The sliced billets are then deposited in the elevator basket, where the primary extractor does the first cleaning of the leaves. The billets are then subsequently taken up by the elevator, and before being unloaded into a transportation vehicle, a secondary extractor carries out a secondary cleaning of the produce (Narimoto et al., 2015). In Nadogo, we found that sugarcane farmers were using cane harvesters,

Figure 10. Cane harvester

but the harvesters could be operated only on flat lands, while sloppy cane fields continued to be manual harvested by the farmers. Although cane harvesters were harvesting cane at a faster rate, it was also responsible for causing soil compaction and damaging the ratoons for the next growing season.

Ratoon management

Ratooning is a method for allowing the sprouting or germination of the ratoons from the new sprouts come from the buds underground during the harvesting process. Ratoons that have not been well maintained after the harvest often increase farmer costs, as farmers will need to replace the ratoons with a new cane sett altogether. But if the ratoons are well maintained, according to the farmers, they produce great yields. To perform

Figure 11. Tractor-driven *scarifier*

ratoon management of the sugarcane crop in Nadogo, farmers were found to be using both animal (Mouldboard plough) and tractor-driven implements (scarifier), particularly for earthing up, stubble shaving, and fertilizer application activities (Fig. 11).

Harvest transportation

Around the world, various modes of transportation are used by the farmers to transport their produce to the mills (Kumar et al., 2018), while in some other countries and depending on the business models, millers also tend to purchase the produce directly from the farmers at their farm gates. We observed that most of the farmers in the Nadogo district used tractor-operated trailers to transport the sugarcane bins, which are filled with the harvested produce from the sugarcane fields, to the railway collection point. The railroad trains then collect the produce and transport it to the mill for processing. Some farmers were also observed using alternative modes of transportation, such as cane trucks and lorries, to transport their produce directly to the sugar mill (Fig. 12).

Mechanised sugarcane production is the process of deploying agricultural machinery to help automate agricultural processes in sugarcane farming, resulting in much faster worker productivity. In Nadogo, we found that effective mechanisation

Figure 12. Three common modes of harvest transportation (lorry, tractor and train)

in sugarcane farming can help to enhance output in three ways: First, by ensuring that operations are completed on time or before the onset of bad weather, which can delay sugarcane farming activities such as land preparation, planting, and harvesting. However, if the bad weather lasts for days, farmers will utilise farm animals such as bullocks and horses specifically for land preparation and interrow cultivation. These bullocks and horses are also utilised for moving or pulling produce out of the fields. In addition, farmers do not prefer to use machinery when they experience bad weather because machines are heavy and lead to soil compaction and degradation. Instead, farm animals are used because they are light in weight and do not lead to soil compaction.

Farmers also reported that animal-driven implements generally took more time and energy when compared to using a tractor or tractor-driven implements. A study by Kumar et al. (2018) found that land preparation with tractors took approximately 11hr/ha while with animals it took almost 120hr/ha. Although the study indicated that tractors took less time to perform sugarcane farming activities, we still need to consider other factors such as fuel utilisation, hiring costs, and machine maintenance costs (machine servicing and replacing parts) to understand its sustainability.

Mechanisation also ensures that farming activities are of high quality. For example, when farmers use tractor-driven furrow openers to make furrows, the furrow lines are straight and evenly spaced in the cane field, but when farmers use animal-driven furrow openers, the furrow lines are not straight and equally spaced. Furrow lines made using tractor-driven furrow openersare exceptionally good because it is easier to position the cane harvesters for harvesting cane. Similarly, the use of a rotovator machine for secondary tillage is highly preferred by farmers nowadays because they have observed that the blades in the rotovator machine provide good soil tilth, which allows better growth for sugarcane setts than those cane fields harrowed using animal-driven implements.

Thirdly, the adoption of machinery in sugarcane farming provides farmers with greater profitability. Historically, non-mechanized sugarcane farming methods were highly profitable due to the availability of abundant labour, allowing farmers to negotiate favourable wages for their workers. However, the shortage of labour and the physically demanding nature of sugarcane farming have resulted in rising labour costs, including the added expense of providing food for workers. To mitigate these challenges, farmers are turning to machinery such as tractors for land preparation, whole-stalk cane planters for planting, and cane harvesters for harvesting, which save them time and reduce costs.

On the other hand, increased mechanisation does not always imply large expenditures for tractors and other mechanised equipment. Sugarcane farmers must select the best power source for any

operation on sugarcane because the amount of mechanisation should effectively and efficiently suit their needs. For example, in the past, land preparation for sugarcane planting in Fiji was entirely performed using animal power (in some parts, this is still the case), and while this consumed time and energy and the quality of work was at times below standard, it was still a viable option for the smallholder systems and is the case for many of the farmers in the Nadogo district also. Farmers are still practicing manual sugarcane planting and harvesting and using animal driven implements for sugarcane farming activities on cane fields, especially where machines cannot operate, even though it is a time and energy-consuming activity. According to the farmers, such an approach is sustainable, and for them, taking into consideration the environmental impacts of mechanisation in farming is paramount.

While sugarcane mechanization has the potential to increase cane yield and quality in an efficient and effective manner, at the same time it contributes to socio-economic and environmental challenges. In mechanized sugarcane farming, most of the field operations are carried out using heavy machines and tillage implements, and the weight of these heavy machines and tillage implements contributes to subsurface soil compaction that affects soil physical and chemical properties. For example, a study conducted by Esteban et al. (2019) reported that using larger and heavier machines in sugarcane production is causing soil compaction in cane fields. Apart from causing soil compaction, machines also contribute to carbon emissions through the combustion of fuel in the engine.

A study by Martin-Gorriz et al. (2020) concluded that operating machines for farming activities results in higher emissions of carbon in the atmosphere. Another problem associated with the use of machines for sugarcane farming activities is the high cost of machine maintenance. Machinery and implements are the lifeblood of every farmer, and they must be maintained (including inspection and servicing costs and repairing and replacing damaged parts) on a regular basis to stay in top shape. However, farmers reported in the Nadogo district that, despite its benefits, machine and implement maintenance demands a lot of upkeep, which increases the overall production cost. In addition, farmers have also claimed that their work in the cane field is delayed due to machine breakdowns or when parts are not available.

Conclusion

Sugarcane mechanisation has the potential to increase productivity and enhance the quality of work in rural areas, however, we need to be mindful of the disadvantages associated with sugarcane mechanisation. The finding highlights that some areas of Nadogo district still require mechanised methods of sugarcane planting, harvesting, and fertilizer and weedicide applications because there are labour intensive activities and the land size and topography suit mechanisation. However, not all areas of the Nadogo district will fully mechanise sugarcane farming because we must keep in mind that there are many smallholder farmers whose land topography does not lend itself to mechanised sugarcane farming. However, when introducing new machinery for sugarcane farming, one must keep in mind that the technology must be both environmentally friendly and user friendly.

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