“Na mata ni Civa au a vakawaletaka”

An ethnobotanical study on kumala (*Ipomoea batatas* (L.) Lam) and its contribution to Climate-Smart Agriculture in Ra, Fiji

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A thesis presented in fulfilment of the requirements for the degree of

Doctor of Philosophy

in

Horticulture

MASSEY UNIVERSITY

School of Agriculture and Environment

Palmerston North, Aotearoa

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2022

Declaration of Authenticity

Statement by Author

I, Ilisoni Lasaqa Vuetinabouono Leweniqila solemnly declare that this thesis is my work and that, to the best of my knowledge, it contains no material previously published, or substantially overlapping with material submitted for the award on any other degree at any institution, except where due reference is made in this thesis.

Signature: Date:

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Statement by Supervisor

The research in this thesis was performed under my supervision and to my knowledge is the sole work of Mr Ilisoni Lasaqa Vuetinabouono Leweniqila.

Professor Nick Roskruge
Primary Supervisor

Professor Peter Kemp
Co-Supervisor

Abstract

Globally, sweetpotato (*Ipomoea batatas* (L.) Lam) or kumala is regarded as an essential, versatile, and under-utilised food security crop. In Fiji, kumala has a strong traditional base, and our ancestors valued this crop as a lifesaver to people during and after natural disasters to act as food security since both the tubers and leaves are consumed. This research weaves together two methodologies; the Fijian Vanua Research Framework (FVRF) which involves ethnobotany studies, and a western sciences (field trials) research element to support and reinstruct **smallholder** farmers on the value of kumala as a significant crop for subsistence and a source of livelihood for rural economic development in Fiji. The three research sites were Nabukadra (<20m asl[1]) located in the coastal land area, Bucalevu (>150m asl) in the high altitude inland, and Burenitu (80-100m asl) in the district of Nalawa which is situated at a lower altitude.

The implementation of FVRF in this research paid specific attention to indigenous Fijian society aligning to future food security issues in an agricultural context. This research sought a solidarity approach for the rural areas in Fiji adopting their systems of knowledge and perception as the basis for inquiry extending the knowledge base of indigenous people and transforming their understanding of the social-cultural world like solesolevaki, which is our current cultural currency. The Dre'e metaphor was generated to discuss the findings from this research. The findings of this research discussed the cultural role of kumala production in the I-Taukei context under four components: values and beliefs, practices, skills, and knowledge. Indigenous Knowledge (IK) exists across all facets of the I-Taukei way of life, which includes health, belief system, and environmental survival.

Given that each genotype or variety of kumala may respond differently to production factors, there was a need to evaluate available sweetpotato genotypes across geographic zones where it can be grown in Fiji. The application of agronomic field trials at different altitudes for this research provided a valuable recommendation that will assist farmers in decision-making for growing kumala at different altitudes in Ra. This will enhance food security and create economic opportunities. Furthermore, this extension of traditional and agronomic knowledge will support climate-smart agriculture (CSA) and help achieve food security in the province of Ra, Fiji Islands.

[1] asl – [metres] above sea level

Thesis-Related Research outputs & Additional Courses

Additional Courses

284.703 (2017): Vegetable Production Science (15 credits)

Conference/symposium abstracts

Leweniqila, I. (2021). “Sa vosa na Vanua” - The Land Speaks: Indigenous Agriculture Knowledge (IAK): Philosophy of life Values & Epistemology and Relationship to Indigenous Kumala Agriculture Farming in Ra. Ethnobiology Virtual Conference. Southern Utah, USA. May 14, 2021:

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Farmers Training on Revitalising Sweetpotato and Agronomical practices in Ra, Fiji.June – August 2018

Guest Speaker – Awatapu Secondary College, Palmerston North, New Zealand. 2018

Career Guest Speaker – Awatapu College, Palmerston North, New Zealand. June 2017

Awards and Grants

- Indigenous People Conference Award, Cedar, USA 2020-2021.
- Ministry of Foreign Affairs Awards Scholarship (MFAT).
- Australian Centre for International Agricultural Research Awards Scholar (ACIAR)

Dedication

"Vakarua 7:9 – Ia oqo mo kila na Kalou ko Jiova sa Kalou o koya na Kalou sa dau dina o koya sa maroroya na nona veiyalayalati me yacova nai taba tamata e udolu sa vakatalega kina na nona yalololoma vei ira sa lomani koya ka dau maroroya na nona i vakaro kecega."

To Peleki and Sokoveti Leweniqila,

A gone vuku sa vu ni marau vei tamana ia na gone lialia sa vu ni cudru vei tinana. Where I am today was through God's vision to both of you despite the challenges we face you ensured that I had the privilege of being well-educated.

To my loving wife, Luisa Latu Leweniqila. Thank you for your continuous love and support. "Vina'a valevu na veicikomi e'i na vosota galugalu mai na yaba'i ece ni'u leva tu mai vale e'i na nodrau qaravi na yaqiti".

Lastly, my precious daughters Muleinakali Kelly Leweniqila, and Adi Kinisimere Dawn Leweniqila always remember the Vanua. "Mudrau guta na lotu ei na vuli ka mo drau liga laulau na kena vukei oira na kawa kei viti ni mataka ka rawati na bula sautu ena noda vanua ko Viti." These are your wisdom, knowledge, roles and responsibilities that I have entrusted you both to continue this legacy.

Acknowledgements

Foremost I would first acknowledge my father God, and it is the most beautiful thing to be loved and honoured by you. This achievement is a testament to God's Grace.

Though this thesis will specify that I am the sole author of this work, numerous organisations, institutions, families and individuals must be acknowledged for their unwavering support and inspiration, which has made this thesis's completion possible.

I would first like to extend my appreciation for the leadership conveyed by my supervisors, Professor Nick Roskruge and Professor Peter Kemp whose own traditional knowledge, as well as western-derived knowledge and experience of teaching and learning, provided me with motivation and inspiration to begin this journey and to complete it. I am deeply honoured to have studied under your guidance and leadership. Vina'a va'a levu matu'a.

I also extend my gratitude to the New Zealand government MFAT scholarship for the three and a half years funding my studies. MFAT Scholarships build potential leaders. You have allowed scholars like me to pursue our studies at a world-class university like Massey University.

Additionally, my sincere gratitude to the Turaga na Gonesau and the people of Nabukadra, Naisogowaqa vua na Turaga na Ratu ni Bure and the people of Burenituand Leweinamatagai na Turaga na Vunivalu and the people of Bucalevu for granting me access to your vanua and community and treating me as one of your own. This study would not have been made possible without the participants in Ra. I offer a special thank you to the Ministry of Agriculture research staff for facilitating and providing me with full technical support during my field studies in Ra. To all Dobuilevu Research Station staff – "cecere na veiqaravi Karoline and Sairusi Wara" and God bless you all.

To the people of Nabouono, the yavusa Dokanaisuva, and Mataqali Drano. I am therefore indebted to the Vua na Sauvou for planting my vicovico (umbilical cord) under his uvi mounds thus ensuring my connectedness to the Vanua, my source of knowledge, wisdom and means of survival. I am of the view that I was destined to be raised there to acquire the sau (power of wisdom and knowledge) of the vanua o Drano and to pass it on to the future generations of Fiji. Vina'a Yaca.

A special thanks to my in-laws, the Taginadavui and Kete families. My father, mother-in-law Ilisoni Taginadavui and Mereoni Marama Taginadavui, Amelia Marama, Ilisoni Taginadavui Jnr, and my late sister-in-law Kinisimere. Thank you for your prayers and tremendous support for Tinaimule. Our daughters and family are grateful for your support.

I offer a special thank you to my maternal links in Nananu Komai Sautini and Nawainovo na Tui Wainovo in Naburenivalu. To you, all my Momo, Nei, Tata, and Nana, thank you so much for all your support during my educational journey. Being part of the Ratabacaca and Seniyaro family since my childhood, they have shared with me what little they had and have taught me the compassion and love that unites us. The role of parents in protecting and nurturing me from an early age until today. I hold the inheritance of this knowledge, wisdom and *sau* dearly from my "wai ni sucu".

I offer a special acknowledgement to my family and friends in Palmerston North. The Daunibau Family, Vunibola Family, Vulimailodoni Family, Kaiwai Family, Whippy Family, Meo & Bulitavo Families thank you for opening your hearts and home to me. Vinaka vakalevu for all your support Tamailiza and Tinailiza "edua madaga na bilo wai vua na tamata ni alo'u sa drau na ena'i sau. To my comrades and my fellow countrymen, Amini, Api, Mesu, Joeli, Jale, Nuku, Wise, Rex, Sani, Funaki, Tika, Kila and Paul vina'a for being a friend through all the difficult times – "Faya na Marau". To all the RKS Old Boys 2000 back in Fiji and the RKS teachers from the years 1997 to 2005. Lodoni deserves this breakthrough in education success.

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Chapter 1

1.1 Introduction

O'yau sa'a

Au vaa'tulou e na noku dela ni yavu mai Drano. O 'au sa mai ena tamata e'na gusu ni vanua o Dokanaisuva e'i na e'na bure tabu au'sema dra tu i'na. I'e sa tu ina noku i tavi lesu me tauco'o na i semai na vanua.

Here I am, I acknowledge the lineage of my tribe and Vanua with respect. I stand to be the voice of my people, a call to demonstrate the values of integrity and good morals, which is the benchmark of our philosophy of service cohesion of the whole indigenous Fijians.

Bula si'a,

O'yau o Ilisoni Lasaqa Vuetinabouono Leweniqila, o yau na a'iCa'e (Udu), mai na 'oro o Nabouono e'na ti'ina co'ovata o Dogotuki. O'yau i'o au vasu turaga i Naburenivalu mai na o'ro o Nananu ena yasana ko Tailevu. Na no'ku tata ko Peleki Leweniqila e'i na marama natina'ku ko Sokoveti Valenilotu Leweniqila.

Na tama'ku o Peleki Leweniqila, na luvei (nai tini/ya'iti duadua) Ilisoni Lasaqa Leweniqila, noqu kuku tagane ka noku yaca na luvei Ilimotama Leweniqila a kuku na kuku tagane nei tama'ku (Tubuku va'arua) oya na Vua na Sauvou ei Udu. O Ilisoni Lasaqa Leweniqla (Yaca) na yavusa o Dokanaisuva, to'a ei na mata'kali o Drano ena 'oro o Nabou'ono, ti'ina o Udu, ti'ina co'ovata o dogotuki mai macuata. O Kelera Bitaki Leweniqila na watina, kuku yalewa, na luvei Waisea Makulau ka vakawati vei Sereima Taciqi mai na o'ro o Vatu, mai na yavusa o Cu'u, mai na mata'kali o Muana'i'Cake, to'a o Korobelo, e'na ti'ina o tawake, ti'ina co'ovata o Saqani mai na yasana va'a turaga o Ca'audrove.

Na Noqu Vasu

A tina'ku o Sokoveti Leweniqila a luvei Saimoni Verenakalou Ratabacaca (no'ku tukai) mai na yavusa o Sautini, e'na mata'kali o Rokotuiloma mai na to'a o Rokotuiloma, a o'ro o Naburenivalu, ena ti'ina ma'awa o Namena, na ti'ina co'ovata o Sawakasa ena yasanao Tailevu. A watina o Anameli Lewanicagi Ratabacaca (no'ku Bubu) mai na yavusa o Nabati, ena mata'kali o Nabati, na to'a o Nabati, ena ti'ina ma'awa o Namena, na ti'ina co'ovata o Sawakasa, na o'ro o nananu ena yasana o Tailevu.

Na Wati'ku *(Wainisucu nodrau a luve' ku)*

Au va'awati vei Luisa Latu Leweniqila (Tinaimule) a rua' ina na luvei rua yalewa. O Tinaimule na luvei Ilisoni Nairoba Taginadavui mai na o'ro o Nasawana, ena Yavusa o Solevu, na mata'kali o Nalagi, na to'a o Nalagi mai na ti'ina o Nadi, ti'ina co'ovata o Vuya na yasana o Bua. Na i'nai wati'ku o Mereoni Marama Taginadavui na marama ni Nairai, na mata'kali o Dalisila, na to'a o drano ena yavusa o Yakava mai na o'ro o Lawaki na yasana o Lomaiviti.

Veimudrau na noku Senibua, Muleinakali Kelly Leweniqila e'i Adi Kinisimere Dawn Leweniqila sa oto ina o ira na we'amurua va'adra dina. Na i vola tamata ni gauna sa toqai oto ina mudrau qai ila ni oira na ena awa era basia mai ina, sa oira na weamudrau dina a me muru sema ina a ila'i ira va'idina.

In the Indigenous Fijian world, it is significant to know who you are and your origin. Knowing those truths will guide you through studying indigenous rural people in Fiji because somewhere on the line, you are connected to that tribe. Indigenous Fijians are known to "*Na yalewa era dau kauta na veiwekani*"; the woman takes or carries the line of our relationship. A metaphor stating when a woman gets married, she brings on the family including the Vanua's relationship linked to the place she is married and in an indigenous Fijian world, we value our *"vasu"* more in the vanua. That shows how a woman in the indigenous Fijian society is valued. As an indigenous researcher, I need to introduce myself in my language and connect all those components.

I am Ilisoni Lasaqa Vuetinabouono Leweniqila and I hail from the village of Nabouono, Udu district, and Macuata Province. The eldest of the four siblings includes. Eseta Talei Leweniqila (Tinai Joshua), Opeti Seniyaro Jnr (Tamai Joy) and Badogo Leweniqila. Our parents are Mr Peleki Leweniqila and Sokoveti Leweniqila. Our father Mr Peleki Leweniqila is the son of the late Ratu Ilisoni Lasaqa Leweniqila. (Tui Drano na Sauvou) my grandfather. The late Ratu Ilisoni Lasaqa Leweniqila was from the Dokanaisuva tribe and the Drano clan the district of Udu from Macuata province. His wife, my grandmother, was Kelera Bitaki Leweniqila the child of Waisea Makulau and Sereima Taciqi (great-grandparents) from Vatu village, the Cu'u tribe, the Muana'i'Cake clan, the Korobelo family unit, from the district of Tawake, Saqani the province of Ca'audrove.

Moreover, the introduction also acknowledges my maternal links.Sokoveti Leweniqila is the descendant of the late Ratu Saimoni Verenakalou Ratabacaca and Anameli Lewanicagi Ratabacaca (my grandparents). Saimoni is from the village of Naburenivalu, the Sautini tribe the Rokotuiloma Clan, from Namena District in the province of Tailevu ni Siga. His wife, Anameli Lewanicagi (my grandma) is from Nananu village, the Nabati tribe and clan, from the Namena district of Tailevu province.

The introduction also recognises and acknowledges, Luisa Latu Leweniqila (my wife). She hails from Nasawana village, from the Solevu tribe, the Nalagi clan, and the district of Nadi in the province of Bua. The two plumeria flowers of my life (Muleinakali Kelly Leweniqila and Adi Kinisimere Dawn Leweniqila) it is your task to know our genealogy and bloodlines. Share them with our generation.

My work experience before pursuing my studies here at Massey University was primarily with indigenous Fijian life in the rural outer islands of Fiji. It has influenced me a lot in living a bula vakavanua life experiencing the reality of being a subsistence farmer where bills must be paid; social obligations, and other matters like the family to feed. It prompts why my dad had to educate me in the village. They taught me the importanceof our traditional local crops to us for survival. It was a reminder that land utilisation and understanding the interconnectedness of the resources and elements are central to daily living and the land was the crux of being related to people, relationships, and culture. Service to people was embedded within my being at an early age when my grandmother said, no matter how high you fly, remember to carry our people with you.

In contrast, working in all agriculture sectors (World Wildlife Fund, Ministry of Agriculture, and the Fiji Development Bank) and experiencing what our rural and outer island indigenous Fijian farmers are going through, that voice of my grandmother echoes to remind me on the importance of your people to you. Therefore, I had to consider a crop alternative to help achieve food security and provide an avenue for climate-smart agriculture, a crop in a short period that will provide them with a quick return.

The title of this research then was conceived, adopted from the Fijian parable "*Na mate ni Civa au a vakawaletaka*," which translates to "the pearl has been neglected" meaning that their purpose has not been recognised. Sweetpotato (*Ipomoea batatas* (L.) Lam) or kumala is often referred to as the "forgotten crop" that has the potential to become a significant crop as a source for food security as well as subsistence and an avenue for climate-smart agriculture leading rural economic development. While kumala has a strong traditional base in Fiji, its potential social, cultural, and economic values are currently under-recognised. The above therefore underpins the importance of this research.

1.2 Research Question

The research question that guides this study is:

How can traditional knowledge and western sciences' knowledge of kumala production contribute to food security and Climate-Smart Agriculture (CSA) of Fijian (I-Taukei) farmers in Ra District?

1.2.1 Objectives

1. To explore indigenous knowledge and the historical context of kumala production in Fiji.
2. To contextualise the loss of importance of kumala within the Fijian society, specifically in the Province of Ra.
3. To evaluate the best-yielding varieties of kumala suited to different climatic zones in the Ra province. Therefore, the null hypothesis: there is no difference among the growth and yield of five varieties at three different altitudes.

1.3 Background

The benefits of agriculture at both the local and global levels are enormous. Previously in agriculture, the hunter-gatherer lifestyle supported about 4 million people globally (Matson et al., 1997). Currently, contemporary agriculture feeds 7.94 billion people annually, and it is estimated by 2050, the global population is likely to be 50% larger, and the global demand for root crops is likely to double (Tilman et al., 2002). Additional growth in agricultural outputs is crucial for climate change and social stability. However, amplifying food production and succour food production at this level presents some significant challenges (Tilman, 1999). In responding to the above, it is crucial to recognise that agricultural systems will regulate the level of food production, in the global environment. Farmers are the primary managers of terrestrial 'useable' lands (Godfray et al., 2010; Reddy, 2017).

Agricultural development involves focusing attention on speeding economic growth, eliminating poverty and vulnerability, and minimizing rural-urban gaps in developing countries. By promoting traditional foods, a renewed focus is being placed on a "new agriculture for development" paradigm to benefit economic growth and address the socio-economic components of development (particularly for rural development). Over 45 percent of the population in developing countries lives in agricultural households, while 27 percent live in smallholder homes, with agriculture providing a significant percentage of their income (World Bank, 2007). The agricultural sector, which employs 65 percent of the labour force in agriculture-based countries and generates 29 percent of GDP on average, is critical to overall growth (*ibid*., 2007). According to recent research by the International Fund for Agricultural Development (IFAD) (2013), over 1.4 billion people live on less than US$1.25 per day, with the bulk of them (70 per cent) residing in rural areas where agriculture is their primary source of income.

There are several reasons for the growing recognition of agriculture's importance in developing countries' economic and rural development. First, agriculture is the major source of employment in many nations and, due to its comparative advantage, will continue to be the most important economic sector. Furthermore, agricultural productivity increase is the most important driver of global poverty reduction measures, as it directly raises farmer incomes and indirectly reduces food insecurity. According to Kim, Larsen, and Theus (2009), the agricultural sector has a much greater potential for growth in terms of poverty reduction than other sectors of the economy. Second, accelerated agricultural growth is widely transformative, in that increases in farm income raise demand for industrial goods, lower food prices, and reduce inflation but also increase overall demand for unskilled workers. Third, rising agricultural productivity can spur broad entrepreneurial activities such as product diversification, market expansion, the emergence of agro-processing industries, and the expansion of rural service sectors (Diao et al., 2008).

Agriculture practised on all islands of the South Pacific is for subsistence agriculture and, in many cases, for sale to international and domestic markets. Agricultural exports are minor compared to imports in most parts of the South Pacific. It is rare for households to meet their food needs on their production alone, and most depend on the market for their food needs. Agricultural production in Pacific Islands countries can be vulnerable to climate change in many ways. The impact of erosion on coastal areas increased pollution of groundwater and river mouths due to saltwater intrusion, and other natural disasters can impair food production individually or in combination (Diao et al., 2006; FAO, 2011).

Food nutritional needs and cultural importance are increasingly buyer-led global agri-food systems, from food commercialization to cross-border companies setting production and exchange conditions along the global value chain (Gereffi, 1994; Ponte & Gibbon, 2005). The World Bank Agricultural Report (2007) aims to save hundreds of millions of poor rural workers from poverty by focusing on small-scale agriculture and livestock production, employment of high-value products, and entrepreneurship and employment in emerging countries. This shows the importance of agriculture to rural and non-agricultural economies in the agricultural sector. The report suggests that this can be achieved first by increasing the productivity and competitiveness of agriculture in general, creating non-agricultural employment opportunities in rural areas, and secondly by increasing the wealth and skills and knowledge of subsistence farmer's households.

The agricultural sector in Fiji is undergoing structural change due to commercialization pressures and increasing reliance on trade, especially imports. Therefore, government policy has become the main driving force behind the structural changes introduced with crop diversification to support this sector (Ministry of Primary Industry, 2009). One of the key bottlenecks highlighted by many analysts of the Fijian agricultural sector is the small size of farms and the inability of local farmers to compete with large-scale agriculture in the west (Barbour and McGregor, 1998; Narayan and Prasad, 2003; Vorelevu & Bhati, 2006; Nacoke, 2007; Young and Vinning, 2007; Asafu Adjaye, 2008; Haszler et al., 2010; Kumar and Bhati, 2010).

The solution to supporting smallholders is to bring small and marginal farm owners together in a standard production system to focus on one product (Barbour & McGregor, 1998; Young & Vinning, 2007; Haszler et al., 2010). First, traditional knowledge and Western science must be woven together, giving access to small and marginal farmers, which until now has been quite limited as the technology is currently only available to those who can gather and obtain information at great speed. The implementation of traditional environmental knowledge has largely fallen into oblivion. Second, smallholders face price discrimination in both factory and product markets, resulting in lower net income streams. Finally, small, and marginal farmers have always competed better than their commercial farmers in terms of productivity and land quality, but they have limited access to technology (Barbour & McGregor, 1998; Young and Vinning, 2007; Haszler et al., 2010).

Agriculture is the primary source of food, income, and employment for the majority of low-income indigenous Fijians, more than 50 percentof whom live in rural areas. Fiji's most recent poverty report shows that the proportion of rural households in poverty increased from 35 percent in 2002-2003 to 37 percent in 2008-2009 (Narsey et al., 2010). Therefore, growing agriculture is imperative to reduce poverty as most of the poor are small and subsistence farmers.

Agriculture's contribution to the gross domestic product decreased from 12.3 percent in 2001 to 10.5 percent in 2008 and further to 8 percent in 2011 (Fiji Islands Statistics Bureau, 2011). It is a common belief that the low productivity of agriculture is mainly due to the negligence of traditional farming methods and the widespread use of low-yielding seeds. Agricultural productivity is also hampered by low government policies and appropriate strategies for approaching and identifying potential crops in each region of Fiji (Asafu Adjaye, 2008; de Boer & Chandra, 1978; Haszler et al., 2010; Ward, 1960).

Technology transfer has been a step forward in increasing productivity and reducing poverty. However, farmers do not adopt innovation immediately after it hits the market (Rogers, 1995). Some farmers choose to be innovators, while others prefer to be early adopters, late adopters, or non-adopters (Rogers, 1962). For Fiji, traditional environmental knowledge and practices are essential to integrate with farmers for sustainable agriculture. Innovative agricultural practices can be difficult to implement because agriculture is a risky business and farmers face multiple risks and uncertainties.

Climate change is an additional set of challenges for agriculture, especially in addressing the predictable increase in meteorological events. The Pacific region was extremely vulnerable to the effects of climate change and natural disasters, which were the major causes of significant agricultural production losses in the past. Therefore, the need to rejuvenate traditional agricultural knowledge, practices and traditional food need to create a platform for a climate-friendly agricultural approach.

The Pacific Islands' infrastructure is also affected by climate change, degrading agriculture due to commercial and subsistence farming needs. Natural disasters have caused turmoil by damaging road infrastructure, directly affecting food supplies to markets, and eroding the lives of rural producers. Traditionally, the Pacific Islands region is known to grow a wide variety of crops, and not all crops are affected by certain dangers such as droughts and cyclones, so some food supply resilience exists (Campbell, 2018; Elmqvist, 2000). Repeated attempts to develop mono-cultural cash crops in the Pacific, coupled with the impact of the cash economy and often the impact of market penetration of cheaper, if not so healthy foods, are numerous. This has helped to weaken the diversity and intensity of local production in the region. These effects have increased dependence on the food market and reduced the resilience of the food supply in the face of threats such as low incomes and relatively high food prices. However, "dietary changes" in the region are associated with an increased incidence of non-communicable diseases (Barnett, 2011).

Rising foreign market penetration and different forms of development aid, as well as increased urbanisation, have all led to changes and, in certain cases, reductions in land tenure security on customary land (Clarke and Thaman 1993; Colding et al. 2003). These attempts to shift toward modern agricultural economies and, more broadly, wealthy industrial societies have frequently failed to recognize the types of traditional foods and resilient agricultural food systems that the Pacific Island countries have overlooked the resilience associated with their traditional knowledge and practices.

Climate-smart agriculture (CSA) is an approach that guides farmers' actions to transform and reorient agricultural systems to support the development and food security effectively and sustainably in the face of climate change. Climate-smart agriculture is not a novel mode of production. From an indigenous perspective, it is a method of determining which production systems and enabling institutions are best suited to respond to challenges such as location, while also maintaining and improving agriculture's capacity to support food security for every household in a sustainable manner. FAO first introduced this concept in 2010 to achieve food security by achieving three main goals: building resilience and adapting to climate change, increasing agricultural production and incomes sustainably, and emerging opportunities in reducing greenhouse gas emissions compared to expected trends (Palombi & Sessa, 2013).

Climate change continues to threaten humanity's ability to secure global food security, eradicate poverty and achieve sustainable development. It has a direct and indirect impact on agricultural productivity, including changes in rainfall patterns, droughts, floods, and geographical redistribution of pests and diseases (Dow & Downing, 2016).

Climate change will have a significant impact on food security and agricultural livelihoods in all Pacific Island countries (Thomas, 2001). The looming effects of climate change on agricultural productivity in the Pacific region could be significantly reduced. Climate change must be confronted with a calculated and strategic approach that incorporates both modern and indigenous agricultural production practices (Motulsky et al., 2018).

Jon Barnett (2011) summarized the potential impacts of climate change in the region:

> *'Climate change negatively impacts the region's food system, including agricultural food supply, national food import capacity, food distribution system, and household food purchasing and availability. Climate change is always sufficient for islanders. Threatens the basic and universal need for access to safe, nutritious foods (p.1).*

Given the unprecedented rate of environmental change affecting the region, a generation of accumulated traditional knowledge about precipitation, temperature, wind and their impact on crop production is at stake (Revuelta, 2018).

1.4 Cyclone impacts on Fiji

Cyclones are a significant cause of lost agricultural production in Fiji; for example, Cyclone Ami caused more than $35 million in crop losses in Fiji in 2003. (Sharma, 2007). In Fiji, severe flooding of the Wainibuka and Rewa Rivers in April 2004 destroyed between 50 and 70 percentof crops (Takasaki, 2016). Due to a lack of irrigation, drought has posed a challenge to agriculture in every region of Fiji. Increasingly intense rainfall events, as well as ongoing deforestation and longer dry spells, may all have an impact on soil fertility. The Category 5 Tropical Cyclone (TC) Winston struck many Fijian islands on February 20, 2016, causing extensive damage and killing 44 people. A total of 40,000 homes were damaged or destroyed, and the storm had a significant impact on about 350,000 people (an estimated 40% of Fiji's population). The total damage caused by TC Winston was 2.98 billion FJ (US $ 1.4 billion) (Mansur et al., 2018; ILO, 2016). The agricultural sector had reportedly lost 90% of its crops in the most devastated areas, leaving families with little or no alternative food sources. The impact on agriculture reached 1 billion Fiji dollars (Mansur et al., 2017; UNOCHA, 2016). TC Harold hit Fiji as Category 4 on the night of April 7-8, 2020. In total, more than 180,000 Fijians were struck by TC Harold and have seen their homes, lives, and livelihoods suffer. The agricultural sector has suffered more than 27 million FJ$ from torrential rains and floods across Fiji (Bureau of Statistics, 2020; FBC, 2020). The extensive damage to staple crops across Fiji through this cyclone has been reported in a recent assessment, demonstrating that food security is a significant concern for all affected provinces of Fiji (FBC, 2020). Recently,in the year 2020 on December 13th, TC Yasa struck Fiji and it was assumed to be the strongest tropical cyclone in the South Pacific since TC Winston in 2016. It was also the second Category 5 severe tropical cyclone in 2020, which had a significant impact on the agriculture sector. TC Yasa affected

23,725 households and 19,678 households depended on agriculture (MPI, 2021). Agricultural damage estimates in Fiji are a minimum total of FJ$500 million or US$246.7 million. Within 45 days TC Ana struck Fiji causing the most damage in the greater Viti Levu area, farmers in the north were the most affected, having been at the receiving end of two tropical cyclones. The estimated total damage to affected agriculture per household was valued at $108.9 million. Reports from the Ministry of Agriculture confirm that the top five most affected crops identified according to their value of damage were yaqona (kava), dalo (taro), cassava, watermelon, and chillies, and for livestock were goat, sheep, bees, cattle and horses (MPI, 2021).

The Pacific Islands are vulnerable to climate change in many ways (Fischer, 2002). Due to the wide distribution of islands, some are more exposed compared to others and have different impacts on different islands (Campbell, 2006). Some Pacific Island states and territories have the highest average annual disaster loss as a percentage of global GDP (Blewitt, 2014). These challenges influence the Pacific region's ability to mitigate and address poverty, achieve sustainable development, and help people realize their human rights and reach their full potential (Edwards, 2010). Effectively addressing these challenges requires effective coordination of regional cooperation, political leadership, and support from development partners, and needs to be informed by a deep understanding of member needs and their context. The solution should be based on a multi-sectoral response in line with national priorities and the application of quality scientific and technical knowledge and innovation (Park et al., 2015; Feresi et al., 2000; Patel, 2009). However, Fiji is also experiencing a change in eating habits. Traditional food is an integral part of the food culture of the community. The revival of traditional food crops can be of immense help in ensuring food security. Increased production and availability of traditional foods reduce reliance on processed foods. Local availability of fruits and vegetables on the market improves diet (Kamphuis et al., 2006).

Ra district in Fiji is highly vulnerable to a variety of hazards, including extreme weather events and pest and disease outbreaks. These hazards can result in significant yield losses for traditional food crops, increasing the risk of famine and food insecurity in Indigenous Fijian communities (Sisifa et al., 2016). In the past, sweetpotato cultivation allowed communities to adjust their farming systems and reduce food security risks before, during, and after disasters (Iese et al., 2018). Sweetpotato's food security benefits have contributed to its adoption as a staple crop by communities on the "edge" of agroecological limits for their traditional crops (Iese et al., 2016; McGregor et al., 2016a, 2016b). It is a supplementary crop that adds nutrition and stability to community food systems. Sweetpotato is currently being grown in many Pacific communities as part of food security and climate change adaptation projects (Evans, 2006; Wairiu et al., 2012; Government of Solomon Islands, 2014).

1.4.1 Pandemic Covid-19 Crisis

In 2021 the entire world is in unprecedented times facing one of the most dangerous pandemic crises in history. Covid-19 has evolved into an economic crisis: in only a few months, it brought the international economy to its knees. The virus does not respect the size, location, or wealth of our countries (Sing, 2020). With the closure of borders since 19th of March 2020, the Covid-19 crisis has destroyed Fiji's primary industry of tourism. The incomes of over a third of formal employees have been reduced. The people and businesses are suffering the worst economic disaster in our history (Tora, 2020). The social impact of the loss of income has been felt in domestic violence and suicides, and the demand for food to feed a family is a concern. The Fijian economy is around 60% driven by informal sectors. Therefore, Fiji needs to focus on small micro-enterprise-type farmers since they play a vital role in the economy (Narube, 2020).

Food security was also a 'major concern'. This was stated by the Minister for Defence, National Security and Foreign Affairs in Fiji as with closed borders and restricted movements, vital supply chains grow more vulnerable (Naidu, 2020). This pandemic outbreak has highlighted some opportunities often neglected in Fiji. The rural outer islands have become a strength, yet government attention to rural outer islands is lacking. This pandemic shows that while the urban economy is collapsing the rural economy is keeping everyone going (Sing, 2020; Narube, 2020; McGregor, 2020). A place we call our Koro (village) which has been detached from most indigenous Fijians has been a haven to the people of Fiji since during the economic crises the traditional safety net is always the strength of the indigenous Fijians in every province of Fiji (Kiran, 2020; Tora, 2020).

The areas that are most affected during this pandemic crisis have been:

- **Jobs:** More than 130,000 workers either have lost their jobs, are on reduced pay or leave without pay, and this is half of the working population in Fiji. Statistically, it is more than one-third of the formal workforce in Fiji. Additionally, this number does not include those in casual employment. This number continues to rise.
- **Businesses:** Most businesses are suffering from lower sales leading to tight cashflows. Most of the micro and small businesses will expect to collapse and never rise again.
- **Government revenue:** The government cannot collect 70% of its budgeted revenue, or $1.5 billion.
- **Debt:** The government revealed in the COVID-19 budget that the national debt would exceed 60% of GDP. With the numerous expenditure demands and the need to rescue the economy, which only the government can do, this debt is expected to rise to more than 80% of GDP

before the crisis is over.

- **Economic growth:** The Reserve Bank of Fiji expects the economy to decline by 21.7% this year. It is the largest economic decline in recorded history. With no end to the virus insight, the economic impact will be devastating.
- **National income:** Given the massive decline in the economy and the reduction of inward remittances, we expect nominal national Income (GNI) to decline by at least $2.5 billion in 2020 alone.
- **Poverty:** Poverty will rise to 50% of the total population. It will thrust an additional 200,000 of our people below the poverty line.
- **Social impact:** Social issues like domestic violence and suicide have increased, reflecting the financial stress and tension in families as they struggle to survive on food and payments without regular income (Unity Fiji, 2020).

1.5 Impacts of Traditional Fijian Foods

There is an opportunity that exists for Pacific countries to return to their traditional foods. The Covid-19 epidemic has demonstrated the limits of international commerce and globalization, as well as the critical necessity for Pacific nations to create resilience and self-sufficiency. These crops are, of course, ancient crops, but they provide prospects for the future since they can be grown locally with little input and a low carbon footprint, and they can increase smallholders' capacity to adapt to climate change and, of course, food security (Lebot, 2019). This research supports the need for scientific information on crops like sweetpotato to help farmers in the region to strengthen and increase the yields of their crops. Returning to the traditional indigenous Fijian diet would also help significantly with health needs while promoting traditional root crops, would help balance diets, and that would strengthen food security.

Land from the perspective of an indigenous Fijian also has the power and influence that always needs to be considered since it has a connection to the traditional food that we consume. These powers can be both positive attributes and support to specific activities done on the land or the negative aspects of not respecting the land (Vunibola, 2020). Its people uphold the values of the land and crops that have been farmed on it via traditional rites and practices that honour the ancestors, and physical and spiritual qualities inside the soil. Departing from these norms is thought to have negative consequences: there are several tales of new developments on customary property that are thought to have failed because they did not proceed in a culturally suitable manner (Vunibola, 2020). As a result, the Rotuman proverb "the land has eyes and ears" (Hereniko, 2013) refers to the concept that vanua is a living thing that observes (with its eyes) and appears physically through disease, accident, and even death (it has teeth).

Traditional crops and agricultural processes are often resistant to changes in climatic circumstances. Many traditional agricultural traditions, however, have deteriorated in recent years, frequently because of commercial production requirements from the last two decades, and the sensitivity of Pacific food and commodities production systems to climatic variability has grown. Regardless of how climate change plays out, there is a clear need to address this heightened level of vulnerability and implement measures that strengthen the resilience of production systems and management regimes. Measures that address present vulnerability while simultaneously developing resilience to future climate change are known as 'no regret' measures; that is, efforts that make sense even in the absence of climate change (Hau'ofa, 1993). Traditional Pacific crops, such as major food sources, are under threat from shifting rainfall patterns into fertile land (Alemu & Mengistu, 2017). Failure of basic crops may be disastrous for the many Pacific households that live on a subsistence basis. In areas where agricultural productivity exceeds subsistence levels, the resulting revenues are frequently critical for clothing and schooling children, as well as purchasing supplemental foods to guarantee a healthy and diverse diet (PACC, 2015).

1.6 Sweetpotato / kumala

Sweetpotato (*Ipomoea batatas* (L.) Lam) is regarded as an important, adaptable, and underutilized food security crop worldwide (Bovell-Benjamin, 2007). Kumala is a root crop, which is the second most important food crop in underdeveloped nations (FAO, 2010). It is one of the few species of the widely dispersed tropical-world genus Ipomoea that produces fleshy and edible storage roots (Cooley, 1951). Kumala originated as a climbing vine and was domesticated circa 6000 BCE, with its botanic origins in the Peruvian highlands (Clarke, 2009; Nuwer, 2013). Research by Zhang et al. (2000), however, opposes this, indicating that it may have evolved in Central America, where the kumala gene pool is more diversified than in South America and the Caribbean.

In the tropics, kumala may be cultivated all year and is often reproduced vegetatively by sowing stem cuttings from which new plants sprout (Bovell Benjamin, 2007). The spreading and erect variants are the most regularly cultivated. Spreading varieties are ideal for arid zones because their vegetative cover helps conserve soil moisture. For moist zones, the erect form with branching nodes is preferred (McGregor et al., 2016). However, in areas where kumala plants cannot overwinter in the field owing to cold weather, kumala tubers are grown under modified circumstances to produce shoots that may be planted in the spring (Harrison et al., 1985).

The crop requires well-drained soils, and excessive soil nitrogen levels can be hazardous to tuber growth (Woolfe, 1992). Once established, the kumala plant is very resistant to prolonged drought, however, Lewthwaite and Triggs (2012) suggest that production and quality may suffer. Kumala may form blooms in warm and humid tropical zones with adequate sunshine length and cumulative temperature, but they seldom set seed. According to Yen (1960), the plant's capacity to reproduce from seed without human assistance is unknown. Underground tubers range in colour from white to purple, mature in 3 to 6 months, and are typically elongated in shape, but can be almost spherical (Harrison *et al*., 1985).

Kumala is a significant 'indigenous' root crop in the Pacific (Roullier et al., 2013). Because of its adaptability, drought tolerance, and favourable impact on food security, it is widely used in smallholder cropping systems (Bovell Benjamin, 2007; Dow & Downing, 2016). In terms of vitamins, minerals, dietary fibre, and protein content, it outperforms most staple crops. While there is a wealth of literature on sweetpotato as a drought-tolerant and food security crop, critical studies that relate its drought tolerance to food security are scarce (Motsa et al., 2015). As a prospective crop for food security and a contribution to climate-smart agriculture, a focus on its drought-related characteristic processes is critical. It has been established that the crop has considerable potential in light of the impending issues linked with drought as a result of climate change (Roskruge, 2007).

1.6.1 Kumala Production in Oceania

The humble kumala is a crop that was introduced to Oceania. The tuber, which is native to South America, has spread throughout Polynesia and the neighbouring Pacific islands, but no one knows how it got there (Yen, 1960). Researchers have narrowed down the journey of the sweetpotato using genetic data from herbarium specimens and current crops, which might offer insights into the travels of the humans who transported it (Handy, 1940; Estrada de la Cerda, 2015). Oceania's current production levels are about 90000 tonnes (see Figure 1).

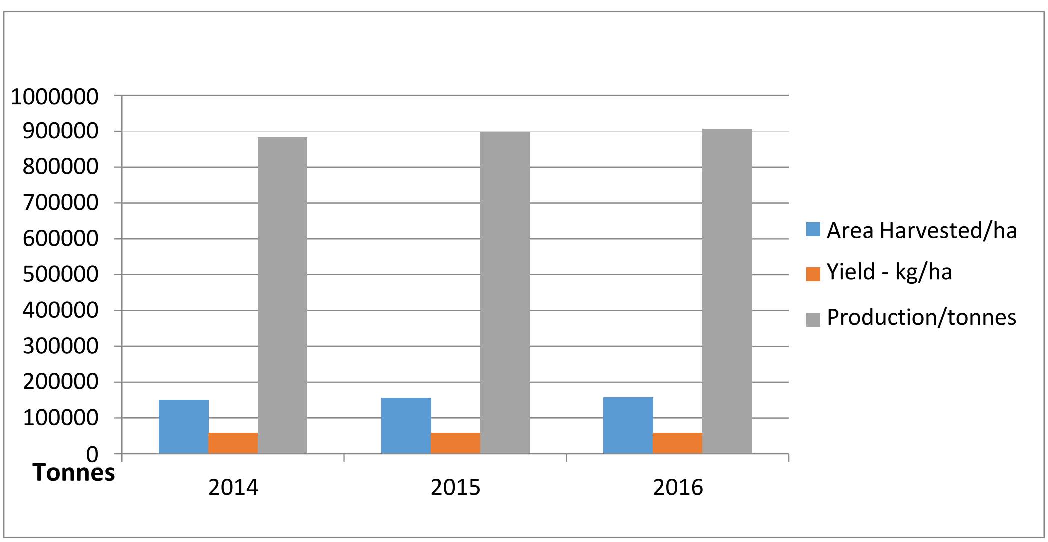


Figure 1: Production of Sweetpotato in Oceania. Source: FAO Stats, 2018.

Kumala is cultivated throughout the tropic zone and in much of the Northern and Southern temperate zones of the Pacific (Hornell & James, 1946; Yen, 1974). It is now accepted that the plant was a staple cultivated food of the Polynesians before the arrival of Europeans. The number of varieties of kumala in the Pacific has been used to indicate the antiquity of the plant's association with the Polynesian culture (Hornell & James, 1946; Chappells et al., 2015). It may be noted then that natural seed formation occurs in the Pacific between the latitudes of 30^0 N and S (Yen, 1960; Spoehr, 1960).

1.6.2 Kumala production in Fiji

In Fiji, kumala production is estimated to be around 9402 tons as of 2012 (see Figure 2) an increase in production from 7464 tons in 2010 and 8635 tons in 2011 respectively (Ag Trade Report, 2013). Despite its importance as a short-term crop with maturity in 3-6 months, huge value-added potential, and, most importantly, its considerable influence on the Fijian economy, the potential worth of kumala is not completely recognized in Fiji. However, according to the Ministry of Agriculture, kumala is a crop that is employed as part of the country's natural disaster recovery program. It has enormous potential and, if properly utilised, has the potential to have a positive influence on the Fijian economy (McGregor et al., 2016). Regardless of its qualities, kumala is of modest importance in Fiji, but it is nevertheless a viable subsistence food crop when compared to other root crops that have historically been regarded as more economically important (McGregor et al., 2016). The crop is extremely nutritious, outperforming the majority of carbohydrate meals in terms of vitamin, mineral, dietary fibre, and protein levels (Mauro, & Hardison, 2000).

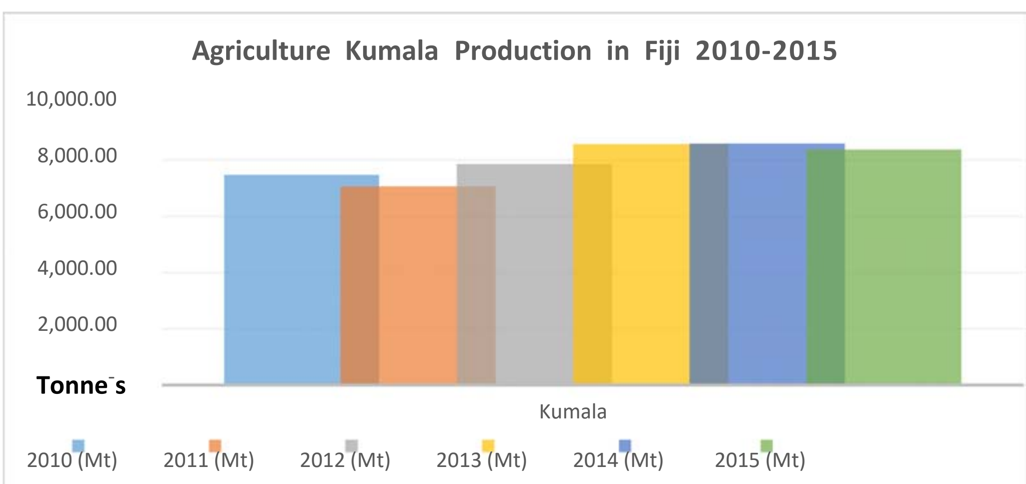


Figure 2: Sweetpotato Production in Fiji from 2010- 2015. Source: Ministry of Agriculture, 2018

Most I-Taukei or indigenous Fijian farmers rely on subsistence agriculture as their major source of sustenance (Sofer, 2018). A considerable part of Fiji's rural and outer island populations practices predominantly subsistence agriculture, relying on their output to cover their food demands (Chappells and Trentmann, 2015). However, given the consequences of occurrences such as tropical cyclones, assessing the capacity of crops to fully contribute to food security poses issues (Bayliss-Smith, 2016). It is thus necessary to employ participatory research and extension support to re-educate smallholder farmers on the importance of sweetpotato or kumala as a crucial crop for attaining Climate-Smart Agriculture in Fiji.

The kumala plant responds differently to production factors depending on genotype or variety; therefore, there is a need to evaluate available sweetpotato genotypes across the range of geographic zones in Fiji where it can be cultivated hence providing better recommendations to farmers for variety selection (Caqumu, 2015). Plants subjected to environmental challenges such as drought and heat stress often respond with creative physiological adaptations, which are accompanied by changes in gene expression (Craswell et al., 1998). Plants' biological responses and tolerance to drought stress, including physiological, biochemical, and transgenic tolerance, be understood (Bammann, 2007). There is also a need to recover traditional knowledge related to the production, harvest, and storage of kumala, which be restored and implemented by I-Taukei farmers at the village level (Janif et al., 2016).

Although kumala is regarded as a minor root crop in Fiji, it is nonetheless an essential supplementary food crop (Harrison & Kete, 2016). Due to its short crop duration of 3-6 months, it has taken on particular importance especially following cyclones and floods when it is grown in preference to other root crops (taro, cassava, and yams) which take 8-12 months to mature (McGregor et al., 2016). A recent Agriculture Trade Report in 2013 reported an increase in kumala production from 518 ha in 2011, to 606 ha in 2012, and 627 ha in 2013 and a decline in the years 2014-2017 to 500 ha. The Fiji Sun, (2010) reported Agro inputs donated by UNDP included 360,000 kumala cuttings distributed tofarmers in the Central and Western divisions that were affected by Cyclone Mick that year. In 2016 after Tropical Cyclone Winston, 800,000 fresh planting materials were distributed to farmers in the Western Division. This distribution does not include the Ministry of Agriculture's incentives in which they supplied planting materials to farmers in different provinces of Fiji every year.

Kumala is a drought-resistant crop that has the potential to improve food and nutrition security, particularly for subsistence and small-scale farmers (Neef et al., 2018; McGregor et al., 2016). At the Ministry of Agriculture demonstration plot in Ba, ten types of drought-resistant kumala are produced (Fiji Times, 2015). This initiative, led by the Ministry's Research and Extension Division, seeks to determine which crops can thrive with little or no water. According to the Senior Agricultural Officer for the Ba province, this was one of the ministry's most significant initiatives.

Drought-tolerant kumala cultivars from Peru have been introduced and tested at the research station.

Moreover, previous studies in Fiji have overlooked the complex social and ecological systems that define the I-Taukei or indigenous Fijians (Gagaeolo, 2014; Magdoff & Tokar, 2010). Instead, the focus has been on the impacts of using local crop varieties (traditional food) and traditional knowledge on community efforts to fight against food security, climate change and its perceived influence imposed on these dependent communities (Movono, 2012; Mbaiwa, 2011; Tao & Wall, 2008; Lin & Wall, 2006; Douglas & Douglas, 1996). According to Roskruge (2007), the Pacific people like Fiji and Maori share the similar indigenous knowledge of kumala. His research has helped reinstate the traditional calendar known as 'Maramataka' which is similar to the I-Taukei people where it is called "Na vula ni Teitei se Yabaki". Yams and kumala were known as the Tei ni Yabaki or the crop of the year to the people. It shows the value of these root crops. Therefore, this research intends to establish baseline information and methods of what can be improved to support kumala production and a move towards climate-smart agriculture in Fiji. The application of a brief experimental trial at three altitudes will help identify the varieties best suited to Fiji's conditions. In addition, results from this trial will assist farmers in maintaining crop production through the dry seasons. This research will also shed light on how I-Taukei people in Ra conceptualise kumala and its function. It investigates the cultural constructions of traditional knowledge on the production system and the historical background of kumala production in Fiji as interpreted by I-Taukei residents of Ra.

1.7 Framing of Thesis

This chapter opened with an O'yau sa'a welcome. It describes the honour of acknowledging the location from where I am speaking to whom I am addressing. The uttering of these words draws attention as I acknowledge our ancestors to those who are reading this thesis. By saying O'yau sa'a, I am admitting that I can speak in this area, to have my voice heard, and to offer respect to the Vanua o Ra who voluntarily participated in this study.

Chapter One: The first chapter describes the rationale and justification for doing this research, as well as the research goals and purpose. The chapter elaborates on the impact of climate change on the economy of Fiji, including natural catastrophes and the COVID-19 dilemma. It highlights the immediate influence on every Fijian's livelihood and emphasizes the potential of kumala to contribute to food security and Climate-Smart Agriculture in the Vanua of Ra

Chapter Two: This literature review chapter examines the challenges facing food security in the Pacific islands and their vulnerability to climate change. The chapter on literature reviews examines how vulnerable the Pacific islands are to climate change and the challenges to food security.

Chapter Three: This chapter provides an overview of the Vanua methodology used in this study. In addition, it discusses Bula Vakavanua, ethnography, ethnobotany, Talanoa, and active research participation. To capture the delicately interwoven threads of the thesis, the first of the two methodology chapters is titled 'Talimagimagi.'

Chapter Four: Nai lavevale explains the methods used in this research in the second methodology chapter. It means to explain how this research was conducted. To ensure that the methods employed were appropriate and relevant in the three different villages in Ra, the buke metaphor was used.

Chapter Five: Chapter 5 describes an experimental trial that was undertaken in three villages in the Rakiraki (Ra) district of Fiji.

Chapter Six: The phrase 'Sa vosa na Vanua' means, "The land has Spoken" in this chapter. These assumptions explored have to capture what they say about the impact of Traditional Ecological Knowledge on kumala production and how kumala has lost its significance in Fiji. The cultural factors of agricultural practice and the well-being of indigenous Fijians in kumala production are investigated in this study.

Chapter Seven: This chapter explores the field trial related to Climate Adaptation on five kumala varieties in Ra. whilst, it explains a variety of trials at three different altitudes. The results from the trial aim to answer the key objectives of the research.

Chapter Eight: This chapter offers a discussion of the findings (Chapter 6) from the vanua of Ra, highlighting how Fiji may use traditional agricultural knowledge and apply it to science-based applications. The second portion of this chapter, based on the findings of Chapters six and seven, introduces the Dre' e metaphor, which gives a standard operating procedure (SOP) as a tool that agricultural researchers may use when investigating an indigenous community in Fiji.

Chapter Nine: An overview of all chapters follows, along with a discussion of the implications and limitations of the study, recommendations for policy and practice, and suggestions for future research. These suggestions may also apply to other Fijian traditional food growers.

1.8 Chapter Summary

This thesis signifies a journey taken in a very indigenous context where a culturally aligned methodology was applied to ascertain how indigenous Fijian communities have been farming, ensuring a sufficient abundance of food while maintaining sustainable agriculture. Agriculture is the common thread that connects the United Nations' 17 Sustainable Development Goals (SDGs)[2]. Investing in agriculture may help to relieve not just hunger and malnutrition, but also poverty, water, and energy usage, climate crisis, and unsustainable production and consumption.

[2] see https://sdgs.un.org/goals

Chapter 2

Literature Review

'Na Su'e.'

A well-balanced, comprehensive approach, according to specific standards and ideals, is essential for the proper governance of Fiji (Qarase, 2006)

2.1 Introduction

The '*Su'e*' indigenous Fijian basket is used by a man in Fiji to collect and store varieties of traditional food as they go out to the plantation. Metaphorically, this chapter signifies the diverse range of literature accessed and relevant indigenous and academic knowledge. Food security has been a concern globally. Hence reviewing the literature on indigenous Fijian communities and how they view kumala ethnobotany, it's difficult to overlook the gap in knowledge about kumala's role in food security and its potential role in achieving climate-smart agriculture in the face of environmental challenges, particularly climate change. In Fiji, studies on ethnobotany, indigenous knowledge, and traditional cuisines are few, and they have typically concentrated on indigenous peoples as recipients of either negative or positive impacts of horticulture. This literature review outlines the mixture of western sciences and the origins of kumala in the Pacific Islands and discusses the importance of kumala as an essential source of food security and its contributions to development in the Ra district and therefore, the role of traditional foods in Fiji to achieve food security and their importance to climate-smart agriculture. It will present and examine the predominant factors based on studies on kumala varieties at different altitudes undertaken worldwide where kumala is commonly cultivated. The innovative responses to improve the Ethnobotany and Traditional Indigenous Knowledge (TIK) of kumala in Fiji and the South Pacific will be reviewed to improve the horticulture system and further knowledge of resilience, and livelihood improvement of our indigenous Fijians that participate in horticulture.

2.2 Food Security

2.2.1 The state of food security in the world

The world's population will almost double to over 10 billion by 2050, increasing agricultural demand. Modern agriculture now feeds 7.94 billion people each year. It is anticipated that by 2050, 70% of the world's population will be living in cities. Lifestyle and consumption habits will alter as a result of this transformation. The 2030 Agenda for Sustainable Development[3], which was accepted by the world community in September 2015, sets out a compelling but hard set of goals. Sustainable Development Goal 2 expressly aspires to eradicate hunger, achieve food security and enhanced nutrition, and promote sustainable agriculture all at the same time by 2030. The purpose of this vision presents a menu of solutions, especially to increase understanding of the nature of the challenges that agriculture, rural development and food systems are facing now and will be facing into the 21st century. Despite urbanisation, rural populations will grow faster, so governments must facilitate the gradual transition to agricultural employment. Therefore, it will require an institutional environment in rural and maritime areas that is conducive to multiple sources of employment and income generation. However, doubling food production again and sustaining food production at this level presents significant challenges (Tilman, 1999). The strength of the Pacific Island states exists more than 80% of the land and resources are possessed by the traditional owners, who are the communal custodians of the natural heritage (Ward, 2000).

Food security is when all people continuously have access to physical and economic availability to adequate, nutritious food that is safe and meets their dietary needs and food preferences for a healthy life (FAO, 2010). In 1996, the Rome Declaration on World Food Security defined its three basic dimensions as availability, accessibility,and utilisation, with a focus on nutritional well-being. Achieving food security is not an ideal purpose. The ideal aim is to have food sovereignty for all people. Food sovereignty was first promoted on the world scene in 1996, when La Via Campesina, an international network of peasants and small-scale farmers, made a stand against the dominant neoliberal agricultural and trade paradigm (La Via Campesina 1996; McMichael 2009; Pimbert 2009). The term was redefined at the 2007 Selingue Food Sovereignty Forum with the Nyéléni Declaration as "Food sovereignty is the right of peoples to access healthy and culturally appropriate food produce through ecologically sound sustainable methods, as well as their right to define their food and agriculture systems" (La Via Campesina 2007). The word "culturally suitable" means that the food supplied and accessible to the public should be compatible with the cultural backgrounds of those who consume it. Food sovereignty for indigenous peoples emphasizes collective and cultural responsibilities that arise out of a network of descent and kinship relationships (Coté 2016; Morrison 2016; Huambachano 2018). While the concept of food sovereignty resonates with indigenous peoples' aspirations, indigenous scholars argue that indigenous food sovereignty

[3] https://sdgs.un.org/goals

goes beyond the legal and human 'rights-based' rooted in the food sovereignty concept. Indigenous food sovereignty is founded on four principles: the importance of maintaining indigenous relationships with the land; indigenous peoples' ongoing work in shaping healthy and culturally appropriate food systems; indigenous peoples traditionally relied on indigenous food production systems; or indigenous peoples' influence over policies at all levels of government (Morrison 2008, 2011; see also Coté 2016; Martens 2015; Manson 2015; Martin and Amos 2017). Indigenous food sovereignty frameworks have also highlighted the need to shift settler ties to indigenous lands by engaging with indigenous cosmovisions [worldviews], struggles, and the global colonial occupation of indigenous territories (Morrison 2008, 2011).

2.2.2 Food security in the Pacific and Fiji

Since the mid-1970s, the Pacific Islands have become more reliant on imported food, which undermines the claim that the Pacific Islands were historically closed systems. There is ample evidence that inter-island trading underpins food security in several regions of the region (Campbell, 2014). However, this interdependence has been partially replaced by reliance on food imported from beyond the Pacific (Campbell, 2006). The rise in imported food prices has raised fresh worries about food security and the vulnerability of Pacific Island countries (McGregor, 2005). Except after significant natural catastrophes, Pacific Island Countries (PICs) have avoided serious food shortages for decades. There have recently been massive, worldwide, quick rises in the pricing of key staples, and the Pacific islands have not been left out of this global food 'crisis' (McGregor et al., 2009). Political, social, demographic, cultural, and economic developments that began before colonization and have persisted to this day are among the major causes of the Pacific Island countries' declining food security. The introduction and consolidation of capitalism into the Pacific Islands during the early colonial era damaged indigenous trademarks (Gaillard and Mercer, 2013). The second set of food security changes is associated with conventional types of catastrophe resistance. Famine foods' prestige has significantly dropped in the Pacific, despite its critical function during natural catastrophes or pandemic emergencies (Campbell, 2006). Traditional food systems appear to have maintained most island societies over millennia; nonetheless, urban communities in PICs are mostly dependent on imported commodities, and food imports have grown more significant even in rural regions (Campbell. 2014).

2.2.3 Traditional Foods

Traditional food systems offered enough security for most societies to withstand the consequences of major weather occurrences. Traditional cuisines also expressed people's culture, history, and way of life. They provide critical insight into dietary patterns and how they evolved throughout time. Traditional foods and practices have been shown to contain possible health aspects that improve an individual's well-being. Traditional food systems have been an integral component of ecosystem stability through practising agroecological biodiversity (Thaman et al., 2002). Tree crops such as bananas, plantain, and breadfruit, for example, will survive floods, whilst yams and kumala (sweetpotato) are resistant to cyclones.

The abundance of output allowed for traditional food preservation and storage, such as the use of davuke (underground storage) to store and preserve breadfruit, kumala, and other root crops (Campbell 2006). These traditional food banks facilitate and enable intra- and inter-community collaboration, where mutual assistance, reciprocity, and indigenous exchange of food and food products are especially vital during times of adversity or extreme natural catastrophes within homes, tribes, and vanua (Campbell, 2015). It was depicted, for example, during Tropical Cyclone Winston in 2016, when several regions in Fiji relied on hardy crops and famine food to survive. Resilient and famine crops in Fiji include dalo ni tana (*Xanthosoma sagittifolium*), via-kau (*Cyrtosperma merkusii*), via (*Alocasia macrorrhiza*), kaile – aerial potatoes and bulou (*Dioscorea bulbifera*), and ota (fern) (*Athyrium esculentum. Diplazium esculentum*) (Clarke & Thaman, 1993).

2.2.4 Future food security threats and opportunities for Pacific Island countries

Traditional food systems used to offer enough security for most Pacific Island societies to be robust to harsh weather disasters. However, colonialism inflicted significant hazards to future food security by modifying agricultural and other societal practices, lowering levels of food security (FAO, 2010). As a result, severe occurrences began to cause disasters, with losses mirroring food security levels. Moreover, population growth is apparent in Pacific countries. Land productivity and degradation in some Pacific islands contributes to the loss of genetic varieties in crops, which might lead to increased agricultural output and resistance to pests and diseases. All of this adds to the disintegration of established coping methods (Iese et al., 2018). Furthermore, limited marketing infrastructure, farm roads, and transportation linkages hinder the capacity of rural and marine farmers throughout the Pacific islands to supply reliably to major metropolitan centres, even when there is strong demand for local goods (Englberger et al., 2008). Low services from extension and research officers have hindered rural and maritime farmers from receiving technical advice whilst, disconnecting these farmers from accessing agricultural inputs and resources (planting material, cost of fertiliser, credit and land) (von Braun, 2007).

Food is an important part of Pacific culture and other indigenous people throughout the world, and this is evident on any occasion. Having enough food for the family and fulfilling socio-cultural commitments are hence the ultimate goals of indigenous Fijians in rural Fiji. Including food security programs in the job structure followed by village members is one method to meet this requirement. Following daily routines have been found to contribute to bula vakaivakarau (disciplined village life) and yalomatua ni vakayagataki gauna (wise use of time), with solesolevaki (social and cultural capital where people pool resources and labour for the common good) serving as the vehicle to achieve weekly routines. When there is an excess of food to meet household requirements and socio-cultural duties, people might sell crops in the market to supplement the family income.

Food security for neighbourhood households offers a secure foundation for long-term community livelihood efforts. Governments or non-governmental organizations support community initiatives, which can also be directed by the community. Food security in an indigenous Fijian community enhances not just local involvement but is also connected to the durability and sustainability of any community livelihood effort. For instance, the Saroni village in Fiji development project is driven and managed by the village members. Initiating economic development through agribusiness was not an easy task due to the absence of people during community livelihood activities (Vunibola& Scheyvens, 2019), which impeded people's involvement in community development initiatives as the majority of their daily time was used in finding food. These initiatives need the collective participation of villagers, as the project officers may visit the village and other activities need to be managed by the villagers. Family food security and participation in community livelihood are positively correlated as improvement in the food systems increase people's participation, leading to the sustainability of community well-being interventions.

2.3 Indigenous farming system: The basis of food security in the Pacific

Pacific Island countries' future options are a cause of concern. They were placed in places with good food security, where people may have lived in 'work arrangements and stable structures' with subsistence affluence but moderate material aspirations (Abbott, 2008). Residents in the region, both rural and urban, are now facing considerable food insecurity, which is compounded by natural disasters (McGregor, 2005). Population growth projections and climate change scenarios imply that food stress may worsen rather than improve unless steps are done to address the existing issues (Bell et al., 2009). As a result, their substantial traditional knowledge and experience gained through living on islands can give useful lessons in adapting to and building resilience to current environmental changes (Mercer et al., 2007).

Traditional Knowledge (TK) is defined by Dei (1993) as a holistic and comprehensive kind of knowledge that is a product of indigenous peoples' direct experience and interaction with nature, and it 'includes the cultural traditions, values, beliefs, and worldviews of local peoples in a community...' (p.105). Hiebert and Van Rees (1998) add to Dei's definition by stating that TK includes cultural beliefs and traditionslearned through experience over a lifetime and passed on to the present generation from their ancestors for their survival. This knowledge has taught the present generation to live in harmony with their environment, highlighting the relationship between trees, soil, and water. In support of Hiebert and Van Ree's (1998) definition, Veitayaki (2010) stated that TK consists of knowledge that has been accumulated and trialled over centuries through experiences of the indigenous people with their environment; gaining knowledge from their environment for their survival; food, medicinal and cultural knowledge. This knowledge is held by elders who transmit the knowledge to their children for a sustainable livelihood. Various terminology has been used to characterize traditional knowledge, such as traditional ecological knowledge (TEK), indigenous knowledge (IK), local knowledge (LK), and indigenous and local knowledge (ILK). According to Dudgeon and Berkes (2003), traditional ecological knowledge (TEK) and indigenous knowledge are inextricably intertwined, with identical literature (Gupta & Gupta, 2008).

Emphasis on conserving and expanding the application of traditional knowledge will strengthen indigenous communities' resilience. The most successful community-level response to climate change is a blend of traditional and scientific knowledge (Lauer & Aswani, 2010). Climate change adaptation is a process of activity and decision-making (Petheram, Zander, Campbell, High, & Stacey, 2010). Insights from indigenous people who have lived on their lands for generations and established traditional knowledge, skills, and practices that allow them to protect and conserve their resources might help us better comprehend climate change adaptation (Turner & Clifton, 2009).

For generations, developing-country agriculture has relied on local resources such as land, water, indigenous knowledge, and traditional foods. It has created physically and genetically varied subsistence farmers with built-in resilience, allowing them to adapt to climate change, pests, illnesses, and other difficulties. The continuation of agricultural hectares under the old, traditional farming system and management in the shape of elevated fields, terraces, polycultures, and agroforestry systems depicts a successful indigenous agricultural strategy and is a credit to their farming systems' 'creativity'. These current traditional agricultural (subsistence farming) models provide suitable models for encouraging biodiversity and sustaining year-round harvests without the use of agrochemicals. Humanity must adopt a new agricultural paradigm that is more ecological, biodiverse, local, sustainable, and socially responsible. It will serve as a foundation for subsistence agriculture, symbolizing a robust community-based traditional farming system that has fed the world for generations.

2.4 Indigenous knowledge in adaptation to Climate-Smart Agriculture

For thousands of years, Pacific cultures have been adjusting to climate change caused by environmental shifts (Nunn, 2007). Bridges et al. (2009) also claim that for many years, the island and atoll civilizations have managed to withstand major, unexpected, and locally destructive changes such as those predicted by future climate change. Adaptation is viewed as a technique for dealing with climate change. Locals have used their local expertise to devise strategies for adapting to changing environmental circumstances (Stigter et al., 2005; Macchi, 2008). For example, Salick and Ross (2009, p. 137) describe that local communities have "fronted and adapted to climatic change" for generations. Smith and Wandel (2006) define adaptation as "local or community-based modifications" to changing environmental conditions. Adaptation is defined by Nakalevu (2006, p. 9) as "the adjustment of natural or human systems to a new or changing environment." Adjustment is the process of modifying one's behaviour to adapt to a changing environment (Psychology Glossary 2013).

According to Mathew et al. (2012), an adaptation plan can be effective if it is executed based on community objectives and concerns about sectors that they believe are most exposed to climate change hazards. Climate-smart agriculture (CSA) will be an acceptable method for Fijian farmers in reforming and reorienting agricultural systems to promote food security in the face of emerging climate change realities (Lipper et al., 2014).

According to Edenhofer (2015), the main goal of CSA is to assist efforts from the local to global levels to promote food and nutrition security for all people while incorporating essential adaptation and capturing possible mitigation (Lobell et al., 2011). To live in changing surroundings, locals have had to adapt to diverse environmental changes and alter their activities appropriately. According to Chapin et al. (2004), significant interactions between local people and their environment can lead to increased adaptive ability. Learnings from previous and contemporary techniques used by communities to adjust to changes can be utilized to make effective adaptation decisions. As a result, effective acts and subsequent behaviours have been recognized. Knowledge exchange and the inclusion of sustainable previous and present adaptation practices utilized can improve adaptive capability (Fabricius et al. 2007). Local populations have adapted to various environmental "hazards," and these "adaptation strategies" can be utilized to mitigate the "adverse effects" of future climate changes (Macchi 2008, p. 5).

2.4.1 Losing indigenous and local knowledge

No one has a monopoly over knowledge. Traditional knowledge in the Pacific Island countries is fading away; it is because of the monopoly of traditional knowledge (Gabi, 2020). The difference between our Pacific Island countries' societies and the westerners is that westerners share their knowledge freely through publication globally for individuals to access and learn. This information of knowledge is shared freely and distributed to academic institutions, and libraries and shared online in modern-day technology for research and educational purposes (Ramirez, 2007). However, indigenous people in the Pacific Island countries, are 'keepers of Knowledge', which westerners do not have. Westerners are known to be 'seekers of knowledge'. For indigenous Fijians, our elders keep the knowledge, who in defence say they are protecting it, but from whom is still to be answered. Traditional knowledge in indigenous Fijian society is passed orally during initiations for every boy and girl at a younger age for the preservation of knowledge (Gabi, 2020).

The colonisation of the Pacific introduced non-indigenous lifestyles, cultures, practices, religions, and education systems. Many Pacific Island societies were introduced to the Western education system in the early 1800s; many young children were sent to schools established by missionaries, where they were taught that traditional practices were wicked and needed to be destroyed (Gabi, 2020). Those who are well-educated returned home saying the traditional knowledge was no match for western knowledge and refused to be taught the old ways of their ancestors. Traditional knowledge had no place in modern Christian society (Ramirez, 2007). The elders noticed that there was no interest among the young men of the tribe educated in the western ways and died with sorrow, knowing their once flourishing culture has ended. They went to the grave with the knowledge they possessed. However, not all traditional knowledge has to be shared freely; some are sacred to a tribe within the indigenous Fijian society and therefore, must be respected. It must remain with the members of the tribe taught to their children and their children's children (Yates & Ramírez-Sosa. 2004).

Traditional knowledge is diminishing because of fast development in Pacific Island countries where indigenous people dwell (Ramirez, 2007). Despite having lived in a specific location for centuries, many people lack property titles (in a western sense) and lack the financial wherewithal to legally defend their rights. Land tenure legal disputes are often settled in the country's capital, and individuals lack the money to go there and engage professionals to defend them (Ramirez, 2007).

Every society wants to grow, and development is an act of civilisation in every sector of our society (Yates & Ramrez-Sosa, 2004). Individuals have diverse ideas on what development is and its significance in communities. No scientist can disagree that development has benefited every civilization since we profit from it. Still, we must be wary of how this progress might be exploited to undermine indigenous rights, as well as social and natural resources (Ramirez, 2007). As a result, development might be a beneficial option for empowering indigenous people and benefiting those interested in ethnobiology, for as long as varied indigenous cultures exist, there will always be individuals with ethnobiological expertise.

2.5 Indigenous knowledge and scientific knowledge

It is widely held that combining indigenous and local knowledge with scientific understanding helps improve adaptive capability and resilience. Traditional knowledge, according to Turner and Clifton (2009), is significant to climate change research because it may provide baseline information for seasonal shifts and occurrences. The observed changes are meticulously reported, meticulously gathered, and meticulously analyzed to present a comprehensive picture of the consequences of climate change and their interactions across time. Non-locals who do not have a strong connection to their surroundings may disregard these findings. According to Leonard, Parsons, Olawsky, and Kofod (2013), traditional ecological knowledge retained by individuals gives in-depth information on ecosystem dynamics at the local level through the usage of calendars, which can advance research and understanding of ecosystems.

Kalanda-Joshua et al. (2011) argued for the combination of scientific weather and climate forecasting with traditional knowledge in Malawi, where farmers' local knowledge may supplement scientific data. They proposed that together, the knowledge would provide complete information that can help rural populations adapt to changing climates. Their findings showed that actual temperature data on regional trends corroborated the climatic patterns and trends stored in local traditional knowledge, validating their opinion that traditional knowledge might influence climate change estimates. Nkomwa et al. (2014) in Eastern Malawi discovered that traditional climatic patterns and scientific data agreed.

Divergent worldviews may also make it difficult to combine traditional and scientific information. Indigenous systems/knowledge takes a holistic approach to social and ecological systems, revealing connections between the two that are sometimes overlooked by scientists who treat social and ecological systems separately. The scientific community's failure to identify the connections limits their potential to profit from the links that can lead to a deeper knowledge of climate change, its consequences, and adaptation (O'Neill et al., 2012). Many indigenous people have a worldview in which all physical aspects have souls, connections, and rights in a community that must be honoured. Such a worldview differs from that of non-indigenous peoples, yet it must be recognized and accepted (Turner and Clifton, 2009).

2.6 Land Tenure in Fiji

Of the total land area in Fiji, about 18,284 km^2 (7.5 percent) is owned by the government, 10 percent is under freehold tenure, and 82.5 percent(15, 084 km^2) is held by the I- Taukei landowning units (Native Land) (Lal et al., 2001; Fison, 1881). The fact that Fijians possess a large share of the overall land area hides the fact that most of that land is unsuitable for intense agriculture, habitation, and development (Chapelle, 1978).

The majority of the arable land has already been leased, primarily in sugarcane regions. Other fertile lands near the community are beneficially occupied by native owners. As the world's population grows, so does the need for arable land. This has been a source of contention among members of landowning units, particularly about non-residents' access to arable land in village subsistence zones when they return to the village (Campbell, 2018; Lal et al., 2001). Fijian landowning units retain native land under customary tenure, which vests in the unit with the right to inhabit and use such land (Cochrane, 2018; Chapelle, 1978). In 1880, the Native Lands Commission (NLC) was founded to survey the borders of the property owned by various native-owning groups, decide future boundary disputes, and preserve records of the persons constituting each unit. The Native Lands Commission maintains a list of surviving members of landowning groupings known as "Na Vola ni Kawa Bula" (Campbell, 2018).

2.7 Farming in the Fiji Islands

Subsistence agriculture in Fiji's rural and maritime communities is both traditional and dynamic, supporting the majority of households as well as creative commercial firms that have expanded into export markets (Sofer, 2018). The subsistence agricultural sector used to account for 32.5 percentof total Fijian informal sector output, but it is currently less than 10%. (Lal and Foscarini, 2006). According to Prasad (2006), the subsistence sector has been a backbone in the development of root crops, fish, kava, fresh fruits and vegetables as major domestic export commodities, as demonstrated during the COVID-19 pandemic when the urban economy collapsed, and the rural economy supplied all Fijians. Traditional starch-rich food crops like yams, taro, sweetpotato, plantain, and breadfruit are referred to be 'kakana dina' or ‘genuine food’ in Fiji (Ravuvu, 1991). In contrast, increased monocropping diminishes the diversity of food crops in local markets, and a scarcity of good, locally produced food leads to poor dietary choices and nutritional inadequacies (Kaiser, 2011).

Farmers in Fiji produce vast quantities of a variety of traditional food crops that people use in their regular meals and food that is important to their life during or after natural catastrophes. Traditional food crops are produced throughout the Pacific Island countries and are recognized as Fiji's ‘hidden power’ (Johns et al., 2017). According to indigenous scholars, the maintenance of subsistence farming is critical to the nation's food security (*ibid*.).

2.8 The failure of agricultural policymaking in Fiji

Indigenous farmers in Fiji demand policies that guarantee food security is more in line with their way of life and vanua. Many food security programs in Fiji have failed to be successful since they lack monitoring and policies imposed on farmers and agricultural authorities (FAO, 2017). As a result, every project must be compatible with the people and their values or culture. According to Ravuvu (1988), maintaining compatibility acts as a substantial impediment to commercial land usage. The land is significant to the I-Taukei people in Fiji; hence, a cultural competence tool is necessary for an approach to the vanua, the land that supports indigenous Fijians and to which we belong (na vanua na tamata), "the people are the land" (Mavono, 2017).

The Reserve Bank of Fiji has identified agriculture as a possible significant driver of improved export revenues and import substitution to reverse Fiji's ongoing trade deficit expansion (Duncan and Wah Sing, 2009). Because Fiji is endowed with agricultural land and rural labour, its agriculture sector should be an important element of the Fijian economy in terms of providing suitable structural plans in rural regions, ensuring food security for society, and contributing to export profits and foreign exchange (McGregor et al., 2009). The agriculture sector is considered to have performed poorly for an extended period despite many pleas for better performance (Duncan and Wah Sing, 2009; McGregor et al., 2009).

Most Fijian villages live on a semi-subsistence basis, with a surplus produced for sale to cover deduction and health bills, as well as food purchases and other expenses such as social and cultural commitments and entertainment (Vunibola, 2020). The Fijian government and agriculture agencies have been focusing on increasing agricultural production and commercialization. These efforts, however, have had limited success (Vunibola, 2020). One of the main challenges faced by rural farmers was the inability of government bodies established to conduct other value chain functions associated with crop yield (such as Fiji Agro Marketing and Food Processors [Fiji] Limited) to ensure the continuity and quality of supplies from village farmers (Vunibola, 2020).

2.9 Research directions

Public research on strategies to protect plants and animals from pests and illnesses, on the other hand, is vital for the conservation of Fiji's plant and animal resources. Soil conservation and other environmental studies are also examples of 'public benefit' research. Basic research that leads to conclusions that should be freely available to everybody is another type of research that the government ought to do, or else it will be conducted at a socially sub-optimal level (Vunibola, 2020).

However, in Fijian agriculture, where the industrial structure is made up of many small farm operations, there is a case to be made for the government to do adaptive research on behalf of farmers (Koko Siga, 2008). Agriculture Department research might collapse due to a lack of skilled experts and limited research budgets (ISNAR, 1991). The few available researchers have mostly served to provide farmers with handouts such as multiplying seeds and seedlings (Duncan and Wah Sing, 2009). The research stations' buildings and equipment are in disrepair. The ministry has been impacted by the reduction in the operational funding for research over the past eight years for capital projects that were shifted to other projects or schemes within the department (McGregor and Gonemaituba, 2002). The majority of the cars owned by the Research Division were acquired with donor monies many years ago and are now old, in bad condition, and extremely expensive to maintain. The current administration is deeply concerned about the department's bad status of agricultural research (Vunibola, 2020).

The Pacific should reconsider research into physiological and genetic routes for drought, frost, waterlogging, and salinity tolerance as well as pest and disease control (Food Security and Livelihood Cluster, 2017). To acquire a knowledge of the underlying degree of tolerance of sweetpotato varieties housed in CePaCT's climate-ready collection, evaluations and testing are required. This can be accomplished by conducting active field tests of several kinds to demonstrate tolerance to water deficit or drought, salt, and combinations of environmental factors.

2.10 History of Kumala in Oceania

Kumala is a commodity introduced by Polynesians to other Pacific Island countries that is noteworthy due to its botanic origins on the American continent. The introduction of sweetpotato to Polynesia has been thoroughly explored, giving birth to several ideas and speculations. The origins of sweetpotato in the Pacific have long been a mystery (Clarke, 2009). Linguistic, archaeological, and ethnobotanical evidence implies that prehistoric human-mediated dispersion activities led to the spread of this American domesticate in Oceania. According to Roullier et al. (2013), sweetpotato was introduced into Oceania from South America in pre-Columbian times and was later newly introduced, and widely diffused across the Pacific, by Europeans via two historically documented routes from the Caribbean. Spanish ships carried the kumala to Spain after the discovery of the Americas, and the crop was eventually introduced to a large number of the newly discovered Spanish kumala varieties (Gibson, 1984). Numerous researchers have previously argued that after introducing the kumala to Southeast Asia, Spanish and Portuguese sailors then disseminated it across Melanesia and Polynesia, according to Dixon (1932) and Lawler (2010). However, there are no historical records to support the latter, and genetic investigations have revealed a clear link between South Pacific and South American samples, ruling out Southeast Asia as a possible midway for its introduction (Clarke, 2009). Traditional Polynesian knowledge says that kumala was existing in the Pacific Island countries before European contact (Estrada de la Cerda, 2015). The Polynesian voyagers are said to have made a landing in present-day northern Peru, a location where, according to Te Rangi Hiroa (1938), the sweetpotato was known as kumar in the native Quechuan tongue. The Polynesian word for sweetpotato, kumala (and all its variations), was derived from this phrase. Table 1 shows some of the vernacular names for sweetpotato used around the Pacific.

Table 1: Vernacular Names of Sweetpotato in the Pacific. Adapted: Roskruge, 2020

Traditional Name	Region
kumar, kumal	*Quechuan dialects (Peru)*
umara, umaa	*Tahiti & Marquesas Islands*
kumala	*Tonga*
'umala	*Samoa*
'uala, 'uwala	*Hawai'i*
kumaa	*Marquesas Islands*
ku'a'ra	*Mangāia*
kūmara	*Te Ika-a-Māui (New Zealand North Island), Rarotonga, Tuamotu Arch., Mangareva & Rapanui,Solomon Islands, Kiribati, Moriori (Chatham Islands)*
kūmera	*Te Waipounamu (New Zealand South Island)*
kumala	*Fiji, Tonga, Vanuatu, New Caledonia, Tokelau, Tuvalu, Rotuma, Mortlock Islands (Bougainvillie,Papua New Guinea)*
kaukau	*Pidgin, Papua New Guinea*
kaema	*Motu language, Papuan region, Papua New Guinea*
tapaiya	*Buin language, South Bougainville, Papua NewGuinea*
kambek	*Biangai language, Eastern Highlands, Papua NewGuinea*
maza	*Bena language, Eastern Highlands, Papua New Guinea*
tumala (pron. S'mala)	*Niue*
camote	*Spanish-speaking countries communities*

Around the turn of the millennium, sweetpotato was already established in Polynesia. Carbonised kumala tuber remnants discovered on Mangaia Island in the Cook Islands have been dated to 1000-1100 CE, making them the oldest archaeological evidence of kumala in Polynesia (Green, 2005; Lawler, 2010). Traditional records, which date events in Polynesia based on the number of generations since, indicate the sweetpotato has been present in Hawai'i since at least 1250 CE and in Aotearoa / New Zealand since 1350 CE (Te Rangi Hiroa, 1935).

Sweetpotato distribution in Pacific Island countries has been extensively researched and well documented (see O'Brien, 1972; Yen, 1974, 1982; Villareal, 1982; Ballard, 2005; Coil and Kirch, 2005a, 2005b; Green, 2005; Ladefoged et al., 2005; Leach, 2005; Wallin et al., 2005a, 2005b; Montenegro et al., 2008; Wenda, 2012). While some experts believe that sweetpotato was spread over the Pacific by birds and ocean currents (Montenegro et al., 2008), all credible evidence indicates sweetpotato's purposeful dispersal and acceptance. Sweetpotato originated in Central America and spread to the Pacific Islands via early Polynesians (kumala line) and European explorers (Camote and Batatas lines). Aside from early Polynesian and European explorers, additional players involved in the sweetpotato spread included missionaries, whalers and traders, exchange instructors, returning students, plantation laborers, and troops during WWII. Colonial agricultural intensification projects have also played a role in sweetpotato dissemination. In Fiji, sweetpotato is referred to by the generic word kumala.

2.11 Historical role of sweetpotato in food security and disaster recovery

The food stability provided by sweetpotato was critical to the cultural growth and population expansion of many Pacific Island cultures. Because of its capacity to grow up to 2,800m altitude, generate significant stored root harvests, and withstand moderate droughts and frosts, the sweetpotato became dominant in the food systems of Papua New Guinea's highlands (Bourke, 2005). The easy availability of sweetpotato resulted in population growth and a rise in the geographical dispersion of communities, allowing people to reside in higher altitude locations. The function of sweetpotato in facilitating the construction of communities and linking individuals in these settlements is recognized and honoured in Papua New Guinea ceremonies (Wiessner, 2005). Sweetpotato is also mentioned in Maori mythology because of its importance in improving food security due to its capacity to be kept and conserved for the winter (Roskruge, 2007). Because of its drought endurance, sweetpotato supplanted taro and yam as the major staple food in Rapa Nui (Easter Island) (Wallin et al., 2005a, 2005b; Tromp and Dudgeon, 2012). The food excess generated by sweetpotato cultivation aided Rapa Nui's population growth and allowed for the construction of the "moai" monuments (Yen, 1974). Because of its capacity to thrive in dry regions and rotate well with traditional staples, Hawaiians preferred sweetpotato (Coil and Kirch, 2005a, 2005b; Ladefoged et al., 2005). Sweetpotato was the only crop that will grow in Kahikinui, a leeward and young volcanic soil located on Maui, Hawaii. Sweetpotato fostered rapid population growth, prompting some to refer to Kahikinui as an "Ipomoean landscape." In Kahikinui, healthful rituals surround the planting, growing, and harvesting of sweetpotato because of its value (*ibid.*).

Sweetpotato has a long history of saving lives throughout the world. When typhoons destroyed their rice crops, the Japanese utilized them. Farmers turned to sweetpotato to feed their families. It saved millions of people from malnutrition in famine-stricken China in the early 1960s and came to the aid of Ugandans in the 1990s when a virus devastated the cassava crop. Sweetpotato has also played an important part in disaster recovery in the Pacific Islands. After two cyclones ravaged the Cook Islands in 1831 and 1846, two missionaries imported the sweetpotato from Tahiti as a rebound crop. The sweetpotato, which was originally grown for trading, helped to ease food shortages, indicating its use-value (Green, 2005). Sweetpotato has also helped prevent hunger in Papua New Guinea during droughts. After taro production was badly harmed by taro leaf blight and other pests and diseases in the 1940s and 1950s, the sweetpotato was swiftly embraced as a primary food crop in Papua New Guinea and the Solomon Islands (Allen, 2005; Bourke, 2005; Evans, 2006).

Sweetpotato was extensively adopted as a tactic in agricultural intensification operations in the 1970s, resulting in enhanced output for food security and economic development in Pacific Island countries (Iese et al., 2015). Sweetpotato's favourable agroecological characteristics enabled populations could get and use healthy food before, during, and after disasters. Unfortunately, sweetpotato distribution was more informal in the past than it is today, increasing the occurrence of pests and illnesses (Wairiu et al., 2012). Despite its storied history, sweetpotato has received relatively little attention from crop improvement research.

2.10.2 The role of sweetpotato in the traditional food system in Pacific Countries

The traditional food system in Pacific Island countries recognizes traditional staple crops and trees that offer a year-round food supply (Thaman, 1990; FAO, 2008). Breadfruit and wild nuts, for example, supply nourishment when yam and taro are in between planting and harvesting seasons. Unfortunately, due to climatic and environmental changes, this traditional food system is quite fragile (Barnett, 2011). Due to the great reliance on rainfall for the planting of some traditional crops, communities are unable to grow them when the rainfall pattern alters or is decreased for an extended length of time. Furthermore, typical fruiting seasons for certain critical food security plants occur with the Pacific Islands' cyclone or "poor weather" season, increasing the danger of fruits being damaged and squandered (Wairiu et al., 2012; Allen, 2015; Sisifa et al., 2016). When availability or accessibility is restricted, these factors can create a "gap" in traditional Pacific food supply networks. Uncontrolled pests and diseases influence traditional staples, expanding the "gap" in food security. Closing this gap is critical to ensuring food security. Sweetpotato has played an important role in closing the food supply gap in several Pacific Island countries, including Fiji (FAO, 2010).

2.10.3 Sweetpotato food security and distribution mechanisms

The role of sweetpotato as a critical risk reduction and food security crop continues. In Pacific Island countries, sweetpotato remains an important risk reduction and food security crop. Sweetpotato characteristics that propelled its diffusion and adoption in the past are still enabling its distribution and production now (SASHA, 2010). However, distribution methods have shifted slightly: in recent decades, worldwide, regional, and national institutions have been established to ease the safe documentation, collection, distribution, and assessment of plant genetic resources, including sweetpotato. This has proven crucial in lowering the risk of pests and illnesses spreading through unregulated and informal sweetpotato distribution techniques (SASHA, 2009).

Distribution of sweetpotato planting supplies to impacted farmers is a growing priority for national and regional food security clusters during disaster recovery activities. Because of its short and flexible growth season, high nutritional content, and ability to thrive in a broad range of settings, sweetpotato is the preferred crop. Sweetpotato may offer food, cash (from the surplus supply), and fodder for animals in post-disaster conditions. For example, after Tropical Cyclone Winston hit the Fiji Islands in 2016, more than 49,100 sweetpotato cuttings were provided together with vegetable seeds to devastated farmers (Food Security and Livelihood Cluster, 2017). Following Tropical Cyclone Ian's devastation of Tonga in 2014, around 20,000 sweetpotato planting supplies were supplied to devastated farmers. These 20,000 sweetpotato planting supplies were utilized to sow and manufacture more planting materials for farmers' recovery. Nishi Trading Ltd, a private-sector partner, provided a tractor to prepare the ground for women to plant sweetpotato for food security recovery on Ha'apai Island. After three months, a yield of 12 t/ha had been gathered, and 80,000 fresh sweetpotato planting supplies were ready for distribution. These sweetpotato planting supplies (vine cuttings) were obtained from the Ministry of Agriculture and farms located away from tropical cyclone paths (SPREP, 2014).

The Pacific Islands have obtained numerous tolerant and valuable sweetpotato types from places such as the United States, South America, Asia, Europe, Africa, and the Caribbean via these methods. Key sweetpotato study regions in the Pacific, including Papua New Guinea, the Solomon Islands, Vanuatu, Samoa, Tonga, and the Cook Islands, have given the most to the CePaCT sweetpotato collection. Several countries have contributed to Fiji's CePaCT collection (Government of Solomon Islands, 2014). The construction of national procedures with strong linkages to regional and international processes and facilities has contributed to Pacific Island countries' ability to enhance sweetpotato output and consolidate sweetpotato's continued food security significance. It has also played an important role in supporting the Pacific region in adjusting to climate change and other difficulties. The Australian Aid Program supported the "climate-ready collection" in response to concerns about climate change. The "climate-ready collection" for sweetpotato concentrates on varieties with qualities resistant to the observed and expected consequences of climate change in the Pacific (particularly salt tolerance, drought tolerance, and waterlogging tolerance) (Tuia et al., 2012; Sisifa et al., 2016). Between 2000 and 2014, a total of 166 sweetpotato varieties were given to Pacific Island countries. The majority of sweetpotato variations originated in Papua New Guinea (50 varieties), the Solomon Islands (28 varieties), the United States (20 varieties), and Peru (13 varieties). These were types developed through breeding efforts, examined, and deemed robust in their respective countries of origin (Sisifa et al., 2016). Other projects that have boosted sweetpotato cultivation for food security risk reduction in Pacific countries include the Adaptation Fund project Enhancing Community Resilience in the Solomon Islands (*ibid.*). Furthermore, the University of the South Pacific and European Union Global Climate Change Alliance (USP-EU-GCCA) food security project in Vanuatu;

the International Fund for Agriculture Development (IFAD) Tonga Rural Development Project (TRIP) implemented by Mainstreaming of Rural Development Innovation Tonga Trust (MORDI TT); and the Live and Learn Environmental Education food security programs. (Tuia et al., 2012; Food Security and Livelihood Cluster, 2017). Along with the above-mentioned formal methods, farmer-to-farmer trade is an important way of distribution and is critical for the adoption of new sweetpotato varieties in Pacific Island countries. Farmers have also been critical in funding field experiments to evaluate sweetpotato varieties as part of the aforementioned official initiatives and methods.

2.10.4 Reclaiming the value of sweetpotato for sustainable living in Fiji

Fiji is dealing with difficulties such as sustainable development, poverty reduction, food security, a growing population, and fast-decreasing renewable natural resources (Veitayaki, 2004). Despite the development methodologies and strategies used in underdeveloped nations across the world to achieve economically, ecologically, and culturally gratifying and meaningful growth, several concerns stand out (Janif, 2014). Indigenous knowledge and experiences provide viable options to aid in the creation and implementation of sustainable development policies. Ironically, much of this, such as food sources, agricultural systems, medicine, social interactions, and resource management, are now mostly lost in most rural regions of Fiji and among many indigenous Fijians (Janif, 2014). Kumala has a strong traditional background in Fiji, but its potential worth is now undervalued, both commercially and socially. It is still undervalued as a food security crop and receives little interest from agricultural researchers (Lebot, 2009).

Experimental trials on sweetpotato are vital in classifying the best-yielding varieties suited to different climatic zones and to evaluating their drought tolerance. Growth traits performance influences the formation and the number of sweetpotato tuber yields. Leaf number variations in sweetpotato plants represent the morphological characteristics of each sweetpotato variety, particularly the form and size of the leaves, which might impact LAI in sweetpotatoes (Tsialtas et al., 2008)

Variety trials are a component of genetic research that emphasize physiological and agronomic responses (Nugroho & Widaryanto, 2017). Leaf quantity and area are determinants of a sweetpotato plant's ability to respond to environmental circumstances. During wet seasons, sweetpotato types cultivated on dry soil demonstrate ongoing leaf area expansion. Because persistent leaf growth affects their tuber formation process (Dubois et al., 2013), photosynthates sustain just a few tubers and their development if vegetative growth is very high and no pruning treatment is used. If the vegetative and reproductive stages are balanced, so will the build-up of photosynthate. According to Agata and Takeda (1982), additional leaves and a high LAI on the sweetpotato plant have an insignificant effect on tuber production. Sweetpotato genetic features are sensitive to altitude, soil moisture, and water supply, according to research from Australia (Harper and Walker, 1984). (Holwerda and Ekanayake, 1991; Xiao and Xiao, 1995). The results revealed that types grown in areas with abundant rain generated a greater number of leaves during both the primary and off-season.

The effect of planting pattern and season is essential for sweetpotato agronomic performances and yield (Bunphan & Anderson, 2019). Bassay, (2017) in his studies found positive correlations between sweetpotato varieties planted in different areas (Coastal, Low and High) and seasons with five planting practices on the number of runners obtain per plant at 60 DAP. Yahaya et al. (2015) discovered a favourable relationship between sweetpotato variety and location, and the number of runners achieved. Mukhtar et al. (2010) and Tewe et al. (2003) interpret the observed considerable variation in plant kinds and number of runners as an indication of the importance of genotype in the control of these features. Several authors found comparable findings regarding substantial diversity in sweetpotato genotypes for several sweetpotato features (Nwankwo & Afuape, 2013). This was supported by Hartemink et al., (2000) where a trial was undertaken at two sites in the humid lowlands and a high altitude of the Morobe Province, Papua New Guinea. Results show that the lowland trialattained fewer runner numbers compared to the high-altitude areas.

Stem length and the total number of runners per plant might potentially be indicators of high-quality planting material, as their numbers grow with decreasing plant density, owing to the production of secondary runners (Somda and Kays 1990a). Mau et al. (2019) supported this with research that tested sweetpotato genotypes on different altitudes and showed large differences in the observed growth variables and vine length. In addition to genetic differences among the sweetpotato genotypes, differences in vine length between studies may have also been caused by differences in environmental conditions where they were grown (Rahajeng and Rahayuningsih 2017a). Chlorophyll plays a significant role in plant growth and is also influenced by genetic factors (Chahal and Gosal 2010; Naidoo et al. 2016).

Sweetpotato establishment percentage is crucial as a critical indication for the climate-smart strategy. When soil conditions are favourable for development, adventitious roots in sweetpotato sprout as early as one day after planting, according to Pardales (1993). Adventitious roots grow and lengthen to some extent in unplanted vine or stem cuttings stored in the shade with high humidity (Pardales and Esquibel, 1997). Sweetpotato has a fibrous root system composed of adventitious roots that emerge from the cut end and lower section of the node of stem cuttings (planting material) that are buried upon planting, as well as attendant lateral roots that often grow up to the third-order. Under typical soil moisture conditions, the formation of adventitious and lateral roots is normally rapid during the first four weeks of growth, as opposed to other root crops, where a high root growth rate may extend up to the eighth or tenth week after planting (Agili and Pardales, 1997; Pardales, 1985). Sweetpotato crops are recognized for their ability to grow in marginal places when other commercial crops may fail (Cock, 1985).

Saitama et al. (2017) observed the tuber yield of sweetpotato and performance varied considerably according to local environmental conditions. Moreover, they suggest that stress is more critical in higher-yielding locations as well as within higher-yielding varieties (Adams. 1967; Thomas et al., 1971; Hamid, 1980). Hence, the intense competition between the yield components may result from intense cold stress imposed simultaneously on all components. It can be deduced that low-yielding environments will generate a small stress factor in so far as at least one of the components is not subject to environmental stress. Thus, the tuber yield of sweetpotato is determined by an interaction between genetic and environmental factors as reported in many studies (Yusuf et al. 2008; Osiru et al. 2009; Moussa et al. 2011; Haldavanekar et al. 2011; Mauet al. 2013; Rahajeng and Rahayuningsih 2017).

Plants have an uncertain growth habit and constantly develop new leaves when harvested. At harvest, these traits allow for large variances in leaf quantity, leaf weight, and leaf dry matter. The percentage of leaves connected to the plant falls dramatically as the number of leaves generated grows over the growth cycle due to shedding (Somda et al. 1991). The number of leaves is determined by the number of branches or growth points, the length of the stem and internode, the pace and duration of leaf development, and the lifespan or shedding of leaves. The total number of leaves per plant varies across kinds and can range from 60 to 300. (Rajeshkumar et al. 1993). With decreased plant density (Somda and Kays 1990b), rising irrigation (Indira and Kabeerathumma 1990; Holwarda and Ekanayake 1991), and nitrogen application, the number of leaves per plant rises (Nair and Nair 1995). However, increasing potassium does not significantly increase the number of leaves per plant. It has been proven that defoliating vine cuttings before planting reduces the number of leaves per plant (Jayakrishnakumar et al. 1990). Sweetpotato cultivars' specific leaf weight (SLW) or leaf weight/area ratio ranges from 2 to 4.4 mg cm-2 (Nair and Nair 1995). The SLW decreases near the completion of the growth cycle, owing to dry matter transfer from the leaves to the tubers (Nair and Nair 1995). SLW rises with plant density and CO2 content in the atmosphere (Sasaki 1991). (Bhattacharya et al. 1992).

According to Ravi and Indira (1999), the branching system in sweetpotato plants is highly impacted by spacing, photoperiod, soil moisture and nutrients. Plant density increases reduce runner length and the total number of branches per plant, possibly owing to increased competition for nutrients and sunlight (Sasaki 1991; Hamid and Sasaki 2001). The production of secondary runners is principally responsible for the rise in stem length and the total number of runners per plant when plant density decreases (Somda and Kays 1990a).

2.12 Chapter Summary

This chapter explores the spread and acceptance of sweetpotato across the Pacific Islands and highlights Pacific communities' resilience culture. In the past and today, indigenous Fijians have opted to produce sweetpotato because it plays an important part in the traditional food system and bridges food supply gaps caused by agroecological stresses such as pests and diseases, fluctuating rainfall, and severe events. In the future, global climate change will increase food poverty, boosting the need for resilient nutritional food sources like sweetpotato. Indigenous Fijians were pioneers in adopting novel varieties and cropping techniques to increase food security in the face of global and local environmental, social, economic, and climatic pressures more than a century ago. Fiji must exhibit this resilient culture once more by adopting future-focused strategies to mobilize and utilize resources, knowledge, skills, and strong partnerships for food security resilience.

Most attempts to improve food security in Fiji have failed because they fail to recognize that food systems must relate to Fijian traditions and culture, as well as the ‘island’ way of life. Indigenous farmers in Fiji continue to employ some of their traditional ways to solve farm difficulties such as soil erosion, droughts, floods, and insect infestations. Traditional farmers are frequently underrepresented and excluded from agricultural policies and assistance programs, with the majority of the government's attention focused on those agrarian sectors that generate significant money.

Chapter 3

Talimagimagi: Weaving Methodology, Research Ethicsand Fieldwork Practice

"Education was a part of everyday life for the first Native Americans." Their books were about rocks, rivers and lakes, trees and roots, the sun, moon, and stars. They fashioned their material civilization from these components. Everything had a creative existence. One loved nature, and nature loved back. The people believed in only one Supreme Being, The Creator, whose immense strength supervises and directs everything from the beginning to the end." (Harold Flett, 2008)

3.1 Introduction

This chapter explains the technique and methodologies used to drive the inquiry into the potential of kumala to achieve climate-smart agriculture in Ra, with a particular emphasis on the function of food security, ethnobotany, and the best climate change-resilient kumala variety at various elevations. This study used a mixed-methodology approach that was purposely pulled from multiple unique methodologies, representing the various fields studied through a blend of qualitative and quantitative approaches. The study will also seek acknowledgement from the two distinct groups under consideration: I-Taukei (traditional knowledge) and Western Science (Roskruge, 2010). The 'Fijian vanua research framework (FVRF)' technique is used in this study, which is supported by features of participatory, ethnobotany, social scientific theory, case study, and experimental field trials employing RCBD design approach.

The technique of qualitative research is for examining reactions to why humans behave the way they do, and it aids in the development of reasons for why things are the way they are. It assists researchers in understanding the social characteristics of our environment, as well as investigations into how ideas and attitudes are formed, why people behave in certain ways, how individuals are impacted by events that occur around them, and why and how cultures have developed the way they have. Qualitative researchers are interested in the research participants' perspectives, experiences, and feelings. Furthermore, it presents social occurrences in their most natural setting (Hancock, 2002). It was chosen for this study because of its mutual link to indigenous knowledge and the historical background of kumala production in Fiji, as well as to contextualize the explanation for kumala's loss of prominence in Fijian culture, particularly in the Province of Ra.

Meo-Sewabu (2015), an I-Taukei researcher, noted that information is appreciated in the indigenous society and is even regarded as holy in some cases. It gives us an understanding of how "people make meaning of their experiences" (Liamputtong & Ezzy, 2005:5). Epistemology is the study of "how we know what we know and how we may (or cannot) know what is true" (Gomm, 2009, p. 114). Ontology, she continues, is "a theory of what exists" and what their nature is. The 'emic' method used in this study will be valuable in terms of ontology and epistemological orientation. The use of an 'inside' viewpoint to characterize Fijian culture rather than a more comparativist approach of an 'outside' perspective or 'etic' approach is crucial here. "Differences between cultures are explained according to a general external norm" in the etic approach (Morris et al., 1999, p.781).

Quantitative approaches are useful since they provide the optimum answer to the problem without even recognizing all feasible options. When there are a large number of feasible choices, only a few are worth considering for selection. Once the problem and conditions are specified, the decision-making process becomes much faster. When the problem is well defined, multiple choices exist, and decision outcomes are easily observable, a quantitative approach to decision-making delivers the best results, as illustrated by (Roskruge, 2007).

"Scientific Research" is perhaps one of the ugliest terms in the indigenous lexicon (Smith, 1999)**.** The major goal of the quantitative approach is to make the best decision possible by employing mathematical and statistical models in situations where the likelihood of all possibilities is unclear (Smith, 2012). The use and implementation of quantitative tools in agricultural decision-making have long been contentious. Despite methodological advances, models have been criticized for missing an empirical grounding and ignoring crucial data that may be difficult to include in the formal framework of mathematical models.

They are, nonetheless, presented to policymakers as the sole foundation for logical decision-making. Many nations' agricultural policy bodies are increasing their desire for immediate efforts to quantify the costs and benefits of different policy options. Statistics, thus, are an accumulation of facts and figures, graphs and charts, that is, any type of factual information supplied in numbers, to an agricultural researcher. However, statistics, in a wide sense, is the discipline of applied mathematics concerned with data-driven decision-making (Davis, 2011). As a result, statistics comprises two fundamental components:

- **Descriptive statistics:** Data collection, organization, presentation, and analysis without reaching any conclusions or inferences (e.g., generating histograms from grouped data, computing mean, standard deviation, median, and mode).

- **Inferential statistics:** This is the science of making decisions in the face of uncertainty, i.e., making the best decision possible based on the limited knowledge available from sample data or experimental data. When we only have a sample from a population from which to conclude, uncertainty is unavoidable. As a result, probability is critical in statistical decision-making.

The use of a quantitative methodology in this research is to ascertain the best-yielding varieties of kumala suited to climatic zones in the Ra province through evaluating the drought tolerance and performance of selected kumala varieties at three different altitudes. No irrigation treatments will be applied. The results will identify the CSA attributes of kumala for the indigenous community in Ra.

There are clear disparities between western and indigenous methodological approaches. (Kovach, 2009, p. 20) Indigenous Pacific methods "define the theory and technique of doing research that stems from an indigenous epistemology." Similarly, Western methodology stems from a distinct "sociological, epistemological, sociological, and ideological manner of thinking and being as distinguished from Eastern philosophy, an indigenous worldview, and so on." Indigenous techniques have been established and used in many Pacific Island countries and cultures such as Tonga's Kakala, Aotearoa/New Zealand's Kaupapa Maori, and the Fijian Vanua Research Framework (FVRF) as research frameworks suited to these indigenous civilizations.

The project's ethical consent required a complex weaving of what is academically sound in the Western world with what is culturally suitable in indigenous research. Human ethics clearance for academics considers risk calculation and management. While there are hazards in any research involving ethics procedures and research design, this chapter shows how western paradigms linked with 'expert knowledge and an indigenous population group's 'lay knowledge' generate some contrasting understandings of ethical activity. It might be claimed that expert knowledge, as defined by hegemonic western concepts of the study, frequently subjugates indigenous knowledge systems (Battiste, 2008; Connell, 2007; Smith, 1999). This same information is appreciated and frequently considered sacred in the indigenous world. Cultural awareness and indigenous knowledge served as a paradigm for responding to the ethical quandaries in this study. Methodological epistemologies are intertwined with indigenous modes of knowing, western and indigenous research ethics, and scientific research methodologies. The Dre'e metaphor below is an example of Fijian traditional epistemology that constructs the weaving process used throughout this thesis.

3.2 Dre’e Metaphor (see Figure 3)

The ‘metaphor’ has defined roles in qualitative research studies (Hesse-Bieber et al., 2010). While the qualitative research paradigm involves a systematic undertaking of empirical inquiry into meanings, a metaphor can be a mechanism to reach these meanings. Meanings in qualitative research are integrative components of reality and metaphors enable the necessary organisation to work to improve our understanding. At times metaphors do not deliver what they are intended for, or the validity tested over time, which is why having an in-depth and thorough understanding of the metaphor is so essential (Hesse-Bieber et al., 2010). In the case of this research, a Dre’e (basket) is the metaphor applied. Dre’e is an indigenous I-Taukei basket which was used by every indigenous Fijian woman when they went out in the bush or farm to collect or harvest root crops and coconuts; nowadays, plastic bags are commonly used. Dre’e is made up of two I-Taukei materials on land and material from the sea. Coconut leaves are plaited to makea basket, and it is then left out in the sun to be dried for four days, and the voivoi is woven together piece by piece using the three plaits for the “ena’i dre’e” (basket handle) which the I-Taukei woman carries with them like a school bag. The dre’e has its significance to the I-Taukei women. The researcher designed this metaphor model to explain and honour our indigenous women who are engaged in agriculture in Ra. This model also explains the weaving of traditional knowledge, ethnobotany, and scientific research ideology for identifying suitable and sustainable agricultural practices and knowledge to revive kumala farming in Ra, Fiji. This model will be an added pillar to the Vanua Research Framework (FVRF).

Two other works: *‘bula vakavanua’* (Nainoca, 2011) and ‘*tali magimagi’* (Meo-Sewabu, 2015) recognise the importance of the FVRF framework and are also components of this framework. *Bula vakavanua* encourages the researcher to engage and live the *vanua* way of life, and one can use *tali magimagi* as cultural discernment to decide the appropriate way of doing things at the *vanua* level.

Through this, the researcher gains the trust of the *tamata ni vanua* (people of the land). This may take time but is needed to explore those differences that separate a foreigner from them and allow for the validity of the data gathered (Vunibola, 2020). *Tali magimagi* also includes the weaving of tertiary-level knowledge with that of indigenous knowledge. As an integral component of all these systems, *talanoa* is not only a data-gathering tool but more a *magimagi* (coconut strand) that binds everything within a *vanua* setting. The metaphor will also be the first of its kind for use in the agriculture sector in Fiji supporting inclusiveness, participation, and benefits for every indigenous community in Fiji, which will be the centre for development. Hence, it will be a tool designed as a guide for the Ministry of Primary industries, or any other organisation, in conducting agricultural research in an I-Taukei society.

Figure 3: Dre'e Metaphor. Designed by: Leweniqila, 2020

3.2.1 Traditional Significance of Dre'e

3.2.1.1 Marama

Women in this model have two roles; firstly, to value the impact of a woman in agriculture. This corresponds with SDG objective five, which calls for women's full and effective involvement in political, economic, and public life, as well as equitable chances for leadership at all levels of decision-making. Secondly, the woman represents the researchers and other government and non-government organisations engaged in agriculture development on rural and outer islands of Fiji. Every government, non-governmental organization, and researcher in Fiji should prioritize inclusion, involvement, and benefits for indigenous populations. Their role is to examine all research before it commences and to ensure that it will be of benefit to the vanua or the I-Taukei farmers. The researcher must know that the I-Taukei people's knowledge will be acknowledged and valued throughout the process and at the end of the research or development.

3.2.1.2 Dre’e

Dre’e signifies the researcher’s role as an outsider with a vast and in-depth level of knowledge and skills entering the I-Taukei community carrying this basket or dre’e, which is loaded on her back with the knowledge of kumala and [in this case] the potential it has on climate-smart agriculture bringing rural economic development and benefits to the people. This model will be an added pillar in the vanua research framework (FVRF) developed by Nabobo-Baba (2006).

3.2.1.3 Drauna

Drauna means leaves, and in this metaphor represents the kumala farming outlook. The fronds of the coconut are plaited to make the body of the basket. These fronds represent the two knowledge systems (traditional and Western sciences) which impact the livelihood and well-being of communities in Fiji and provide an avenue for climate-smart agriculture. The population of leaves on the vines provide a better production of kumala at harvest. Every level of farming has some outlook or manifestation on kumala production. It might also be the different methods of agricultural agronomy practicesthat farmers apply to their land.

3.2.1.4 Kabe

A kabe is made of a coconut leaf which is split in half and made into a circle or oval shape, making the hard skeleton called kabe form the solid brim. The kabe representssolesolevaki as the only tangible element of the basket, determining its oval shape and its durability and holding the basket together. The fronds of the coconut were plaited to make the body of the basket. These fronds represent the three villages in Ra to revitalise solesolevaki, and each frond has a stick forming the spine that adds strength to each frond. Fronds are interwoven, converting the leaves into a more robust body to contain and carry a more significant load. All these processes make the basket (the community) strong enough to hold the benefits of solesolevaki, which brings meaningful life to the vanua for its people. The base is thickly plaited to avoid weak links. In the initial plaiting phase, each frond is weak, and when the plaiting layers progress, the strands become interwoven, making it stronger, depicting unity and unison of vision. The layers represent time, and the people are united and stronger together, by practising solesolevaki over time (Vunibola, 2020).

3.2.1.5 Ena’i’ dre’e

Ena’i dre’e (basket handle) which the I-Taukei woman carry with them like a school bag. They are produced from the Voivoi (*Pandanus caricosus*), which is historically utilized in indigenous villages to weave mats. Its leaves are prickly, similar to screw pine leaves. When the leaves reach five or six feet in length, they are chopped off, the thorns and midrib are boiled, and the leaves are dried in the sun. Next, the 'wawalui or walui' process occurs. Walui or the scraping is done for five days using black mussel shells from freshwater or sea to enhance the material's durability and flexibility which allows the weaving process to be more comfortable for the women. After the voivoi is scraped, they are then rolled into coils and kept until they are needed for weaving. As I-Taukei, the wawalui or scraping process is essential in every agricultural research. While kumala has a strong traditional base in Fiji, its potential social, cultural and economic value is currently under-recognised. Therefore, the implementation of walui of all the knowledge supported with other methodologies like bula vakavanua and tali magimagi will provide opportunities for I-Taukei farmers in Fiji. The ena'i' dre'e represents the support mechanisms for rural subsistence farmers which connects the outsider to the Vanua (people) on their traditional knowledge.

Roskruge (2007) in his work which was both Kaupapa Māori and ethnobotanically centred, noted the following:

> *"When dealing with Māori, major complications might develop if an improper research technique is used." It includes Māori unwillingness to reveal information in the future if they consider the knowledge they have contributed has been misapplied or benefitted the researchers [exclusively] rather than themselves. This problem of misappropriation of indigenous knowledge is common among many indigenous peoples across the world, as Western scientists have lately trademarked grain varieties that they have nurtured for hundreds of years (Benjamin, 1997). The issue of cultural ethics has also been discussed as part of the kaupapa Māori research approach. These ethics are mostly founded on tikanga or good cultural practice, which includes aroha "ki te tangata (respect), kanohi kitea (face to face contacts), titiro, whakarongo, korero (look, listen, speak), manaaki ki te tangata (generosity), and others."*

Like Roskruge's (2007) position, it is also pertinent to ensure that the appropriate indigenous Fijian knowledge base is considered when researching indigenous Fijian agricultural communities. Since the beginning of the project, it has been recognized that if the study technique is too technical, potential informants may not be able to grasp it properly. As a result, the employment of walui is required. To acquire and absorb the proper information rapidly, the research needed to employ terminology that all stakeholders could understand. According to the authors, conversational and casual interviews can yield substantially more meaningful information than rigorous, formal interviews (Royal, 1993). The contact greatly aided the Vanua of Ra's procedure of working with prospective informants.

This study will use both a qualitative and quantitative approach. Figure 4 depicts the mixed technique utilized by participants in Fiji. The vanua framework and the talanoa procedure, both qualitative, are the common techniques employed throughout the three study trial locations. An experimental design was employed as the quantitative technique. The insider/outsider position is explored here, as are the ethical quandaries encountered throughout the study process and the weaving of the threads that resulted from this research, shaping the Dre'e metaphor. I started with the Vanua methodology, which is the overall methodology employed in this chapter.

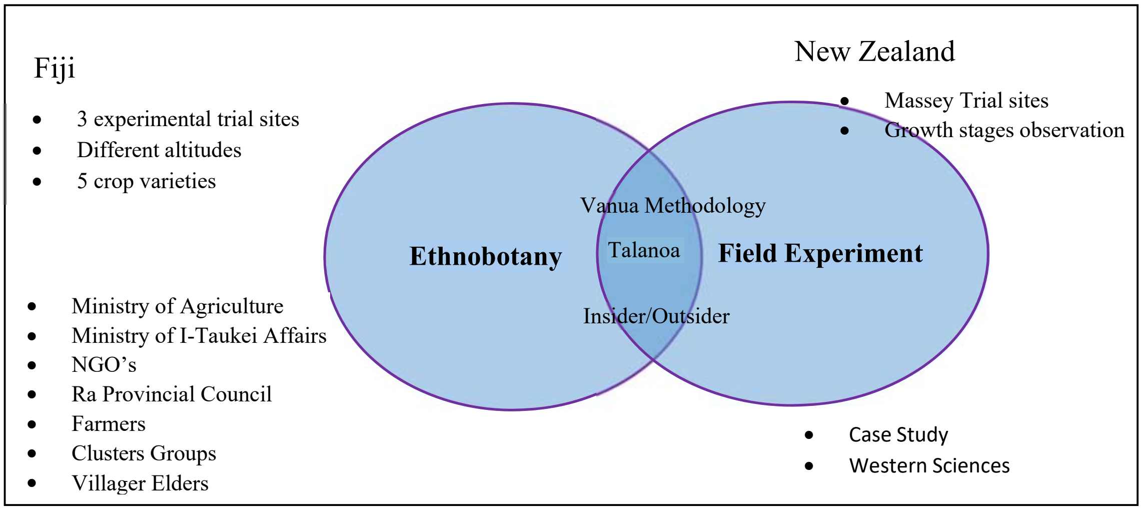


Figure 4: Methodological Approach of Research

3.3 Ethnobotanical framework

This is an ethnobotanical study since it is based on indigenous peoples' traditional knowledge, customs, and values (Roskruge, 2007). Martin (2010) describes the ethnobotanical framework as the study of plant-human interactions and relationships through time and geography. It encompasses both modern and traditional cultures' usage, knowledge, beliefs, management methods, categorization systems, and language for plants and their associated terrestrial and aquatic habitats (Prance, 2007). Human life would not exist if plants did not exist. Plants are essential to human existence in a variety of ways, and we continue to rely on them for many of our possibilities to improve human life quality (Aalbersberg et al., 1997; Prance, 2007; Wiryono, 2007). The phrase 'Applied Botany' (Villamar, 1997 as quoted in De Albuquerque & Hanazaki, 2010) was used in the beginning; however, ethnobotany is now more widely used (Estrada de la Cerda, 2015; Roskruge, 2007). Ethnobotany is critical for understanding and enhancing the sustainability of our interaction with the living world (Spooner, 2014). The intellectual vs utilitarian debates in ethnobotany are part of an anthropological idea known as cultural particularism and relativism versus cross-cultural overviewing and comparison; essentially, a concentration on one culture versus a general approach. Berlin (1992) asserts:

"In their mental perception of the biological variety of their natural surroundings, human people everywhere are bound in roughly the same ways- by nature's basic plan." Human society, on the other hand, creates social organization, rituals, and religious beliefs." (p. 8)

Ethnobotanists have described their research activities as aiming towards at least one of three objectives, as mentioned (Tora, 2020; Given & Harris, 1994: p.9): First, rescue missions – associated with a near-extinct culture, including the systematic recording of ethnobotanical knowledge; second, industrial studies – the interaction between plants and commerce; and third, cultural improvement – when possible, linking science and culture. Because they incorporate both ecological and living cultures, ethnobiology and ethnobotany must be participatory by definition (Roskruge, 2007). Their science is a synthesis of research on people, plants, and land, each of which is distinct.

3.4 The [Fijian] Vanua Research Framework (FVRF)

The Vanua research framework created by Nabobo-Baba (2006) was utilized to guide the case study technique in this study. According to Nabobo-Baba (2006), the method is founded on traditional Fijian epistemology, which is centred on the holistic integration of people, land, and spiritual components. The fundamental sinnet[4] weaved across this study is the Vanua technique, which ensures that respect, humility, and traditional Fijian cultural traditions are followed.

A growing movement of scholars has advocated for the decolonising of indigenous research. Much of the research undertaken in the Pacific has been done by foreigners using mostly quantitative methods to examine indigenous communities (Chambers & Buzinde, 2015; Smith, 1999). It is argued that although such pursuits provide valid and useful insights, they contain deficiencies and have shortfalls in their ability to address the true nature of indigenous communities (Hau'ofa, 1993; Nabobo-Baba, 2008; Smith, 1999; Swisher, 1996; Thaman, 1997). Lagi (2015) revealed and acknowledged that indigenous communities in the Pacific are multi-layered, multi-dimensional, and involve much sensitivity and embrace many protocols that cannot be captured by quantitative methods alone. This was further supported and agreed upon by Vunibola (2020) and Movono (2017). Nabobo-Baba (2008) in her study of indigenous Fijian communities, suggested that it is critical to unearth realities by using a process that acknowledges society, earns people's trust and includes immersive conversations to facilitate accurate perspectives.

Vunibola (2020) identified that some quantitative applications in indigenous communities are neo-colonial because these studies do not acknowledge or appreciate the multi-pronged and very social nature of indigenous interactions. This suggests that there is immense value in the study of indigenous

[4] A sinnet in the context of wawalui and the tali dre'e which is made out of Voivoi (*Pandanus caricosus*) that is plaited for durability.

communities through the use of immersive studies undertaken primarily by indigenous people within their communities. Indigenous scholars who have researched communities in the Tongan, Samoan, and Maori communities in New Zealand, concur with the views of Nabobo-Baba (2008) and have paved the way for decolonising research in the Pacific. Studies conducted by Vunibola, (2020), Movono (2017), Smith (1999), Thaman (1997), and Nabobo-Baba (2006, 2008) all call for the revisiting of research design, approaches, and methods to ensure indigenous communities (in the Pacific) are not exploited but respected and placed at the centre of research. The vanua research framework provides a theoretical approach that is embedded in I-Taukei worldviews, knowledge systems, experiences, representations, and values, giving power and recognition to all things Fijian (Nabobo-Baba, 2008). Thetheoretical attention of this research on social and ecological systems and the sustainable livelihoods theories blended well with the use of the Vanua Research Framework in its application in research.

An essential characteristic of the movement to decolonise Pacific research is that it encompasses research that is empowering, participatory, engaging, and beneficial and that respects indigenous communities. This thesis contributes to the decolonisation of indigenous studies research by implementing the Vanua Research Framework (FVRF) (Nabobo-Baba, 2008) as a core paradigm for research methods. This paradigm was chosen as a set of beliefs that has provided sound guidance and structure for the proper conduct of empirical research which has informed this thesis supported by the experimental field trial (Denzin & Lincoln, 2000; Ponterotto, 1995). To understand a given phenomenon, indigenous researchers "examine people, their issues, and their difficulties in the subjects' environments" (Walsh, 2003, p. 67). As a result, in using the FVRF to steer its methodological orientation, this work follows a postmodernist perspective.

The term *Vanua* includes all the elements of the Fijian social and ecological system and recognises all the relationships that exist within this system (Vudiniabola, 2011). For indigenous Fijians, the term *Vanua* refers to a sacred overarching structure that unites the individual with the community, and the community to the land, sea, and air and includes spiritual connections between people, past and present (Movono, 2017). According to Vudiniabola (2011), the traditional Fijian worldview is built on three interconnected levels of human existence: Lagi (heaven), Vuravura (the physical universe), and Bulu (earth) (the afterlife world of the spirit or underworld). Fijians prefer to attribute all allusions to their customs, traditional practices, and international events to the three interconnected notions. Lagi is the home of the Christian God (see Figure 5), while Vuravura is the actual world in which we reside. Bulu is the world of spirits, which includes ancestor spirits, as suggested by the name (Nayacakalou, 1978; Lasaqa, 1984; Vudiniabola, 2011).

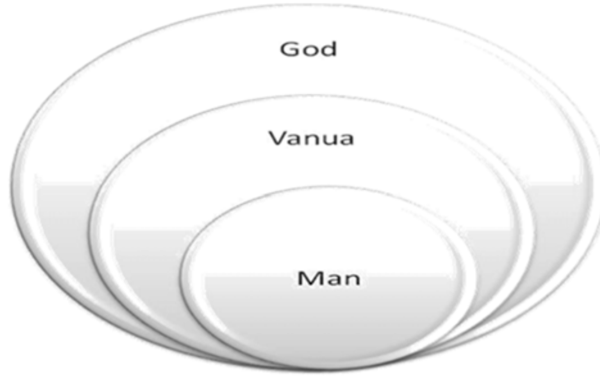


Figure 5: The Indigenous Fijian worldview of a person. Source: Vudiniabola, 2011

The I-Taukei perspective on a person as specified by Nayacakalou (1978) is made of three dimensions: God/ancestral spirit, land, and physical existence. All references to a person (or a family) are to the three composites listed. Either alteration or disruption in any of a person's components will affect the other two dimensions remarks (Vudiniabola, 2011). This point of view is critical in this research on kumala farmers' traditional Fijian knowledge in Ra District. The data collecting procedure, the selection of relevant and acceptable protocols observed in a traditional Fijian environment, and the analysis and interpretation of data for this study are all guided by the indigenous Fijian worldview of ethnobotany and their indigenous epistemology.

The FVRF is an indigenous context explicitly established for use when exploring indigenous Fijian communities (Nabobo-Baba, 2008). Chambers and Buzinde (2015) and Carson and Koster (2012) suggested that the adoption of both western and localised research paradigms helps to improve the conduct of research while ensuring cultural sensitivity. The constructive–interpretive, modernist paradigm offered by the FVRF, like other qualitative approaches, is well suited for this study because it integrates qualitative and quantitative techniques and allows the researcher and participants to co-construct the research process and its findings through interactive engagement and dialogue (Nabobo-Baba, 2015; Ponterrotto, 1995). Furthermore, the FVRF has allowed participants and researchers to communicate and engage in a localized context to better understand their experiences and the meanings they attach to them (Grant & Giddings, 2002). As an indigenous Fijian researcher dealing with indigenous communities as participants, the use of interpretive social science and the FVRF blended with the experimental field trial was justified as a means of enhancing knowledge. The unique skill sets, and the internal knowledge about heuristics, traditions, and cultural insights have enabled the researcher to interpret with greater accuracy what was observed and to provide better decision-making. So, it is not only the process that was an enabling factor but the researcher himself who had suitable qualifications and experience to extract the insights. It is not to say that the findings cannot be replicated by other non-indigenous researchers as alluded to by Nabobo-Baba (2008), but rather that special attention is given to the community being researched and a focus on good qualitative practice was essential.

The FVRF paid specific attention to factors that are integral to indigenous Fijian society and allowed this study to tailor its methods and principles with which to explore insights into and understand the Fijian context. In essence, this study has validated Nabobo-Baba's (2008) position, that:

> *"It raises the potential of broadening indigenous people's knowledge base and reshaping their view of the social-cultural world by placing indigenous people at the centre of study and using their systems of knowledge and understandings as the foundation for inquiry and analysis" (p. 141).*

The principles of the Fijian Vanua Research Framework are:

1. The research on Fijians must support individuals, particularly the investigated group.
2. The emphasis should be focused on the needs of indigenous peoples and take into account indigenous cultural values, protocols, knowledge processes, and philosophies, particularly those related to knowledge access, legitimation, ethical processes, indigenous Fijian sanctions, and clan 'limits or boundaries,' all of which influence knowledge and related issues.
3. Fluency in the Fijian language and/or dialect of the population being studied by the researcher.
4. In collaborative research scenarios, the usage of an I-Taukei as a principal researcher or researcher.
5. Researchers should accept and validate existing elders, Vanua systems, and procedures with respect and reciprocity. In terms of reciprocity, researchers must guarantee that there are adequate ways to express gratitude to individuals so that their love, support, time, resources, and expertise freely provided are appropriately returned.
6. Researchers must guarantee that representatives of the I-Taukei community are included in the study team. This is a technique for increasing local capacity while also benefiting the research community in a variety of ways.
7. Researchers are held accountable for their study techniques by meaningful reporting and meaningful feedback to the appropriate persons and community.
8. All 'researchers' (research) conducted in Vanua must be approved by Vanua chiefs, village chiefs, and elders at all levels. (Nabobo-Baba, 2008, p. 144-145).

In the context of this study, Vanua methodology guarantees that respect, humility, and traditional Fijian cultural procedures are followed, embracing what both Western and Indigenous researchers hope to achieve: minimizing possible harm to participants. In indigenous frameworks, reducing damage requires respecting kinship and ties among individuals. According to Creswell (2009), "researchers must respect research for it to be kept undisturbed after a research study, and interviewers must be aware of their influence to minimize disturbance of the physical environment" (p.90). Creswell could have meant reasonably undisturbed, as every study disrupts a research location to some degree. Respect in a research site in the indigenous context entails addressing the existing levels of governance within the research environment. Addressing the various systems entails acknowledging kinship within the village and among the participants; this frequently disrupts village norms, but it is an ethical component of what is culturally appropriate when entering the study context.

Conducting a study with volunteers known to the researcher is typically deemed unethical in western research paradigms because of the implied lack of objectivity in such circumstances. As indigenous researchers, we were educated about our behaviour patterns as children when we entered a connected vanua. Knowledge of the proper study site for an indigenous researcher might be based on what the research alludes to as our relation to the Vanua and knowledge of the empirical world and social order or socio-cultural interactions in the village. So, performing this research in any other village in Fiji would suggest the i- Taukei people's common concept, which is to provide the best of what they have to the vanua to increase their well-being. As a result, the research was carried out in Ra, also known as my Au'vu. Being an 'au'vu' means that I am treated with respect; Chapter 5 delves into the complexities of this connection. Besides, professional experiences in Fiji have enabled essential connections to be made with the kumala farmers and the participants, which is pertinent for capturing the diversity of their knowledge and experiences.

I have scrutinized and identified that the Vanua will respect such an act in conducting cultural protocols of entering the Vanua; by engaging in this process, we are also weaving the strands of the Dre'e using highly skilled experts who helped conduct appropriate customary practices within the Vanua and the Fijian community. Failure to follow the proper process will result in curses and the anger of the ancestors inside the country we have visited. Because of our spiritual ties to the land and our ancestors, the idea maintained is that incorrect behaviour has bad spiritual consequences that might appear in the physical world (Nabobo-Baba, 2006; Ravuvu, 1983).

3.5 Talanoa Method

This study also utilised talanoa, which is widely used by Pasifika researchers in research with Pacific communities and participants. Talanoa is described as a methodology by Nabobo-Baba (2006), Otsuka (2005), Vaioleti (2006), and Latu (2009). Talanoa is a good technique for gathering and analyzing data within an oral tradition, such as those found in Fiji and many other Pacific Indigenous societies. According to the vanua approach, performing the research on and with my 'au'vu' confers benefits and ensures a productive 'talanoa' by the researcher and participants. Because many aspects of human values, culture, and relationships cannot be properly articulated via quantitative research methods, this study will heavily rely on talanoa methodologies (Streubert & Carpenter, 2011). The cultural constructs of traditional knowledge of kumala production in Fiji will be explored as perceived by the I-Taukei people in Ra and will also contextualise the loss of importance of kumala within society. Talanoa is a face-to-face conversation method used to cover any subject matter from general through to more constructive discussions. The talanoa method is a reciprocal manner of addressing a topic without borders that is used at various levels of Pacific society (Kingi-Uluave & Olo-Whanga, 2010). Talanoa is defined by Cappell (1991, p115) as "to converse, to tell stories." Across the Pacific, storytelling is a common cultural practice that corresponds to the western idea of therapeutic discourse (Kingi-Uluave & Olo-Whanga, 2010).

According to Cappell (1991, p.214), the term 'Tala' means "to clear away, replant, transplant, load or unload," and it also implies "to dispatch, inform, or order" (Kingi-Uluave & Olo-Whanga, 2010 p.36). According to Vaioleti (2006), tala means to "inform, tell, narrate, order, beg, or apply." The term 'noa' implies "yesterday" (Cappell, 1991, p.115), however, it is not used alone (Nainoca, 2011). The Ministry of Primary Industry refers to such initiatives in Fiji as 'talanoa sessions,' which normally take place over a bowl of yaqona (kava). This is inspired by the Fijian tradition of talanoa. These talanoa meetings are for discussing topics, stating positions, and discussing ideas (old and new), but not for recording talks. Otsuka (2006), on the other hand, notes that during an interview, the Fijian respondent would not just say "yes" or "no," but would instead react with a 'talanoa,' a narrative. The talanoa is a tool that is used in conjunction with a "long question probe," such as "talanoa taka mada vei au na," which means "tell me the narrative about.... "

Because everything is related, a talanoa response to a question makes greater sense (Vaioleti, 2006, p. 25). As an indigenous Fijian researcher who is aware of indigenous Fijian protocols and familiar with its use in recent publications, *talanoa* stood out as a vital part of this study's data collection strategy (Movono, 2012; Movono, Pratt, & Harrison, 2015; Pratt,Gibson, & Movono, 2012). This technique works well by establishing and fostering a conducive and cordial environment to enable rich exchanges, reflection, and genuine engagement with participants. The *talanoa* sessions will be informal, semi-formal, or formal when required, and will usually necessitate elements of the traditional protocol.

3.6 Participant Observation

The unique nature of this study required that specifically designed and adapted ethnographic techniques were used to match the objectives of this research, the attributes of the researcher, and the nature of the community being researched. Tracy (2013) highlighted that there are several ways to undertake participant observation and that it is critical to choose one that best meets the study's aims. In this study, the researcher assumed the role of a complete participant-observer, thus providing multiple opportunities to study contextually. Tracy (2013) reiterated that participant observation, in whatever form, must be accompanied by various techniques that match the fieldwork being conducted. This entails immersion and requires the researcher to participate in daily activities and adapt to life in the village (Tracy, 2013). Swisher (1996) suggested that complete participant observations are ideal when researching indigenous communities because of the ready access to available data and the often obscure front and back stages of communities. In this study, complete participation provided the researcher with the ability to identify subtle cultural and social associations that may otherwise go unnoticed and not be interpreted (Tracy, 2013), and cultural phenomena occurring within the community (Wu & Pearce, 2013).

"Participant observation is commonly acknowledged as the core research method for cultural anthropology," wrote DeWalt and DeWalt (2011; p. 2). It is a method that permits the researcher to become a member of the community, population, or organization being investigated, allowing researchers to "get new understanding via experiencing the phenomenon for themselves," according to the author (Ritchie & Lewis, 2003, p. 35). In the context of this study, being a part of the community allowed the researcher to experience their daily life routine inside the village environment and be a part of the village events and activities, capturing interactions as they occur. This strategy allowed me to join in village events as an insider, rather than as a simple observer, which would be culturally unacceptable. Furthermore, as an insider investigating my au'vu's vanua, I was expected to engage in the community's everyday activities. Participant observation, according to Jorgenson (1989, p. 15), allows "direct experiential and observational access to the insiders' world of meaning."

3.7 Semi-structured formal/informal interviews – talanoa

Veal (2006) suggested that interviews guided by a framework or structure have immense value in measuring complex variables and interwoven relationships across various contexts. Unstructured interviews are less rigorous than structured interviews, but they nevertheless need a list of probing questions that allow for interaction and highly nuanced conversations (Tracy, 2013). The main research topics and aims of this study were reflected in a series of probing questions. The participants included the heads of various committees, (kumala farmers, provincial council committee, MPI officers, youth, women, church, and development) and administrative bodies, including the village headman (*Turaga ni Koro*), youths, women, and village elders of Nabukadra, Burenitu and Bucalevu villages. Semi-structured questions were used to guide the exchange and discussion between specific, influential leaders and persons directly involved in development in Ra who was observed as having authority on specific issues. Questions about historical events, specific experiences, processes endured, and developments were raised as key talking points.

3.8 Semi-structured group interviews - talanoa

Representatives of existing community organizations in Ra were interviewed in semi-structured group interviews to generate jointly determined development measures. Wu and Pearce (2013) highlighted the value of the use of group interviews as a means to thoroughly understand community aspirations and collective points of view and to identify patterns. The findings from the group interviews were a critical starting point allowing key participants to be selected and identifying critical issues. Group interviews were conducted with all of the village subcommittees, which included the women's committee (*Soqosoqo vakamarama*), development committee (*Veivakatoroicaketaki*), youth (*Tabagone*), and the religious committee (*Lotu).*

3.9 Data recording, coding, and transcription

The free-flowing and engaging nature of this study required that data recording tools such as digital recording devices (phone and recorder), digital cameras, and laptops were used to record data. Ethnography demands that researchers have an organised and logical approach to data recording, transcription, coding, and analysis, which was adopted in this study. The researcher used multiple recording instruments for this study, depending on the context and situation in the field. For instance, a mobile phone voice recorder was used to record the outcomes of group or individual interviews because it could be used discreetly to record lengthy exchanges. The phone recording medium was most suitable and effective in recording and preserving the raw data.

Data from these conversations were then transcribed from the Fijian language and coded before meaningful categories and themes were organised, every two or three days. This allowed for regular and consistent processing of data, which enhanced opportunities for deep reflection and preliminary analysis of data. From time to time (every three to four weeks), the researcher detached himself from the community for between two to three days to allow for a "breathing period" and reflection on the work done. These breaks of about three days were appropriate since the researcher was not completely detached, and his absence from the village was not noticed, thus maintaining momentum and local rapport. Movono (2017) stated that regular breaks must be taken by the researcher when using complete participant observations to allow for deep reflections as a researcher, to make sense of the data, and to eliminate bias. These detachment periods facilitated clear perspectives and allowed for the examination of the links between empirical knowledge and theoretical knowledge by the researcher (Tracy, 2013).

3.10 Case Study

In this study, case studies were also utilised. According to Yin (2003), a case study technique should be employed when asking "how" or "why" questions about "a contemporary phenomenon within its real-life setting" (p. 13). Case studies entail a deep and intensive examination of a single case or the examination of two or three cases (Bryman, 2004). Stake (1995) contrasts between 'intrinsic' case studies, which focus on analyzing one instance in isolation, and 'instrumental' case studies, which pick specific situations to examine more general concepts. Instance studies employ a single case to gain insight into an issue or to provide a broader understanding of phenomena. The "collective case study" (Stake 1995; Yin 2003) was used in this study to "give a broad understanding using various 'instrumental' case studies that either occur on the same site or come from several locations" (Harling 2002, p. 1). The three separate research locations were chosen to investigate and give some significant insights regarding kumala's potential for climate-smart agriculture.

The determination or definition of the case is an important part of case studies. The examples in this study were found using the MPI farmers' profile list 2016/2018 and a portfolio of locations at various elevations. These sites are spread in several districts in Nakorotubu and Nalawa (tikina). The district of Nakorotubu includes Nabukadra on the shore and Bucalevu on the high plateau, as well as Burenitu, which represents the district of Nalawa. Case studies should have a certain function, which is to provide value to the study topic stated (Yin, 2003). The three locations were chosen because they have qualities that set them apart from other sites, and they are thoroughly described in Chapter 4. In this study, the case study technique evaluates the similarities and differences between villages, and data obtained from many case studies (Yin, 1994) is frequently considered more persuasive, so the total study may be deemed more robust. According to Roskruge (2007), the case study has become an acknowledged qualitative approach in particular research areas. According to Hamel et al. (1993), a case study is an approach rather than a technique that utilizes a variety of approaches such as interviews with participant observation and field investigations. According to Roskruge (2015), the Chicago School of Sociology developed a unique approach to case studies in the 1930s, favouring on-site observation, open-ended interviews, and document gathering to achieve their purpose.

3.11 Science Theory

Roskruge (2005) states that science is about investigating ideas and establishing probable connections between them through observed occurrences. These ideas serve as the foundation for the variables that comprise the hypothesis that underpins scientific investigations. The process of developing trustworthy variables from ideas and generating hypotheses from these is fundamental to research, particularly social science'; from the hypothesis emerges an appropriate technique that may be pushed (Hamel et al., 1993; Hoover & Donovan, 2001).

Western Science has become the dominant science method globally, according to Chalmers (1999), and it is built on the study, creativity, discussion, and accessibility. Scientific knowledge is based on what humans can see, hear, and touch and is obtained from rigorous observation and experiment. Indigenous peoples say that their knowledge base is an applied "science" since it is founded on the same concepts and procedures (Roskruge, 2001). Positivism (Burns, 2000) is the commonly held opinion that Western scientific knowledge is the sole true type of knowing. Hypotheses are extensively used to prove if scientific ideas are correct or incorrect, and it is one of the basic foundations of research. Western science, on the other hand, has bounds and must be reproducible, thus it must be conducted using a methodology that meets all these criteria. The approach should always correspond to the theory. In western science, research is often conducted using a quantitative technique that relies on the process and findings being measurable using established methods, such as statistical analysis or treatment differences.

3.12 Indigenous Research Process and Ethics

The research processes and ethics of indigenous Fijian researchers are not usually the same. The indigenous Fijian research methodologies and ethics that were employed were based on Nabobo-Baba's FVRF research expertise and are described below.

The indigenous research process used in this research comprised four steps:

1) *Vakavakarau* (Preparation): This is the planning step, which included a Vanua fact-finding activity to help me integrate into the community.

2) *Na isevusevu* (Gaining Field Entrance): The guest presents yaqona when they arrive at the house, community, or gathering where they are asking permission to enter. The sevusevu etiquette is suitable and respectful of the host (Nabobo-Baba, 2006).

3) *Vakasokomuni i tukutuku* (Data gathering in the field): There is an implicit attire and behaviour code in the town. Women are not permitted to wear trousers or shorts in the workplace. Dresses and skirts must be below the knee. Caps and flowers in the hair are not allowed. The anticipated behaviour of researchers and researchers alike is influenced by Fijian values. These values include loving one another (veilomani) (Seruvakula, 2000; Ravuvu, 1983; Qalo 2006; Tuwere, 2002), respecting one another (veidokai) (Seruvakula, 2000; Ravuvu, 1983), and caring for one another (veikauwaitaki) (Seruvakula, 2000; Ravuvu, 1983). "Vanua values of veidokai and veivakarokorokotaki are also significant guides as behaviours demanded of the researcher (knowledge seeker) towards the giver," writes Nabobo-Baba (2007, p. 2). Veidokai is how a "person behaves or reacts considerately in the presence of others," according to Ravuvu (1983, p. 104), whereas veivakarokorokotaki is respect.

4) *Na vakavinavinaka* (Thanking the participants): Fijian giving is "to demonstrate thanks to individuals so that people's affection, support, time, resources, and expertise freely provided are promptly repaid," according (Nabobo-Baba, 2007, p. 3). "Knowledge is considered a gift by Fijians," says Nabobo-Baba (ibid). "Thus, within the framework of Vanua inquiry, the gift is searched for and derived accordingly." "Traditional protocols, tailored to local conditions, may involve reciprocity or diplomatic giving, reciprocal help outside of the limits of academic research," Louis and Grossman (2009, p. 5) wrote about the traditional protocol. What exactly do we mean by "offerings"? It is providing you with something valuable. What does that mean to you? Are you willing to trade something as important for life stories? Do not allow anyone to make you feel guilty for offering to share someone's story. Anderson and Campbell (2009), p. 12. For me, I wanted to give back to the community something essential to me: time and knowledge, in addition to the typical gifts of clothing and yaqona.

3.13 Ethical considerations

The primary goal of ethics is to safeguard all study participants. To safeguard the identities of the respondents, pseudonyms/name codes are utilized in this study. The identification of case study locations will be withheld for some components of social capital and traditional indigenous knowledge information to explore some of the findings. Over the last 15 years, Mohawk sociologist Brant-Castellano[5] (2004, p. 107) has defined ethical principles for aboriginal research by several agencies[6]. When building a Fijian ethical approach for my study, I utilized this as a set of recommendations to give vital direction for concepts and procedures. According to Weber-Pillwax (2004, p. 80), "natural laws or principles of ethics are simply described as caring, compassion, respect, and sharing." They are meant to supervise our interactions with all other living beings and forms of life" (Pillwax, 2004, p. 80). Kindness, caring, sharing, and respect are all important virtues in Fijian culture. Apart from respect, language, and reciprocity, which are all important in the Fijian setting, this guideline emphasized the necessity of honouring ancient procedures. The Australian Aboriginal and Torres Strait Islander communities have established six values: (1) spirit and integrity, (2) reciprocity, (3) respect, (4) equality, survival and protection, and (6) responsibility (Cochran et al., 2008). The "Kaupapa Maori: Maori research by, with, and for Maori" study in New Zealand reflects a culturally appropriate research strategy for Maori (Roskruge, 2007). The following are four ethical principles appreciated by a researcher in an Indigenous Fijian society, based on the work of Fijian academics and authors (Ravuvu, 1983; Seruvakula, 2000; Tuwere, 2002; Qalo, 2006; Nabobo-Baba, 2006) and the standards described above:

1. ***Veidokai*** **(Respect):** This is a virtue that is expected in most societies, including the Fijian community, where showing respect is highly regarded.
2. ***Veidolei*** **(Reciprocity):** The community has provided time, energy, and most importantly, information, and proper reciprocity must be followed. Non-indigenous researchers are not required to reciprocate Fijian hospitality.
3. **Vosota (Patience):** Life in the village community moves at its tempo, and patience is always required, as impatience is considered impolite. Meeting the turaga-ni-koro, starting a talanoa session, or interviewing a major informant might all be delayed. A death in any of the district's villages might sometimes cause the week's visit to be cancelled on

[5] Marie Brant-Castellano is a Mohawk of the Bay of Quinte Band and Professor Emeritus of Trent University.
[6] According to Brant- Castellano the most comprehensive set of Aboriginal-specific guidelines is found in "The Report of the Seminar on the Draft Principles and Guidelines for the Protection of the Heritage of Indigenous People" which treats research ethics as one aspect of protecting Indigenous heritage. [United Nations Economic and Social Council, Report of the Seminar on Draft Principles and Guidelines for the protection of the heritage of Indigenous People (June 19, 2000) E/CN.4Sub,2/2000/26].

short notice (tikina). Rather than becoming frustrated, I used the time to focus on other elements of my study, such as transcription or reviewing prior drafts of my work.

4. **Veimaroroi (Protection):** Participants in the research must not be distressed at any point during the procedure, from the beginning to the end. Throughout the talanoa, researchers must be vigilant to participants' reactions. If participants exhibited any discomfort, whether verbally or by body language (e.g., bending their heads in quiet), changing the topic of the conversation is the acceptable reaction.

University research ethics may be defined as a set of moral standards that guide how individuals make judgments and act when it comes to planning, conducting, and reporting research (Vurebe, 2018). Thus, ethics need the researcher to consider what the institution demands, which is procedural ethics, and then ethics in practice. Before beginning the survey, the Massey University Human Ethics Committee obtained Low-Risk Ethics clearance, as necessary for this research (Appendix 8). Other Ministry of I Taukei Affairs procedures will be reviewed in Chapter 4.

3.14 Chapter Summary

The third chapter provides an overview of the methodological and ethical procedures used in this investigation. Finding common ground on what is ethical from both worldviews without compromising what is culturally suitable was the goal of the interface. The "Dre'e" metaphor expertly constructs the academic research process, including the ethical process. Cultural discernment, as an indigenous researcher, ensures that the research method is ethical within the cultural context of the study environment. Understanding and knowledge of the Fijian way of life, the Vanua, and associated cultural processes and norms were crucial in this research.

Chapter 4

Na I Lavelave Ni Vakadidike: Methods

Nai lavelave refers to methods used, or instruction given, to accomplish something (Meo-Sewabu, 2015).

4.1 Introduction

This chapter contrasts the research strategy used in this case study. The data collection process is broken down into two stages: participant recruitment and two data collection periods that included the combined use of 'Talanoa' for the Vanua of Ra (Nabukadra, Burenitu, and Bucalevu villages) and field experimental trials to help determine the kumala variety best suited to different altitudes in the Ra district. Talanoa was chosen because it allowed all participants to be present at the same time inside the confines of a hamlet. *Talanoa* facilitated asking the questions of how? why? and when? The main event's timeline included attending school, church, MPI Agricultural show, Bose ni Vanua o Nakorotubu (village meeting), MPI meetings and other daily activities.

4.2 Vanua o Ra Protocol (as defined by the Vanua)

The Vanua is essential for research with indigenous Fijians. As Nabobo-Baba (2006) highlights, it shapes the process as well as the product of the research. Besides, the knowledge generated reflects the knowledge of the people in, or from, the vanua. This is particularly so regarding ethical procedures that need to be followed. These involve the integration of the Vanua o Ra ethical procedures into western research ethics. The vanua o Ra ethical procedures include ensuring the research benefits the vanua and no harm is done to it; for instance, only publishing information authorised by the vanua and not publishing information that may jeopardise relationships between the researcher and the vanua and its people. Also, the researcher must follow culturally appropriate procedures such as presenting the i-sevusevu when entering the vanua to request the conduct of research and the researcher must wear appropriate attire. Also, the researcher must use an appropriate tone and language. Furthermore, the researcher must makecorrect gestures, such as not making eye contact with the elders. Also, when addressing elders, it is appropriate that the researcher use i-kemuni (formal pronoun (you) instead of o' iko (informal pronoun (you) used when referring to someone of the lower or same status as the speaker). As highlighted in the definition of vanua, culture and tradition are encompassed in the concept of vanua. Hence, in researching Ra, strict observance of the vanua o Ra protocol is paramount. The vanua o Ra protocol includes i-sevusevu and i-kerei (request for entry and to research), which two essential protocols or rituals are related to the formal request from a researcher/s to enter the village and to collect and use information. It includes wearing appropriate attire, adhering to social, and linguistic rules, observing communication etiquette and understanding the vanua (Thaman, 2009). Doing this is critical in establishing a connection and building trust with the vanua. Once the researcher has been accepted as part of the *vanua,* only then will participants feel comfortable about giving out information without reservation. At the end of a visit, an i-tatau (traditional request for permission to leave) must be presented for the vanua to give its blessings for the return journey and future prosperity of the visitor. When researching with the vanua of Ra, the responsibility of the researcher does not end when the research is completed. After the study is documented, the researcher must return to the vanua for the *vakarogotaki* (report). Once the report has been presented, the researcher may publish the findings. Following the publication, the vanua, in celebration of the success of the study, may hold a *vakacirisalusalu* (feasting and celebration) to thank everyone for the researcher's contribution to the success of the study. The outcome of the study, therefore, does not belong to the researcher alone but is shared with the vanua of Ra.

4.3 I-Taukei Ontology in Ra

This study uses the Interpretivist Research Paradigm, where its ontological assumption asserts that knowledge is created through social and contextual understanding (Lagi, 2015). A person's participation is in the context in which they live, and interaction allows the person to co-create and have a better understanding of the knowledge being created. This perspective complements the epistemological standpoint that people create knowledge through a continuous process of socialisation. In the I-Taukei society, traditional environment knowledge (TEK) exists in the *vanua* and is learnt and interpreted throughout an individual's life through socialisation (orally, and through observation, imitation and guided practice). Ravuvu (1983) explains that the *Vanua* has four unified extents: the physical, social, cultural, and spiritual dimensions. This corresponds with Dr [Sir] Mason Durie's Te Whare Tapa Whare model (see Roskruge, 2007) for working with Maori. The social and cultural systems are set up as a foundation for the establishment of a harmonious, prosperous and cohesive society (see Figure 10). They provide members of the *Vanua with* an identity and a nous of belonging to the *Vanua*. The *Vanua* functions as a source of *mana* (power) and is the place where one's ancestors and elders keep an eye on what their descendants are doing and what might become of their vanua.

Ancestors advise their descendants through dreams or in-person through elders to maintain and nurture the *vanua*. When descendants do not follow the advice given, they may receive the *kudru ni Vanua* (angerof the land) and are therefore punished, usually in the forms of sickness or death.

4.3.1 Physical Dimension in Ra

The physical dimension of the *Vanua* represents the land and water that the flesh (*lewe ni vanua)* or members of the *Vanua* use for gardening, hunting, fishing or building traditional ancestral house sites or foundations. Every I-Taukei is said to have a *yavutu* (connection) with the *Vanua*. There are no marked land boundaries as they are said to 'live' in the minds of the I-Taukei whose land is owned communally and shared by everyone.

4.3.2 Social Dimension in Ra

The social plane includes social hierarchies and the relationships between people in the Vanua. All I-Taukei people in Ra are related and bear the responsibility for taking care of one another. The social hierarchies include fundamental relationships from a nuclear family (*vuvale*) to an extended family (a-*tokatoka*), clan (*mataqali)* and tribe (*yavusa)*. Relationships within this system are organised in a way that ensures the resilience, survival and continuity of the *Vanua*. Kinship is essential for indigenous Fijians, andthrough it, a person's rights in terms of access to land are determined. It is through blood relationships and marriage that land ownership is decided.

4.3.3 Cultural Dimension in Ra

The cultural component embodies values, ideas, and accepted ways of doing things. Caring and sharing are two important parts of the vanua of Ra value system that individuals demonstrate via their behaviours. To preserve the survival of their kinsmen and vanua, indigenous Fijians in Ra should be yalomatua (knowledgeable), yalomalua (humble), have vakarokoroko (respect), veivukei (helpful), veinanumi (be considerate), veilomani (loving), vakarorogo (attentive and obedient), and yalovata (work together).

4.3.4 Spiritual Dimension in Ra

I-Taukei people in Ra believe in the presence of the spirits of the owners of the *vanua* isa *vanua tabu* (sacred place). The *vanua tabu* (sacred place) is feared, revered, and respected by the people. Sau tabu (chiefs' burial grounds), yavu (housing foundations), and Vanua sauvi are examples of sacred locations (land and sea areas restricted to be used so they can restore their power and wealth). The existence of spirits is nothing new to indigenous Fijians for they have always been a part of their lives. The spirits are believed to be invisible but have the power to implicate good or evil. Therefore, they are respected and revered. According to the indigenous Fijian ontology in Ra, the spirit or the inner being gives wisdom and grounds the people giving them their sense of place and space. It enables them to access and use their TAK that cuts across the social, cultural and spiritual dimensions to ensure the survival and continuity of the indigenous Fijian descendants. The Fijian ontology serves as the foundation for indigenous Fijians' methods of knowing, being, doing, and living. To maintain their survival and continuation, indigenous Fijians' methods of knowledge influence their ways of being, define their ways of doing things (customs and traditions) and dictate their everyday ways of living. According to Rosiana (2015), the Vanua concept can also be described using a salusalu (garland) in which different flowers represent the various parts of the Vanua (physical, cultural, social, and spiritual); each flower performing its roles complementing each other and ensuring the Vanua's survival. If one of the blossoms falls, the entire salusalu (garland) will disintegrate (see Figure 8). When a Vanua member fails to fulfil their obligations and responsibilities, it can result in the destruction or discontinuity of the Vanua.

4.4 Recruitment and Selection Phase

Farmers in Fiji are divided into three categories: subsistence, semi-commercial, and commercial. The list of farmers questioned in each village was used to choose volunteers for this study. This survey included a list frame and stratified random sampling. The identities of the producers were collected from the Ministry of Agriculture, Rakiraki office, depending on their degree of productivity. The growers were divided into subsistence (<0.8 ha farm) semi-commercial (0.8-2.0 ha farm) and commercial (>2 ha farm) groups with the assistance of the Ministry of Agriculture extension staff. Selecting farmers for the experimental trial was challenging with three different experimental sites[7] at different altitudes. The Ministry's Extension Department has information on the portfolio of farmers and portfolios of farmer schemes, youth, and women's groups. As introduced in Chapter 3, this is the '*dre'e'* process of whom to choose, how many to choose, and knowing that the target audience will provide quality feedback or outcomes. Five kumala varieties were used in this research trial; two from the farmer's choice and three from the Ministry of Agriculture Research Department. Therefore, selection was discussed by the three parties: the vanua, matanitu, and the researcher. Knowledge and results shared by the three parties were woven together using the dre'e metaphor explained in chapter three.

The research was guided by a series of questions. Prior to coming to the village, I reviewed interview themes with my supervisors and personnel from the Ministry of I-Taukei Affairs and the Ministry of Agriculture. This was a useful method for ensuring that the questions asked correctly gathered information on the themes covered and that the language used was regarded as courteous and acceptable

[7] The experimental sites were Nabukadra (Coastal area), Burenitu (Low altitude land area) and Bucalevu (Highaltitude land area).

for the occasion.

Participants were selected from each of the three communities. Participants were given further information about the study after they were chosen and before the research began to verify that the specifics of the study were correct. After then, each participant was asked if they still wanted to participate in the study. Many people said, "Why not?" They were pleased to be a part of the research. Participants were all eager to engage, and they were promised that declining to participate would have no negative consequences and that it was a personal decision.

The 'cultural discernment' group was in charge of any potentially harmful material disseminated at the start of the inquiry. I stress that I had to be certain that everything I did during the study process did not insult participants; as an insider, I must live with the repercussions indefinitely. It wasn't something I was willing to put at risk. Learning to let go of control of the research process allowed for and aided in the implementation of numerous factors that contributed to the study's success.

The approach empowered participants since it was clear from prior experiences that anytime an outsider came to the community, they were there to teach them. When the tables were 'turned,' so to speak, the participants were ecstatic at the prospect of educating me; they wanted to teach me everything they knew about the traditions that persisted, and they were ready to show me everything and explain why. The participants' desire to educate and exchange information was quite intriguing. The study's information sheets were produced in the I-Taukei language. In Fiji, data was collected using questions that were translated into English. When appropriate, the usage of the I-Taukei language was retained and utilized interchangeably with English, ensuring that all participants could express themselves. Participants were assured of their privacy and advised that any data acquired would be kept secret and maintained in a safe area within the institution, accessible only to the researcher. Participants were also informed that they might opt out of the study at any moment; all participants completed the trial.

4.5 Getting into place in the Matanitu

The research ethics protocols were conducted in the early phases of the study. The Human Ethics Committee at Massey University authorized a low-risk notice (Appendix 8). The Ministry of I-Taukei Affairs (MTA) is in charge of executing, creating, and evaluating government initiatives aimed at the well-being of all indigenous Fijians. They serve as a direct link between the government, I-Taukei institutions, and administration throughout Fiji's fourteen provinces. The ministry is the keeper of official documents on I-Taukei land, fishing grounds, headship titles, traditional knowledge, and cultural manifestations. It is devoted to resolving disputes over land, fishing grounds, chiefly and traditional headship titles, as well as protecting and preserving language and culture through advocacy activities. Even I-Taukei researchers require ethical consent to study with their people, according to the existing government's laws and procedures.

In an I-Taukei administration, there are several layers of structure which come under the Ministry of I-Taukei Affairs[8]. Therefore, receiving approval from the Permanent Secretary's Office allows the applicant to enter those layers under the Ministry of i- Taukei and have access to the community. An approval letter from the Ministry was obtained[9] for this research was granted (Appendices 6 & 7). After this process, onlythen can the research proceed. Attaining this approval from the government and the vanua is something unique in the I-Taukei culture where we value the *"sau or mana"* that the Vanua has recognised: "*The land had eyes and ears*".

4.6 Getting into place in the Vanua

Indigenous Fijian culture is highly reciprocal and involves the exchange of kava and other gifts as a sign of respect for each other. Fijians place immense value on conformance to tradition, respect for kinship ties, and relations that are contextualised in the use of the kamunaga or tabua (whale's tooth) and yaqona or kava. The researcher offered a yaqona to request the participation of the community in the initial stages and used it at the end of the fieldwork to thank the villagers, and in particular, the family who hosted the researcher. The use of kava, food items, and groceries as tokens of appreciation is more commonly used at the community level. These were given by the researcher and are required when seeking entrance to people's homes and while joining various groups for collective discourse.

Figure 6: Sevusevu presented to the chief of Nakorotubu.

The researcher performed the *isevusevu* (see Figure 6) ceremony upon arrival to seek the blessings and the approval of the community, through its elders and the village chief, to conduct the study. The sevusevu was performed in all three village halls in the presence of the whole village and involved the exchange of kava, accompanied by a sombre exchange of words explaining the researcher's

[8] Chapter 5 further explained on the next chapter under the Fijian Administration structure.
[9] Reference MTA: -4/99/8-2. Approval on Research Request for Mr Leweniqila attained on the 13th ofJuly 2018.

traditional lineage and intentions.This ceremony was reciprocated by the village elders after which entry was granted for the researcher to be a part of a family, clan, and village. When fieldwork was completed, a similar ceremony following similar protocols, the *itatau and vakavinavinaka,* was conducted to thank the villagers and to seek their blessings and approval to leave the community.

4.7 Traditional living in Ra

A total of 5-6 months was spent with the I-Taukei community (see Figure 7) Bula-vakavanua was practised for building a relationship with my au' vu, this will enable the researcher to gather quality information needed to be discussed and published for the world to know that the bula vakavanua is a core component of the vanua methods used in an I-Taukei community (see Figures 7 & 8). The researcher lived in the three-village research sites while carrying out the fieldwork for the study. In Nabukadra, I was part of the Bici family, in Burenitu, the Seniqai family hosted me, and at Bucalevu, the Delai family accommodated me for four months. Fijian culture and tradition encourage immersion via the development of relationships and long-term friendships through one's loyalty to their family or kinship.

Figure 7: Bula vakavanua at Burenitu village

I had to travel from the field research village to the other village covering 35km (Burenitu to Nabukadra) whereas, the distance from Nabukadra to Bucalevu was 100 km. By being a part of these three families, the researcher was made aware of the traditional status, relationships, and special links between specific individuals and families within the village—this is information shared only through close kinship. The relationship with the host families and the Vanua was cordial and was instrumental in allowing the researcher to weave into the fabric of Ra society indeed. The researcher, upon arrival, assumed the roles and responsibilities of an ordinary member of the family and participated in daily household and community chores, and donated effort, and time to the family, clan, and village obligations. These enabled the researcher to achieve sincere engagement critical for unobstructed observations and participation.

Figure 8 Bula vakavanua at Nabukadra village

Historical records of what was progressing in the village were relayed to me in parables and storytelling, demonstrating that everything in the village served a purpose and had a relational meaning to village members and the way they lived; this, I believe, was the philosophical glimpse into Vanua's knowledge (Nabobo-Baba, 2006; Ratuva, 2007; Ravuvu, 1987; Tuwere, 2002; Meo- Sewabu, 2015). A western researcher, or even a non-Western researcher who was not authentically linked to the community or whose way of thinking was highly impacted by western ideologies, would have missed the significance of this talanoa and the capacity to acquire rich and nuanced data. Different interpretations and meanings of the data collected from the study are also likely to be shallow.

4.8 Data Collection and Talanoa as a Method in Ra

In the Fijian cultural setting, talanoa (see Figure 9) refers to the process of two or more individuals conversing and sharing ideas and is frequently the method through which communication is formed between two or more parties. The veitalanoa sessions were ideal for facilitating in-depth discussion and layering more accurate and detailed responses to the critical research questions. The pre-established groups representing youth, women, and conservation groups, to name a few (detailed in previous sections) were targeted to hold individual and group talanoa sessions.

Figure 9: Women's group at Nabukadra Village

Depending on the urgency and priority of the matter at hand, the context and levels of formality between veitalanoa sessions varied. Some veitalanoa were more formal than others, with the most formal accompanied by a prayer and frequently accompanied by the ingestion of kava or yaqona. Informal veitalanoa (see Figure 10) meetings were more friendly, involved less procedure, and frequently resulted in more in-depth and intimate sharing discourse and conversation.

Figure 10: Women's group in Bucalevu Village

4.9 Participatory Learning Appraisal in Ra

The Participatory Learning Appraisal featured talanoa sessions led by the researcher who used study questions developed from the research goals (Meo- Sewabu, 2015). This method was implemented to allow the participants to exchange information on the issue while learning from each other and passing on the knowledge learnt to other members of their community (see Figure 11).

Figure 11: Farmers training at Burenitu village

A participatory workshop session was held at the three research sites and other village settlements in Ra (see Figure 12). The Ministry of Agriculture and the vanua selected the dates for the farmer training. Each training day was one that everyone in the village was able to attend, including children and their parents.

Figure 12: Farmers training in Bucalevu Village

4.10 Vakadidigo (Observation) in Ra

Observation and imitation is a pedagogic approach used by indigenous Fijians to optimise learning (Roskruge, 2010). It is essential for locals to vakadigova (observe) and analyses an action or skill before they imitate or practice it. Therefore, an indigenous Fijian researcher was also an observer of the behaviour and actions of the participants of the research (see Figure 13). Thus, while the researcher veitalanoa (talked) to the elders, conducted the participatory workshops and lived among the participants, observations were made, and notes are taken of what was observed.

Figure 13: Youth training at Burenitu village

4.11 Photographs

Information collected from the field study included photographs (see Figures 14 & 15). The researcher obtained the consent of the participants of the study before taking photos. The pictures aid the reader's understanding of the study and its context through visualising relevant places and events. They have also been used as crucial information during the writing process of this thesis.

Figure 14: Prof Roskruge training farmers at Nabukadra Village (2019)

4.12 Field notes

To record observations related to the research issue, a notebook was employed. The observations were primarily concerned with changes in the environment and the reactions of the participants to those changes. Field notes were taken in both Vosa Vaka-Viti and English. In addition, the notes were triangulated with data gathered from images, observations, interactive workshops, and talanoa sessions (Figure 16).

Figure 15: Talanoa with a Kumala farmer at Burenitu

Figure 16: Scheme farming group in Bucalevu

4.13 Questionnaires

To lead the talanoa, the researcher employed an open-ended questionnaire (Appendix 13) created from the study topics. An open-ended inquiry cannot be answered with a simple "yes" or "no." They are inquiries phrased as statements that demand an answer. The response can be compared to previously known information by the questioner (Lagi, 2015). The collected data was recorded and validated during the talanoa sessions held at the research sites (see Figures 17 and 18).

Figure 17: Talanoa Season at Bucalevu village

Figure 18: Advising farmers on the importance ofsoil tests.

4.14 Analysis

Qualitative and ethnographic research involves a constant interaction between data collection and analysis and requires the researcher to become intimate with the data (Stake, 1995). In this research, the analysis began with the literature review and extended tothe conclusion of the thesis write-up. For the current study, the process of proper "data analysis" commenced at the end of the first day of fieldwork, immediately following thefirst conversations, interviews, and observations. This was done to ensure that from the outset, a rigid routine was established to ensure that the data collected was consistently analysed and used to identify immerging themes.

On-site, the researcher, established a two-hour time slot from 6 to 8 pm every evening to transcribe interviews, take notes, and reflect on the data collection activities that took place during the day. This routine ideally fitted within the regular program of the village, which requires that family devotions and "quiet times" for each family be observed every evening. Qualitative data analysis is a creative process where the researcher plays a central role in siphoning meaning while capitalising on ordinary ways of making sense. Therefore, there is no one fixed way of analysing qualitative data (Esterberg, 2002).

Indigenous Fijians in Ra are often reserved when conversing with outsiders, and this is due to their cultural values and beliefs. Therefore, the analysis of data for this study involved much more than the line-by-line stages of analysis suggested by Creswell (2009). Data analysis considered the feelings, emotions, and cultural orientation of participants interviewed by the researcher. Such attention to detail allowed the researcher to efficiently record and collect data but, more importantly, to analyse and interpret the data collected accurately. As a consequence of the researcher's understanding of the active interactions and tensions between the researcher's biases and the participants' meaning-making processes, the following themes developed from this study.

4.15 Limitations - Research Language

The essence of TEK lies in the language of the knowledge holders. The participants of this study preferred to speak in the I-Taukei language. It was therefore culturally appropriate for the researcher to communicate in the participants' dialect so that the essence of the TEK could be understood clearly. Language, therefore, was not a limitation for the researcher. However, the limitation lies in translating some of the indigenous Fijian terms or concepts into English. Some Fijian words have no English equivalent, so they needed to be described to make their meaning clear. Difficulties arising from language use are common among those who research a language that differs from their own or the one used to report research findings.

4.16 Background of the site and Trial Establishment

Supporting the trials in Ra, an early kumala trial was undertaken at Massey University, Palmerston North, New Zealand over the summer of 2017/18 whereby the crop inputs could be monitored and measured to determine the best parameters for measuring the future Ra trials. According to Dr Roskruge (2017), the selected site was previously planted with kumala in December 2016, and before that was a selection of leafy vegetable crops, and previously kumala was planted in the summer of 2015-2016. The pH of the soil at the location was 6.5, and the other nutrient levels (see Appendix 11) were appropriate for kumala cultivation (Wallace, 2000). According to Nedunchezhiyan et al. (2012), sweetpotato demands a fairly mild temperature of 19-26°C and a soil pH of 5.5-6.5. Heavy rain, high temperatures, and excessive cloudiness all promote vegetative growth (Sreekanth, 2008). Close spacing (250-300mm) is often advised for sweetpotato to ensure optimal root output (Nedunchezhiyan & Reddy, 2002). Anderson et al., (2007) went on to say that sweetpotato is best harvested between 90 and 150 days following planting, depending on region and season. The varieties planted were Radical Red, Owairaka Red, Rekamauroa and Pukekohe. Soil analysis was first done on the site ploughing on the 20th of November 2017, followed by the second ploughing on the 21st of November 2017. The selected varieties were then planted on the 23rd of November 2017. A total of 700 kumala stem cuttings were brought from 'Aunty's Garden' in Hastings. The average length of the cuttings was 15cm length. For its production period, 750-1500mm of evenly distributed rainfall was sufficient (see Appendix 12).

4.16.1 Experimental Plots

The experiment trial was arranged in a Randomised Complete Block Design (Gomez & Gomez, 1984). The research area consisted of six rows with two guard rows on the side and four different sweetpotato varieties. The four sweetpotato varieties were randomly distributed among each row using the randomisation procedure for an RCBD (see Appendix 14). Each treatment combination on a plot (treated as a block) was replicated four times (see Table 2).

Table 2: Treatment Combination for Massey Trial (2017)

Treatments	Combinations of Variety in a Row
Block 1	V1, V2, V3, V4
Block 2	V4, V3, V2, V1
Block 3	V3, V4, V1, V2
Block 4	V2, V1, V4, V3

4.16.2 Data recording for each site

The following parameters aboveground were measured (Leaf number, length of vein and internode, number of runners, establishment rate and chlorophyll content). During harvest, below ground parameters included; number of tubers per plant, total root fresh weight, and average mass of storage root. This was to investigate the performance of each sweetpotato variety.

4.17 Supporting Field Experiment Trial in Fiji

To support the collation of traditional knowledge for climate-smart agricultural practice,a simple trial for variety and yield was undertaken over the next two seasons at three altitudes in the Ra province. Sweetpotato researchers have used field trials to determine the potential of varieties and experimental lines at different altitudes (Vallejo & Mendoza, 1992). Li (1971) revealed that in Taiwan, it was found that the optimum plot size for the sweetpotato yield trials was 6-12 m long, practising the traditional way of planting and 8-12m long. Vallejo and Mendoza (1992) conducted a trial at three altitudes (110m, 238m, and 800m) on the coastal, lowland, and highlands of Perú. These previous trials align with the purpose of this trial.

4.18 Trial Design and Treatment Combinations

This research comprised one trial conducted at the three sites using five varieties at each site (Nabukadra, Bucalevu, and Burenitu) in 2018 and 2019. At each site, five kumala varieties were planted in a Randomised Complete Block Design (RCBD) (Gomez & Gomez, 1984). Each treatment combination on a plot (treated as a block) was replicated four times across the three different altitudes. Regassa et al. (2015) used RCBD design on three altitudes replicated three times in 2014-2015, and it aimed to identify sweetpotato varieties with the best yield and other valuable agronomic characteristics with no fertiliser and other chemicals applied.

The traditional I-Taukei method of planting called ‘buke’ or mound was used in this field trial. Each row had 10 ‘buke’ representing each variety; therefore, a total of 50 ‘buke’ were planted in one block (Figure 19 and Table 3). This was replicated four times in each area and surrounded by guard rows. A total of 240 plants were used for data collection - 5 plants from each block (see Appendix 5) undertaken weekly. Weather data and rainfall were also collected every week.

Table 3: Treatment combination for trials in Ra (2018/9)

Treatments	Combinations of Variety in a Row
Block 1	V2, V4, V1, V3, V5
Block 2	V1, V2, V5, V4, V3
Block 3	V4, V1, V3, V5, V2
Block 4	V5, V3, V2, V1, V4

Key:
V1- Golden BrownV2- Carrot
V3- Papua
V4- Local PurpleV5- Vulatolu

Figure 19: Buke or Mounds known in Fiji where kumala is planted

4.19 Data recording for each site

4.19.1 Phenological and growth-related traits.

The following parameters were recorded from 5 plants in each plot (see Figures 20 and 21).

1. Number of leaves
2. Length of the main vine
3. Length of internode

4. Number of runners per plant

5. Chlorophyll content

6. Establishment Rate (runner number and lengths)

4.19.2 Yield components

1. Root fresh weight/per plant

2. Above-ground biomass yield/per plant

3. Above dry-ground biomass

4. The average number of storage roots per variety at each block

5. The average mass of storage root per variety at each block

6. An average number of tubers per plant.

Figure 20: Data collection at Burenitu Site

Figure 21: Data Collection at Bucalevu Site

The use of a quadrat of 50x50cm was used during harvest for activities 2, and 3. The leaves were separated at the petiole-lamina junction and counted. For each plot, all leaves and sterns were removed and weighed before random sub-samples (10% by weight) were obtained. Before weighing, the stem and leaf sub-samples were oven-dried at 80°C for five days. Roots larger than 5 mm in diameter were collected. Three roots (diameter 2.5 - 4.5 cm) were randomly selected and sliced in half longitudinally from each collected plot. Three halves were placed in a brown paper bag and dried at 80 °C for five days to calculate the percent dry weight.

4.20 SPAD Meter Measurement

Green leaves are critical to the operation of terrestrial ecosystems (Wright et al., 2004) because they are the major organs of net primary production, gas exchange, and evapotranspiration. In practice, the chlorophyll concentration of leaves is frequently utilized to forecast their physiological status as impacted by numerous natural and anthropogenic influences (Carter, 1994; Zhao et al., 2016). The chlorophyll meter from Soil Plant Analysis Development (SPAD) is one of the most widely used diagnostic instruments for determining crop nitrogen status. However, the meter's measuring method may have a substantial impact on the accuracy of the final estimate. Typically, the chlorophyll content of kumala is evaluated by sampling plant leaves (5 plants per variety at each block). The top leaves that are exposed to light are typically chosen and measured. The purpose of this experiment is to discover the correlations between extractable chlorophyll and SPAD values in sweetpotato cultivars.

Chlorophyll determinations in leaves are as follows (Figures 22 to 27):

1. Cut a sample off a leaf with a 1cm diameter leaf punch
2. Immediately add to a labelled, aluminium foil-covered falcon tube containing 5ml of 80% acetone.
3. Homogenise with a smooth metal rod ensuring no solvent is lost.
4. Incubate the samples for 1 hour
5. Filter the solution and read on spectrophotometer at 663.6, 646.6, and 750.
6. Calculate Chls a + b using the following equation

   Chls a + b = 17.76 *(A646.6-A750) + 7.34 *(A663.6-A750) (Porra et al, 2002)

Using biochrom libra Spectrophotometer samples from each variety, these were then placed inside to determine the amount of chlorophyll in each variety. A statistical examination of these variances would inevitably help to crop selection and development, improve agronomic practice, and raise fresh tuber yields.

Figure 22: SPAD meter reading was taken

Figure 23: Leaf sampling with a 1cm diameter punch

Figure 24: Kumala leaf added to a tube

Figure 25: Tube containing 5ml 80% acetone

Figure 26: Each sample was stirred

Figure 27: Biochrom libra Spectrophotometer machine

4.21 Fieldwork

Fieldwork was conducted in two separate stages, both lasting between four to six months, and allowing for two months for reflection, analysis, and reporting between the first and second phases. This was to ensure that data collection was appropriate, follow-ups made, interviews revised, and the design was improved for the second phase. A longer timeframe may have provided more detailed data; however, this was not achievable owing to financial and time restrictions. Support was also gained from the Ministry of Agriculture, which supplied the kumala planting material. At each site, before any activity proceeded, farmers (see Figures 28 and 29) were requested to share some of their traditional knowledge and their suggestions, this allows for cooperation between the two parties. For example, how are cuttings stored before planting? The kumala planting supplies were placed in a drum of water and were ready to be planted early the next morning. This was the procedure that was followed when all the fields were planted. The farmers agreed to our plans and on Monday 23rd of July 2018 the Bucalevu fieldwas planted on Tuesday the 24th the Bucalevu field was planted, and lastly on Wednesday the 25th of July the Nabukadra field was planted.

Figure 28: Farmers training at Bucalevu Village

Figure 29: Farmers training at Burenitu Village

4.22 Data Recording & Training of Farmers

Data recording was done on Tuesday morning each week (see Figures 30 and 31). At the end of the trial, the recording sheet will be accessible to farmers and future researchers in Fiji.

This research enabled farmers to participate in the process. Farmers were trained on how and where to take measurements and the importanceof measuring these parameters. One week of training plus the four weeks together during data collection provided them with a vast knowledge of kumala. In the coastal and lowland areas, women were involved in the data recording training exercise.

Figure 30: Farmer at Bucalevu research site

Figure 31: Data recording at the Burenitu research site

4.23 Crop Management

During the kumala establishment stages, plants need enough water supply to support growth, especially during any prolonged drought period. Hosepipe was bought and distributed to the three sites to support the crops during the dry season. Watering was done twice a day, in the morning and afternoon. A 40L plastic barrel was placed in the centre of the field at various locations to hold water for irrigation of the crops.

4.24 Analysis of Data

R statistical package version 3.4.0 was used to analyze the data (R Core Team, 2017). Data were compiled and analyzed using the standard analysis of variance (ANOVA) for randomised complete block design (RCBD) procedures outlined by Gomez and Gomez (1984). Tukey's HSD test was also used to compare mean values. The F-Test was employed to test for treatment differences at the 5% level, and LSD values were utilized to compare the five kumala kinds grown at different altitudes with their level means and interactions. Each variety underwent regression analysis (see Appendices 1- 4).

4.25 Chapter Summary

Chapter four discusses the approaches used to collect data as an academic and researcher woven together. The methods utilized in this study were chosen as appropriate to the research context. Participant observation was suitable in all three village contexts. This chapter also looks at how this study combined indigenous and western research approaches. The research included both qualitative and quantitative methods. Data was gathered through the use of talanoa (with people or groups), observation, and text and document analysis. All themethods of survey used in the indigenous study were discussed as the rationale for their inclusion in the research method. It is also acknowledged that all results obtained were due to the cooperation of the farmers of Ra and with the support from various government institutions in Fiji.

Chapter 5

Ko Ra: *The Origin*

A'u ri'a se wara na vano qo ena vano ga

"Indigenous rights are those that concern indigenous people, their way of life, their land, resources, and origin." They are interconnected by nature and indigenous people's birth rights." (Ratu Joni Madraiwiwi, 2006).

5.1 Introduction

This chapter explores our origin, and where it all started. It has been said that all dispersal and distribution of food and the kawa I-Taukei originated in Ra. The study was carried out in three villages in Rakiraki district, Fiji: Nabukadra near the coast (20m asl), Burenitu at a low height (120-150m asl), and Bucalevu at a high altitude (180m asl). A description of these villages, their location, history, traditional roles, worldviews, and knowledge systems will be made in this chapter. The chapter ends withan explanation of the importance of selecting the three sites for study. The term 'origin' in I-Taukei means 'tekitekivu,' meaning the place where everything originated. This includes language, values, culture, and commercial agricultural production. The sugarcane belt is mainly found along the coasts of the Rakiraki and Saivou districts. It has spread to the flat plains of Nalawa, and coconut is a substantial source of revenue along the Nakorotubu coast, with common subsistence cultivation happening on the slopes of higher terrain in practically all regions of the province. These colonial agriculture systems have been practised in this era. There is a need to identify a potential cropwhich will suit and adapt well in a particular area in Ra, and this can only be achieved through research (experimental trials).

The Province of Ra is one of eight (8) provinces of Viti Levu Island, Fiji. It encompasses roughly 1,341 square kilometres or 12% of Viti Levu in the Fiji Islands. Fiji is located in the southwest Pacific Ocean in latitudes ranging from 15 to 22 degrees south and longitudes ranging from 177 to 174 degrees east. Fiji is an archipelagic nation made up of over 300 islands spread across 1.3 million square kilometres of the South Pacific Ocean (See Figure 33). Viti Levu (10,400km2) and Vanua Levu (5,540km2), the two largest mountainous islands, account for 87 percentof the entire land area (Cook, 2016). The Republic of Fiji has a population of 912,241 (2018) and an annual population growth of 0.8% (Fiji Government Statistician, 2017), an increase of 90,424 from the previous census in 1996. However, Fiji's population is expected to be a million in 2023 (UNDP, 2008).

Figure 32: Map of the Fiji Islands Source: Mapsouthpacific.com

The structure of chapter 5 is illustrated in Figure 33 below:

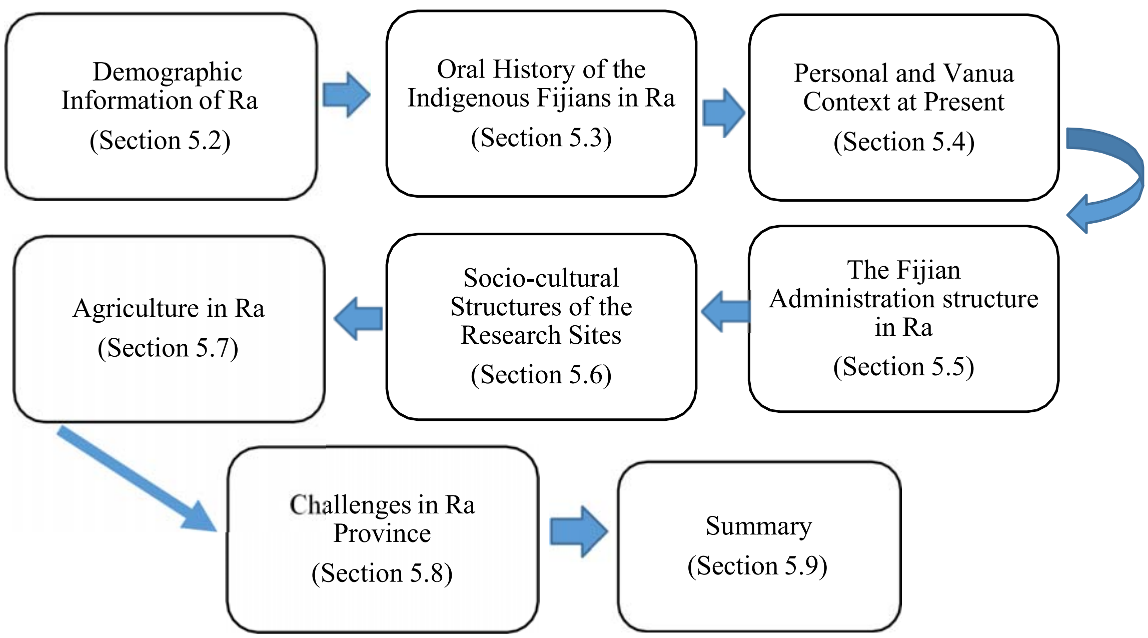


Figure 33: An Overview of Chapter 5

5.2 Demographic Information of Ra

On the north-eastern coast of Viti Levu in Fiji is where the Ra province is situated and has a total of 93 - Taukei villages, 20 districts or Tikina. It has four main tribal boundaries of the Vanua known as the Vanua Rakiraki, Saivou, Nakorotubu and Nalawa, which are all managed by the Ra Provincial Council (see Figure 34).

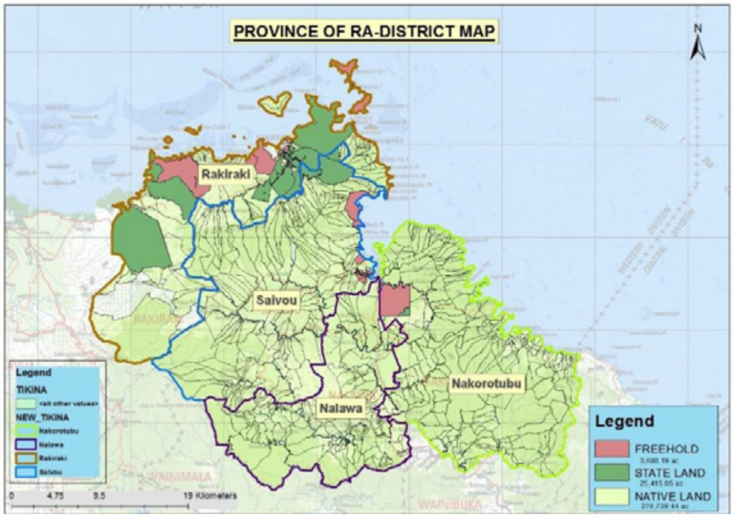


Figure 34: Map of the research site at Ra District. Source: MPI, 2018

Rakiraki (Ra) has a population of 29,464 people (Fiji Bureau of Statistics 2012). Figure 35 depicts the province's age-sex demographic pattern, whereas the national pyramid is stable. There is a significant number at the bottom of the pyramid with the categories of 0-4, 5-9, and 10-14 years old, indicating that Ra province has a high birth rate, a high mortality rate, and a poor life expectancy. Despite being fewer in number, women in Ra province outlive males.

Population changes by ethnic group and locale from 1996 to 2007 (see Figure 36). Ra Province's overall population declined by 4.7 percent from 30,904 in 1996 to 29,464 in 2007. Between 1996 and 2007, the Indo-Fijian ethnic community in Ra decreased by 27.4 per cent, from 12,239 to 8,888. During this time, the I-Taukei population increased by 10.3 per cent, from 18,373 in 1996 to 20,259 in 2007. Rakiraki town's urban population increased by 2.4 percent from 4,863 in 1996 to 4,952 in 2007. The Indo-Fijian population in urban areas followed the provincial pattern, dropping by 25% from 3,285 in 1996 to 2,606 in 2007. In contrast, the number of I-Taukei residing in urban areas increased by 33% during the same period. It is worth comparing some of these Figures for Ra against the national averages for the inter Census period 1996-2007 (Figure 36). The population of the country increased by 8%. The national rural population fell by 0.8 percent during the same period, while the urban population increased by 18.2 percent. The I-Taukei population increased by 20.9 percent nationwide, while the Indo-Fijian population declined by 7.4%.

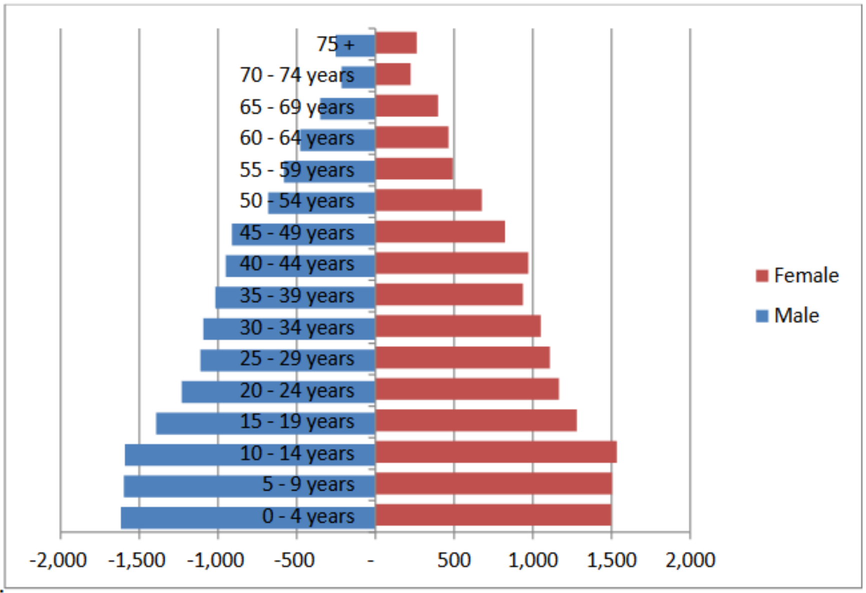


Figure 35: Province of Ra population pyramid. Source: FBS, 2013

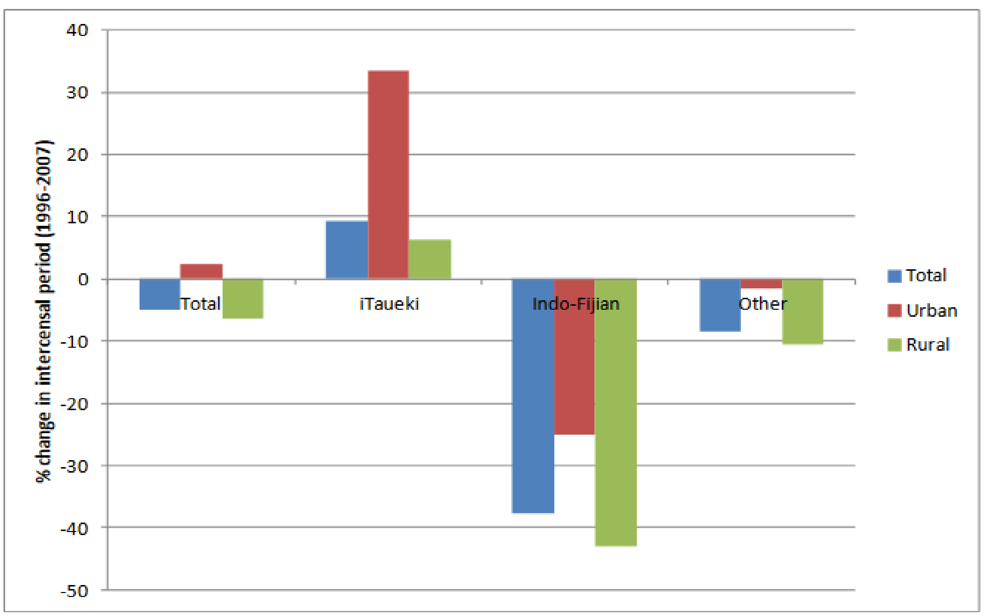


Figure 36: Geographical distribution of population and population change, Source: Bureau of Statistics, 2012

5.3 Oral History of the Indigenous Fijians in Ra and Fiji

Uluivuda from Nakorotubu the origin

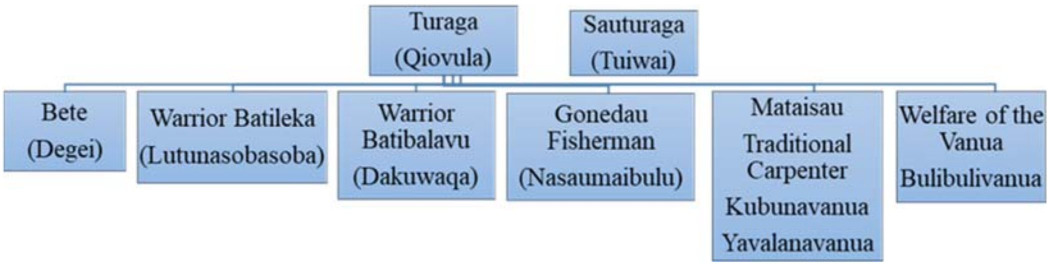
The chiefly village of Uluivuda or Nakorowaiwai in Nakorotubu has many differences from Uluda in Nakauvadra in Rakiraki. Uluivuda, in comparison to the two, is more ancient.

Today in Fiji there are still critics and arguments around the origin of the people. Some indigenous Fijians believe that nakauvadra was where they originated. Still, the realityis that nakauvadra is a mountain occupied with rocks where nothing grows in it. In contrast, Uluivuda is located at the hillside in Nakorowaiwai, Nakorotubu in Ra and is a place where land is rich for farming. Uluivuda is the land where our ancestors lived and cultivated their land for the survival of the people.

It was believed that Ratu Naikanivatu and Adi Naivikabuta were sent away from the garden as they had eaten the forbidden fruit which was the fruit of knowledge known as the Nautonitoga which is named after the hills at which Nakorowaiwai in Uluivuda is located. They were then sent to Uluda, Nakauvadra, which gave birth to the 7 Yavusa's, which have morphed into 8 Yavusa's (see Figure 37 and Table 4).

Table 4*: *Traditional roles and responsibilities in Fiji. Designed by Leweniqila, 2019

Batiblavu	These were the chief's inner guards and bodyguards; there were also Bati Kadi, who were mercenaries for hire.	*Dakuwaqa*
Gonedau	The *Gonedau* (fisherfolk) are the protectors of the sea and provide fish for the *Turaga* (chief) whenever requested and during traditional occasions.	*Nasaumaibulu*
Matanivanua Herald	Responsible for the welfare of the Vanua. They act as the spokesperson of the Turaga (chief) anddeliver messages to and from him	*Bulibulivanua*
Mataisau Craftsmen	The men performing this role build the house and the canoe of the chief. The women weave his mats and also tend to histeitei (garden).	*Kubunavanua/Yalavanua*



	Description of Role	Tribe
***Turaga* Chief**	He leads the *vanua* and is responsible for the welfare of the people under him. He also holds the title of *Turaga ni Yavusa* (Tribe Leader). He is also supposed to be wealthy, as this demonstrated how well his people are thriving. His wealth should also be used for the benefit of the people under him. His wealth reflects his people's work. However, his wealth is used for the service of his people.	**Qiovula**
***Sauturaga* Chief Executive**	Installs the *Turaga* (Chief of Fiji) and gives him the *sau* (power, blessings) of the *vanua*. As a chief executive, he advises the Turaga (chief) and helps to enforce his decisions.	**Tuiwai**
Bete	The priest has a very close relationship with the *Turaga* (chief). They are allowed to touch his body or his food. He also provides medicine for the *Turaga* (chief). Moreover, as the link to the spiritual world, he acts as a seer. He informs the *Turaga* (chief) of future events and advises him about making important decisions.	**Degei**
Batileka	This is the second of two warriors or *Bati* classes. *Bati Balavu* would be the outer guard, protecting the chief from afar, while *Bati Leka* would be the inside guard.	**Lutunasobasoba**

Figure 37: The eight traditional roles Fijian ancestors were anointed from Uluivuda, Ra Source: Viti Makawa

At present all the traditional roles, functions, traditional matanitu vanua and other links that were established have resulted in many conflicts/misuse/disagreements in issues regarding our links, bonds, roles, land, and fishing grounds.

Uluivuda simply is the original ancestral ground of the forefathers of the I-Taukei people (Indigenous Fijians) who all come under the 12 Tribes in Fiji. Nakorowaiwai is the resting ground of our ancestors' totems (an Octopus plus a white shark), and they are said to guard and protect Fiji. Uluivuda has a green vegetative landscape while Nakauvadra is dry. During their days, their connection to the foods and trees was shown in their regular daily routine as they travelled to new places. Plants revealed information about their recent locations. These ranged from different species near coastal areas or in the interior of the mountains. Plants also showed them when the cold or drought season was near, and more importantly, they indicated a beginning of theyear or annual festivals. This connection allows people to choose which food to feed at each time.

It's worth noting that the traditional roles of indigenous Fijians can be linked to Howard Gardner's Multiple Intelligence Theory, which includes Linguistic Intelligence (word smart), Musical Intelligence (music-wise), Intrapersonal Intelligence (self-smart), Interpersonal Intelligence (people smart), Naturalistic Intelligence (natural smart), Bodily-Kinesthetic Intelligence (body elegant), Spatial Intelligence (picture wise), and Logical Intelligence (logic (Gardner, 1993). Gardner's Linguistic and Interpersonal Intelligence corresponds to the Matanivanua (Heralds) or spokesman job, which is often filled by language specialists who use their linguistic abilities and expertise to successfully interact with the chief and people of the villages. Intrapersonal and Naturalistic Intelligence is comparable to Bete or priests' spiritual expertise, which allows them to communicate with the spiritual realm. The Mataisau or carpenter's position, who’s creative and carpentry abilities aid them with the considerable construction of dwellings in the community, might be connected to bodily kinaesthetic and spatial intelligence. Similarly, the Bati, or warriors, are blessed with combative abilities and knowledge that aid in the protection of the vanua. Gonedau (fisherfolks) have fisheries abilities that allow them to maintain and manage marine resources. Logical Intelligence is analogous to the Turaga or Chief and Sau Turaga or Chief Executive, who use critical and analytical thinking abilities to make vital choices for the smooth operation of a community.

Vanua, according to the participants in Ra, is stated as:

> *Vanua sa i koya na tamata, qele, manumanu, koro kei na veiwekani ni veikabulakece; na veikabula ni ra solia mai na ivakatakilakila ni draki kei na gauna ni vuata, teitei, qoli kei na gauna e cava kina na yabaki* (*Vanua* includes the people, land, animals, village and the relationship with all living things; the behaviour of living things show signs for the approaching weather, seasons and the end of a year).

The same participant also highlighted that: *e vakatawani na veiyasana ni vanua kece katabu na vakasosa* (all spaces in the *Vanua* are occupied, and it is forbidden to make a noise). It is seen as disrespectful to make loud sounds. Therefore, ‘*e bibi na vakadirorogo, vakarokoroko kei na doka na vei yasani vanua kece’* (silence, honour and respect are to be maintained for every part of the *vanua)* (Mrs M Wati, 2013: pers. comm).

This knowledge of the *Vanua* is passed on to the next generation using the Ra dialect. Knowledge is transferred via stories, chants, songs, *meke* (traditional dances) and by parents being role models.

Others responded that: *Vanua* means *tamata, keina na bibi keina rokovi ni veiliutaki vakavanua kei na i-tutu ni veiqaravi* (people and their traditional roles, the significance of and the respect for leaders in a village (Mr Epiyame, 2018: pers. Comm). Another interviewee highlighted that *Vanua* stands for *itutu vakavanua, qele mamaca kei na iqoliqoli*, (traditional status, dry land, and fishing grounds (Mr Acura, 2018: pers.comm) yet another one defined *Vanua* as *tamata; tamata ga e na qarava na vanua*, (people and it is the people who are caretakers of the land) (Mr Emitai, 2018: pers. comm). The same sentiments were echoed by the son of the *tui nalawa* who said that *vanua* meant *tamata, qele, i-tovo/valavala vakavanua, veilomani kei na cakacaka vata vaka kawa tamata* (people, land, indigenous customs and traditions, love, and working together as people of the same root (Mr Nuidamu, 2018: pers. comm).

Vanua according to the participants of this study can be summarised as referring to people, land, sea, traditions and customs, traditional status and leadership, relationships,space, spirit, silence, respect and honour that is accorded to every part of the land and every relationship among all living things. It can be said that when our ancestordeclared ownership of the *Vanua,* he was not only referring to ownership of thephysical land but to its social, spiritual and knowledge system as well.

5.3.1 World View

The people of Ra view *Vanua* holistically. *Vanua* includes every living being, their customs and traditions, kinship and cooperation for the smooth running of the village.It is knowing one's place in the village and performing one's allocated roles and respecting people's space so that *e sautu na vanua* (there can be peace and prosperity)in the *Vanua*. Elders are role models for the young. Children are expected to learn their place, role, and responsibilities towards each family member and their *vanua*. If children do not fulfil these expectations, it brings shame to the family and the *vanua*. Elders are responsible for the misbehaviours of younger generations and are expected to teach them how to behave sensibly.

5.4 The Fijian Administration structure at Present in Ra

A Provincial Council, led by the Roko Tui and aided by the Assistant Roko Tui, governs the province. Each village sends a delegate to the Tikina Council, which sends two members to the Provincial Council on behalf of the tikina (see Figure 42). The leaders of the different village committees are chosen by the members of the village council. They might include respected members of society such as retired professors, public employees, and business owners. The structure serves as the foundation for the villages' corporate development plans and programs aimed at achieving self-sufficiency. The Ministry of Fijian Affairs oversees the Provincial Council (currently known as the Indigenous Affairs). The constitution and legislative system of Fiji are based on the British model. Since Fiji's independence in 1970, the constitution has been modified a few times, often as a result of coups. Following the first coup in 1987, the original constitution was replaced by a new one in 1990. Despite the coups of 2000 and 2006, the 1990 constitution was revised in 1997 and remains in force.

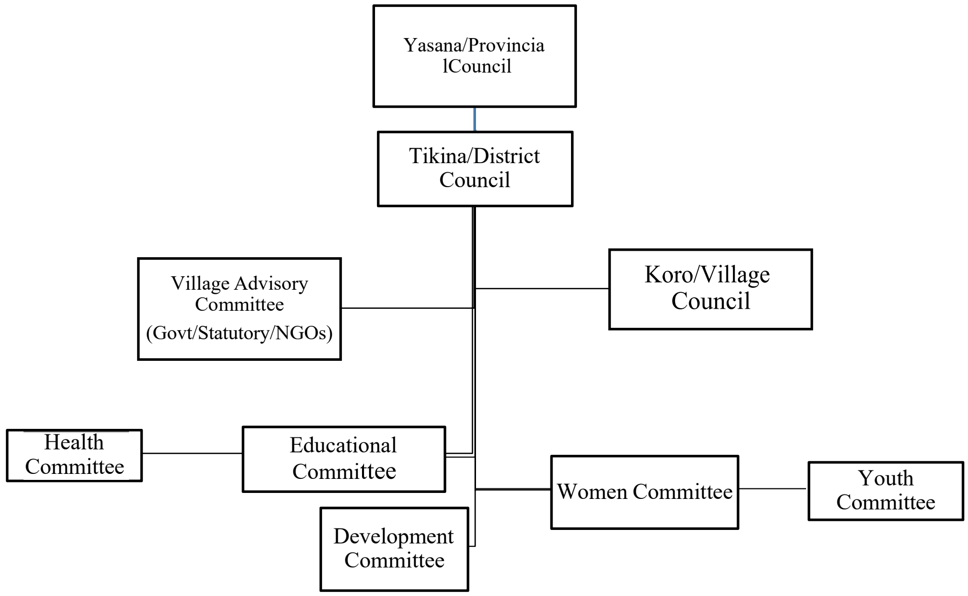


Figure 38: Fijian Admiration Structure. Adapted by Meo-Sewabu, 2015

5.5 Socio-Cultural Structures of the Research Sites

5.5.1 The Combined Districts of the Research Site in the Province of Ra.

The truths shared by our ancestors during the Fijian Administration of 1920 regarding our ancestral links and the fate of indigenous Fijians and their local foods like Kumala have been mostly forgotten now. Still, it is our belief as indigenous people that our local foods will be valued and revitalised in future. This project is another in the journey of cultural restoration within Fijian society.

The three research sites all have a robust chiefly connection among them. The district of Nakorotubu has been divided into two Nakorotubu I Wai (near coastal areas) and Nakorotubu I Vanua (Highlands), and its links to Nabukadra and Bucalevu village have been inhabited by the descendants of Salabogi from Nayavunitu which gave birth to Navokavoka who was the ancestor of Bolanavuravura. Nabukadra and Bucalevu are in the same district but situated in two distinct locations where Nabukadra (20m asl) is located in the coastal land area whereas Bucalevu (>150m asl) is in the high altitude inland. Burenitu (80-100m asl) is in the district of Nalawa which is situated in a low area. The people in Ra have been distributed into their *kanakana* land (a piece of land given to them to cultivate) which belongs to the Mataqali (Tribe).

5.5.2 Nabukadra village – Nakorotubu District (Coastal 20m asl)

The story behind Nabukadra village is that they are known for two things since the coastal area locates them; fishing and farming in Kumala (see Figure 43). Their ancestors cultivated kumala as a *"Magiti ni Vanua"* the main crop for the village in ceremonies. Since there is a scarcity of suitable land available and soil has measurable salinity in it the primary crop which suits them is Kumala. Their stories indicate how they value kumala in the past, yet now people are living on their land and cultivating cassava. Nabukadra people were known to cultivate kumala in past years. Most of the land now has been idle for years, and they have opted to go fishing and on-sell those daily catches to purchase their root crops from the neighbouring villages without access to the sea. For them, the cropping of the site has always been on a "first come, first served" basis. Those who cultivate first onto a land allow the other to go onto the next depending on his farm scale. Subsistence farming is common in Nabukadra village now, and NGOs have been helping people to diversify into semi-commercial farming. Through thedistribution of cropping sites, the people are rekindling their kinship roles. The decision on crops to be planted is crucial, and for Nabukadra village it is always a family decision where they sit and discuss options since crop rotation methods in Nabukadraare commonly passed down from their elders. This is an act of sustainability to them.

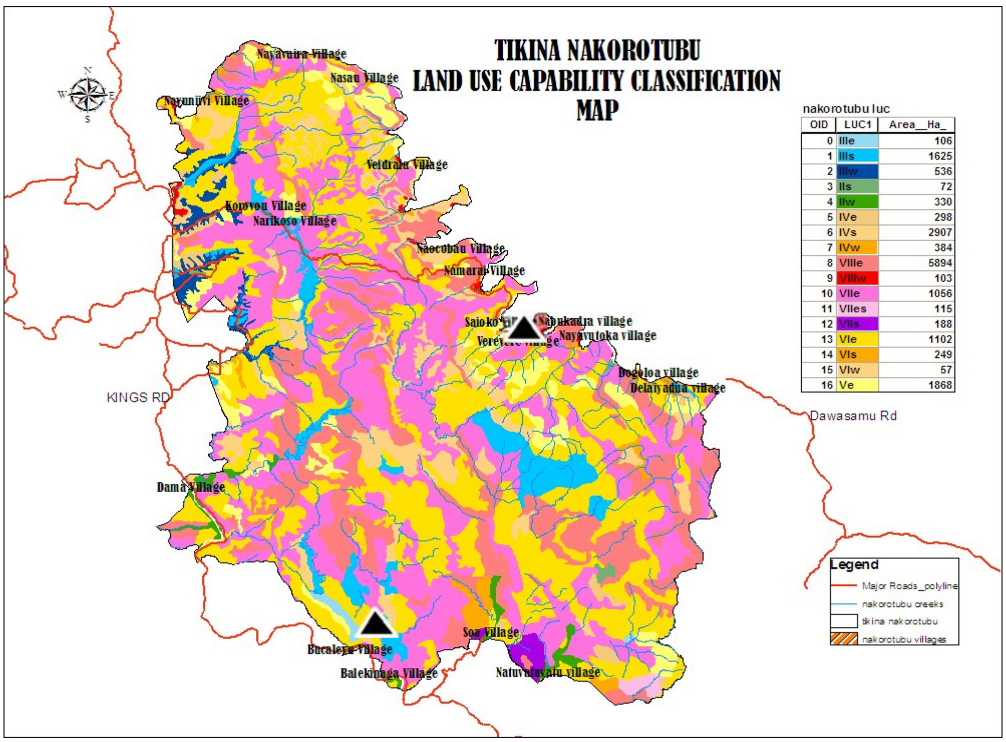


Figure 39: Nakorotubu district which consists of Bucalevu and Nabukadra Village
Source, MPI, 2018

5.5.2.1 Bucalevu Village – Nakorotubu District (Low – 120-150m asl)

Bucalevu village is known to be the mother of kumala production in the district of Ra (see Figure 43). They have strong ties to kumala farming from their ancestors to this present generation, but the problem now is that only a few varieties remain. Land distribution for cultivation is through the chief of the village who distributes the kanakana (land to cultivate or feed) to the head of the Mataqali, who then distributes it down to each family. There the head of the family (dad) distributes their children kanakana for them to cultivate. In Bucalevu, the sequences for them are the family will practice crop rotation between their kanakana (land to cultivate or feed) every six months to practise soil sustainability. Also, it has been practised where the head of families can discuss switching land for cultivation among their families annually. This practice will allow the old ones to be farming close to the village rather than walking a long distance and the young ones must use lands which are far from their village. Since the availability of flat land is limited in Bucalevu village terrace planting is practised. Terraces are made to provide a small patch of level land this prevents soil erosion. Rotation of crops during planting is standard in Bucalevu village. This refers to the growing of several crops one after another in a fixed rotation to maintain the fertility of the soil. The rotation of the crop may be complete in a year. Following cereal crops, any legume crop is cultivated. Legumes such as mucuna (*Mucuna prurians*) can fix nitrogen in the soil. Crops that require a lot of fertilizer are cycled with cereal crops. Crop rotation is determined by soil conditions as well as the farmers' experience and insight.

5.5.3 Worldview

Kinship is a fundamental value that guides the actions of most Indigenous Fijians. This also applies to vast areas of the fieldwork conducted in this thesis. For example, the *vasu* (brother's sister's children) have rights to their maternal uncle's resources which can be either land or goods. In this relationship, the brother plays the vital role of protecting and providing for his sister and her children concerning farming and other matters. This relationship begins when the sister gets married. During her wedding, her brother and *mataqali* (clan) will gift her a *covi ni draudrau* (a piece of land) on which she and her children can live and use for farming. *Na vugodra* (their sister's children) are always cherished and respected, and *vakamenemenei* (petted) have the right to *vasuta (*take anything) from their *momo* (maternal uncle's) land. Sisters and their children reciprocate this by giving something to their maternal uncle that has an equal or higher value than what they have taken. Due to the significance of this relationship, *veivugoni (*maternal uncles and maternal nieces and nephews) may not directly speak to each other if they happen to be in the same place (avoidance or taboo relationship). However, more comfortable relationships exist between their children, who have a 'joking' relationship with one another.

Understanding one's place in Nabukadra and Bucalevu village from the district of Nakorotubu is essential. Knowing one's place in their *Vanua* enables locals to perform their roles and responsibilities correctly, as will be discoursed in the next section of this chapter, each member of the *Vanua* Nakorotubu (Nabukadra and Bucalevu) belongs to a clan and has traditional roles to play. These roles are taught to the young by the elders through observation, imitation and practice. Failing to know their place in one's clan, means not knowing one's roles and responsibilities towards the *Vanua* which is thought to lead to conflicts and instability in the *Vanua*.

5.5.4 Burenitu Village - Nalawa District (High >180m asl)

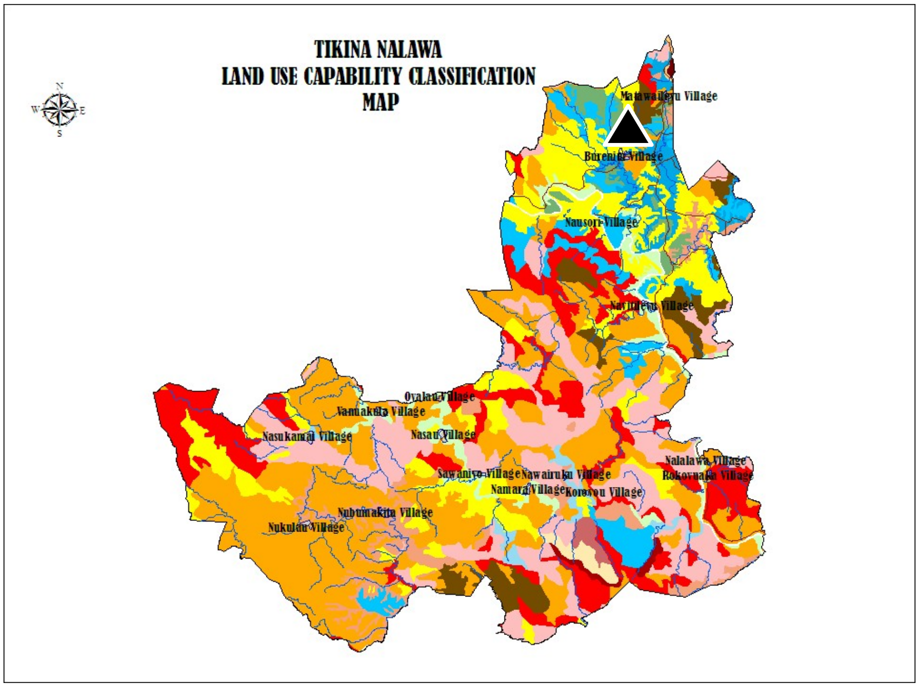


Figure 40: Burenitu village which consists of the Nalawa district. Source: MPI, 2018

Burenitu village is situated in the lowland area region of Nalawa under the leadership ofthe Tui Nalawa (see Figure 44). The district of Nalawa has villages of Matawailevu, Nausori and Burenitu of which Matawailevu is the place of origin for Tui Nalawa, the eldest son of Nabulibuligone which also includes the people of Nausori. There are two chiefly blood links which include Nabulibuligone and Turaga Ni Bure. Land distribution in Burenitu is like Bucalevu village. So, from their kanakana, each family has to use their land to feed themselves. The decision on farming (what andwhen to plant) is always discussed by members of the family chaired by the head of the family (Dad). A decision will be based on the significance of each commodity chosen to their health and well-being.

Burenitu village has an advantage in farming since the village is located less than 3 kilometres from Naicocolevu Research Station which provides farmers with varieties of root crops like kumala and assorted vegetables but sadly now the village of Burenitu has succumbed to sugarcane farming. Therefore, those earlier varieties of kumala have mostly become extinct, and only two varieties remain. Since the year 2018, when the Rakiraki sugar mill has been declared closed by the government, the people of Burenitu have looked for alternative incomes for survival as the government did not prepare them for this change. For the farmers in Burenitu, it was a shock; they had to return to the farming systems their forefathers practised. Food security for their forefathers was a priority so families could be self-sufficient with food. Kumala farming was common since all their land is flat in Burenitu.

Burenitu has been encouraging some of their youth back from urban areas to cultivate their land. However, the problem now is planting material. Therefore, family heads have decided that every youth who needs planting material has a day a week to come to a family which has planting material and work with them to be rewarded with planting materials for various root crops like kumala. That is how the Burenitu farming system works.

5.5.5 Worldview

For the Burenitu village kinship is highly valued among them from their forefathers; hence most of the people from this village are tribal from Nakorotubu. To the *vanua,* the relationship between them and the vanua o Nakorotubu (Bucalevu and Nabukadravillage) is significant. Children from Burenitu value, honour and perform their roles and responsibilities towards the *Vanua* Nalawa and Nakorotubu as expected in order not to suffer traditional shame. Sharing of knowledge through farming and their connection to their food is familiar to their families. As the population of the village expands, new relationships are formed in the village and new arrivals are taught their responsibilities towards each member of the village and the vanua. The *veinanumi* attitude is common to these people through this act; it allows them to share their skills through farming. It also allows elders to teach the younger generation how plants interact and what they are telling them with the responses to climate.

Like Nakorotubu, the elders of Burenitu are expected to teach the young ones about traditional relationships and the importance of their roles. Failure to teach children will lead to conflicts and confusion amongst the children and shame to the *vanua.* Hence, everyone in the village bears the responsibility of instilling these traditional values in the children. Nevertheless, the primary onus is on the elders to display good behaviour and be role models.

The people of Burenitu perceive the *Vanua* holistically. Every member of the village, irrespective of where they come from, belongs to the *Vanua* and is therefore expected to perform their roles and responsibilities accordingly. Failing to perform within these roles and responsibilities will lead to disharmony in the *Vanua.*

In the three communities, the work structure is a critical mechanism of resilience (Nabukadra, Bucalevu and Burenitu). Bula sautu is a method for achieving comprehensive and inclusive well-being. Spiritual well-being, environmental well-being, socio-cultural, familial well-being, and economic well-being are all components of bula sautu, according to Spiller et al. (2011), which are associated with relational well-being and an ethic of compassion. The three communities in these case studies have highlighted the relevance of work organization as a pattern for bula sautu from their forebears. It enables people to share their agronomical information about a crop as well as their traditional skills and experiences. Work structure aligns them with weekly activities, where they should be done, and what they need to accomplish.

Food security is an important pillar in the three communities' overall well-being. According to the case studies, the three villages had included a food security program in their job structure and monthly work schedule. This initiative has helped them to attain food security and access to a diverse range of healthful foods. People collaborate through employing cultural capital solesolevaki as a vehicle for development within the working framework, as addressed in Chapter 6.

5.6 Agriculture in Ra

Ra is a rural province, with most of the population directly dependent on the agriculture sector (Parke, 2006). There is evidence that Ra province has the most extensive traditional farming system that draws on traditional knowledge and wisdom; an exampleis seen in mountain streams being diverted to irrigate mountain terraces and gardens (Mansur et al., 2017). There are more farmers in Ra with mixed cropping (crops and animals) than those who are entirely dedicated to crops and livestock (MPI, 2017) . Ra Province's inhabitants continue to farm the land despite a long history of crop production. However, they have lost traditional knowledge and practices evident on the hillside of the Nakauvadra Range since the introduction of Indian labourers to Fiji on sugarcane farms during the colonial era (Harrison et al., 2016).

Figure 41: Total of Indigenous Fijian farmers in Ra

Climate change is high on the agenda for Pacific Island governments, (Fiji Sun, 2015). However, in Fiji, the conversation has been largely centred on the effects of increasing sea levels and rising temperatures on the physical environment, notably the challenges that are currently being faced in locations like Ra due to sea intrusion or tropical cyclones. The reforms will have a huge impact on many firms, particularly those in agriculture. Climate change will undoubtedly have a significant influence on two crucial sectors in Ra: food production, notably agriculture, and water supply. These natural calamities have contributed to fluctuations in Fijian kumala output (Figure 42). Access to the availability of sufficient water will have a direct impact on agriculture. Scientists in various major nations are now investigating these two crucial topics (Fiji Sun, 2015). As a result, the Fijian Ministry of Agriculture has the problem of identifying robust varieties of root crops that can better adapt to climate change.

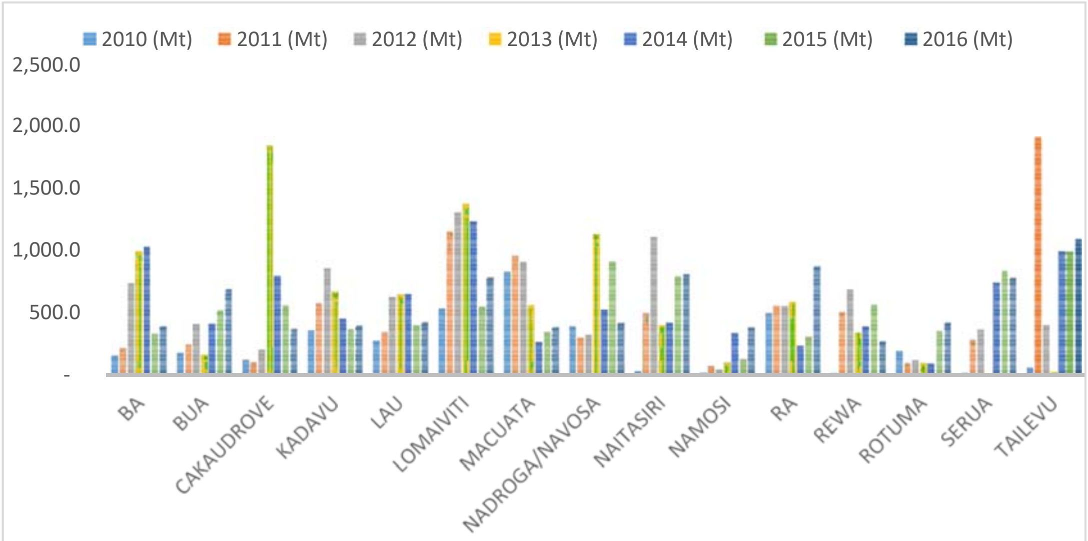


Figure 41: Kumala production in Ra compared to other Provinces of Fiji. Source: MPI, 2017

5.7 Challenges in Ra Province

Over the last 37 years, Fiji has documented 124 natural disasters that have impacted the entire country. Tropical cyclones accounted for 50% of the incidents, followed by floods (33%), and earthquakes (8%). (Holland 2009; Lal et al. 2009). These natural calamities have had a significant influence on the inhabitants of Ra's lives and livelihoods. Between 1970 and 2007, the total direct cost of catastrophic occurrences in Ra was projected to be $532 million (Lal et al., 2009). Only 17% of all events were responsible for 86% of the overall expense. These figures only include the 104 catastrophic incidents (51 percent) for which the government provided cost estimates. Cyclones were the largest contributor to overall expenses recorded from 1970 to 2007, demonstrating their severity domination (Lal et al., 2009). The January 2012 flood cost FJ$36.4 and FJ$12.2 in the two Ra catchments, respectively (Brown et al. 2014). These were followed by another major flood in March of that year, which caused FJ$24.1 and FJ$8.4 in damages in these two catchments (Brown et al., 2014). Crop destruction was exceptionally severe, accounting for well over 80% of total damages recorded for both floods and Cyclone Evan in the same year. Direct damage to homes and durables, whilst not insignificant, was minor in contrast. In compared to agricultural losses, livestock losses were relatively minor (Brown et al., 2014).

Traditional practices have a role to play in the vanua as a response to cyclones. To maximise TEK and to prepare for such a natural event, the bati (warrior) bete (priest) and gonedau (fisherfolk) must work together. The matanivanua (herald) also plays an essential role during this time as he passes on the advice given by the climate experts to the individuals of the villages. After the cyclone has passed, it is the mataisau (craftsmen) who are needed to assist with repairing homes. Also, the bati (warrior) and the gonedau (fisherfolk) play a role in the aftermath of a cyclone, helping rebuild farms and providing food for the vanua. This illustration shows why it is vital that the vanua knowledge of Rakiraki (Ra), is researched, documented, and passed on to younger generations. Failure to do this may result in the loss of traditional knowledge which is essential for the Vanua o Rakiraki's daily activities, relationships, survival and continuity as a kawa tamata (race).

Through a rural transformation centre (RTC) method, the current National Agriculture Development Goal strategic action 7.2 (MoA, 2014) focuses on creating modern agriculture as an organized system of producing, processing, and marketing crops, livestock, and aquaculture products. It refers to both (rural and urban) communities since ensuring food security is a top priority for the national government, in conjunction with the main economic development goals of increasing income and job possibilities in rural areas. The major goal of the development agenda is to align with these goals, with an immediate outcome to be achieved by 2020 and based on a study of selected development goals. The primary objective or purpose of this project is to develop a diverse, commercially and ecologically sustainable agriculture sector in Fiji (ibid.). With minimal current research or publications in Fiji, the government is still unsure how to attain their Fiji 2020 agriculture agenda policy objectives. Kumala has been proven as a crop been neglected or forgotten by the ministry since it has no development programme, yet crop material is distributed to villages around Ra after every cyclone. Through this research, the Vanua of Ra has enabled them to create germplasm collections of local kumala varieties and enable the Vanua of Ra to voice outor vosa na vanua (Chapter 6) on the importance that kumala has to them, and importantly, the relationship they have from their ancestors.

5.8 Chapter Summary

The title 'origin' in I-Taukei means ***'tekitekivu'*** where it all began, this includes language, values, culture, and traditional knowledge which includes various agricultural practices. Ra is where it all started. If Ra was the origin, then imagine the potential it hason kumala agriculture farming in Fiji. There is a need to identify a potential crop/swhich will suit and adapt well in a particular district in Ra, and this can only be achieved through research (experimental trials). This chapter has explored the eight traditional roles in which our ancestors were anointed, including agriculture. This role justifies that indigenous Fijians were wealthy based on what they produced on their farms and agricultural farming was practised in the past times.

The locals of the three villages involved in the fieldwork of this thesis all belong to the vanua o Ra. They share the understanding of the meaning of *vanua* as physical, social, cultural, and spiritual knowledge systems of a place. This knowledge evolves aroundthe kumala agriculture farming in Nabukadra, Burenitu and Bucalevu. The eight traditional roles had allowed them to live peacefully and to attain a wealthy life achieving food security and sustainable agriculture, whereas today we live almost in the opposite. Understanding one's traditional role and performing it as expected is vital in the smooth running of the vanua. Some aspects of the initial knowledge and values havebeen lost due to colonisation processes and during times of intertribal wars. The three research sites had a traditional governance system that assisted with the organisation of daily activities.

Each member of the vanua o Ra needs to pick up the necessary skills to filltheir role within the community effectively. If the knowledge is not passed on correctly, it may affect the smooth running of the *vanua*. The vanua knowledge of Ra must be researched, documented and passed on to younger generations. Failure to do this may result in the loss of traditional knowledge which is essential for the Vanua o Ra daily activities, relationships, survival and continuity as a kawa tamata (race).

Chapter 6

Finding One: "Sa vosa na Vanua" - The Land Speaks

Indigenous Agriculture Knowledge (IAK):
The p*hilosophy of life values& epistemology and relationship to kumala production in Ra.*

"The objective for Indigenous peoples' land is undoubtedly protection, but it is also utilization." We are so inextricably linked to our land that our protection is inextricably linked to our practice, and our practice is inextricably linked to our protection. We survive from the resources of our land." (Rebecca Adamson, 2018).

6.1 Introduction

The goal of this study is to generate an ideology of how Indigenous Agriculture Knowledge (IAK) or Traditional Environmental Knowledge (TEK[10]) impacts agriculture in a Fijian way of life, with a focus on traditional environmental knowledge (TEK) and its relevance in kumala farming in Ra province in Fiji. This adaptation can be achieved by using Fijian Vanua Research Framework (FVRF) which involves *Talanoa* or dialogue, Bula vakavanua, observation, literature reviews, informal and formal meeting to discuss on outcomes that will permit a way onward.

Indigenous knowledge (IK) permeates in many aspects of Fijian life, including health, spiritual beliefs, and environmental survival. Indigenous Fijian people have lived and survived in their ecosystems for millennia by establishing and practicing knowledge systems that have instilled resilience in their mataqali, yavusa, and vanua. Veitayaki (2002, p. 396), a Fijian academic, highlighted how the Fijian TEK on seasons is preserved in the traditional calendar indicating "sources of food accessible at different periods".

In this study, I applied Berke's knowledge-practice-belief complex (2008) of TEK to explain the results of TEK's function in kumala production in a traditional Fijian setting in four elements:

1) values and beliefs
2) knowledge
3) practices
4) skills

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[10] Where TEK is used in this thesis the term environmental is used interchangeably with ecological

Section 6.2 to 6.7 examines the influence TEK has on kumala production and how we have potentially lost a sense of their importance, especially with some lost traditional varieties in Fiji.

6.2 Traditional Environmental Knowledge: values and beliefs on crop production in Ra.

6.2.1 Understanding TEK in kumala production

The ambiguity of the concept or term TEK requires proper insight to define "What is TEK" According to Berkes (1993), many scholars today find it difficult to associate with the term *traditional* simply because of the equivocation of its definition; hence they avoid it altogether. Likewise, there are misperceptions between the understanding, and inquisitiveness in the validity and reliability of the terms TEK, Indigenous Agricultural Knowledge (IAK). Some prefer to use the term IAK due to the intimate relationship people have to its "localness, embeddedness, contextual bound or commitment to local context" (Tora, 2019), or due to its "uniqueness to a particular community or ethnic group" (Houde, 2007, p. 158; & Pinkston, 1998). For some ethnobotanists, there are also difficulties with how the term *ecological knowledge* directly translates to local nomenclatural systems of specific indigenous communities (Tora, 2019) but a horticulturist, prefers traditional environmental knowledge (Roskruge, 2007). For example, indigenous peoples in Canada's far north refer to it as knowledge of the land instead of ecological knowledge (Berkes, 1993; Leopold, Sewell, & Brower, 1949). This is comparable to the Ra people:

"The land is like a parent. It offers everything. It safeguards. It promotes healing."
(Turaga ni Koro,2019)

This traditional environmental knowledge has enabled the people of Ra to be self-sufficient with kumala in the past. This local agriculture knowledge has previously enabled them to achieve a wealthy and healthy life through sustainable agriculture year-round and has protected them from famine and other climatic challenges. Kumala production requires a critical understanding of environmental systems for effective horticultural management practices. It is important to note that TEK in whatever form, connects in varied dimensions and levels and is not just restricted to an indigenous group of people but to generations of living cultural existence in a particular place (Houde, 2007; Ticktin & Spoon, 2010). Likewise, when linking TEK to agricultural management, it is critical to comprehend the complexities in the relationship between TEK and Traditional Agriculture Knowledge, understand the dynamics of these diverse dimensions, and the factors that influence crop production in different indigenous communities (Ticktin & Spoon, 2010).

6.2.2 The role of TEK within Ethnobotany

Ethnobotany is commonly defined as the study of plant-human interactions and relationships through time and geography (Prance, 2007). Paramount within this study is the use of TEK and practices. In the three case studies (Nabukadra, Burenitu and Bucalevu), some people possess extensive knowledge of the properties of plants, an indication that traditional botanical knowledge is extensive and that earliest humans were early ethnobotanists (Schultes, 1994). The ethnobotanical knowledge of indigenous people plays an essential role in cultivating the land and its agricultural practices that support biodiversity. Such knowledge evolves and is continuously changing (Schultes, 1994). Indigenous people have a deep respect and admiration for their flora and fauna resources. A holistic worldview drives them to have a personified connection that relates their resources as cognizant and communicative subjects rather than as an inert or insignificant objects to them (Snodgrass & Tiedje, 2008). Timoti, Lyver, Matamua, Jones, and Tahi (2017) cited and defined worldview in series as:

> *"…coherent collections of value orientations and cognitive maps that allow people to orient and make sense of their world (cited in Aerts et al. (1994); Van Egmond and De Vries (2011); Van Opstal and Hugé (2013); Vidal (2008) … a worldview (or cosmovision) is the way a certain population perceives the world (or cosmos). It includes assumed relationships between the human world, the natural world and the spiritual world. It describes the perceived role of supernatural powers, the relationship between humans and nature, and the way natural processes take place (cited in Haverkort and Reijntjes (2006).worldviews represent the ethical basis, principles, and assumptions around which people and populations organise themselves to interact with nature"(Allport, 1935; Haverkort & Reijntjes, 2006).*

The indigenous worldviews and local communities are essential for agriculture globally.The Vanua of Ra views themselves as an essential component of the ecosystem through their diverse set of cultural values and worldviews. These sets of values are derivedfrom the traditional belief systems that are based on yavu (see Figure 48). In Fiji, the most important Kalou-vu deity was Degei, who was a god of the Rakiraki District but was known across most of the Fiji Islands. He was regarded to be the origin of all tribes in Fiji, and his authority was greater than that of most other gods. He was frequently depicted as a serpent or as a half snake and half stone (Derrick, 1957:11).

When Degei shakes his head, it rains fertiliser, beautiful fruits dangle from the trees, and the kumala and yam fields produce a bumper crop. Ravuyalo, Rakola, and Ratumaibulu were Degei's sons and patrons of carpenters and canoe-builders, respectively, while Ratumaibulu ensured the prosperity of garden crops. Ravuyalo would be on the lookout for departed souls on the way, hoping to catch them off guard and club them. His goal was to prevent them from reaching the afterlife (Bulu). Dakuwaqa is a shark god. Fishermen much respected him because he protected them from any danger at sea and sometimes protected them from evil denizens of the sea and provided fish.

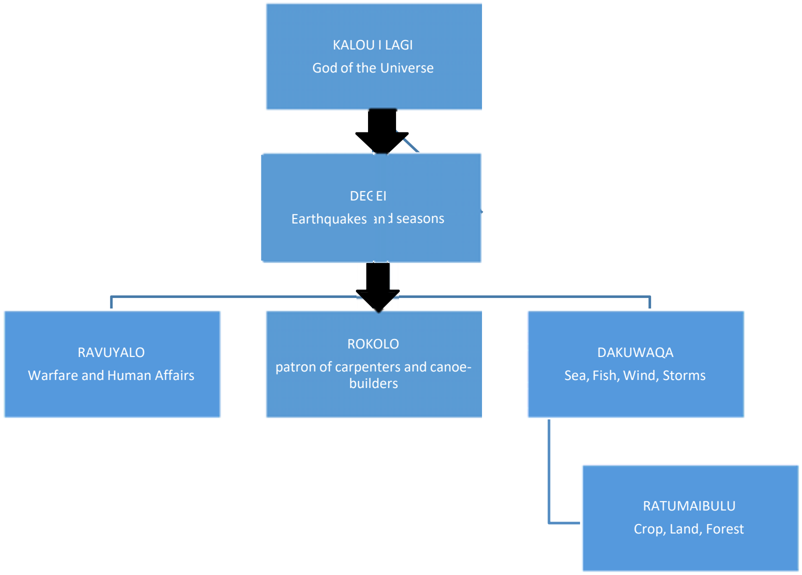

Figure 42: The environment as a family - Yavu ni Kalou mai Ra.
Source: Viti Makawa, 2013

6.2.3 TEK and Ethnobotany impacts on Kumala Production in Ra

Traditional environmental knowledge (TEK) explains how the understanding of the dispersal of resources, the functioning of ecosystems, and the correlation between the environment and their culture can coexist. As a concept of TEK, this combined understanding also allows groups of people to intimately appreciate the relationship and connection with their environment, sanctioning them to value their local food by "promoting environmental, biological, and climatic change adaptation and resilience approaches" (Tora, 2019). TEK comprises a broad spectrum of information that overlaps greatly in terms of the type of knowledge, the identity of knowledge holders, and the method of knowledge acquisition in terms of its diverse practices and vast terminology interpretation (Houde, 2007). TEK has been primarily expressed by its definition (Davis & Ruddle, 2010).

Berkes (1993) suggested that today's literature lacks a globally agreed definition of TEK that identifies or incorporates all localized worldviews. However, it is critical to acknowledge the workers employed by various scholars on this subject and on indigenous communities of interest, which has, helped build into what is now widely defined as *traditional ecological knowledge*. TEK exists worldwide in native societies independent of ethnicity. In the Pacific, for instance, indigenous communities have "*over centuries, acquired extensive traditional Agricultural knowledge (as a form of TEK) about their land*" (Tora, 2019). This knowledge is holistically observed and adaptive by nature, gathered and passed over generations orally and observations by indigenous people whose lives depend on its practices (Gadgil et al., 1993).

Furthermore, the value of TEK holds a significant purpose in kumala production and applies to the communities of the research locations. Theorising these values requires a critical understanding of the diverse features of traditional environmental knowledge and can also be observed as unique cultural wisdom of the past that holds our future as expressed through this Hawaiian proverb.

I ka wa ma mua, i ka wa ma hope.

This Hawaiian adage means "in advance of time, behind time," which means the future is behind us because wisdom from the past is ahead of us (McMillen et al., 2017, p. 579).

6.2.4 The Existence of TEK

TEK is observed under four primary contributors in the itaukei way of life (*bula vakavanua*) during Agriculture farming in Ra (see Figure 43).

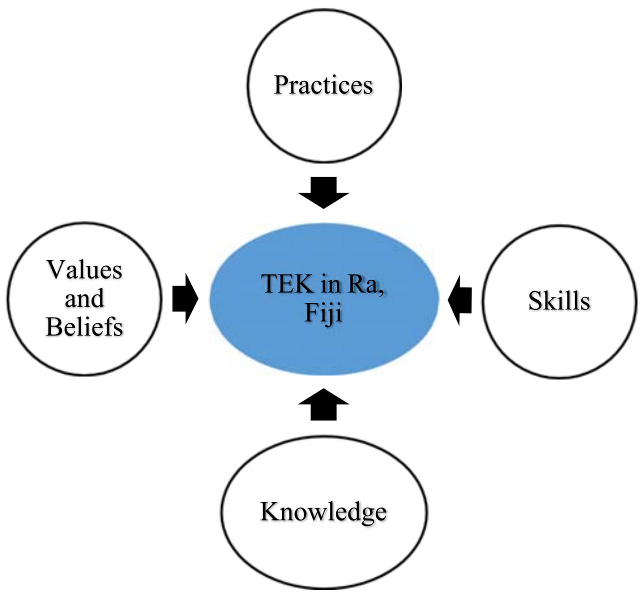

Figure 43: TEK in the traditional Fijian agricultural way of life. Leweniqila, 2020

Environmental values are ethical principles and ideas that govern resource usage and influence individual and group behaviour in traditional Fijian society. Yalomatua (roughly "ancient soul") is a highly appreciated phrase for wisdom. Yalomatua is a word that may be used to describe a person, an attitude, or an activity. It is mirrored in the concept of 'no wastage' in the environmental context, which supports the optimal and full use of his land in implementing his indigenous agricultural skills. In Ra, the virtue of respecting living things in the environment involves respecting animals, such as fish processing and the hunter's attitude, as described by (Fraser, Coon, Prince, Dion, & Bernatchez, 2006). Fraser et al. stated there is respect for animals in a hunt, for example, since non-human creatures have brains, are perceptive, and can act freely. According to Berkes (1999), the Cree believe that the animals control the hunt and that the fish allow themselves to be captured by the fisher. Rasalato et al. (2010) examine how "ancestral stories and myths.... give light on links between these animals, root crops, and indigenous people" in Fiji. Berkes et al. (2000) point out that not all belief systems are environmentally conscious, citing Diamond (1993), who noted that some Papua New Guinea (PNG) tribes continued to have a major influence on their natural biota. Seruvakula (2000) explains how the indigenous Fijians connect to Ratumaibulu (God of the Land). For this case study in Ra, when kumala production or any crop production is done, it is imperative to be mindful that all the area of work is clean, and all cutting should be cleared up and covered. There is an act of respect to the God of land and Mother Nature.

The compliance of reciprocal connections between humans and non-human animals includes some customary rules and beliefs for demonstrating respect in various societies. These must be followed, such as returning bones to their natural habitat (Sherry & Myers, 2002). In the case study sites in Fiji, Nai sevu is a crucial practice at harvest where our fathers had to present the best crop to the Bete, Chief of the Mataqali and the Chief of the Vanua as an act of respect to the Ratumaibulu. These enabled them to be blessed fruitfully in the next season of farming. Moreover, it shows the Ratumaibulu that we are not greedy where you have the heart to give. The people of Ra have responded to this belief that bula sautu (wealth) is obtained from this practice. The respondent in Ra stated that February is the month of the year when they had to present their Nai sevu.

"Lack of mutual respect will have severe effects like low yield quality and reduced sizes of crops like kumala," Sherry and Myers (2002, p. 350). These are exhibited in the case study location, where teitei processing requires respect (farming land). Because its four components, values and beliefs, practices, skills, and knowledge, are integral to the Fijian way of life, TEK is critical to the thought and practice of revitalising kumala production in Fiji. The four elements are also part of an integrated Ra society's kinship network. The participants from the three villages remind us of the *'The land speaks'* meaning that the people who own the land had spoken out their knowledge, skills and practises would enable them to fight against food insecurity and this will provide them with an avenue to achieve climate-smart agriculture through kumala farming.

6.3 Practices in Kumala Agriculture Farming in Ra

TEK activities are carried out for survival while also working to maintain the environment, and food security, and providing an avenue for climate-smart agriculture. In Fiji, activities include the adoption of sustainable agricultural methods and soil conservation. The practice relates to solesolevaki as social capital in the indigenous Fijian community. Solesolevaki has a considerable effect on kumala production in Ra. The four components, which are visibly present in the Fijian way of life, are trust interactions; reciprocity and trade; standard standards, norms, and punishments; and connection and networks (Vunibola, 2020). Kinship (veiwekani) serves as a conduit for social capital transactions in a linked Fijian community. Solesolevaki in kumala agricultural farming had been part of the pre-historic lives of the vanua of Ra and is a threat to indigenous livelihoods in achieving holistic wellbeing.

Robert Putnam's community studies, first in Italy (1993) and later in the United States (1994), made social capital a well-recognized idea in the 1990s (2000). Putnam (1993) defines social capital as "those elements of social organizations, such as networks, norms, and trust, that allow action and co-operation for mutual gain," whereas Fukuyama (1995) claims that "the presence of social capital inside a group encourages co-operation." "The social networks, norms, and punishments that allow cooperative behaviour among people and groups," according to Halpern (2005, p. 39). To oppose the devolution of natural resource management to natural resource owners, there is a pressing need for a greater understanding of social capital among indigenous communities administering the resource. According to Tai (2006), "pre-existing social capital drives collective action". As mentioned, collective action is the collaboration of community members to address collective issues, and social capital is a valuable framework for understanding how cooperation is produced in communities (Ahn & Ostrom, 2008). Bonding social capital was significant in this study because of the kinship relationships in the three villages, and it was a pivotal contributor to getting tasks done by directly mobilizing intra-community interpersonal relations, a strong collective action, and it was a pivotal contributor to getting tasks. Because kumala production is founded on kinship spanning generations, and in some cases as far back as shared ancestral god claims, indigenous social capital is important (Ravuvu, 1983).

6.3.1 Solesolevaki as the social capital in I-Taukei kumala production

Every household in the three villages has a yavu: a piece of land allotted in the community where they may build their house for the related terrestrial grounds. Various mataqali own land on the outskirts of the community, which they may cultivate. In cropping systems, solesolevaki has been the main engine of life in Ra, where the hands of many share the responsibilities (see Figures 44 and 45). Solesolevaki revitalises traditional agricultural practices which connect to the agronomical practices of our traditional foods like kumala. People use solesolevaki on two essential concepts: na gauna ni vuavua’i and na veivukei vaka veiwekani. Na gauna ni vuavua’i refers to the seasons following the vula vaka Viti (Fijian lunar calendar) which depicted the season to cultivate the land for specific crops which are flourishing, harvesting specific land and sea resources and this requires the whole village to do it and sharing the produce later on (Vunibola, 2019). Na veivuke vaka veiwekani (helping your relation) does not depend on seasons or resources, but it is how individuals respond to the need of a particular person in the village.

> *Auvu ni dua qai sucu mai edua na kawa I taukei sa drodrova tu mai na nona dra oya na bula ni solesolevaki eda dau solevaka na veika kece me vaka nai teitei, tara vale, tali ibe kei na veika tale eso. Na bula ni solesolevaki e da sega tale ni da dau waraka me lako mai vei iko na i tukutuku ena teitei keimami edua solevaka na neimami I teitei. Ena loma ni dua na vula e va tiko na macawa ena veimacawa oqo keimami vaka porokaramu taki keimami tu kina ena neimami solevaka tu nai teitei ni neimami turaga, Mataqali, tamata yadudua (Noke, 2018: pers. comm).*

> *When indigenous Fijian is born, solesolevaki is embedded within our beliefsystems that determine our actions to realise without anybody informing that our relationship needs help, and we will also know what we can do about it. In farming, they practise solesolevaki every month (Figure 61). Since we have four weeks in a month every week, there is work that will all have to attend to including individuals. So, in the first week will be the chief, then the Mataqali farm, then the individual (Noke, 2018: pers. comm).*

Work structure in solesolevaki is a critical mechanism for resilience in an indigenous Fijian society. It is a strategy for achieving comprehensive and inclusive well-being that includes:

- Spiritual wellbeing
- Environmental wellbeing
- Socio-cultural and kinship wellbeing.
- Economic wellbeing

> *Na veivukei vaka wekani esega ga me baleta nai colacola eda veivukei talega ena kena sagai me vakalesui tale ka wasei na kila vaka teitei vei keda nai taukei. Ena gauna sa sega ni vakvulici na kila vaka oqo e koronivuli ka sat u vei keda nai bolebole ena gauna oqo. Ena so na matavuvale sa sega ni malele nai tubutubu ena kena wasei na kila vakaqo. Ia ena gauna vaka na solesolevaki erawa ni botani kina na leqa vaka oqo. Ka me rawa ni vueti lesu tale mai kina na kila vaka teitei me baleta na kumala (Mr Penioni L, 2018: pers. comm).*

> *Respondents in Ra (Nabukadra, Burenitu, Bucalevu) further explain that solesolevaki is not only a way of helping your relatives, but it is a way where elders are helping the younger generation with agricultural farming practices on our local foods like kumala and uvi. Solesolevaki is a way of bridging the gap from family to school. Since this is not taught in school and most families' parents have no interest in teaching their children about our agriculture traditional practices (Mr Penioni L, 2018: pers. comm).*

The phrase **"everyone knows everyone else"** is frequently used to characterize networks in tiny and close-knit communities, highlighting their interconnected and interdependent nature (Mavono, 2017). Internal links exist within the community's formal hierarchical system, attaching each home to a sub-clan or tokatoka, tokatoka to a mataqali, and mataqali to a yavusa or tribe, which is related to a wider vanua or tikina (Ravuvu, 1987; Brondizio et al., 2009). Veiwekani, social interactions serve as links that bind people in the community. Bonds were found to structurally reinforce traditional Fijian norms and beliefs such as veivakaturagataki, veidokai, and solesolevaki, which promote acceptable behaviour and compliance and sustain communal togetherness (Coffe, 2007). Veivakaturagataki and veidokai may be roughly translated as humility and respect, respectively, although the third phrase, solesolevaki, is a little more ingrained term that refers to the polar opposite of individuality.

Figure 44: Solesolevaki in Kumala agriculturefarming

Figure 45: Solesolevaki eases the burden of anindividual

6.3.2 Solesolevaki allows indigenous Fijians to achieve a wealthy and healthy life.

Our forefathers often lived for 80 years or more and had achieved a wealthy life and foodsecurity. The indigenous Fijians in Ra were self-sufficient with their local foods practising sustainable agricultural practices. The present concerns such as food security and climate change highlight the concern that traditional foods like kumala are becoming lost. There is a challenge for Fijians to combat this issue.

> *Auvu ena solesolevaki keimami vulica kina e levu na kila ka vaka i- Taukei. E da mai veisoli taka i loma qo na kila me rawati vata kece na noda tiko bulabula. Na bula sautu ena rawati ga ke tiko na yalomatuaoya e tiko e bula ni solesolevaki. Sa da raica ena gauna oqo sa levu na mate dole satu ena vuku ni kakana eda dau kania. Solesolevaki e solia veikeda na dodonu meda kania na kakana bulabula kina yagoda. Mai liu era sautu ena kakana draudrau, vuata, kei na kakadina me vaka na kumala kei na uvi. Qo ena vuku ni solesolevaki (Mrs Selai D, 2018: pers. comm).*

> *Through solesolevaki young generation has learnt more from our elders. Here, knowledge has been shared through practice. We are fortunate that this research, has enabled us to revive this knowledge to where it should be placed. Wealth and abundance of food are achieved through wisdom. Solesolevaki produces and provides this wisdom to us through practice. This wisdom will enable us to achieve abundance and have excess to a healthy variety of food (Mrs Selai D, 2018: pers. comm).*

Solesolevaki is their cultural currency; it is a practice where no one is left behind; this means people have an equal share of varieties of fruit trees, vegetables, and root crops in their land. Solesolevaki allows every family an opportunity to choose which root crops and vegetables to eat; more importantly, it promotes healthy living. Through solesolevaki, the healthy living patterns in the I-Taukei world also enhance the sharing of burdens, and there is always laughter and songs, making the tasks more enjoyable.

Na vanua o Ra keimami veiwekani tiko ga ka sa bibi vei keimami me keimami na yavu ni neimami veiwekani, nai balebale din ani veiwekani oqo mai vei ira na neimami qase yaco mai oqo baleta sai koya ga qo na yavu tu dei ka bou ni neimami duavata ka keimami tiko sautu kina (Koroi U, 2018: pers. comm).

The Ra people are all related. Our role as individuals is to guarantee that we understand how and why we are linked, and we are obligated to recognize and respect those relationships by acting mainly, which is what provides unity and wealth to our community (Koroi U, 2018: pers. comm).

This participant argues that wisdom exemplifies the importance of solesolevaki not only as a component of social-life networks but also as a trait of indigenous culture that enables villagers to successfully pursue common goals and achieve unity and solidarity within their society as a whole. Everyday living and communal partnerships are highly reciprocal and contribute to the growth of social capital.

6.3.3 Solesolevaki: a tool to revitalise kumala varieties to the Fijians

Respondents in Nabukadra, Burenitu and Bucalevu all expressed their concern regarding the importance that solesolevaki has to revive the traditional agricultural knowledge that has been forgotten and retain the lost glory we had for kumala varieties. In Ra, there were only two varieties of kumala still widely grown. This also signifies that there has been no kumala research done in recent decades.

Na solesolevaki era dau bula taka tu oira na noda qase eliu ia na kawai ena taba bula oqo oya ena kena rawa ni vueti tale se vaka bulabula taki tale oya na bula ni da solevaka na teitei. Ke da vinakata me lesu tale mai eso na kila ka vaka teitei era dau bulataka tu eliu na noda qase kei na kawa ni kumala sa yaga meda vakabulabula taka tale na solesolevaki (MrLenati K, 2018: pers. comm).

Solesolevaki needs to be revived since it allows the preservation of every kumala variety in Fiji. It also discloses our traditional safety net of Veivukei (helping each other) on their plantation (Mr Lenati K, 2018: pers. comm).

From an agricultural perspective Vunibola (2019) restates the concept that when a child is born to a family in an I-Taukei setting, it is called 'luve ni vanua' meaning that all the people, the land, culture, and traditions are responsible for nurturing the child. From these case studies, solesolevaki contributes to this social safety net when individualsfeel out of place from the systems that influence their lives. To the vanua of Ra, solesolevaki is also; 'karua ni vuvale' (second family), 'neitou koronivuli' (our tertiary school) or 'i yavu ni neimami veimositi va'a veiwe' ani' (strength of our kinship) to the villagers. Solesolevaki was a second home to the indigenous Fijians. It is a library where all local agricultural knowledge is kept in this ambry where an individual can share with everyone.

This library has also proven to society in Ra (Nabukadra, Burenitu and Bucalevu) that those who drop out of the educational system have been successful and can survive to provide for their family, vanua, and lotu. The solesolevaki at this level is like a school, and it offers bridging courses for youths on agronomical practices of traditional foods like kumala cultivation. It is a place where proper behaviours are encouraged for the youths to achieve *'the same collective system supports and maturity* (Vunibola, 2019).

6.3.4 Solesolevaki allows food sovereignty to exist.

Food sovereignty is practised by indigenous communities, local farmers, small business cooperatives, and others concerned with growing and distributing nutritious food to counteract government-controlled food security initiatives, according to the report (Cohen, Andrews, & Kantor, 2002; War on Want, 2013). Food sovereignty and indigenous Fijian values are inextricably linked, with indigenous Fijians asserting their right to establish food and agriculture systems using environmentally sound and sustainable means. The government ministries have not yet identified the potential crop that suits them relevant to the soil type and their landscape in Ra. Exporters have been dominantin manipulating the Indigenous Fijians on their agricultural demands rather than the Vanua's choice.

> *Sa vaka eda sa mai vakasaurara taki tu me da tea na ka era vinaka kata oira na dau bisinisi (exporters) mai na tea na ka eda vinakata. Kakeimami kureu ena tei vovou sa ra kau tu mai oqo baleta ni keimami segani kila na walewale ni kedra qaravi (Mr Ledua K, 2018: pers. comm).*
>
> *Farming for us now is like labour for someone's demand. We have been forced to cultivate commodities which they export most or commodities which have markets. Most of these new commodities that have been introduced to our communities need training and trials to be done since we do not know them. These have led to the forgetting of our traditional crops in Ra.*

Enhancing the viability of traditional food-producing methods is also critical. Pohnpei (Federated States of Micronesia) has a similar situation, with people shifting away from indigenous foods and toward imported processed foods, resulting in NCDs and micronutrient deficiencies. The Island Food Community of Pohnpei, a local non-governmental organization, launched the "Go local" food campaign. Along with community awareness efforts, gene bank collections of traditional carotenoid-rich cultivars of sweetpotato, bananas, pandanus, breadfruit, and taro were developed. The movement resulted in a beneficial shift in attitudes, as well as an increase in the consumption of local foods (Englberger et al., 2013). The success of this initiative may serve as a model for similar projects aimed at preserving the genetic variety of traditional food supplies and ensuring food security in island countries such as Fiji.

6.4 Kumala production skills in Ra

In traditional society some skills are acquired from birth and strengthened through oral transmission and instruction over generations, highlighting the importance of TEK in families and kinship networks. The essence of the I-Taukei vanua structure is on the individuals who are born into their sub-clans and said to have special i-solisoli (gifts or talent) which is the innate ability, skills and talent to function in their environment. A child is immersed within the sub-clan doing solesolevaki on specific responsibility, and this is the place where informal learning occurs through watching the elders at work, talanoa (engagement in conversations) and there comes a time of practising through the watchful eyes of the elders until the mastering of skills. Children grow through their youth and become elders adopting the skills and the art of undertaking tasks through the hands of many people. For example, a traditional carpenter would use his TEK to pick the best wood and his carving talent to create a boat for a fisherman. As a sign of gratitude, the fisherman will bring delicacies from the sea to the carpenter. These include the traditional commerce system inside our yavusa, mataqali, an example of social capital interconnection and TEK lived out within the kinship structure in the bula vakavanua.

In kumala production, there are skills associated with all production phases of kumala cropping in Ra, which are presented from the three research sites. These skills provide for food security where individual homes could choose which foods they prefer to eat ona particular day. Through solesolevaki, this opportunity is shared among all equally in Indigenous Fijian society, everyone has agriculture skills within them. Respondent in Ra has justified this in their story

> *Auvu na ka duatani kina o keimami I Ra oya rawa ni duidui na nodai tutu vaka vanua ia na walewale ni teitei se na kena qaravi nai teitei eda kila vaka tautauvata ka sega edua me lecaika kina. E sega ni vinakati sara mo vuli vinaka mo kila nai walewale oqo ni dua e sucu mai sa rau sucu vata tu kei na kila oqo. Ia ena loma ni solesolevaki na walewale ni kila oqo era sa qai raici ka vakaraitaki ena matana votu ena gauna eda sa qai solevaka tiko na nodai teitei (Viliame M, 2018: pers. comm).*

> *Auvu, for us here in Ra wisdom and knowledge on the farm, is not always taught in schools but through the blood which connects us. When someone is born, he or she has inherited this knowledge and the guidance of the elders during solesolevaki allows them to practice that knowledge and to put it in reality (psychomotor skills (Viliame M, 2018: pers. comm).*

6.4.1 Kumala production in Ra

6.4.1.1 Kumala varieties

Respondents were asked about the names of the kumala varieties they planted and their characteristics.

> *Mai liu au kila ni sivia na lima na Mataqali kumala ma tiko ena koroqo. Qo sa rua ga na Carrot kei na ka lokaloka. Na kumala gone mai 3-4 vula sadau kaya tu ira neimami qase ni oqo e kumala vinaka mera dau vakania kina oira na gone dramidrami kei ira na tinani gone me vaka tawa ni sucu vinaka. Era dau kaya na qase ni 3-4 vula qo na kamica ni kumala e sereka saraga mai kina (Mr Vereimi K, 2018: pers. comm).*
>
> *The majority of participants in Nabukadra, Burenitu and Bucalevu indicated that in the past more than 5 – 10 varieties of kumala were used in the Ra district compared to the two cropped now: Karoti (Carrot) and Lokaloka (Honiara). People from Nabukadra stated that baby kumala ranges (harvested immature from 3-4 months)were fed to toddlers (gone dramidrami) since they provided rich supplements kina (Mr Vereimi K, 2018: pers. comm).*

Moreover, this baby kumala is best for any mother who is breastfeeding their children since they assist mothers in providing more protein and nutrients to their milk. This name is also connected to their knowledge of the variety. An example of this includes its softness once cooked and is very sweet. These attributes make it ideal for babies. *Baby* kumala can be harvested 3-4 months after planting.

Furthermore, a respondent in Ra stated;

> *Sa ra yali nai tei ni kumala dau laurai tu ike ilu ia na gauna qo sa rua ga na Honiara kei na Carrot. Ia rau sega soti ni dau vaka lewe vinaka me vaka I liu. Oyau noqu cakacaka tu ena tabana ni teitei I Dobuilevu keitou dau bucina kece na kawa ni kumala kei na uvi koyae tu vei keda e viti, oti saraqa veisoliaki na vei korokoro e Ra ia na gauna oqo sa sega. Ena gauna oqo sa levu na kawa ni kumala era saveiraurauvinaka kei na draki veiveisau sa da sotava tu na gauna qo. (Mr Jone W, 2018: pers. comm).*
>
> *We have not preserved some of our traditional kumala varieties, yet Honiara and carrot is the most common one which has been cultivated for now in every village in Ra. These two varieties now have a problem in producing quality tubers. I remember being employed at the research station in Dobuilevu we have gene banks for every kumala variety in Fiji. These gene banks supply planting materialto farmers in Ra (Mr Jone W, 2018: pers. comm).*

Kumala from the baby variety stores well both after harvesting and in-field. The baby variety can be planted in both wet and dry conditions. There is a high demand for the baby variety in the local markets where it is highly sought after by consumers. *The baby kumala* was also recommended to farmers by the government bodies (MOA and I-Taukei Affairs Board). The findings show that some old varieties such as Kabara, *Lokaloka* and *Papua* have been lost due to the shift in the cultivation of crops which are demanded from the exporters, yet these traditional root crops are tolerant to drought so have an inherent value to farmers.

6.4.1.2 Division of labour

Communal work is practised among the indigenous Fijian society, and activities are assigned to different members of the community based on their social class, gender and social structure. Informants noted that it is still practised in Ra where the division of labour for different kumala activities starts from land clearing to harvesting. Respondents from Nabukadra, Burenitu and Bucalevu identified that men and women have different tasks in both settings but share a common ground in decision-making. Itis the responsibility of men to clear the land and prepare mounds. Women collect the kumala cuttings and plant them (see Figures 46 and 47).

Figure 46: Solesolevaki practises in Ra

Figure 47: Solesolevaki involves a division of labour

6.4.1.3 Planting of Kumala

Respondents at the three research sites were similar in using traditional planting methods of kumala. Kumala cuttings were taken at 30cm length from the tips of the kumala vines in new gardens (2-4 months old). Many respondents preferred cuttings with 3-5 nodes. The cuttings are planted directly in the prepared mounds. For instance, planting the cuttings at a depth of 20-25cm allows good development of the tubers and easy harvesting. Shallow planting is not good because it exposes the tubers to the sun, which renders the tubers unpalatable. Besides, deep planting makes it difficult for harvesting, especially in clay soils. Sandy soil is the preferred soil for kumala due to its good drainage properties. Mounds are practised in planting kumala in an indigenous Fijian village.

> *Auvu vei keitou i nakoro e wara na duidui keimami vakamuria kece tiko ga e va nai walewale ni tei ni kumala me vaka okoya e vuki na vanua cabe mai na mata ni siga, V-shape, ko bulia na ono, ko davo ena loma ni qele. Ni dau musu nai tei ni kumala e levu era dau musu 3-5 na ba oti ka sad au tei vaki saraga me 20-30cm na tekitaki sobu ka bale. Na kumala esega ni vinakata mo tei vaka sara me titobu na wakana dau dredre na kena cavu ena gauna ni matua (Mr Mikaele V, 2018: pers. comm).*

The four traditional methods of planting kumala in Ra are straight (L shape), vertical, sideways facing where the sun rises, and the shape of six. Farmers in Ra clarified that using the four planting methods produces benefits including high yields, upright kumalaplants, rapid rooting and ease of harvesting. Moreover, they stated from their forefathers the common one was three stems coil the end to form six placed in the soil facing wherethe sun rises which is an everyday use in all altitudes and soil types (see Figures 48 and 49). There is also crop assurance when multiple vines are planted because if one vine dies, the others will grow. Replacement is easy as cuttings are easily sourced. Planting is either done early morning before sunrise or at sunset.

Figure 48: Males are responsible for plantingKumala

Figure 49: Kumala planted on mounds (buke)flowering

6.4.1.4 Crop maintenance

The use of traditional knowledge is essential in effective maintenance practices to achieve a quality harvest. In all research sites (Nabukadra, Burenitu, and Bucalevu) participants responded that weeding and hilling up are maintenance practices they used. They stated that weeding is crucial because it helps to protect the kumala tubers from rats, allows sufficient sunlight into the kumala crops, and makes the garden looks neat as the overall presentation or appearance of one's plantation forms others' perception of a farmer. These are essential points from a cultural context. Weeding also prevents competition between the kumala plants and weeds, and most importantly, improves yields. Respondents also stated that they weed the crops before the vines cover the ground. Furthermore, they reported that hilling up is vital because it allows gooddevelopment of the kumala and prevents damage by rats.

Farmers from Bucalevu and Nabukadra stated weeding and hilling up were carried out as it offers the following benefits - aerates the soil, achieve high yield, protects the kumala crops from rats, prevents competition between weeds and the crops, and improve growth. In contemporary kumala systems, while weeding is carried out hilling up (manual) is not, and this is because the kumala are now planted in ridges.

One of the unique traditional elements for all Pacific cultures associated with crop production is garden taboos or rules, which are also crucial in the traditional cultivation of kumala for high yields and protection against pests and diseases. According to the respondents, failure to comply with or observe these taboos will result in low or no yield. In the past, severe punishments were imposed on the offenders. However, these days few garden taboos are still used in kumala cultivation. Additionally, all three locations stated one of the taboo ones must not continuously go to the garden anytime he/she wishes to. It is also considered taboo for a woman to go to the garden while she is pregnant. During visits to the garden, it is common practice for farmers to talk to the plants like they are humans (give them compliments). The same taboos were also stated by a few participants in Nabukadra and Bucalevu. Compared with contemporary kumalasystems, garden taboos are generally not implemented.

6.4.1.5 Kumala preparation and management during natural disasters

Given the consequences of climate change on agriculture output and food security, farmers must be vigilant in their crop planning and management. In Nabukadra, most of the participants stated that during drought, most of the kumala planted are the spreading type since they provide shelter and provide soil moisture. The erect type is planted near cyclone seasons. They also suggested when planting the cuttings, only a shorter portion of the planting material is exposed while the rest is covered in the soil.

During periods of drought farmers from Burenitu and Bucalevu stated that they water their kumala plants and no weeding is conducted, and this is to maximise shade and also retain soil moisture. Matured kumala are harvested early and are used for consumption. The respondents reported in Nabukadra that kumala could sustain them and their families during extreme weather conditions because it is more tolerant to droughts and cyclones, and if stored well, kumala tubers can last for some weeks. Similarly, in Bucalevu and Burenitu, kumala has also sustained their lives during extreme weather conditions. This is because when compared with other crops that arecommonly grown in Fiji, kumala is more tolerant to droughts and cyclones, it can be harvested at any time and can last for several weeks.

6.4.1.6 Harvesting

Kumala has the potential to be harvested year-round today whereas in the I-Taukei traditional season February would be the best since the first fruits of the season had to go through Sevu. The first harvest or “Na i Sevu” has to be offered to the chief of mataqali or yavusa and the priest. Moreover, a thanksgiving service has to be taken honouring what has been achieved by the farmers and seeking blessings for the next season. In Ra, participants stated that farmers determine the ideal time for harvest by identifying cracks in the mounds. It was reported that harvesting is done manually. They use their hands to scrape out soil from the mounds to expose the roots. Respondents also revealed that a spade or knife is sometimes used in heavy soils. When using the mentioned tools, care must be taken because the roots are very close to the ground surface. Respondents also stated that extreme care is taken to avoid damaging the roots when using a knife or spade because this can reduce the storage length of the tubers. Moreover, on another role, respondents also planted kumala, especially for social purposes, e.g., marriages, Christmas and New Year festivals. The crops were harvested for these festivals.

Christmas Food" Nai coi ni Siga ni Sucu kei na Soqo ni Vanua e Nakorotubu participants mention that not only Kumala is a food people of Ra would be expecting during Christmas, but it is used for the vanua ceremony. These show how they value crops like Kumala and other local foods. The term used was ***"Magiti ni Vanua."*** *During this season families in all tribes gather together all those months till the end of January or before school starts it has been a norm for all I-Taukei villages, so Kumala is a crop that we feed our* tribes. *Our people love them due to their different colours and taste (MrJosevata, 2018: pers. comm).*

6.4.2 Post-production of kumala

6.4.2.1 Storage

After harvesting kumala crops, storage methods used are crucial either for short or long-term purposes. Most of the participants stated the standard storage methods they use include the following: field storage, bag storage, basket storage and food bed storage. All can be considered traditional practices. Participants provided more information on these storage methods, including their benefits.

6.4.2.2 Field storage

Field storage is used when the kumala crops are kept in the field, and the mature tubers are harvested on demand. Participants in the three search sites stated that the benefits of using field storage include the following: a continuous supply of food for sustenance, and easy and convenient access to food when needed. However, the disadvantages are that rats may damage the tubers; and the tubers can become fibrous and lose their flavour.

Davuke, (see Figure 50) or storage pits were common in the Ra district. It has been widely used during a severe droughts. Nevertheless, now it has been forgotten in some of the villages, but the people in Nabukadra are still using them whereas in Burenitu and Bucalevu it was suggested that they no longer use them.

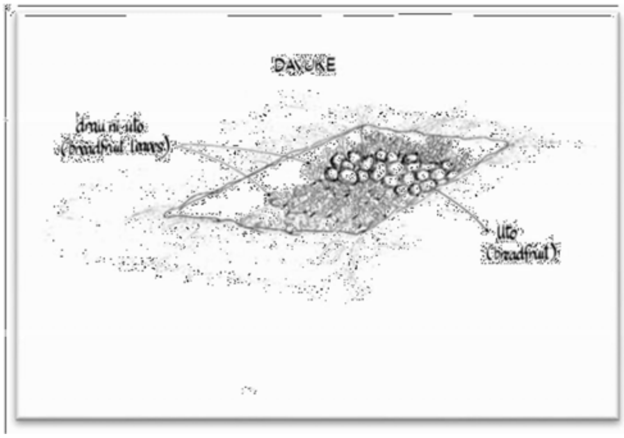

Figure 50: Davuke - Fermentation Pit. Source Lagi, 2015

A *davuke* is used to preserve foods such as banana, breadfruit and cassava through fermentation so that they can be consumed during times of *lauqa* (famine) when there is not much food available. In contrast, Lolo has still been practised by all three research sites in Ra. ***Lolo*** (see Figure 51**)** refers to a thatched house made from local timber and coconut leaves in which *Yabaki* (yams) and kumala are usually stored after they have been harvested. Nowadays, other crops such as *tivoli* (wild yams) and taro are also stored in the *lolo* so they can be used in times of need.

Figure 51: Lolo - Storage for root crops like Yams and Sweetpotato in Ra. Source: Lagi,2015

Out of the above storage methods, field storage is the most common. It also helps the roots to have the most extended shelf life compared to the other storage methods. Despite that, the quality of kumala roots stored in the field also deteriorates with time. All three storage methods were easy to use and are also cheap.

6.4.2.3 Traditional Trading

During ancient times, tribes were encouraged to participate in a system of exchange known as veisolisoli or veidolei, which might refer to prepared or raw food. The trade was usually of commodity goods, allowing both sides to sample each other's meals and break up their repetitive diet. When there is an excess of production, communities from the high and low-altitude parts of Ra transfer their products, such as kumala, to the coastal villages in return for fish and marine staples. These traditional food banks facilitate and enable intra- and inter-community cooperation, where mutual assistance, reciprocity, and indigenous exchange of food and food products are especially vital at times of adversity or extreme natural occurrences within homes, tribes, and vanua (Campbell, 2015). This facet of TEK, according to Houde (2007), refers to knowledge about the environment, including the ecology of living organisms, ecosystems, and their interconnections. Furthermore, the usage (past and present) of our surroundings. Ra's traditional calendar (see Table 5) for kumala production is based on the Fiji traditional calendar (see Table 6). "Fijian knowledge as exemplified by the traditional calendar based on what sources of food existed at different times, reflecting the people's intimate interaction with their surrounding environment," states Veitayaki (2002, p.396). In Ra, kumala is planted in July, when the days are short. The twelve months of the Fijian calendar are likewise named after chores to be completed or environmental phenomena to be observed. There is also a resemblance to the native Tanyuwa tribe of Australia, who had a 12-month calendar that shows their understanding of animal and plant resources (Baker, 1993, p. 137).

Table 5: Ra Traditional Calendar (Leweniqila, 2021)

January • an abundance of rabbitfish (Nuqa) • land crab (*lairo, qari*) and spawns • *kaikoso* matures • An abundance of *ma*rine shellfish *(sici, yaga and golea)*	**July** • abundance of octopus*(kuita)* and *ta* • the flowering of the *vaivai* and *drala* plants • digging up of gardens, planting of kumala, • spawning of the fish *kawakawa*
February •*wi* and *ivi* plants bear fruits • the abundance of citrus fruits	**August** • the abundance of octopus (*kuita)* • the flowering of three species of mangroves
March • digging of gardens to plant yams (*uvi*) • *gasau* plant flowers • crab and *kuka* mature • cover the fish when sun-drying to preventspoilage	**September** • the flowering of mango plants • transplant of yam sprouts • spawning of *kawakawa*
April • the abundance of the fish big-eye scad, (*tugadra*) • *salala* • *kaudamu* plant flowers	**October** • *makosoi* and *dabi* plants flower • *vesi* plants produce fruits
May • *doi* plant flowers • the abundance of *vavai, mumu* • plant taro for the Christmas season • abundance of *salala* • matua na uvi leka • Octopus *(kuita)* start appearing • the fish *ta* start to fatten up	**November** • pineapples and *kavika* ripen • crab (*qari)* well filled with spawn • the abundance of the fish *walu* • the best time of the year to set up fish fences • harvesting of kumala
June • the abundance of octopus (*kuita)* • the fish *ta* spawns • the abundance of and spawning of the fish silverbiddy (*matu)* • the abundance of the fish *Ceva, daniva* • fruiting of the tree *dakua sasalu* • weeding to plant yams (*uvi*), kumala	**December** • the flower pods of the *sinu* plant popopen, making a distinctive sound • baby sharks appear close to the coast, and opentheir eyes • the abundance of the fish *nuqa* • the flowering of the *sekoula* tree • spawning of the fish *saqa* • the land crab *lairo* getting ready to spawn

Table 6: Indigenous Fijian Traditional Calendar. Adapted: Veitayaki, 2002

January *Vula iNuqalevu* (Month of rabbitfish) - The abundance of rabbitfish (*nuqa*) and edible shellfish and bivalves, land crab (*lairo)* spawn, kaikoso - Mango and breadfruit trees bear fruit	**July** *Vula iCukicuki* (Month of digging in gardens) - The abundance of octopus (*kuita*) and rock cod (*kerakera)* - planting of kumala, Yams
February *Vula iSevu* (Month of first fruits offering) - Yam, *dalo* (taro), cassava gardens mature - The offering of first produce (*sevu*) made to chiefsand the church	**August** *Vulaisenidrala* (Month of *drala* plant flowering) - Octopus still in abundance and the little fish priest (*vaya*). - freshwater shellfish (*kai*) matures
March *Vulaikelikeli* (Month of digging in gardens) - Crabs(*qari)*, mud lobster *(mana)* and *kuka* matureand have eggs - yams are dug for consumption	**September** *Vulaivavakada* (Month of sowing seeds) - Yams begin to sprout and sticks are put in place to support the plant. -Rock cod (*kawakawa)* spawns - Mango trees flower
April *Vulaigasau* (Month of reeds) - Big-eye scad *(tugadra)* plentiful - Reeds (*gasau*) thrive and flower	**October** *Vulaibalololailai* (Month of less *balolo*) - Some sea worms (*Eunice viridis, balolo)* collected - breadfruit matures, *makosoi* trees flower, *vesi* trees bear fruit
May *Vulaidoi* (Month of the *doi* plant) - The abundance of chub mackerel *(salala)* - *Doi* plant flowers and bears fruits	**November** *Vulaibalololevu* (Month of abundant *balolo*) - Abundance *balolo* worms - *Makosoi* trees flower - Pineapples ripen and the *kavika* plant bears fruit
June *Vulaiwerewere* (Month of weeding) - Clearing of new yam gardens begin - the abundance of fish silver biddy (*matu*), sardine(*daniva*) and gold spot herring *(herring)*	**December** *Vulainuqalailai* (Month of small rabbitfish) - The abundance of small rabbitfish (*nuqa*) while trevally (*saqa*) spawn - *Sekoula*, *kuasi* and *buabua* trees flower

Agriculture knowledge has provided a way to know and understand what history has indicated on the journey of kumala to the Indigenous Fijians. It has enabled me to voicewhat the people of Ra have said in their story; Sa vosa na vanua indirectly means thatthe land has spoken. The land is like a mother to all indigenous Fijians; it provides everything, protects, and heals. Ra knowledge is handed down from generation to generation in two ways: verbally, via observations, and by learning. According to Olsson et al. (2004, p. 77), "knowledge acquisition is a continuing dynamic learning process." In the Fijian context, this process occurs on two levels: the younger generation learns from the elder generation, while both generations constantly learn to integrate information from the changing environment to employ TEK and live. In Fiji, oral transmission of TEK takes several forms, including stories, myths, legends, songs, and chants. These modes of transmission are linked to places and the basis of an indigenous Fijian's sense of place or feeling of home and identity:

1) Stories (*talanoa*) and myths/legends *(tukuni)*: Like Aesop's fables, there are numerous stories and myths in Fijian society that serve the purpose of passing on values and beliefs to the next generation.

2) Idioms (*ivosavosa* or *i'bole*): This parable is an instance of being sa vosa na vanua in this chapter.

3) Songs (*sere*) and chants *(vucu)*: D'Arcy (2006, p. 71) defines seafaring in Oceania as "songs were meant to keep the crew awake, confident, and aware of risks and landmarks." D'Arcy cited keywords in song phrases and how the meanings were not always clear, such as in the Marshall Islands sailing songs.

4) Dances *(meke)*: Ladies and men dance separately, sitting or standing, with women using fans and males using spears or clubs. As D'Arcy mentioned (year), the meke has a few terms whose meaning is unclear. When I asked the locals (Ra) what the meke was about, they said it depicted their forefathers' journeys over land and water. They told me that the meke was unique to their town and that it belonged to them. It was only done on extraordinary occasions.

The traditional knowledge in Ra has provided a story from their stories on the journeyof kumala to Fiji. This also contextualises reasons why there is a loss of thisagricultural knowledge and the loss of some local varieties of kumala in Ra and remindsus of the importance of kumala to their Vanua (Land).

6.5 The origin of Kumala and its journey to Fiji.

In Fiji, the full history of kumala is still unknown and debated how it arrived. In the three research sites, elders have given their stories on kumala. This information hasbeen passed down generationally, but their stories were not heard as for the people living in the coastal areas:

> *Nau "Va," an elderly woman in Ra said at the age of 15 (1969) he still reckons when her grandfather the "Sauturaga" who was 85 years old (1839) mentioned that Kumala was brought through our forefathers who first settle in Fiji. Moreover, through trade with other Pacific Islands (16th-17th centuries), kumala had dispersed among themselves. These were before Missionaries came. Trade using Drua or Waqatabu as means of transportation. She mentions her grandfather added in 1855 Tonga and Fiji invented a design of their canoe with a combination of Kalia and Drua. These were for transportation and trade among themselves (Mrs Vinaisi S, 2018: pers. comm).*

Respondents also mentioned:

> *Mai vei watiqu noqu kila ni o Ra na vanua ni tei kumala. Mai vei watiqu au kila ni sa tu ike na kumala 1960's – 1970's. Ena gauna e liu era kila tu na veisolisoli era dau caka tu oira na noda qase kei irana vei yanuyanu ena Pasifika e rawati mai kina eso na kakana vaka oqo na kumala ka ra dau sokowavoki tug a ena nodra waqa drua. Kakeimami kila me vaka na kena soli na kia ki vei ira na kai Maori kei Samoa. Mai na gauna ya keimami kila ni Kumala esa tu makawa e viti bera ni ra tadu mai na dau kaulotu. Ka ra vakabauta ni oqo e kau mai vei ira na kai Maori. Me yacova mai oqo keimami dau gunuti coi tu ga ni kakana na Kumala (Mrs Kuini R, 2018: pers. comm).*
>
> The people in the lowland areas in Ra believe that before the missionaries came to the Pacific, they were trading through their canoes in Fiji known as the "Drua." Through this trading, they believe Kumala was introduced to the Indigenous Fijian probably from the Maori people since they were links where our Godmother from the north shared their ***Tattoo ritual*** known as "Kia" which has been named after an island back in the north of Fiji. This form of barter system as they believe kumala was given. These were their staple food before, and today they still have kumala in their everyday meal *(Mrs Kuini R, 2018: pers. comm).*

Although the debate about kumala is ongoing, the people of the high altitudes of Ra believeand supported that kumala was with them between the 16th -17th centuries during the times the Pacific people were trading with each other. From their explanation, it is believed that the crop had the Maori origins of the Polynesian people since Lau and other islands of Fiji have associated links to the Polynesian group.

Se yabaki 1959 (5yrs) au sa va kani tumai kina na kumala mai rauna noqu I tubutubu nodrau talanoa taka tu mai ni kumala ese tu ike ena loma 16th and 17th cenituri. Ka rad au kaya tu ni ma soli mai vei ira na wekadatou na polenisia. E sega ni dua na kakana oqo e kauta mai oira na daukalotu. Oira na tubuda era sa veisolisoli tu iliu keira na kai pasifika tale eso ena nodra vakayagataka tu na Drua (Mr Inoke K, 2018: pers. comm).

For instance, since 1959 when he was five years old one informant's parents had told him a story about how their forefathers have been surviving in Ra, and one of the crops that have been secured to them was Kumala. His parents, still consider that it was through the Polynesian people who shared this crop with the indigenous people of Fiji (Mr Inoke K, 2018: pers. comm).

One of the kumala "gurus" in Ra who has been awarded the kumala farmer of the year by the Ministry of Agriculture annually from 2000-2018 has spoken out on his story:

Auvu se yabaki 1959 (5yrs) au sa va kani tumai kina na kumala mai rau na noqu I tubutubu nodrau talanoa taka tu mai ni kumala ese tu ike ena loma 16th and 17th cenituri. Erau dau talanoa taka tu mai ni oqo na kumala na kena era veisoli taka mai na qase ena gauna eliu kara vakabauta ni a gole mai vakaoqo I Polonisia kara vakabauta nimai vei ira na kai Maori. Qo edua na kawa tamata eda dau veisolisoli vakalevu ena gauna ya. Baleta ni oqo na kumala edua nai tei erawa ni vorata na draki kecega, kakana erawa ni cavu ena gauna lekaleka ga, ka erawa ni maroroi tu ena gauna dede. Mai nagauna ya erau dau vakayaloqaqa taki yau tu ga na tubuqu neitou tubu cake mai medau tei vakalevu na kumala yacova mai oqo. (Mr JD, 2018: pers. comm).

JD believes that it was through trade with the Polynesians, and he mentions that most of our trade was with the Maori people. He mentioned in 1959 when he was five years old this time my great-parents were still alive, they told me that kumala had been here from the 16th -17th centuries and this was a commodity our forefathers havebeen trading with other Pacific islanders due to its storage capabilities, food security tolerant crops and a short term crop. They influenced me to cultivate this crop till today, and this crop has a connection to us all the people in the Pacific (Mr JD, 2018: pers. comm).

Interestingly how this knowledge was passed orally from generation to now, I wonderedhow these kumala stories and knowledge were never kept being recognised in the I-Taukei world. Some of the younger farmers shared their stories stating:

Auvu, au bau kalougata niu qai sucu mai sa ra tei tu na kumala qai otubuqu erau bula tu mai na 17th – 18th cenituri rau mai talanoa taka vei Tamaqu ni kumala ma sat u ena gauna erau bula cake mai kina. Ka ra vakabauta ni oqo na kakana e soli mai vei ira na kai Polinisia vakai ira na kai Maori ena gauna era dau veivoli tu kina vakakakana sei yau (Mr Maika V, 2018: pers. comm).

I was so blessed when I was born Kumala has been already here and my great parents who lived in the 17th – 18th century shared theirstory with my father that kumala has been a staple food for the peoplein Ra when they grew up. He believes that it was brought by through those days of trade back then when our fathers have been trading with other Pacific islands (Mr Maika V, 2018: pers. comm).

One of the youths added:

All I know is that kumala was here before I was born since I got into this world, I have been eating kumala since I was a baby. My great-father once shared with me a story that he thinks that kumala was here in the 16-17th centuries because their forefathers use to share stories with them when they grow up on how my tribe used to travel around searching for places to settle this was the only food that takes with them (Mr Koli M, 2018: pers. Comm).

With these stories being retold it is clear the Ra people still have the knowledge of the connection this crop has from their forefathers, yet few publications have been done on kumala in a Fijian context, and this has kept the indigenous Fijians in a silent mode on kumala origins.

Both Roskruge (2007) and Estrada de la Cerda (2015) stated that among all the main crops transported to Polynesia and Melanesia, the kumala (kumara in the Maori language) or sweetpotato stands out as the notable outlier due to its botanic origin on the American continent. The origins of sweetpotato in Polynesia have been thoroughly investigated, giving birth to several ideas and speculation. Given the widespread cultivation of kumala and its prominence in the far reaches of Oceania, and assuming that the era of extended inter-Polynesian and Melanesian voyages ended after the 14th century, Montenegro et al. (2007) argue that the crop was introduced in the Pacific at an earlier stage than usual.

Recent genetic investigations of ancient kumala specimens acquired by early European explorers suggest that the crop was introduced to the South Pacific in three stages, a model called the tripartite theory (Clarke, 2009; Denham, 2013). First, the kumala entered South America in pre-European times (*kumala* lineage), then the Spanish introduced it from Mexico to the Philippines (*camote*lineage), and then the Portuguese introduced it from the Caribbean to Indonesia (*batata* lineage). Clarke (2009), states that while this model is congruent with current knowledge, several aspects exhibit obvious inconsistencies, a scenario in which more research will assist.

In any case, the existence of kumala in the Pacific remains the most contentious academic component of food plant distribution in Oceania, as well as the most conclusive proof of early interaction with South America. This idea is supported by cultural knowledge (Yen, 1963; Yen, 1974; Estrada de la Cerda, 2015).

Yen (1963) stated ethnological literature frequently admits the substantial number of pre-European kumala variations in the Pacific, including Fiji. According to Saner (as reported in Yen, 1963), kumala diversity throughout the Pacific, particularly Fiji, can only be illuminated by indigenous peoples introducing a vast number of kinds or by vegetative mutations of the original forms. Yen (1963) believes that the actual number of types transferred to New Zealand by Maori was probably low, after taking into consideration the existent plant remnants and the challenges involved in transporting vegetative material across Polynesia. However, Te Rangi Hiroa (1935), "a route through Melanesia would have been far more practical, with most of the crops being brought from Indonesia and New Guinea all the way east to Fiji."

Because of the kumala's position in Fijian society, several accounts abound. A frequent concept in defining a local relationship - through a person or location – to the kumala, therefore emphasizing its significance and direct association to them. From historical discourse and I-Taukei knowledge, there is clear doubt that the Polynesian people, particularly the Maori, introduced kumala as cargo on later trading journeys across the Pacific in their canoe named Drua.

6.5.1 A crop that can feed a nation, but it has been forgotten

Kumala is being marketed as a food security crop in the face of natural disasters (Steak, 2018). This is due to its good agronomic characteristics such as yielding in marginal soils, tolerance to drought and short growth cycle (Steak, 2018). Kumala is also recommended for its nutritional value, which includes high carbohydrates, carotenoids, phenolics, and Vitamin C, and E. (Lebot, 2010).

Burenitu respondents supported the above statement saying:

> *Nai tei ni veivakacokotaki se tei ni sabaya na vanua ni bera ena gauna ni Cagilaba se lauqa (Mr Kelepi K 2018: pers. comm).*

Sweetpotato is a crop that provides security for every household during and after cyclones and is the only crop which is tolerant during drought seasons (Mr Kelepi K 2018: pers. comm).

Respondents explained that before our forefathers were known to be gatherers and hunters as they moved around places searching for their survival so kumala was a crop, to begin with since they knew that kumala was a crop that can cater for them arriving in a new place and it was planted for natural disasters due to it short term crop and their longevity after harvest.

Additionally, Bucalevu respondents stated that kumala is:

> *Tei ni tiko bulabula*
>
> *A crop for healthy living (Mr Kelepi K 2018: pers. comm).*

This crop provided for a healthy life as the leaves are also eaten boiled and was a typicalfood to cater for them during special gatherings. These show how they value crops like kumala and other local foods. The term used is "Magiti ni Vanua." Kumala has not only fed them but has helped them in promoting a healthy eating society.

6.5.2 The vanua of Ra has spoken on the reasons: knowledge and the importance of kumala have been forgotten.

1. Market driven (Capitalisim)

Nai vesu mai vei ira na dauveivoli. (Na Vanua ko Ra, 2018: pers. comm).

Respondents were clear the drive for business from exporters has influenced our system.The young generation now tends to forget the importance of how I-Taukei does things, yet the commercial focus has influenced the move from local foods to planting more crops which exporters require.

Respondents from the three research areas stated that this was a problem that they believe was the main reason many traditional crops like kumala, uvi, Tivoli and Kawai have been forgotten since people were more focused on commodities for export demand. They believed that they had been influenced by money rather than focusing on their local foods which can sustain them from disasters and improve their health.

A quote given by one of the Turaga ni Koro in Ra goes

"Cassava has made the Ra people drunk." Sa vei vakamatenitaki nai tei oqo na tavioka.

> *Oqo edua na vuna sa yali kina oira na tei makawa (uvi, tivoli,kumala) kei na so na kila vaka dau teitei vei keda na I-Taukei sa sega kina nira dau kila kina oira na gone oqo eso na i vakarau ni teitei e tu vei keda. Baleta gona oqo era sa mateni taki tu ena tei tavioka matai ni tavioka e rawarawa na kena qaravi ni sa bula ga sa biutu karua era sa tea ga na tei koya voli rawarawa mai vei ra na exporter. Na kawai me baleta na nodai tei kei na kena maroroi na noda kila vaka teitei sa sega ka sa na sega ni ra na kawai kina oira na tabagone nira sa kila nio keda na qase ni vanua sa da lecai ka tu (Nemani R, 2018: pers. comm).*

He has used a metaphor of drunk as young people nowadays have been lost in the farming of our local root crops like kumala. This local food has stories and knowledge embedded in them that consolidates its connection to the indigenous Fijians. However, young people are now driven by the demand of exporters. So, it is a challenge to the older generation to restore the importance aligned to local crops.

2. Inappropriate Government or MOA plans and strategies for the indigenous farmers.

> *Na tabani teitei sara sega ni vakabitaka nai tei vaqo ka ra sa mai vei keimami eso nai tei ko vou ka keimami sega ni kila na kena qaravi.* Oqo era sa tukuna tiko ni sa na sega ni vukei edua na dau teitei ko sega ni teitei me bisinisi *(Norani M, 2018: pers. comm)*.

Inadequate Agricultural Annual Corporate Plans on Rural Outer Islands have been asignificant drawback to the indigenous Fijians. Survey respondents stated that one of the reasons they have a loss in valuing the importance of kumala crop but as a spokesman of their traditional foods in their villages was that the Ministry of Agriculture has been introducing other commodities to them such as rice which is new to them and the agricultural practices. "To them, it is more than culture shock". MOA has encouraged farmers in the rural and outer islands to produce commodities which are new to their culture and their land. In comparison, kumala is a crop reintroduced to them after any disasters. For them, kumala has been rated as an option rather than a priority for the indigenous Fijians. The Government bodies must be reminded that it is essential for them to identify suitable crops for Ra based on factors such as soil, climate and landscape. Interestingly, respondents stated that it has been over a decade since any soil tests were done. They are not aware of their soil physiology or chemistry, which is particularly important.

The government and the Ministry of Agriculture want the indigenous Fijians to follow indo-Fijian (commercial) practices in agriculture. This performance has enabled some of the i- Taukei people to forget and lose interest in their local food and the knowledge of local practices. The Ministry of Agriculture now has stated that commercial farmers will be their priority. For the indigenous people in Ra who are subsistence farmers, this statement and action from the Ministry of Agriculture have affected their activity.

Due to rapid development in many locations where indigenous people dwell, traditional knowledge is being forgotten. Because of political demands on the Ministry of Agriculture, indigenous people have been evicted to make way for development projects such as tourism and retirement homes (Duncan & Sing, 2009).

A respondent in Burenitu explains:

> *Na veivaka torocake taki kei na so na veika era solia rawarawa tu namatanitu oqo e vaka vu na nodra vucesa na kawa I-Taukei. Qo me vaka na soli wale ni card ni basi, kakana, lavo vei ira na dau teitei. Oqo eso na sala koya vaka vuna na kena yali nai tovo, kila ka kei na tei na I-Taukei. Vei keda sa vinaka tuga vei keda meda vakani tiko gaena sevuni mai na bunoca naka. Oqo na bula ni veivakayagataki vei keda koya vakavuna tiko na bula dravudravua ka levu sara biuta na vanua sa ra lako yani kina ki tauni (Norani M, 2018: pers. comm).*
>
> *A Burenitu respondent further elucidated the disadvantages of Freebies and some development from the government. Some of the development and freebies, such as free bus fares and food vouchers that the government has been offering had encouraged people to be lazy. They have observed this has allowed people to go to town every day, and ignore what is necessary to be done in their families. Moreover, all the government plans for agricultural incentives does not necessarily suit what is appropriate in different areas with different soil types or landscape, but the ministry applies the same strategic plans to all farmers in every area (Norani M, 2018: pers. comm).*

3. The research development role is dependent on concepts in Agriculture.

Sa sega na vakadidike ena tabana ni teitei me vaka eliu (Maika, 2018:pers. comm)

Increasing the production of agricultural products in rural and outer islands is of paramount importance, and research and development can support this. Farmers and agricultural scientists generate new and improved inputs and production processes, increasing R&D efficiency and leading to potential improvements for agricultural goods while reducing demand for natural resources.

Traditional crops like kumala varieties have been trialled at Dobuilevu Research Station (Ra District) in previous years, and planting material has been provided and distributed to farmers around the Ra district. However, now there are few or no research trials being sponsored by the ministry, and this is the main reason why there is a loss of kumala and yam varieties in Ra.

> *Auvu i liu e dau bucini tu I Dobuilevu research station na i tei ni kumala era veiwaseyaki mai ena vei korokoro, ia na gauna oqo sa sega (Maikeli K, 2018: pers. comm). Respondents in the three research areas explained how kumala planting material was to be grown and stored in gene banks at Dobuilevu Research Station andthen supplied to villages (Maikeli K, 2018: pers. comm).*

This statement was supported by a retired Agriculture Officer, stating that:

> *Na gauna au se cakacaka tu kina ena tabani teitei e via tini na kawa ni kumala keitou dau bucina tu e Dobuilevu. Ka dau veiwaseyaki enaveikorokoro i Ra, sega vakadua ni dua na yabaki me lailai na I tei ni kumala ena vanua ko Ra. Ia na gauna oqo sa sega ca via rua walegana kawa kumala keimami se vei soliyaka wavoki tiko qo (Tui K, 2018: pers. comm).*

> *More than ten local varieties of kumala were previously maintained in their gene banks and supplied to all villages in Ra. One respondent mentioned that there was not a year Ra has been without Kumala planting material until the present (Tui K, 2018: pers. comm).*

The lack of planting materials for kumala has made many farmers lose interest in farming kumala, and Ra has lost its reputation as the central district for planting kumala,and now only sugarcane is grown.

4. Rural to Urban drift

> *Sara veivaka calai na levu ni kawa tamata tani era sa gole tiko mai oqo na matanitu sa sega ni rawa tuvana rawa edua nai tuvatuva me sabaya na kedai tei nai I-Taukei (Emosi B, 2018: pers. comm).*

> *Migration has influenced the taste preference across Ra. Respondents explained that through immigration of these different nationalities to Fiji, there had been a risk not only to our culture but to the livelihood of what we eat (Emosi B, 2018: pers. comm).*

Exposure to other cultures, food preferences and urban activities has impacted many i-Taukei, especially the youth, who have quickly adapted to these new foods. When urban dwellers return to the village, they then influence other youth in their village, and this is now a trend for the people in Ra.

5. Education System

> *Auvu na gauna oqo edua na vanua bibi mera tuberi kina na gone oqo me baleta na kila kei na ka me baleta na keda kakana oqo e koronivuli. Na vuli na gauna oqo sa duidui vakalevu sara sega ni vakatavulici na gone me baleta na kilaka vaka I-Taukei kei na ka me baleta na walewale*

ni teitei eda dau bula taka (Merani K, 2018:pers. comm).

The educational system in Fiji has to teach this traditional knowledge from primary, and secondary schools and finally to tertiary. Bridging these gaps has to be the government institute's priority (Merani K, 2018: pers. comm).

Schools and Tertiary institutions are a place where knowledge of how to grow traditional foods should be taught but sadly it is not in the various curricula. So, respondents from the three research sites believe if it has been neglected to be taught by parents at home, then the government of the day have to include this in the education curriculum.

6. Less Family Time

Most of the knowledge in agriculture farming in an indigenous Fijian family has been transferred easily through family moments. This is a safe and the most comfortable way to interact with each other in the family. Moreover, within this space, dialogue between parents is essential. Every evening, after family prayers, they get down to evaluate what they have accomplished throughout the day and what needs to be improved or done. Parents share their knowledge and the importance of any crop to be grown. Parents should also control what to eat and what is to be planted at their home. These were what their forefathers practised. So, from their family time, the respondents stated that this would be the safest place to share yet people have neglected this.

Respondents stated that:

O keimami i Ra ena tiko na neimami gauna vata ena veiyakavi ni oti na lotu vaka vuvale me keimami dau vei talanoa taka na vei kakece mebaleta na teitei na mataqali tei cava metou na tei ni mataka, vula oqo.
Oqo na matai ni koronivuli e vale. Sa levu na gauna oira na turaga na qase ni vanua era dodonu mera liutaka se ra wasea na kila qo era qai ia na sosoqoni e veiyakavi na gugunu yaqona koya na kauta mai vei ira na vucesa (Talica K, 2018: pers. comm).

Family is where this knowledge should be shared first if schools and universities do not play their part. At home, after prayer in the evening, they sat and discussed what they had to do the next day or month. Fathers and elders share some knowledge that they need to apply in this type of landscape or soil type. However, some of the elders in their village are busy out drinking kava this would be a reason why knowledge and why kumala have been neglected in their village. Man, nowadays, it is lazy to plant this precious crop (Talica K, 2018: pers. comm).

6.6 Integration of TEK and western sciences and their contribution to sustainable livelihood

Western science (scientific research trial) and TEK have complementary functions. Neither should be discounted or favoured over the other since both have strengths and weaknesses in the adoption of suitable kumala agricultural techniques, skills, and knowledge that will affect the Vanua of Ra's livelihood.

The differences between TEK and non-indigenous knowledge result from different motivations and worldviews throughout its genesis and ongoing evolution, according to Berkes (2008). TEK sprang from the indigenous peoples' organic development of their culture and their living experience in the environment. Non-indigenous knowledge is more interested in comprehending the planet, which has resulted in economic supremacy and western environmentalist concepts of sustainability. Negotiation, according to Armitage et al. (2007, p.27), is "a type of communication that allows parties to re-examine their worldviews... and co-managers must also agree (or agree to differ) on principles and goals. Integration requires stakeholders to "sit down at a table of negotiation and conversation in a society where diverse epistemologies are welcome.... establishing agreed-upon views" (Reid et al., 2006, p. 320). These include listening to and contemplating diverse worldviews and cooperating to uncover similarities to build new models and new environmental philosophies (Olsson et al., 2004).

Armitage et al. (2007, p.5) identify four important characteristics of adaptive co-management: "learning by doing, cooperation and power-sharing across the community, regional, and national levels, and managerial flexibility." In this part, I draw on the 'integration of diverse knowledge systems' component of the adaptive co-management concept. I believe that combining TEK and non-indigenous knowledge as part of an adaptive co-management strategy draws on the benefits of both TEK and western science. Berkes (2009) advocates for knowledge co-production, and hence the creation of new models, through collaborations and conversation between traditional knowledge and western science (see Figure 52), bargaining "for the mutually accepted stance" (Reid et al., 2006, p. 320). These are particularly pertinent now since "there is rising recognition from within the scientific ranks of the necessity for input into kumala farming, scholarship from knowledge traditions other than western science" (Chambers, 2009, p. 197). The concept of co-production and integration can overcome the tendency for one type of knowledge to appear superior to the other or to thrive in agriculture without the other because both have essential complementary roles to play in resurrecting kumala in Fiji.

Foale (2006) expresses concern about integrating TEK with knowledge of kumala agriculture experiments, however, Veitayaki (2002) asserts that TEK must be integrated into agricultural management procedures. According to Houde (2007), some of the benefits of incorporating TEK include the advancement of western scientific knowledge and vice versa, as well as the adoption of decentralized and suitable agricultural management regimes. This is also consistent with Houde's (2007) recommendation of merging TEK with western science for EIA work. According to Houde (2007), the integration will also inspire new environmental ethics for both TEK and non-indigenous knowledge.

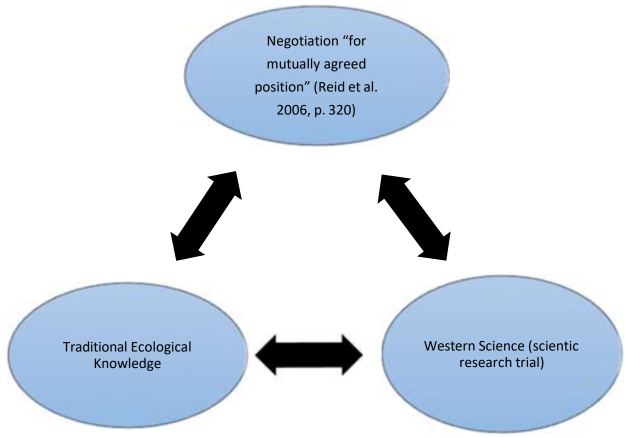

Figure 52: Integration between Non- indigenous knowledge and TEK using negotiation. Adapted by Tora, 2020

Integrating TEK with western science has its own set of challenges. According to Reid et al. (2006, p. 319), some scientists show a general lack of regard for traditional and local knowledge. Lack of a common language is another hurdle to integration, especially when TEK is developed and transmitted in a language with a cultural background distinct from non-indigenous knowledge (Casimirri, 2003). Apart from that, "not all traditional behaviour and belief systems were ecologically adaptable in the first place, and some became maladaptive over time owing to changing conditions," according to Berkes et al. (2000, p. 1252). Unlike non-indigenous knowledge, TEK does not consist solely of visible data.

6.7 Chapter Summary

This chapter has briefly outlined some of the functions that the Fijian way of life (bula vakavanua) plays in encouraging the development of kumala agricultural farming in Ra, with an emphasis on Traditional Environmental knowledge (TEK). Based on field experience and Berke's knowledge-practice-belief complex, TEK is analyzed in four components: values and beliefs; practices; skills; and knowledge (2008). Solesolevaki is a tool for personal and family growth, communal development, fulfilling sociocultural commitments, economic development, minimizing rural-urban migration, and putting many hands to work in reconstructing a vibrant community. Through solesolevaki the indigenous Fijian could be self-sufficient with food; hence it will provide a future avenue for climate-smart agriculture.

In the last decade, livelihood views have become essential to rural development theory and practice. However, where do such viewpoints originate from, what are their intellectual foundations, and what forces have impacted their evolution? Traditional agricultural and production practices based on kumala bring people together and link them to the environment. Local communities collaborate and assist one another. Local farmers gain knowledge and skills through listening to, interacting with, and observing their elders. This connection is crucial in the transmission of information from elders to the next generation. Participant responses confirm that traditional knowledge plays an essential role in contributing to the sustainable livelihoods of farmers. Participants in Nabukadra village stated that kumala could sustain the livelihood of people in their community because it provides a sustainable food supply for them during excellent and extreme weather conditions. It also provides aconstant source of income, is the primary source of food during community feasts, can be sustainably produced, and ensures a continuous supply of food throughout the year.Kumala is also widely used in cultural ceremonies.

Likewise, in Burenitu and Bucalevu, the use of traditional knowledge in kumala production has and will continue to endure the livelihood of the people in the community. Government entities and outsiders should accept, respect, and recognize the Vanua of Ra's principles and beliefs. The ambitions of the community, as well as their values and beliefs, should be represented in the Ministry's yearly cooperation plans. Strategies should include the conservation and improvement of agricultural expertise, and the Ministry of Agriculture should prioritize native foods like kumala, Uvi, Tivoli, uto, and kawai in rural and outlying islands in Fiji. These findings shed light on the current state of kumala production and the decline of kumala variations. Furthermore, they support the ability of kumala to contribute to Climate-Smart Agriculture in Ra and throughout Fiji in general.

Chapter 7

Results

Multi-environmental Trial: Climate Adaptation on Kumala in Ra.

A case study trial of drought-tolerant and best-yielding kumala variety suitable to climate conditions in the villages of Nabukadra, Burenitu and Bucalevu in Ra.

7.1 Introduction

Neither traditional knowledge nor Western science alone can provide all the answers needed to revive kumala agriculture farming for the Ra district, but traditional farming knowledge and the need for food security will provide an avenue for climate-smart agriculture in the district of Ra. The significance of collaborating with both Western science and Indigenous Knowledge, also known as Traditional Environmental Knowledge, to address Ra's discursive difficulties is central to the research endeavour in this thesis. However, in the procedure of integrating two diverse knowledge systems into kumala agriculture farming, the study has confirmed that experimental trials in the three altitudes have set a benchmark for future kumala farmers in Ra. The null hypothesis of this multi-environment trial (MET) has been explained in chapter one. Moreover, the experimental design and data collection methods, and data analysisprocedure are briefly explained in chapter four and the field layout of this MET is concisely detailed in Appendix five. The Ministry of Agriculture in Fiji maintains around 44 sweetpotato accessions in their research collections, only nine of these are local varieties and five are currently cultivated by farmers. The five common varieties which were used in this research trial were Honiara (purple skin & white flesh), Vulatolu (white skin & white flesh), Local Purple (purple skin & white flesh), Carrot (orangeskin & orange flesh) & Golden Brown (brown skin & golden brown flesh).

Detailed measurements were obtained during the physiological growing stages and final harvest stage (see chapter 4). Results for the measurements were taken across the three different sites representing the three different environments. The relationship between tuber yield (TY) and tuber dry matter (TDM) was also shown using tables (TDM). The genotype by environment interaction (GEI) will potentially have an impact on variety selection.

The Additive Main Effects and Multiplicative Interaction (AMMI) model was used to analyze the adaptability and stability of five kumala genotypes and to understand the influence of GEI. An AMMI biplot was created to plot genotypes and environments against their respective means. The AMMI model is widely used as a statistical tool in the analysis of multiple-environment trials. It serves two purposes: comprehending complicated GEI and enhancing accuracy. MET is a practice used to evaluate high-potential varieties over multiple years and multiplelocations to identify superior individuals (Acquaah, 2012). In MET, the main effect of environment (E), genotype (G), and GxE interaction using appropriate statistical systems are determined. Also, through MET we can estimate yield, identify stable varieties in different environments, and provide a guide for selecting superior genotypesfor planting at new sites (Crossa, 1990). METs are widely used in the evaluation of grains and cereals, legumes, vegetables, fibre crops, and other crops. In sweetpotatoes, MET has been used for testing and screening for improved tuber yield and disease resistance (Paget, 2014).

The structure of this chapter is depicted in Figure 53 below:

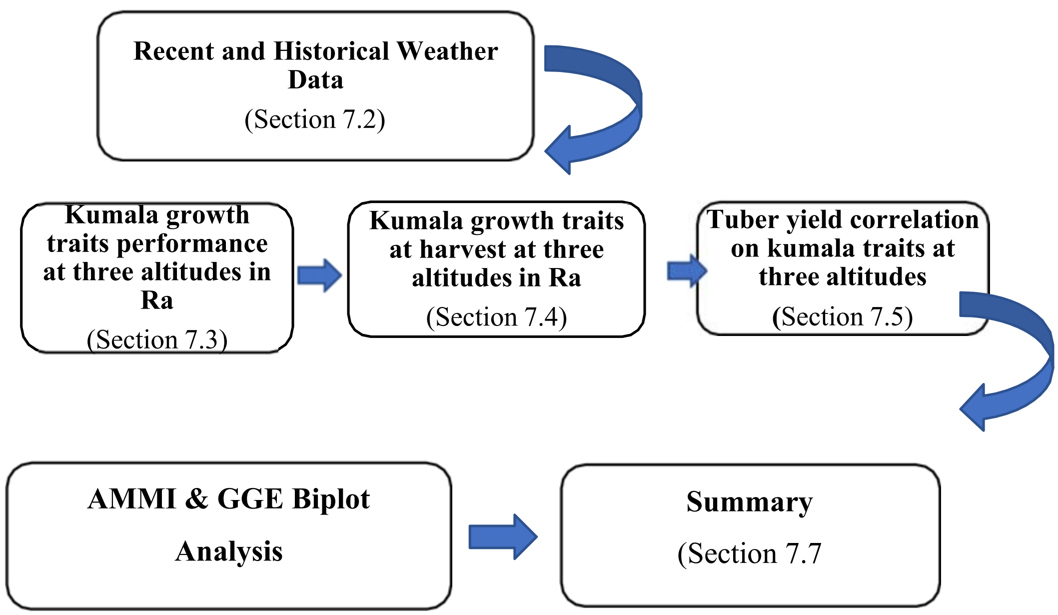

Figure 53: Outline of Chapter 7

7.2 Recent and Historical Weather Data

Recent (2017-2019) weather data from the kumala growing months of July to January 2019 revealed a higher mean temperature in Burenitu (30.8°C) and Nabukadra (29.7°C) than in Bucalevu (28°C), with more than a 5°C rise from the 1967-2016 (44 year-average) data across these locales (see Table 7). Furthermore, a closer look at long-term temperature data shows an increasing trend across sites, with Burenitu experiencing the greatest increase from 22.7°C to 31.5°C (see Table 7) in June and July, correlating with the Ministry of Environment's (2016) prediction that warming as a result of climate change in Ra will be significant at greater elevations.

Table 7: Recent and historical weather data in kumala traditional growing months (June- December) in Ra. Source: NIWA, 2018

Parameter	June	July	Aug	Sep	Oct	Nov	Dec	Mean Temp (°C)	Total Rain (mm)
				Sweetpotato Growing Months					
Nabukadra (20m asl)									
Recent: 2016 - 2019									
Temp (°C)	29.2	28.7	31.5	30.4	30.6	29.3	28.7	29.7	
Rain (mm)	56.4	63.4	63.4	78.9	82.4	80.2	89.4		514.1
Historical: 1971 - 2015									
Temp (°C)	23.6	23.5	23.5	24.7	24.4	25.4	26.1	24.5	
Rain (mm)	57.4	65.4	64	79.8	86.5	87.5	81		521.6
Burenitu (120-150m asl)									
Recent: 2016 - 2019									
Temp (°C)	31.5	31.2	31.5	30.4	30.6	31.8	29.2	30.8	
Rain (mm)	39.2	39	50.3	54.3	45.3	48.3	43		319.4
Historical: 1971 - 2015									
Temp (°C)	23.6	22.7	22.7	23.5	24.4	25.4	26.1	24	
Rain (mm)	51.4	58.4	50.3	45.6	89.4	67.5	72.3		434.9
Bucalevu (>180m asl)									
Recent: 2016 - 2019									
Temp (°C)	26.5	27.6	27.8	28.3	27.3	29.5	29.5	28	
Rain (mm)	79.6	83.5	87.5	100.6	102.3	106.5	106.9		666.9
Historical: 1971 - 2015									
Temp (°C)	23.6	23.7	23.7	23.5	24.4	25.4	26.1	24.3	
Rain (mm)	83.4	84.5	88.5	102.4	104.6	107.3	106.9		677.6

Bucalevu had the most days with temperatures below 30°C, which are ideal for kumala tuber growth, whereas Nabukadra and Burenitu had a higher number of days in the 25-29°C range and 30°C (Table 7), which are thought to delay tuber growth, respectively (Levy and Veilleux, 2007; FAO, 2008). It is important to note as well that the number of days within the 25-29°C range and ≥30°C increased in the recent season (2017/2018) as compared to previous years (1971-2015), especially in Nabukadra and Burenitu, suggesting a recent incidence of more severe heat stress.

On precipitation in recent seasons (2016/2019), total rainfall was below optimum for kumala production in Burenitu (319.4mm) and Nabukadra (514.1mm) and optimal in Bucalevu (666.9mm) (Table 7). A comparison of the 2016-2019 average with the long-term 1971-2015 (44-year- average) data showed a minor decrease in rainfall in the three research sites (Nabukadra,Burenitu, and Bucalevu). A f declining rainfall which contributed to water scarcity in Burenitu and Nabukadra from July to August 2018 concurring with sweetpotato vegetative and tuber initiation stages was observed. Only Burenitu endured genuine drought conditions due to its reliance on precipitation for sweetpotato crop production, although Bucalevu got extra irrigation and some rain from June to August. Long-term rainfall data throughout the kumala growth seasons, on the other hand, reveals a decreasing tendency in all three research sites. Reduced soil moisture was forecast in many sections of Eastern and Western Fiji, although with greater rain in Eastern portions and drought conditions expected in Western Fiji, according to a report by Rhee & Yang, (2018).

7.3 Kumala Performance at Different Altitudes

7.3.1 Number of Leaves

Table 8 shows the leaf number / plant obtained for each variety at different altitudes. The ANOVA results of the average mean (μ) number of leaves at Nabukadra, Burenitu and Bucalevu (Appendix 1) show a highly significant positive interaction of location and days after planting (DAP) ($P<0.001$) on the number of leaves. In contrast, there was no significant ($P>0.001$) interaction of location with varieties for leaf numbers. The average mean (μ) values were similar for the Bucalevu site (high altitude) ranging from 12.7 to 17.1 on average. The mean average number of leaves for Golden Brown, Carrot, Local Purple, Vulatolu, and Honiara are respectively: 17.1, 12.7, 14.0, 14,1 and 14.2. For the Burenitu site (low altitude), the Golden Brown variety has the highest average mean (μ) number of leaves (32.7) compared to Local Purple (29.6), Honiara (27.4), Vulatolu (27.4) and Carrot (25.0) with the least average means number of leaves.

Moreover, at Nabukadra (coastal) Golden Brown (28.8) has the lowest average means numberof leaves followed by Carrot (32.7) whereas Honiara (43.8), Vulatolu (42.8) and Local purple (42.1) have the average means (μ) number of leaves. Leaf number variations in kumala plants are impacted by morphological changes, particularly the form and size of the leaves, which may alter LAI in sweetpotatoes (Tsialtas et al., 2008). The Burenitu location, which was more susceptible to drought, had a greater leaf number. Some parameters, such as total leaf area and the number of leaves affect high LAI. The capacity of kumala plants to adjust to changing environmental circumstances is determined by the quantity and area of their leaves. During wet seasons, kumala types planted on dry terrain produced and grew continuously. In sweetpotato crops, persistent leaf growth will substantially inhibit tuber production (Dubois et al., 2013). Agata and Takeda (1982) found that the sweetpotato plant's larger leaves and greater LAI would have a detrimental influence on tuber development.

Kumala leaf, stem, and tuber yields are substantially lower in the hot-dry season than in the cool-wet season. These findings are consistent with research from Australia, where sweetpotatoes were planted at various times of the year and various elevations (Harper and Walker, 1984). These are explained in part by the susceptibility of sweetpotato genetic features to altitude, soil moisture, and water availability (Holwerda and Ekanayake, 1991; Xiao and Xiao, 1995). Results also show that more leaves were produced by varieties that were planted in areas with excess rain both during the primary production season and off-season, whereas in this study, comparable results were recorded from varieties planted at the Bucalevu site. For forage purposes, the sweetpotato could be planted year-round. However, outside of the primary season, biomass output will be decreased, as demonstrated in this study. The reaction to soil moisture differs depending on genotype (Demaganteet al., 1989). Golden Brown, for example, outperformed the other types during the hot-dry season. This might indicate that different genetic stocks should be recommended for each season of the year. The native Fijian (local purple) variant outscored all other types in this study.

7.3.2 Number of Runners

There was a highly significant interaction between altitude, as indicated by the sites and the five kumala varieties ($P<0.001$) used in this study (Appendix 1). There was also a significant interaction between days after planting (DAP) and a variety of sweetpotato for runners (Appendix 1). Table 8 shows the average mean (μ) number of runners obtained from each variety at different altitudes Carrot, Vulatolu, and Local Purple at Bucalevu had the same mean (μ) average number of runners at 5.18 while Golden Brown has the lowest mean (μ) average number of runners at growth. Honiara (7.14) had the highest average mean (μ) number of runners during the growth stage. As for Burenitu (low altitude) site, the Vulatolu variety has the highest average number of runners followed by the Local Purple variety. Both Carrot and Honiara varieties had the same average number of runners while Golden Brown provided the lowest mean (μ) average number of runners. At Nabukadra (coastal area) site, the Golden Brown variety had the lowest mean (μ) average number of runners followed by the Carrot, Vulatolu and Honiara varieties in that order. Local Purple had the highest mean average number of runners at their growth stage. This result is comparable with data from Bunphan & Anderson (2019), who tested the effect of planting pattern and season on some agronomic performances and yield of three sweetpotato varieties, showing a highly significant difference by variety for the number of runners. Bassay (2017) found a positive correlation between sweetpotato varieties planted in different areas andseasons with five planting practices on the number of runners obtained per plant at 60 days after planting (DAP).

Overall, the average mean number of runners averaged over the five kumala varieties was highest for the Bucalevu site, followed by Burenitu and Nabukadra. Hartemink et al. (2000) showed that low altitudes produce lower runner numbers compared to the high-altitude areas in Papua New Guinea. The study by Yahaya et al. (2015) found a substantial interaction between variety and location on the number of runners. The large variation in plant kinds and number of runners seen in their experiments was interpreted by Mukhtar et al. (2010) and Tewe et al. (2003) as an indication of the importance of genotype in the control of these traits. Several writers had made similar discoveries on the great heterogeneity in sweetpotato genotypes for a variety of sweetpotato features (Nwankwo & Afuape, 2013).

7.3.3 Length of Runners

Results show (see Appendix 1) on ANOVA that there was a highly positive significant interaction ($P<0.001$) on the runner lengths at the three research sites. The five kumala varieties at each different location showed a significant interaction among themselves. Additionally, there was a significant positive interaction ($P<0.001$) of the length of the runners on different days after planting among varieties at each altitude. Table 8 shows the average length of runners. At the Bucalevu site, the Honiara variety had the highest mean (μ) average length. Vulatolu, Local purple, and Carrot variety had similar runner lengths, whereas Golden Brown had the lowest runner length. At the Burenitu site (low altitude), the Vulatolu variety had the highest mean (μ) average runner length compared to the other kumala varieties: Local purple and Carrot were similar in value and Golden Brown was the least. The five sweetpotato varieties grown at Nabukadra produced a high mean (μ) average length of runners. Results in Table 8 show that Local Purple had the highest mean (μ) average length of runners followed by Honiara, Vulatolu and Carrot in that order. Golden Brown variety had the lowest mean (μ) average length of runners among the five varieties of sweetpotato grown in the Nabukadra site. The increased length of runners and the total number of runners per plant at decreasing plant density was primarily due to the formation of secondary runners (Somda and Kays 1990a).

The highest average length of runners was gained by Local purple grown at Nabukadra (coastal area). The Golden Brown variety grown at the Bucalevu site (high altitude) had the lowest mean average runner length. The average of the five varieties for each of the three-research sites results shows that the varieties grown at Nabukadra had a higher average length of runners than those grown at Burenitu. The varieties grown at the Bucalevu site had the lowest means (μ) average length of runners. Mau et al. (2019) evaluated sweetpotato genotypes at different altitudes and significant differences in vine length were recorded and observed. In addition to genetic differences among the sweetpotato genotypes, differences in vine length between the present study and the previous studies may have also been caused by differences in environmental conditions where the sweetpotato genotypes were grown (Rahajeng and Rahayuningsih, 2017).

Table 8: Kumala performance at different altitudes in Fiji.
Error bars indicate a ± standard error of the means. Different letters in a column indicate means a statistically different on Tukey's HSD test (P< 0.05)

		No. of Leaves (numbers/plant)			**No. of Runners** (numbers/plant)			**Length of Runners** (cm)			**Chlorophyll** (%)			**% Establishment rate**		
ENV	**GEN**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
BUCALEVU	**Carrot**	12.66a	5.403	42.66	5.18c	1.504	21.07	27.36c	28.643	83.95	36.26a	4.046	11.16	72.92a	3.632	4.98
	Golden Brown	17.1a	5.34	31.27	3.18a	1.271	39.95	22.7a	26.362	116.13	41c	5.898	14.39	100b	0	0
	Honiara	14.2a	5.469	38.62	7.14b	1.747	33.72	34.12b	29.191	106.68	38.96b	5.171	13.27	100b	0	0
	Local Purple	14.0a	5.46	39.02	5.18c	1.747	33.72	27.36c	29.108	106.06	38.99b	5.151	13.21	100b	0	0
	Vulatolu	14.1a	5.464	38.63	5.18c	1.747	33.72	27.45c	29.187	106.67	39b	5.185	13.3	100b	0	0
BURENITU	**Carrot**	24.95a	20.707	82.99	3.4ac	0.579	10.42	33.35c	21.577	55.38	35.97a	4.103	11.4	70.6a	7.125	10.09
	Golden Brown	32.7ab	21.406	65.52	2.4a	0.664	27.64	29.88a	21.22	71.01	40.7c	5.786	14.22	100b	0	0
	Honiara	27.41ab	20.865	76.13	3.4ac	0.664	19.52	33.35c	20.759	62.25	38.71b	5.362	13.85	83.33c	0	0
	Local Purple	29.61ab	21.294	71.91	4.4bc	0.664	15.09	36.01d	21.271	59.08	38.77b	5.435	14.02	91.67d	0	0
	Vulatolu	32.67b	20.863	76.23	5.56b	0.664	19.52	38.96b	20.8	62.36	38.18b	5.378	14.09	83.33c	0	0
NABUKADRA	**Carrot**	32.65a	23.521	72.03	3.6ab	0.954	21.87	49.31b	32.478	63.04	36.15a	4.097	11.33	73.26a	8.949	12.21
	Golden Brown	28.8a	14.312	49.71	2.36a	0.954	40.4	34.9a	23.946	68.62	40.83c	5.818	14.25	100b	0	0
	Honiara	43.75b	31.55	72.11	3.44ab	0.767	22.27	49.61b	35.894	72.35	38.46b	4.832	12.56	100b	0	0
	Local Purple	42.1b	31.076	73.76	4.36b	1.071	28.57	51.52b	35.131	71.07	38.42b	4.968	12.93	100b	0	0
	Vulatolu	42.8b	30.919	72.29	3.75ab	0.944	26.25	49.43b	35.413	71.81	38.73b	4.99	12.88	100b	0	0

7.3.4 Chlorophyll Content

Chlorophyll plays a significant role in sweetpotato growth. ANOVA shows that there was a highly positive significant interaction ($P<0.001$) on the chlorophyll content of the five kumala varieties grown at different altitudes. In contrast, there was no significant interaction between the collective chlorophyll content and the 3 different research sites. Interestingly there was a highly positive significant interaction ($P<0.001$) on the chlorophyll content from the five kumala varieties at different days of planting (DAP).

Table 8 shows the average chlorophyll content of the five kumala varieties at different altitudes in Ra. Golden Brown variety has the highest chlorophyll content among the varieties grown at Bucalevu. The other three varieties, Vulatolu, Local purple, and Honiara had similar values with no significant difference ($P>0.001$) between them. The Carrot variety had the lowest average chlorophyll content at Bucalevu. In Burenitu, comparable results were observed for Golden Brown with the highest average chlorophyll content followed by Local Purple, Honiara and Vulatolu. There were no significant differences ($P>0.001$) among these three varieties. At Burenitu, the average chlorophyll content was lowest for the Carrot variety. At the Nabukadra site, the Golden Brown variety had the highest average chlorophyll content, Vulatolu, Honiara, and Local purple had a similar chlorophyll content (no significant difference amongst them) and Carrot had the lowest.

The highest overall average chlorophyll content was achieved by the Golden Brown variety grown at Bucalevu while the Carrot variety grown at Burenitu achieved the lowest average chlorophyll content. Rahajeng & Rahayuningsih (2016) state that the highly significant differences in chlorophyll between varieties on different altitudes indicate that high variability is due to phenotypes and genotypes or environmental factors. Regarding the three research sites, the chlorophyll content of the five varieties grown at Bucalevu had more average chlorophyll content than the kumala varieties grown at Nabukadra and Burenitu. The results indicate that they are more likely influenced by genetic factors (Chahal and Gosal, 2010; Naidoo et al., 2016).

7.3.5 Establishment Rate

The establishment rate of the varieties (Appendix 1) indicates there was a highly positive significant interaction ($P\leq0.001$) on the five kumala varieties' establishment rate at different location sites and among the varieties. In contrast, there was no significant interaction between the establishment rate percentage on different days after planting (DAP) among the varieties at the three research sites.

At Bucalevu and Nabukadra, four varieties (Golden Brown, Honiara, Vulatolu, and Local Purple) had a consistent establishment rate of 100% while Carrots at both sites had a lower average establishment rate. At Burenitu the Golden Brown variety achieved the highest average establishment rate compared to the Local Purple. Vulatolu and Honiara showed no significant differences in their establishment rate. Pardales (1993) discovered that adventitious roots in sweetpotato sprout as early as one day after planting when soil conditions are favourable for growth. Adventitious roots grow and lengthen to some extent in unplanted vine or stem cuttings stored in the shade with high humidity (Pardales and Esquibel, 1997). Normally, lateral roots grow up to the third order, with their density decreasing as the order of lateral branching rises. The first-order lateral roots appear immediately after the adventitious roots have extended, but the second and third-order lateral roots need some time to appear.

The Carrot variety had the lowest average establishment rate at the three research locations, Results show that the five varieties grown at the two lower altitudes (Bucelevu and Nabukadra) responded and adapted well to their environmental conditionand soil type whereas in Burenitu the average results show that they had the lowest establishment rate but still ranged above eighty percent. These results show that the five kumala varieties adapted well to the Burenitu soil type and weather. Kumala has a fibrous root system that consists of adventitious roots that emerge from the cut end and lower section of the node of stem cuttings (planting material) that are introduced into the ground at planting, as well as their attendant lateral roots, which grow in a three-order pattern. In comparison to other root crops, where rapid root growth can extend up to the eighth or tenth week after planting, the adventitious and lateral root formation is normally rapid during the first four weeks of growth under normal soil moisture conditions (Agili and Pardales, 1997; Pardales, 1985). Sweetpotato crops are renowned for their ability to grow in marginal places when other commercial crops may fail (Cock, 1985). Izumi et al. (1999) found this to be true in their investigation. Because root development and function are found to be closely related to stress tolerance and play critical roles in crop growth under such stressful conditions (Yamauchi et al., 1996), it is widely assumed that sweetpotatoes are capable of maintaining root growth and development under fluctuating soil moisture conditions.

7.4 Kumala Traits at Harvest in Different Altitudes

At harvest, measurements were taken on the following traits: yield, tuber dry matter, leaf number, fresh weight and dry matter, runner numbers and chlorophyll levels.

7.4.1 Tuber yield at harvest

Table 9 shows the mean (μ) average tuber yield of the five kumala varieties at the three locations. Results show (see Appendix 2) that there were no significant differences ($P \geq 0.001$) in the average tuber yield at harvest. At Bucalevu Golden Brown had the highest mean (μ) average tuber yield followed by Honiara, Local Purple and Vulatolu varieties in that order and the Carrot variety had the lowest average tuber yield. At, Burenitu, the Golden Brown variety had a higher mean (μ) average tuber yield at harvest than Vulatolu, Local Purple andHoniara which had no significant differences ($P \geq 0.001$) among them at harvest. The Carrot variety again had the lowest mean (μ) average tuber yield at Burenitu. Interestingly at the Nabukadra site, the five varieties followed the same pattern where the Golden Brown variety achieved the highest mean (µ) average tuber yield followed by the three varieties Local Purple, Honiara and Vulatolu. The differences were not significant ($P \geq 0.001$). Again, the Carrot variety had the lowest mean (µ) average tuber yield at harvest. Among the five sweetpotato varieties grown at the three sites, Golden Brown (8.10kg) variety grown at Nabukadra provided the highest tuber yield and the Carrot (3.83kg) variety grown at Bucalevu attained the lowest tuber yield (App. 2).

It is interesting to observe that tuber yields of three introduced varieties included in the present study produced a higher mean (µ) average yield at harvest than the two varieties that farmers in Ra were already cultivating (Local purple and Carrot). Saitama et al. (2017) noted that the yield performance of these varieties varied considerably according to environmental conditions. Moreover, it has been noted that stress is more critical in higher-yielding locations as well as within higher-yielding varieties (Adams. 1967;Thomas et al., 1971; Hamid, 1980). As previously observed in research, sweetpotato tuber production is regulated by a combination of genetic and environmental variables (Yusuf et al. 2008; Osiru et al. 2009; Moussa et al. 2011; Haldavanekar et al. 2011; Mau et al. 2013; Rahajeng and Rahayuningsih 2017). Martin (1988) also noted that in hot tropical climates, sweetpotatoes may be planted at any time of the year and harvested throughout the year with some seasonal variation in yield.

Practical impediments to year-round agriculture include water availability and yields that vary according to the season. Franklin (1988) proposed that most sweetpotato cultivars yield best in the tropics when planted from June to September and mature in February-March. Short days encourage the formation of storage roots. Long days, according to McDavid and Alamu (1980), enhance branch length, decrease branch number, promote leaf growth, and postpone senescence. Rainfall and irrigation can also have an impact on sweetpotato development. Excessive watering results vegetative growth and yield reduction. Haynes et al. (1967), indicated the optimal climate for sweetpotatoes in the tropics would be one with consistent rain at planting and during establishment, and ample sunlight during the period of store root development. Excess water and a lack of oxygen in the soil are thought to be linked to insufficient storage root formation. As a result, well-drained soil is preferable.

Table 9: Kumala Traits at Harvest at Different altitudes (A) in Fiji
Error bars indicate a ± standard error of the means. Different letters in a column indicate means a statistically different on Tukey's HSD test (P< 0.001)

ENV	Variety	Tuber Yield (kg/ha)			Tuber Dry Matter (g/kg)			Leaves Fresh Weight (g)			Leaves DM (g/kg)		
		Mean		SE	Mean		SE	Mean		SE	Mean		SE
Bucalevu	Carrot	3.83 c	±	0.131	64.55 a	±	1.109	4.35 a	±	0.065	23.28 a	±	0.386
	Golden Brown	7.85 a	±	0.119	88.68 b	±	0.336	2.68 b	±	0.149	20.74 a	±	0.1
	Honiara	6.85 b	±	0.26	77.39 c	±	2.966	4.23 a	±	0.075	21.83 a	±	0.856
	Local Purple	6.6 b	±	0.238	80.68 c	±	1.981	3.29 c	±	0.109	21.16 a	±	0.238
	Vulatolu	6.58 b	±	0.214	74.19 c	±	1.449	3.38 c	±	0.153	21.61 a	±	0.513
Burenitu	Carrot	3.88 c	±	0.111	59.8 a	±	2.63	4.15 a	±	0.194	23.78 a	±	0.586
	Golden Brown	7.9 a	±	0.135	84.68 b	±	0.653	2.68 b	±	0.149	20.98 a	±	0.342
	Honiara	5.58 b	±	0.075	72.89 c	±	1.267	4.23 a	±	0.075	22.83 a	±	0.262
	Local Purple	5.63 b	±	0.075	75.43 c	±	1.246	3.29 c	±	0.109	21.81 a	±	0.31
	Vulatolu	5.68 b	±	0.063	71.84 c	±	0.713	3.38 c	±	0.153	22.35 a	±	0.458
Nabukadra	Carrot	4.65 c	±	0.029	63.8 a	±	0.645	4.5 a	±	0.041	22.9 ab	±	0.844
	Golden Brown	8.1 a	±	0.108	89.43 b	±	1.553	2.68 b	±	0.125	20.51 ab	±	0.151
	Honiara	7.25 b	±	0.079	75.14 cd	±	2.669	4.36 a	±	0.063	23.69 a	±	2.352
	Local Purple	7.3 b	±	0.071	82.18 c	±	2.965	3.31 c	±	0.083	20.29 b	±	0.169
	Vulatolu	7.21 b	±	0.031	72.69 d	±	0.473	3.44 c	±	0.075	21.91 ab	±	1.033

Table 10: Kumala traits at harvest at different altitudes (B) in Fiji
Error bars indicate a ± standard error of the means. Different letters in a column indicate means a statistically different on Tukey's HSD test (P< 0.05)

ENV	Variety	No. of Leaves (numbers/plant)			No. of Runners (numbers/plant)			Length of Runners (cm)			Chlorophyll (%)		
		Mean		SE	Mean		SE	Mean		SE	Mean		SE
Bucalevu	Carrot	20.5 a	±	0.129	5.25 a	±	0.25	115.6 a	±	5.101	37.23 a	±	0.015
	Golden Brown	26.5 a	±	0.129	9.25 b	±	0.479	131.45 b	±	0.104	44.35 b	±	0.024
	Honiara	23.28 a	±	0.189	7.25 c	±	0.75	126.08 b	±	0.214	41.48 c	±	0.049
	Local Purple	23.18 a	±	0.193	7.25 c	±	0.75	126 b	±	0.183	41.47 c	±	0.057
	Vulatolu	23.25 a	±	0.171	7.25 c	±	0.75	126.05 b	±	0.222	41.49 c	±	0.036
Burenitu	Carrot	79.5 a	±	0.147	2.5 a	±	0.289	82.6 a	±	0.129	36.41 a	±	0.472
	Golden Brown	88.47 a	±	0.075	5.5 b	±	0.289	95.5 b	±	0.129	43.48 b	±	0.171
	Honiara	82.55 a	±	0.104	3.5 ac	±	0.289	85.5a	±	0.129	40.51 c	±	0.115
	Local Purple	86.47 a	±	0.155	4.5 bc	±	0.289	90.6 ab	±	0.129	41.35 c	±	0.775
	Vulatolu	82.52 a	±	0.111	3.5 ac	±	0.289	85.5 a	±	0.129	40.54 c	±	0.108
Nabukadra	Carrot	84.75 a	±	3.66	3. a	±	0	85 a	±	1.08	36.52 a	±	0.49
	Golden Brown	23.75 b	±	0.75	5 b	±	0	116.75 b	±	4.626	43.38 b	±	0.137
	Honiara	108.5 c	±	4.992	4 ab	±	0	128.5 c	±	2.363	40.4 c	±	0.136
	Local Purple	109.25 c	±	10.27	4.5 ab	±	0.289	125.75 c	±	2.496	40.54 c	±	0.134
	Vulatolu	109.5 c	±	4.77	4.25 ab	±	0.25	127 c	±	1.915	40.34 c	±	0.117

7.4.2 Tuber dry matter at harvest (gms)

The tuber dry matter (TDM) ANOVA results (see Appendix 2) showed no significant differences ($P \geq 0.001$) among the TDM of the five varieties at the three trial sites. Table 9 shows differences in the mean (μ) average TDM at different altitudes. At both Bucalevu and Burenitu sites, the Golden Brown variety provided a higher mean (μ) average dry matter content than Local Purple, Honiara and Vulatolu with no significant difference ($P \geq 0.001$) among them. Carrot has the lowest mean (μ) average tuber dry matter content. At Nabukadra, the Carrot variety again achieved the lowest mean (μ) average TDM content. TDM contents were not significantly different ($P \geq 0.001$) among the varieties Vulatolu, Honiara and Local Purple (see Appendix 2) and Golden Brown had the highest TDM. Anshebo et al., (2003) research reiterated that local varieties regularly have the potential to produce high dry matter at a range of altitudes which aligns with this result.

7.4.3 Leaf weight at harvest (gms)

Table 9 shows the mean (μ) average difference among the tuber yield of the five kumala varieties. ANOVA results on the leaf weights (see Appendix 2) showed no difference ($P \geq 0.001$) among the three trial sites. At Bucalevu, Carrot and Honiara varieties had similar leaf weights (not significantly different) which were higher than Vulatolu and Local Purple. There were no significant differences ($P \geq 0.001$) between the leaf weights of Vulatolu and Local Purple. The Golden Brown variety achieved the lowest mean (μ) average leaf weight at harvest. At Burenitu and Nabukadra, a similar result to the Bucalevu site was obtained. The Golden Brown variety had a lower average leaf weight at harvest followed by the Local Purple and Vulatolu varieties (no significant difference between the two). Honiara and Carrot had the highest average leaf weight at Nabukadra with no significant difference between them. The Golden Brown had the lowest average leaf weight across all sites and the Carrot had the highest mean (μ) average leaf weight.

7.4.4 Leaf dry matter at harvest (gms)

Table 9 shows the mean (μ) average leaf dry matter of the five kumala varieties. The ANOVA results (see Appendix 2) show no significant differences ($P \geq 0.001$) in leaf dry matter values at harvest among the five varieties across the three trial sites. All varieties had similar average LDM.

7.4.5 Number of leaves at harvest (gms)

Results show (Appendix 2) that there were no significant differences ($P<0.001$) in the total number of leaves at harvest between varieties. However, there were significant differences ($P<0.001$) when the five varieties were averaged for each site in the average number of leaves at harvest between sites. Table 10 displays the average number of leaves which was produced by the five kumala varieties at harvest. For the Bucalevu site, Golden Brown had the highest mean (µ) average number of leaves. At the same site Honiara, Vulatolu, and Local Purple had the same number of leaves at harvest, i.e., there is no significant difference among those varieties. The Carrot variety had the lowest average number of leaves at harvest in the Bucalevu site. At Burenitu the Golden Brown variety had a superior average mean (µ) number of leaves at harvest compared to other varieties. Local Purple had higher values than the other varieties. Honiara and Vulatolu had the same values while Carrot had the lowest mean (µ) value. At Nabukadra, the Golden Brown variety hadthe lowest mean (µ) average number of leaves followed by the Carrot. The highest number of leaves were produced by three varieties (Vulatolu, Local Purple, Honiara) at the Nabukadra site with no significant difference in the averages among these varieties.

Sweetpotato cultivars with prominent stems and leaves that extend into a horizontal, shallow canopy near the soil surface help the plant to capture maximum light energy. Leaf form varies across types. The leaves might be circular, reniform, cordate, triangular, and deeply or moderately lobed. Plants have an unrestricted growth pattern and constantly create new leaves. The large variances in their fluctuating leaf number, leaf area, leaf weight, and leaf dry matter at harvest demonstrate these traits. The percentage of leaves connected to the plant falls dramatically as the number of leaves generated grows during the development stages owing to shedding (Somda et al. 1991). The total number of leaves is determined by the number of growth points or branches, the length of the internode and stem, the pace and duration of leaf production, and the lifespan or shedding of leaves. The total number of leaves per plant ranges between 60 and 300 depending on the variety (Rajeshkumar et al. 1993). With decreasing plant density (Somda and Kays 1990b), cumulative irrigation (Holwarda and Ekanayake 1991; Indira and Kabeerathumma 1990), and N fertilizer application, the number of leaves per plant increases (Nair and Nair 1995). The number of leaves per plant is reduced when vine cuttings are defoliated before planting (Jayakrishnakumar et al. 1990). The specific leaf weight (SLW) or leaf weight/area ratio of sweetpotato varieties can differ (Nair and Nair, 1995) with the decline of SLW during the growth period caused mostly by the dry matter translocation of leaves toward the tubers (Nair and Nair,1995).

7.4.6 Number of runners at harvest

At harvest, there was no significant difference in the number of runners across the five kumala kinds at the three trial locations ($P>0.001$) (see Appendix 2). The average mean (µ) number of runners harvested at three research locations is shown in Table 10. According to Ravi and Indira (1999), the total number of runners varies from three to twenty, and the stem length ranges from 0.5 to 2.2 meters. In their studies, (Rao et al., 1992; Rajeshkumar et al., 1993; Jeong and Oh 1991) agreed. Sweetpotato plant branching, on the other hand, is highly impacted by spacing, photoperiod, soil moisture, and nutrients.

7.4.7 Length of runners

The ANOVA findings (Appendix 2) reveal that there is no significant variation in runner length across the five kinds at the three trial locations (P>0.001). According to Ravi & Indira (1999), spacing, photoperiod, soil moisture, and nutrients all have a significant impact on sweetpotato plant branching. Due to increasing competition for resources, cumulative plant density reduces runner length and the total number of branches on a plant (Hamid and Sasaki 2001). The production of secondary runners is responsible for the rise in stem length and the total number of runners per plant when plant density decreases (Somda and Kays 1990a).

7.4.8 Chlorophyll content at harvest

The ANOVA results (Appendix 2) show no significant differences ($P \geq 0.001$) in the chlorophyll content at harvest among the five kumala varieties at trial sites. Golden Brown had the highest average chlorophyll content at harvest. The varieties Vulatolu, Honiara and Local Purple had the same average chlorophyll content at harvest and Carrot had the lowest measurement. At Burenitu and Bucalevu Golden Brown had the highest average chlorophyll content followed by Local Purple, Vulatolu and Honiara with no significant difference. Similarly, at Nabukadra, Golden Brown variety had the highest average chlorophyll content at harvest whereas the three varieties Local purple, Honiara and Vulatolu had no significant difference ($P \geq 0.001$).

Changes in chlorophyll concentration occur in three stages throughout growth. Chlorophyll content rises steadily from the second WAP (weeks after plating) in the first phase, reaches a plateau between the 8-16th weeks after planting (the second phase), and falls during the third phase at the end of the growth period, owing to leaf shedding, mutual shading, and reduced light intensity in the lowermost leaves. During the second phase, the highest chlorophyll concentration varies amongst cultivars (Bhagsari and Ashley, 1990). Chlorophyll content rises as air temperature rises (Mukhopadhyay et al., 1991), photoperiod or N application rises (Chowdhury and Ravi 1990), and soil moisture rises (Bhagsari and Ashley, 1990).

7.5 Tuber Yield Correlation with other kumala traits

As previously established, sweetpotato tuber production is regulated by an interplay of genetic and environmental variables (Yusuf et al. 2008; Osiru et al. 2009; Moussa et al. 2011; Haldavanekar et al. 2011; Mau et al. 2013; Rahajeng and Rahayuningsih 2017). The findings of the study, as summarized in Appendix 4, are consistent with prior research findings showing tuber yield is positively correlated with tuber number per plant, tuber length, and tuber diameter (Sasmal et al. 2015; Mbusa et al. 2018). A positive correlation between tuber yield and tuber yield component traits (leaf weight, tuber dry matter, tuber number per plant, leaf dry matter, leaf number, runners' number, runners' length, and chlorophyll content) implies a primarily linear relationship between them, where tuber yield will increase or decline along with the increase or the decline of the eight traits. In addition to the generally good performances in tuber yield component traits, the five varieties in this trial also recorded positive relationships to most growth variables such as leaf number per plant, which ultimately support the optimum photosynthesis process for maximum tuber growth and development (Bhagsari and Ashley 1990). Mau et al.(2019) further explain that these differences might be due to the differences in the genetic background of the tested sweetpotato clones as they were all evaluated in the same environment.

It is assumed that sweetpotato tuber production is governed mostly by sink capacity rather than source potential (Kao et al. 1992). However, tuber yield can be limited by both sink capacity and source potential. During the crop growth cycle, the relative contribution of sink capacity and source potential to tuber output varies by variety. During the early development stage, the source potential is more limiting than the sink potential, although both are important in determining tuber production later in the growth period following tuber formation (Li and Kao, 1990). Several studies have found a positive relationship between leaf weight and tuber weight, indicating that tuber growth is strongly related to runner growth (Mukhopadhyay et al. 1992, 1993). Other research, however, shows a negative relationship between leaf weight and tuber weight (Goswamy 1994). Tuber growth is thus, to some part, dependent on runner growth. Excessive runner development consumes more photosynthates and does not promote tuber growth. According to research, the quantity of runners has a negative relationship with tuber yield (Thankamma and Eswariamma 1990). However, chlorophyll has a positive relationship with tuber output (Chowdhury 1994). Sink factors such as tuber number per plant have a substantial positive link with tuber production (Zang and Lian 1994). Sink parameters such as tuber dry matter and length, fresh weight per tuber, and bulking rate have a substantial positive link with tuber yield (Chowdhury 1994). Tuber yield had been reported to be positively correlated with tuber dry matter content (Bhagsari and Ashley 1990), but Mbusa et al. (2018) reported no correlation between these two variables. The implication is that the correlation between these two variables in sweetpotato is dependent on the genotypes used. Moreover, the yield performance of these varieties varied considerably according to the environmental conditions. Thus, the tuber yield of sweetpotato is determined by an interaction between genetic and environmental factors as reported in the previous studies (Yusuf et al. 2008; Osiru et al. 2009; Moussa et al. 2011; Haldavanekar et al. 2011; Mau et al. 2013; Rahajeng and Rahayuningsih 2017).For this project, the results (Table 11) have shown no consistent pattern exists for the five varieties under study (Table 12). In the majority of outcomes, the variety 'Golden Brown' has a stronger habit and higher yield than the other varieties. The varieties Vulatolu, Local Purple and Honiara all carried similar values with Carrot consistently giving low values or a low correlation between characteristics and final yield. But by site, and therefore by altitude, the varieties Golden Brown and Vunatolu were consistentin their correlation of traits to yield at Burenitu and Bucalevu. Nabukadra - at sea level or <20m asl – however, gave fewer convincing results and favoured the varieties Golden Brown and Carrot in several categories measured.

Table 11: Tuber Yield Correlation with other kumala traits.
Different stars in a column indicate means are statistically different on Tukey's HSD test (P< 0.05)

ENV	GEN	Leaves Weight (g)	Tuber Dry Matter (g/kg)	Leaves Dry Matter (g/kg)	Leaves Number (numbers/plant)	Runners Number	Length of Runners (cm)	Chlorophyll (%)
		Correlation Values						
BUCALEVU	**Carrot**	0.54*	0.61*	-0.01	0.93**	0.95**	0.58*	0.17
	Golden Brown	0.96**	0	-1	0.76**	0.51*	0.81**	0.35
	Honiara	0.19	0	-0.3	0.55*	0.66*	0.65*	0.55*
	Local Purple	-0.08	0.06	-0.94	0.85**	0.89**	0.84**	0.21
	Vulatolu	0.27	0.55*	-0.93	0.79**	0.9**	0.92**	0.37
BURENITU	**Carrot**	-0.99**	0.73**	-0.01	0.82**	0.39	0.64*	0.67*
	Golden Brown	0.99**	-0.93	0.06	0.66*	0.64*	0.86**	0.66*
	Honiara	0.78**	-0.81	0.52*	0.16	0.58	0.26	0.56*
	Local Purple	0.06	0.17	-0.6	-0.56	-0.19	-0.6	-0.44
	Vulatolu	0.76**	-0.53*	0.56*	0.63*	0.69*	0.72**	-0.18
NABUKADRA	**Carrot**	-0.71*	0	-0.93	0.35	0.37	0.27	0.6
	Golden Brown	0.37	-0.09	-0.54	0.93**	-0.7	0.9**	0.69*
	Honiara	0.84**	-0.36	-0.36	-0.32	-0.45	-0.09	-0.61*
	Local Purple	0.86**	-0.04	-0.31	-0.46	0.82**	-0.05	-0.78**
	Vulatolu	-0.24	-0.94	0.53*	0.01	-0.13	-0.21	-0.82**

Table 12: Correlation factors with Total Yield

Location by Altitude	Tuber Dry Matter	Leaf Fresh Weight	Leaf Dry Matter	Leaf Number	Runners	Length	Chlorophyll
Bucelevu (High altitude)							
1 (Golden brown)	0	√√√√√	xxxxx	√√√√	√√√	√√√√√	√√√
2 (Honiara)	0	√	x	√√√	√√√	√√√√√	√√√
3 (Vulatolu)	√	√	√√√√√	√√√√	√√√√√	√√√	√√√
4 (Local purple)	√√√	x	xxxxx	√√√√	√√√√√	√√√	√
5 (Carrot)	√√√	√√√	x	√√√√	√√√√√	√√√√√	√
Burenitu (Medium altitude)							
1 (Golden brown)	x	√√√√√	√	√√√	√√√	√√√√√	√√√
2 (Honiara)	√√√	√√√√√	√√√	√	√√√	√	√√√
3 (Vulatolu)	√√√	√√√√√	√√√	√√√	√√√	√√√√√	x
4 (Local purple)	√	√	x	xxx	x	x	x
5 (Carrot)	√√√√√	xxxxx	x	√√√√√	√	√√√	√√√
Nabukadra (Coastal)							
1 (Golden brown)	x	√	xxx	√√√√√	xxxxx	√√√√√	√√√
2 (Honiara)	x	√√√√√	xxx	xxx	xxx	x	xxx
3 (Vulatolu)	x	xxx	√√√	√	xxx	x	xxxxx
4 (Local purple)	xxxxx	√√√√√	xxx	xxx	0	x	xxxxx
5 (Carrot)	0	xxx	xxxxx	√	√	√	√√√

KEY:

Positive ranks	Negative ranks
Weak √	x
√√	xx
Moderate √√√	xxx
√√√√	xxxx
Strong √√√√√	xxxxx

7.6 AMMI & GGE Biplot Analysis

Because of the significant yield fluctuation related to geography, which is irrelevant to variety evaluation and mega-environment inquiry (Yan et al., 2000), the AMMI and GGE biplot were chosen as acceptable approaches for analyzing the MET data. Figure 54 also shows a comprehensive stability study of the tested genotypes based on their IPCA scores using GGE biplot analysis.

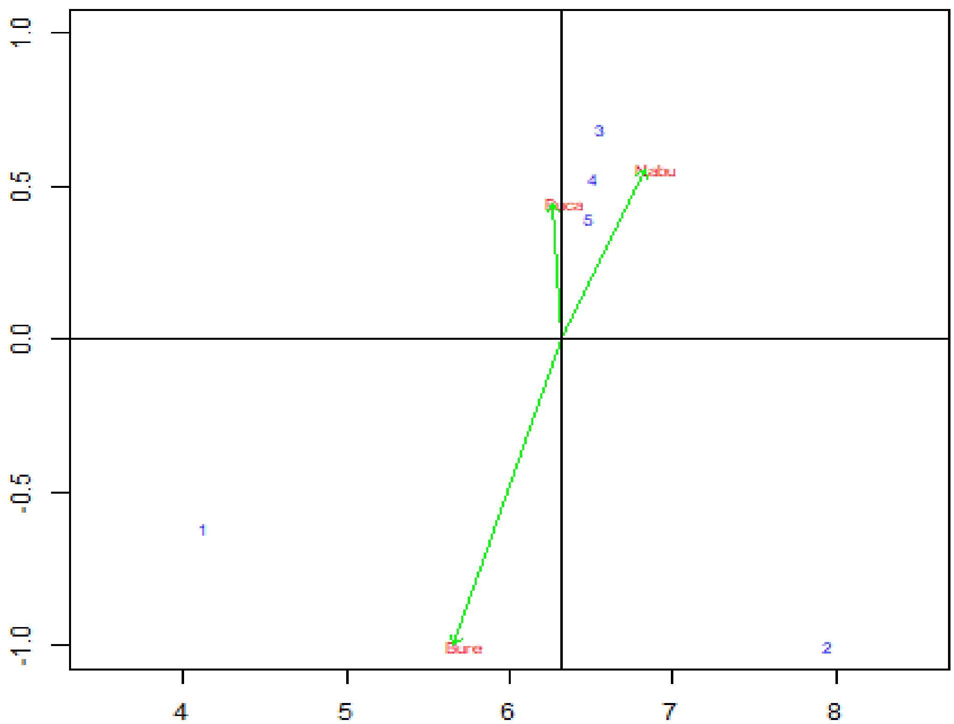

Figure 54: AMMI biplot of IPCA 1 scores against tuber yield for the test genotypes across three environments

1 = Carrot, 2=Golden Brown, 3=Honiara, 4=Local Purple and 5=Vulatolu.

The AMMI model's biplot for GEI allows for the depiction of changes in the interaction of the primary effects (tuber yield). Figure 54 depicts the AMMI biplot of the tuber yield of genotypes cultivated in three sites. The y-axis indicates IPCA1 scores, whereas the x-axis reflects genotype tuber yield (primary influence). Environments or genotypes on the same parallel line relative to the ordinate have equal tuber yields, while genotypes or environments on the right side of the midpoint of this axis have a larger yield than those on the left.

As a result, in this study, the high-yielding settings were Nabukadra and Bucalevu, whereas the average-yielding environment was Burenitu. The Golden Brown variety produced the top-producing genotypes with above-average tuber yields in all conditions. Vulatolu, Honiara, and Local Purple genotypes were more suited to Bucalevu and Nabukadra sites, but Golden Brown and Carrot genotypes were more connected to Burenitu. It was also discovered that Golden Brown, Vulatolu, and Honiara performed well there but required more time (an extra month) for root formation. These types would be suitable for food security in Burenitu village. Closely related genotypes are likely to have comparable tuber yield responses to the environment. Bucalevu and Nabukadra sites were the most stable, but Burenitu was the most unstable, resulting in substantial interaction. Golden Brown was the best genotype overall, combining relative stability and high yield, whereas Honiara, Vulatolu, and Local Purple were the best local varieties, which were stable but produced less than Golden Brown. The Carrot genotype was the worst of the genotypes due to instability and low yield. AMMI allows for an explanation of commercial production and climate-smart agriculture. According to the average tuber production figures, all five types may be farmed at various altitudes and contribute to food security but the variety Golden Brown was consistently the best yielding one.

AMMI analysis has frequently been employed in recent years for G x E (Genotype x Environment) experiments, such as those undertaken by (Crossa et al., 1991). The current study also clearly suggests that sweetpotato outcomes should be examined using this multivariate approach. The current findings imply that cultivating sweetpotato for high yield and complete adaptability is feasible. Furthermore, the need for separate trials for low- and high-yielding conditions is disputed (Atlin and Frey, 1989). Selection is frequently conducted in high-yielding conditions because variations between types are greater in high-yielding environments than in low-yielding ones. In terms of tuber yield, three types were identified: I high-yielding with complete adaptation, such as Golden Brown; (ii) high-yielding with specific adaptation to medium- and high-yielding environments, such as Vulatolu, Honiara, and Local Purple; and (iii) high-yielding with specific adaptation to low-yielding environments. Substantial mean yield differences among genotypes under different altitudes indicate the presence of interaction effect of genotype by the environment, where the expression of varieties controlling the tuber yield trait depends significantly on the variety and water level condition. (Ali and El-Sadek, 2016). Most of the drought tolerance indices used to select the drought-tolerant sweetpotato genotypes are influential across many crops (Fischer and Maurer 1978; Bidinger et al. 1978; Farshadfar and Sutka 2002; Moosavi et al. 2008; Mau et al. 2011; Ali et al. 2013; Mauet al. 2014; Mau et al. 2019). The five selected sweetpotato varieties also exhibited high-yielding performance in the stressed condition a positive trait which correlates with drought tolerance (Moosavi et al. 2008; Farshadfar and Elyasi 2012; Ali et al. 2013; Mau et al. 2019). Thus, the five selected sweetpotato varieties are not only drought tolerant but also high yielding in the same conditions.

7.7 Summary

This experimental trial was set up to identify the best-yielding varieties of kumala suitedto different climatic zones and to evaluate the drought tolerance ability and performance of selected kumala at three different altitudes of Ra province. Results of the kumala growth trait's performance at different altitudes, at harvest, included looking at the tuber yield correlation on other kumala traits. An AMMI & GGE biplot analysis was introduced and discussed around understanding interrelationships and the response between varieties at different altitudes. This is critical for developing a successful kumala germplasm program in Ra.

These studies were conducted to explore the relationships between yield and yield-related characteristics. The findings revealed a considerably favourable relationship between types, planting places, and planting dates. The tuber yield correlation study revealed a substantial positive association with both genotypic and phenotypic levels. Because of the strong estimated positive association and positive direct influence of biological yield and harvest index on tuber yield (t/ha), these characteristics would be most suited for indirect selection in kumala improvement projects aimed at increasing tuber production. Furthermore, the results reveal that the five kumala cultivars examined can grow in Ra at any location for food security needs. In terms of production, studies demonstrate that each variety has its own best environmental condition for producing a greater number of tubers. The number of tubers per plant for the five kinds ranged from 4 to 8 tubers (see Appendix 2). This characteristic is the most important guideline in cultivating kumala as a crop for food security and climate-smart agriculture.

Chapter 8

Discussion

“Tali magimagi taki ni kila kei na yavu ni vakatulewa”

Weaving Western Sciences and Traditional Agricultural Knowledge on Sweetpotato Farming to achieve Food Security and Climate-Smart Agriculture in Ra.

Ngdiak kobetik er ngii er cheroid eme douchii ra rebai Without looking far afield, it was found behind the house
Sometimes we look far and away for a solution when, in fact, the solution might befound close at hand.
From the folk tale of Mesubed Dingal of Ngardmau, Palau

8.1 Introduction

In developing countries like Fiji, it is difficult to balance defending the integrity of environmental systems with improving local living conditions. There are different approaches to development that are used, but, as a result of sustained human activity, the environment is altered. To ensure that sustainable development is possible, environmental resources must be maintained. People have begun to recognize the relevance and value of traditional knowledge over the past few years as they discover that such wisdom and knowledge allowed people to live in their particular surroundings for thousands of years. As a result, people have begun to appreciate and acknowledge the value of traditional knowledge in sustainable agriculture.

Traditional knowledge and practices of traditional crops have made a significant contribution towards sustaining the livelihoods of people (Shava et al., 2009). It has been vital for the survival and well-being of many cultures. For instance, in Fiji, most of the rural population in the Ra district still depend on subsistence agriculture immersed in tradition for their livelihood, and the same trend also applies in other Pacific nations (Chand, 2005). The research question which guides this study was how traditional knowledge of kumala production could contribute to Climate-Smart Agriculture (CSA) achieving food security for Fijian (I-Taukei) farmers in Ra District. This has provided an opportunity to determine how traditional knowledge contributes to sustaining livelihoods. It has been found that Fiji can incorporate traditional agricultural knowledge into science-based applications based on findings from the vanua of Ra. Thus, bridges can be built to link traditional knowledge with the science of horticulture, which will contribute significantly to the achievement of food security and provide an avenue for climate-smart agriculture (CSA), contributing to Ra's sustainable development. A discussion of the findings will be presented in this chapter.

The use of mixed methodologies was applied in this research to explore relevant TEK and its practices which have been a pillar to achieving food security, and those practices have been a safety net for resilience to climate change. Reviving this TEK will allow bula sautu or a return to the vanua of Ra which aligns with the ethnobotanical driver for the research, especially how the indigenous farmers in Fiji are connected to their plantsor food and their land. This research has adapted Berke's knowledge-practice-belief complex of TEK to discourse TEK's role in kumala production on the Dre'e metaphor under four components (values and beliefs, knowledge, practices, and skills) in the traditional I-Taukei context.

Secondly, solesolevaki and social capital are represented as components of CSA and food security. Solesolevaki, a cultural currency where people with kinship collaboratively pool their resources and effort without any financial return, is particularly evident where farmers have spoken out about the agricultural practices that have guided them from the past and compared to now where individuality has compromised TEK, or it has been forgotten or denied. Solesolevaki is a dying tradition, but the results presented show that while maintaining the tradition can be challenging it is possible with an appropriate enabling environment. Solesolevaki, as an element of social capital, has many benefits, and it creates a web of relationships between farmers and society as a foundation for achieving climate-smart agriculture. Work structure is birthed from solesolevaki and it enables everyone to achieve food sustainability and therefore food security.

Thirdly, an experimental trial which gives introductory outcomes will assist the Ra farmers in the long term for decision-making. The Dre'e model has been introduced as acomponent of FVRF which was used to attain and implement knowledge around kumala production to the Vanua of Ra. The Dre'e model has generated procedures that every researcher can follow in terms of agricultural development in rural and maritime areas in Fiji. The thesis outcome acknowledges the indigenous kumala farmers at the centre of this research and this thread of knowledge will create a strategic kit for future kumala farmers in Ra.

8.2 A model of a solidarity Agriculture approach for CSA achieving food security in Ra

The findings from the study have led to the creation of an indigenous model for customary land in Ra, which is unique to the Pacific (see Figure 55). The model acknowledges The Fijian Vanua Framework for Research (FVRF) by Nabobo-Baba, which supported the generation of the dre'e model specifically for every indigenous agricultural farmer in rural and maritime islands around Fiji. This model will allow the indigenous communities to be the centre of any agricultural development. The dre'e model has guided the researcher to explore TEK in Ra and has been designed as a way to revive TEK of traditional foods like kumala and place them back to where they should be, and that is to be practised back to the people.

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Figure 55: Na'i Dre'e metaphor to show how TEK and kumala farming can be the basis for food security and climate-smart agriculture

8.3 Drauna (leaves) – Capturing Traditional Environmental Knowledge andpractices

Reviving TEK requires quality approaches from an outsider to capture what practices still exist and the forgotten practices. Just as a kumala leaf is planted pointing towards the sunrise to capture sunlight. The use of selective methodologies (Chapter 4) has exposed values and beliefs on crop production in Ra.

The selection of appropriate and culturally safe methodologies was used to unlock the potential of indigenous knowledge systems in agriculture and resource management. TEK is examined under four indicators during farming practices: values & beliefs, knowledge, practises, and skills. It is explicit that indigenous knowledge (IK) on kumala exists across all facets of the Fijian way of life (health, food security, spiritual beliefs, and environmental survival) all pertinent to climate-smart agriculture. In Ra district traditional Fijian knowledge on kumala, agricultural systems, social relations and resource management is known and used but the impact of contemporary issues such as climate change, soil salinity levels or crop agronomy pressures from pests or diseases means other knowledge systems including horticultural science must now support the traditional knowledge. I-Taukei farmers in Ra were quick to acknowledge the opportunities that need to be developed for future generations to succeed on the land.

Capturing TEK in kumala farming promotes yalomatua (wisdom) which reflects the notion of no wastage (see chapter 6) and encourages the optimum and full use of land and builds resilience towards a CSA concept to guide indigenous farmers. Gathering this TEK has shown the connectivity of values and belief systems to the land duringfarming, for example, it is essential to be mindful that all the areas of work are clean,and all cuttings should be cleared up and covered. This is an act of respect to Ratumaibulu (the God of land). When comparing other indigenous people with the people of Ra, it becomes clear that for indigenous communities in which TK and cultural beliefs are intact, the indigenous people can use their TK around kumala practices, and abilities to cope with food security needs which provide an avenue to climate-smart agriculture. The loss of knowledge leads to the incapability of adaptingand coping with changes in the environment, as in the case of some indigenous communities in Africa (Charapa et al., 2012). A similar loss has been documented in the indigenous communities of Samoa (Pa'i, 2012).

Capturing Traditional knowledge for kumala pre-production - First, both traditional and modern calendars were used to determine the best planting days and months for planting kumala. For instance, the indigenous Fijian traditional calendar shows how TK is closely linked to the land, sea, atmosphere, and people. It also shows what people ought to do for survival and adapt to the physical conditions of an environment that is subject to the vagrancy of the weather. Failure to appropriately respond to signs and indicators of changing weather would lead to an inability to adapt successfully. From an i-Taukei perspective the indigenous Fijians' traditional calendar is vital for the survival of the people and kumala agricultural production. Understanding and using it enables locals to be fully informed about their environment and the seasonal changes in it, which fruit trees are fruiting, which fish is spawning, which fish is poisonous and when to harvest. This resonates with other Pacific cultures, for example, Setak (2018) highlighted indicators used in Vanuatu agricultural systems such as the full moon, or flowering and fruiting of the *navasvas* tree. Similarly, Roskruge (2007) promoted the use by the Maori of the maramataka (Maori calendar for fishing & planting) in the production of kumala (locally called kumara in New Zealand). Secondly, for those using a modern calendar, kumala is planted year-round based on the environmental needs of the crop. This finding is consistent with reports about kumala being planted in other tropical or semi-tropical regions taking account of rainy seasons in Uganda (Abidin, 2004; Bashaasha et al., 1995) or high-altitude regions of South America. Furthermore, year-round cultivation of kumala also depends on the varieties, for instance, and some can only be planted from March – June annually (Setak, 2018).

Capturing traditional knowledge used in land clearing for kumala. There were as expected, modern tools used to clear the land of weeds, shrubs, and trees. There is a traditional belief associated with this practice, which is to allow the soil nutrients contained in the vegetation to return to the soil. These allow the nutrients to be used by subsequent kumala crops. The land is left to dry for a few days before soil preparation. The waste plant material is then moved to the sides of the garden and can compost naturally. Most of the farmers conduct this method of the land clearing while only a few use the slash-and-burn method. Native plants - hardwood (Dakua, Damanu, Vesi, Drala) are left alone where softwoods are cut down. This practice allows plants to complement each other, has been stated by our forefathers that the native plants allow the replacement of nutrients back into the soil.

Capturing traditional knowledge in selecting the planting sites for kumala. The criteria used include primary forest or fallow land, old yam gardens, and slope areas. These are considered the best because of their high soil fertility, less labour required, and good drainage. This finding agrees with other Pacific cultures used in selecting a suitable site for their kumala gardens (Vunibola, 2020; Roskruge, 2012; Setak, 2018).

Capturing traditional practices and skills for kumala storage - Traditional storage is a vital tool for climate-smart agriculture for social resilience in the food supply. In Ra, it was evident from the findings that their forefathers practised traditional methods, yet now only a few are still using them. Therefore, there is a need to revive this traditional storage method of kumala including field storage, bag storage, basket storage, and food bed. The most preferred storage method is field storage because it provides a continuous supply of food for farmers' sustenance and easy access when the crops are needed. This aligned with findings of the continuous supply of roots over time as reported in Uganda (Ebregt et al., 2007) and the availability of kumala during the off-season (Motsaet al., 2015a). The field storage method is very suitable when the climate is conducive, so, soil type is essential because poor drainage will affect the kumala roots. For example,in heavy clay soil, water-logging can occur, resulting in rotten roots. Other benefits of using the bag, basket and food bed storage include easy access to food when needed, ease of transport to the market, and sweeter kumala as higher sugar levels can be achieved through the curing when starch is converted to sugar. However, there are limitations to these storage methods, such as damage by rats, decay and sprouting. It is evident in the findings that storage is not considered very important to the Fijian farmers. A possible explanation for this is that kumala is cultivated year-round in tropical climates, and farmers do not recognize the importance of storing the crops after harvesting. However, given the effect and rising occurrence of extreme weather events induced by climate change, this is a component that needs to be better understood.

Farmers are increasingly using modern tools to prepare mounds or ridges for the kumala cuttings. Examples of these tools include the spade, hoe, or pick. These modern tools have the advantage of making work more comfortable and help to increase the area of production. Most of the farmers prefer to use these tools instead of traditional tools which they believe have low tillage capacity. For farmers who used traditional tools the most used one is the *na i-sau,* these are used for digging the soil because they are strong, and they are also freely available. According to farmers' traditional belief, the *na i-sau or* sticks (Figure 56) are used because it is a high-yielding tree, and its use will contribute to high yields for the kumala with low soil tillage. Similar findings were reported by Roskruge (2012) about the traditional tools such as *Hoto* (blade-like spade), *Puka* (shape of spade), *akeake*, *kanuka* and wooden spades used by Maori which have generally been superseded by modern tools/equipment. Setak (2018) also explains similar practices in Vanuatu kumala farming using *namamaua* sticks.

Moreover, both small and big mounds (see Figure 57) were prepared, and this depended mostly on the number of cuttings to be planted. For example, a small number of cuttings were planted on small mounds while a high number of cuttings were planted on large mounds. In Vanuatu diameters of the mounds ranged from 30 to 70cm and are 15 to 20cm in height. A spacing of 1m x 1m was used by the farmers (Setak, 2018). This is because it allows good ground cover and reduces weeding times for those varieties with long vines compared to the bushy varieties with only short vines. Mounds are often used around the Pacific. In NZ, commercial producers use rows because of scale, but some non-commercial farmers still use mounds (N. Roskruge, personal communication, 14, April 2019).

Figure 56: Traditional farming tool used in Ra

Figure 57: Buke or mounds is a traditional way toplant kumala

Traditional knowledge was used in the selection, handling, and planting of kumala cuttings. Farmers also select varieties (see Figure 58) based on their knowledge of each variety's attributes, various subjective (qualitative) traits as well no doubt based on farmer intuition. For instance, farmers preferred varieties with a sweet taste, high yields,high market demand, early maturity, and drought tolerance. Similarly, in other producing countries such as Tanzania, farmers favoured specific varieties for attributes such as prompt maturity, resistance to diseases, high yield, drought tolerance and elliptic root shape (Ngailo, Shimelis, Sibiya, & Mtunda, 2015). In Uganda, local varieties were adopted because of their maturity period, taste, and high yield (Zawedde, Harris, Alajo, Hancock, & Grumet, 2014). In the case of Ra, the farmer's in-depth knowledge of each variety's attributes and market intelligence were the most significant factors that help them determine the best varieties to cultivate.

Figure 58: Identifying the suitable plants for planting material selection

Research also revealed a division of labour involved at the different stages of kumala production during solesolevaki. Men, women, and children have a role to play from land preparation to harvesting. For example, it is the men's task to clear the land, and prepare mounds and plants, whereas women conduct planting, tending the plants, and harvesting. These findings concur with practices elsewhere. A division of labour based on status is evident for different crop activities among Māori in New Zealand, for example, the rangatira allocated to a whanau the accountability of the crop management practices (Roskruge, 2007). Also, according to Roskruge (2018), "the *rangatira,* dressed with modesty, [who] leads his people as a garden worker with his *ko* orimplement stick, a valuable tool of the times" (para. 13). Setak (2018) also noted this in her research at Vanuatu. For Maori in New Zealand, the males carried out the physical work (land preparation) whereas grading and storage were done by women beyond childbearing age (Roskruge, 2007). According to Ngailo et al. (2015), there are changes in responsibilities and traditional roles in kumala production due to increased market demand and broader societal changes. There is also astrong participation of men in kumala production (Ngailo et al., 2015). For example, findings in Nigeria have shown more males participating in kumala production than females (Olagunju, Fakayode, Babatunde, & Ogunwole-Olapade, 2013). Communal work in Ra is a customary practice; groups often comprise women, men, and youths. In Chile, with Mapuche people, the women do crops as men have left for work opportunities, so not all are available for agronomic activity (N. Roskruge, personal communication, 22 March 2018). These also concur with a previous finding of Mapuche women being the leading player in agriculture (Faron, 1986).

The selection of planting material is very vital in sweetpotato production. Therefore, there is a need for adapting other methods of raising planting material from other Pacific peoples (e.g., Maori) or nations. These methods of raising planting material on seedbeds allow quality and diseases free sweetpotato cuttings. Moreover, their planting techniques involve planting four fresh cuttings evenly on the mound. The second method uses cuttings that are left in a cool place for a couple of days, thus allowing the cutting to wilt and making establishment easier. Farmers in Uganda also employ thesame method of storing cuttings in a cool place to wilt or pre-root them before planting (Bashaasha et al., 1995).

Similarly, in New Zealand Māori put the tipu or cutting in a mud pool for a day before planting them (Roskruge, personal communication, 17 April 2019). Then 3-4 cuttings were planted in either a slanted or an upright position. These findings are also consistent with planting methods used by farmers in Ra, where two to four cuttings were planted in an upright or slanted position (Kirchhof, 2009). There are numerous benefits of each of the different planting methods, and the main ones identified are higher yields, crop assurance, and rapid rooting. (Pers. Comm. Kaumatua Tahuri Whenua Inc.11 March 2018) Also, all the varieties can be planted using the second method in less fertile soils.

In Ra, the application of traditional knowledge and beliefs were also evident in crop maintenance. For instance, weeding was one of the standard practices conducted by farmers, and this was done to promote pest control and make the garden look neat; this reflects their expository status and aligns with traditional Māori based on orderliness andvisual etiquette. It also allows adequate sunlight for profitable plant growth, avoids competition for nutrients, and promotes higher yields. The farmers did two weeding rounds. These are like the practice of farmers in Uganda (Abidin, 2004), Vanuatu also executes a similar practice (Setak, 2018), and also by Māori (Te Warihi Taiapa, personal communication, 11 March 2018).

Furthermore, In the highlands of Papua New Guinea, three weeding rounds were sometimes carried (Kirchhof, 2009). The amount of weeding depends mostly on the variety planted and rainfall. Another important finding revealed that farmers do not conduct specified soil fertility, pests, and disease management techniques; instead, they use their intuition in determining critical crop management responses. These recognise the very localised knowledge that farmers may have but not exposure to contemporary issues. In old times the pressure on land-use rotation will have been much less than now.

Some of the Pacific Islands also have farming taboos and beliefs associated with kumala production, with high yields, and protection against pests and diseases. For example, no unnecessary visits should be made to the garden; women in their menstrual period cannot go to the garden and talking about the kumala crops are an essential aspect of farming. Strict adherence to these beliefs and taboos, for instance, is crucial to avoid bringing evil spirits to the kumala crops and possible contamination of the crops (Setak, 2018). Maori also conducted similar taboos because kumala is a sacred crop that was especially important as a marginal growing area supported by the gods. Trespassing in the kumala gardens was the main offence when the kumala was planted, and in certain cases, individuals were murdered for trespassing (Best, 1976). The kumala farms were forbidden by the gods, and it was considered a horrible crime to enrage the gods (Best, 1930). In Fiji, it is also taboo for other farmers to go to the kumala - gardens. Taboos are essential from a cultural perspective to protect the kumala crops and obtain a good harvest.

The harvest of kumala crops is also determined by traditional knowledge. The ideal harvesting time of the crop depends on the variety planted. Generally, for all varieties, this occurs when the cracks start appearing on the mounds, and the vine colouralso indicates the roots are ready. These can be at any period from 4-6 months after planting. These tubers are then harvested by scraping out the soils from the mounds.The farmers also use contemporary tools such as na ikabi balavu and the na ikabi leka,to harvest kumala in heavy clay soils. Tuber selection and sorting (see Figure 59) are also done according to sizes, and this is to identify the ideal for consumption, market, and Sevu. Besides, one-time harvesting is done for tubers intended for the markets while piecemeal harvesting is done for home consumption. The harvesting technique used is vital in maintaining the quality of the tubers. Similar findings were reported by Bashaasha et al. (1995), where one-time and piecemeal harvesting is practised in the case of kumala in Uganda and the Melanesian islands. Low harvesting techniques can also lead to loss from decay which reduces the storage period from a food security perspective storage factors and harvest criteria are therefore crucial in maintaining root quality over time.

Figure 59: Women in Ra usually do kumala grading

One TK technique used by indigenous Fijians is the instalment of a *davuke* (pit) (see Chapter 6) for fermenting kumala and breadfruit to be consumed during and after a cyclone. However, now it has been mostly forgotten, this technique needs to be reintroduced to farmers and villagers as they could adopt pit storage because it can increase the storage period of kumala compared to the current methods. Studies have shown that pit storage can extend the shelf life of kumala, for instance in New Zealand kumala can be stored for up to 9 months if appropriately cured before storage (N. Roskruge, personal communication, 9 February 2018). In Tanzania, they found that kumala can be stored for up to 12 weeks (Van Oirschot et al., 2007) without curing. Similarly, in Nigeria, kumala could be stored for up to 5 months using sawdust which is moist in a stilted box with layers of sand (Dandago & Gungula, 2011), and, in Malawi, pit steps storage extended the shelf-life of kumala to 6.5 months (Abidin et al., 2016).

The findings in this study have shown that farmers applied some practices in preparation for, and management of, their crops in response to extreme climate change events, for example, droughts or tropical cyclones. The spreading types were purposefully planted out of the cyclone season since they provide shelter and retain soil moisture. The erect type is planted near cyclone seasons. In preparation for droughts, Rafarmers harvest matured tubers, store water, refrain from weeding, and intercrop kumala with cassava. These actions are conducted to manage the crops during droughts better.

When planting the kumala cuttings, only a short portion is exposed, the crops are watered, no weeding is done, and only matured tubers are harvested.

Communities in Ra have long been aware of seasonal variations and everyday weather patterns. The use of environmental indicators as an early warning system improves their ability to respond to adverse weather. Chapter 6 discovered that communities use cloud patterns, wind direction, changes in animal behaviour and the nesting and migratory patterns of local birds, variations in the number of fruit harvests, and changes in the growth patterns of local plants to predict forthcoming weather events. Farmers in Ra employ indications and indicators to forecast the weather as well as prepare for extreme disasters. The ability to foresee weather and climate conditions using traditional knowledge assists societies in adapting to existing weather patterns and preparing for future changes in weather patterns.

Recent studies also show that kumala are generally considered drought-resistant (Lebot, 2010). These are partly because of its prolific root system; however, for sprouting and establishment of the plants, additional irrigation is needed (Leighton, 2007; Mukhopadhyay et al., 2011). Different kumala varieties respond variously to water stress, and yields can be reduced (Jaleel et al., 2009). For example, varieties that have small leaves, short stem lengths, and small canopies can producehigher yields compared to those with broad leaves and long stems (Wilson et al., 1989). "Higher yields in thin canopy kinds might be due to plants maximizing store root growth and expansion beyond extension." (Motsa et al., 2015, p.4). Therefore, both traditional and contemporary knowledge is useful for farmers to consider during periods of droughts. Local farmers rely on their knowledge of the traditional seasonal calendar to make judgments about what crops to cultivate and when to plant and harvest them. These are extremely important for farmers to schedule their actions throughout the year. These are highly significant for farmers so that their activities are well planned throughout the year. In Vanuatu, in preparation and management of kumala crops for cyclone season farmers harvest and store matured kumala, prepare andstore sufficient food supplies and prune trees growing near the gardens. Kumala tubers stored in short-term storage methods are found to be very useful during the cyclone season (Setak, 2018).

8.4 Kabe (Solid brim) – Support mechanisms in agriculture

The *kabe* signifies the support systems that enable the revival of kumala production at its best ncapacity. These support systems function when indigenous communities explore the world surrounding their TEK supported with the use of western science as mechanisms to draw on these TEK and improve their livelihood and well-being.

Solesolevaki is a social capital for sweetpotato farmers in Ra. Solesolevaki from a Ra perspective is a safety net system for social resilience adopted from their forefathers and could be a tool for climate-smart agriculture. The Ministry of Primary Industry needs to activate this in every community in Fiji if sweetpotato production and TK are to be revitalised. Examining social capital at the community level highlights its role as a public benefit. The research in Ra has focused on villagers' experiences, perspectives, and views to better understand the complex changes that have resulted from their engagement in agriculture. The interrelated and embedded components of traditional Fijian culture were conceptualized and experimentally examined using complex adaptive systems (CAS) and Social Capital theory. The emphasis on the three communities explains how their engagement in sweetpotato production has changed their tradition of solesolevaki or communal collaboration.

Moreover, the study contends that social solidarity and people's access to diverse types of capital, rather than money, drive progress. According to Movono and Dahles (2017), indigenous Fijian communities are complex, adaptive systems with a distinct mix of social and ecological features that connect individuals through traditional knowledge and rituals, livelihood activities, and special totemic linkages. Furthermore, it is associated with social cohesion and collective well-being (Meo-Sewabu, 2016). Traditional indigenous knowledge is transmitted both verbally and practically via unique cultural and daily practices (Ravuvu, 1987; Ravuvu, 1983; Seruvakula, 2000). Traditional trading knowledge sharing is facilitated by customary livelihoods practice, which retains certain practices and abilities unique to a given community that have been passed down from generation to generation (Derek, 1957; Nayacakalou, 1973; Seruvakula, 2000). Indigenous Fijian ideas of time and location, as well as cultural knowledge and totemic linkages, influence the activities and interactions between indigenous Fijians and the environment.

Communities are made up of territory, social institutions, and social interactions. Natural, cultural, human, and financial capital is therefore the four basic categories of capital entrenched inside a normal society. Social capital, unlike other types of static capital, is productive because it may improve levels of trust, respect, and collaboration in society, enabling a wide range of socioeconomic and political transactions to take place. As a notion, social capital is based on the fundamental assumption that the goodwill that people feel for us is valuable. Although not always monetary, social capital, like other types of capital, maybe turned into financial capital. As a result, social capital is a helpful vehicle for fostering collective activity and supporting action to adapt to changing socio-economic and environmental circumstances—at all societal levels, including individual, family, and community, as has been the practice in Ra. Thus, rules, norms, social order, and customs should be included in the scrutiny of social capital since they usher a community together for cohesive action. It was clearly shown in Ra that in every aspect of activity solesolevaki had been a tool where everyone must work together from a Ra perspective. This act in agriculture allows everyone to produce crops and assorted vegetables and to share produce as appropriate.

Additionally, Vunibola, (2019) explains that solesolevaki was the main engine of life in the Fijian village where the hands of many share the responsibilities. People use solesolevaki on two essential concepts: na gauna ni vuavua'i and na veivukei vakaveiwekani. Na gauna ni vuavuai refers to the seasons following the vula vaka-viti (Fijian lunar calendar) which depicts the season to cultivate the land for specific cropswhich are flourishing, harvesting specific land and sea resources and this requires the whole village to do it and sharing the produce later on. The food is preserved and stored in food banks in various homes. Na veivuke vakaveiwekani (helping your relation) does not depend on seasons or resources, but it is how an individual responds to the need of a person in the village. Vunibola further stated that solesolevaki is the capital that allows indigenous Fijians to venture into business capitalising on the essential resources of customary land and veiwekani (kinship relations). These prove that it could also be applied to sweetpotato farming in Fiji. Indigenous Fijians could produce sweetpotato through commercial farming on their customary land.

8.5 Marama (woman) – Women in agriculture, NGOs, and Government stakeholders

The SDG'' Objective Goal Five intends to guarantee women's full and active involvement in political, economic, and public life, as well as equitable opportunities for leadership at all levels of decision-making. According to the findings of this study, indigenous women in Ra are key partners in the battle against hunger and malnutrition. Identifying and highlighting their social and economic relevance is critical to achieving food security. Ra's indigenous women are food providers, guardians of native seeds, and custodians of traditional knowledge. These were proven during the research from land preparation of kumala through to planting, woman in the three villages contributed either the preparation of kumala cuttings or their distribution to every mound. Indigenous women are the backbone of Ra's indigenous communities, and they are critical to achieving food security. They also have an important collective and community role as keepers of indigenous ancestral knowledge, having historically cared for natural resources and managed seeds and medicinal plants. Furthermore, they frequently take the lead in defending indigenous lands and territories and pushing for indigenous people'' collective rights globally. The FAO Policy on Gender Equality provides a framework for promoting indigenous women's rights within the context of the 2030 Sustainable Development Agenda by pushing for the promotion of gender equality and women's empowerment as a key to eradicating famine and poverty. Similarly, gender parity stands out as a basic value for FAO's Policy on Indigenous and Tribal Peoples, and it serves as a guiding principle in all the organization's work.

Women also represent researchers, and government and non-government organisations engaged in agricultural development in Fiji. As discussed in chapter 3, the dre'e framework was conceived during this research and it has allowed me to understand howthe people of Ra perceive their biodiversity. For the dre'e model to function standard operation procedures (SOP) are necessary. The importance of these SOP is to provide detailed instructions that will guide Government Ministries, NGOs, and researchers in exploring the indigenous Fijian world. These SOP will allow outsiders to fully understand what they need to apply and most importantly, the time of application. The SOP is as follows:

1. "Di'eva se Di'gova" –- Observation

"Digidigi ena vua ni niu e loma" is an indigenous proverb which is a metaphor for the observation process in choosing the best. When exploring I-Taukei society observation is a tool to quickly capture their ways of doing things, for example, in this research, the TK on sweetpotato farming. Chapter 3 explains how women choose their *Voivoi* (*Pandanus caricosus*) for weaving; observation is much needed for them to understand and know which leaves will be the finest. In chapter 6, during the sweetpotato field observation, activities such as how they plant sweetpotato, and why they do tasks allowed the researcher to delve further into sweetpotato knowledge and to observe and listen to their stories. The researcher further observed why solesolevaki was being done and how important it was to them. Therefore, to any outsider or insider, observation is a vital activity that will allow them to the next stage, which is:

2. “Niti se Digidigi” – Selection

Digidigi is a vital component which allows you to peel away layers and understand theirknowledge and value systems, weaving those with western sciences and contributing to sustainability and reciprocity. These become an outline to attain a better and more sustainable future for indigenous Fijians. Knowing this will allow researchers and others to digest and understand what has been developed. In this research, the author has used identification as a screening stage where he chose what worked well for all parties. The Walui or the scraping (Chapter 3) which is done for five days using a black mussel shell to enhance the weaving material’s durability and flexibility allows a more straightforward weaving process for the women and is a metaphor for identification. This metaphor has a similar meaning to the indigenous Fijians; to know them, we have to spend more time with them. The author has explained the bula vaka vanua, meaning living, eating, and sleeping with them. “Me mamaca saraga na yavamu” means that your feet must be dry. Then you can know them. These apply to both outsiders and insiders if the identification process needs to be successful “Me mamaca saran a Yavamu”.

3. Va’a tovotovo or Va’bubutu – Experimentation

What needs to be implemented must be proven (preferably scientifically), so experimentation needs to be done. Western science has contributed alongside TK on food security, and that is often through research trials. In this research, the author has done a variety trial at three altitudes to support the selection of varieties to adapt and produce the best yield at different altitudes. The outsider and insider must be aware that doing this scientific research assists farmers in a climate-smart agriculture approach andalso food security. An I-Taukei idiom states that ‘na qari ena muri aga na qaiqai ni tinana’; it refers to a young mud crab which will always walk and follow its mother’s path. Experimenting is a way to allow future farmers to follow and improve the techniques in kumala production.

4 “Matana” – Implementation

Implementation is the final stage of an SOP of the dre’e framework. The researcher at the end of this research will provide a package to the farmers of Ra. The model explainsthe package as a **“dre’e”**, an indigenous *I-Taukei* basket which was used in the modern days for women in Ra to store their sweetpotato at harvest on their way home. This dre’e or package is essential to the outsider or insider since they are carrying a package that contains appropriate knowledge and ideology that will improve the livelihood of indigenous Fijians.

Weaving TK and Western Science are essential to this research as they benefit each other in a way to explain what and how the farmers in Ra can achieve food security and climate-smart agriculture. The research has also provided insights for external parties that sweetpotato has a massive opportunity for rural and outer islands in Fiji for food security. The Climate Smart Agriculture approach in this research is about decision-making aligned to food production systems; the experimental trial supported this.

Ethnobotany has played its role in understudying literature and through talanoa on the connection of kumala to Fiji society. These have helped explain the importance of the relationship of sweetpotato to the people of Ra.

Traditional knowledge (wisdom and experience), is appropriate and applicable to communities in Fiji. It must be included in sustainable development planning, modern development policies and resource management plans. Efforts must be taken to guarantee that the knowledge owners or purveyors have appropriately transmitted it to modern users, who must ensure that the owner'' rights are recognized, respected, and safeguarded. Contemporary communities can benefit from traditional cultural'' lessons. Initiatives in resource management will only be effective if they are comprehensive and part of a larger resource management strategy that makes sense to everyone.

Traditional knowledge and science play critical roles in mobilizing action to explain sustainable lifestyles at the societal level. Monitoring and assessment of resource management actions are required. Members of the indigenous Fijian population must understand how conservation programs benefit them. Those activities that are properly presented and compelling will be noted in this period when resources are becoming limited and monetary requirements are growing. As a result, a mix of tradition and science is necessary to persuade people that donations are made for their benefit and that individuals must be devoted to them even when they are in need. An I-Taukei proverb 'Lutu na niu, lutu ki vuna' can be translated as 'A coconut falls close to its roots and means our children's personality or behaviour will closely imitate what they have been taught (or how they have been reared) in their homes. Concerning indigenous farmers in Fiji, the output that they will produce is determined by what they are taught, both at home and by other experts.

8.6 Ena'I dre'e – (carrying cord or string): Summary – weaving all the sinnets of knowledge

Enai'dre'e refers to the weaving of all these sinnets to achieve food security and providean avenue for climate-smart agriculture approaches. Traditional agricultural knowledge and science can be incorporated to allow a better understanding of how ecological systems operate, which has been demonstrated in the Dre'e Model. Given that each genotype or variety of a plant species responds differently to production and environmental factors, evaluation of available sweetpotato varieties across geographic zones in Ra contributes to understanding and the development of climate-smart agriculture through specialised knowledge. The improved knowledge of kumala planting materials will allow for better recommendations to assist farmers enabling them to achieve optimum production levels and enhancing their economic and social well-being, whilst supporting the sustainability of the environment.

The development and use of the Dre'e model and integration of traditional knowledge and crop observations have generated a strategic kumala package (SKP) as given below:

i. Nabukadra Village–- Coastal area

- Kumala for Food Security & Commercial Purposes–- Golden Brown &Vulatolu.
- Socio-cultural obligation – Honiara, Local Purple, and Carrot.

ii. Burenitu–- Low altitude

- Kumala for Food Security & Commercial Purposes–- Golden Brown &Carrot.
- Socio-cultural obligation–- Vulatolu, Honiara, and Local Purple.

iii. Bucalevu Village–- High altitude

- Kumala for Food Security & Commercial Purposes–- Golden Brown &Vulatolu.
- Socio-cultural obligation–- Honiara, Local Purple, and Carrot.

The kumala trial undertaken at Massey University in the summer of 2017/18 allowed for the experience of the agronomic practices applied in this trial and introduction to the trial sites in Ra.

Science should be utilized to back up traditional knowledge and shed light on how people interact with and are impacted by the environment in which they live. The best instrument for now transferring the research results is through demonstrations in the farmer's fields along with the extension service. This research was carried out on farmers' fields incorporating their local knowledge and ensuring farmer inclusiveness, participation, and benefits throughout.

Traditional knowledge of kumala contributes towards achieving climate-smart agriculture and sustainable livelihoods with food, income and meeting cultural obligations. It provides a continuous supply of food for the people living in both settingsand thus provides and enhances food security. This is constant with the results of Minh et al. (2015) and Setak (2018) about the continuous harvesting of kumala and other crops in home gardens.

It is also evident that the blending of both traditional and contemporary knowledge can provide each household with a constant source of income or income opportunity.

These findings also concur with previous studies by Minh et al. (2015) and Munyua and Stilwell (2013) about knowledge systems improving economies in local communities and improving cash income. It is also significant to consider that there are other sources of livelihood that people are involved with such as the sale from copra, the sale of other crops, cattle, pigs, timber, kava, and wages from seasonal work. These additional sources of income help people adapt to droughts and cyclones or better prepare their families and community for extreme weather events.

Kumala in this research also represents other traditional foods in Fiji. These crops or plants generally refer to food plants that were not usually consumed unless there were natural disasters or failures among the commonly harvested crops. Traditional agricultural techniques in Ra have proven adaptable to change, with households integrating the cultivation of traditional indigenous crops.

Adopting a neo-traditional agricultural approach to farming would allow for the combination of scientific and local indigenous knowledge for the enhancement of farming systems, as well as make the native populace more adaptive. It is consistent with the I-Taukei people's conservatism as well as institutional and regulatory limits. Traditional agricultural practices complement and enhance the island's way of life. Land-use models should be built on a blend of traditional and contemporary agricultural techniques, adopting, and reflecting the best management practices of both. Uprooting indigenous agricultural practices and replacing them with conventional agriculture would thus be a mistake.

Chapter 9

Conclusion & Recommendations

"Sa mai cava to'a i'e"

'If an act of Agriculture fails, everything else will fail.' (Swaminathan, 1947).

9.1 Reflection on Aims and Objectives

The study's findings are summarized in Chapter 9. It discusses the study's implications and focuses on the research procedures and findings. This thesis aims to explain the impact that traditional environmental knowledge woven with western science knowledge of kumala production could contribute to Climate-Smart Agriculture (CSA) achieving food security for every Fijian (I-Taukei) farmer in Ra District. The following objectives were determined at the beginning of the research:

Objective 1: To explore indigenous knowledge and the historical context of kumala production in Fiji. The concepts of traditional environmental knowledge (TEK) to the vanua of Ra are explained in Chapters 2 and 6, and the historical movements of kumala in Fiji are offered. Chapter two provides the basis backed by works of literature for the movements of kumala to the Pacific islands, including Fiji, whereas chapter six portrays some of the farmer's stories on how kumala came to Fiji. It also discusses the importance that kumala and other local foods have to the Vanua of Ra.

Objective 2: To contextualise the loss of importance of kumala within the Fijian society, specifically in the Province of Ra. Identifying the loss of importance of kumala is essential in this research since it has enabled understanding as to why it happened. Moreover, it has exposed some strengths of how Fijian farmers could revive that knowledge and contribute value back to the Vanua of Ra. It was clearly stated in chapter six, whereas chapter eight discussed the way forward.

Objective 3: To identify the best-yielding varieties of kumala suited to different climatic zones in the Ra province. The response of the five varieties in their yield was summarised in Chapter 7. Findings from the field trial have enabled the researcher to create a package or dre'e for the kumala farmers in Ra (Chapter 8).

9.2 Conclusions

The use of mixed methodologies in this research has contributed to answering the research question aligned to the role of traditional knowledge of kumala production to contribute to Climate-Smart Agriculture (CSA) thus towards achieving food security forI-Taukei farmers in Ra. The dissemination of the research findings will be an essential aspect of the process of creating a climate-smart agriculture approach in Fiji.

According to the findings of this study, farmers in Ra are well-equipped with TEK for sweetpotato growing, but the government and related ministries have yet to establish a climate-smart agricultural approach to ensuring food security. This study provides a better understanding of the I-Taukei way of life, bula vakavanua, and how it relates to the implementation of community-agricultural development, with a particular emphasis on social capital and traditional knowledge (TK) in the pursuit of food security and climate-smart agriculture.

The concerns of land degradation, agro-deforestation, and food security in Ra can be addressed, at least in part, by propagating concepts that appreciate the traditional relationship between the land and its people. Given the small size of landholdings, the prevalence of rain-fed agriculture, Fiji's high sensitivity to climate change, and worldwide market volatility, it is critical to implement food production methods that bridge the gap between traditional and contemporary land usage. The method of integrating two distinct knowledge systems into kumala production establishes a standard for future Ra kumala farmers.

The use of the Fijian Vanua Research Framework (FVRF) in this study has revealed the hidden strength of the indigenous farmers in Ra, which applies to other indigenous rural and marine farmers in Fiji. Ra's village structures are founded on ancient social customs, government, culture, and religion. Kumala farming occurs at the village level, and any external project introduced into this village context should fit into the existing system and dynamics to maximize its chances of success and assure the sustainability of the initiatives, keeping in mind that 'village' life is not static. This research has captured that solesolevaki is the cultural currency and cultural capital of the vanua of Ra. Within this solesolevaki is the work structure as its substantial component. The work structure is a significant component of the resilience of this solesolevaki in an indigenous community.

It is a method of achieving comprehensive and inclusive well-being, also known as bula sautu. The work structure aided in the establishment of normal tasks for the villagers, who often collaborate by utilizing the resources at their disposal. The three communities studied revealed the significance of work organization as a blueprint for bula sautu. It promotes agricultural diversity achieving food security. Also, traditional food preservation techniques exist in the vanua of Ra from their forefathers. Traditionally in Ra, food preservation (davuke) was commonplace from their forefathers it has been fading away. These practices are essential for disasters, preparedness, and recovery. In Ra, crops destroyed by natural disasters could be preserved for future use.

Furthermore, this research has acquired that in Ra traditional and local trade networks (intra and inter-community cooperation) of kumala and other traditional food is a key component for climate-smart agriculture. Cooperation within and between communities is essential for traditional food security. The cyclic view taken in this research is critical in terms of understanding I-Taukei's knowledge of the environment. The vanua ofRa conceptualises time or gauna as a cyclical process which repeats, reproduces, and refreshes itself in an endless and boundless fashion. They proclaim that the spirits of the dead do not fade away but live on within their vanua or land as guardians of kumala and other traditional food and marine life, as well as of human beings. The vanua of Ra develop their indigenous calendar (vula ni yabaki) following the cycle of growth of fish and plants. The chronological space between two similar events constitutes a full cycle rather than space between two linear events. In the vanua of Ra, this bioenvironmental cycle also becomes the cycle of human transformation and life since they all correlated with each other. This interlocking process synthesises the human, plant, and animal worlds into a single cosmological embrace. Ultimately, this research has now advocated the discovery of the importance of our famine foods (traditional foods). Kumala has been branded as a rehabilitation or famine crop in Fiji.

9.3 Recommendations

Globally, the markets control food production systems. This is the reason why the saying '*volitaka na kakana tei lai voli mai na kakana tawa i tini'* (selling crops to buy canned and processed food) still prevails and contributes to poor health in the Pacific. It is prejudicial to blame the villagers. There is a need to look at interconnected components and systems that affect lives in the Pacific and beyond. There is also the so-called flooding of development projects in Pacific communities yearly and when it will be time for these communities to sustain and control their development and control their food systems. Most projects to improve food security in Fiji have failed because they do not recognize the need to adapt food systems to the traditions and culture of the indigenous Fijian people. This study showed that farmers are still using many of their traditional methods to address issues such as soil erosion, drought, flooding, insect, and pest attacks on their farms. The Fiji 2020 Agenda for the Agricultural Sector (Ministry of Agriculture, 2014) advocates the conversion of agriculture from subsistence and semi-commercial to commercial agriculture. There are many ways it marginalizes the importance of indigenous knowledge and healthy and nutritious diets in food production systems. Traditional farmers are often left out of agricultural policies and support schemes, with most of the government's focus being placed on agrarian sectors which are major revenue generators.

TEK and its socio-cultural safety net system have guaranteed food security and well-being in the face of climate change. This social safety net serves as a platform for the members to develop leadership, innovate, and realize their full potential. A solidarity agricultural approach must be implemented where the well-being of people is the centre of development in Fiji. Focus areas are as follows:

i. Indigenous Entrepreneurial Ecosystem

- Allow connections across the agricultural value chain enabling the sharing of information from farmers to Universities, Researchers, NGOs, MPI, Financial Institutes, Exporters and the Government.
- Weaving Traditional Knowledge and Western Sciences
- Promoting Food Sovereignty
- Revive Traditional Food Storage Preservation for food security (Traditional safe Net)

ii. Providing Gene banks in every District or Village

- These will allow an excess of planting materials or seedlings to rural and outer island people in Fiji.
- Gene banks or germplasm collections of seedling and root crops will help prevent the transfer of pest and plant diseases.
- These will promote agricultural households and family farming, improving production with an increase in available food surplus.

iii. Agriculture Policies

- Food sovereignty and legal frameworks that safeguard traditional food security are being revitalized: famine foods, resilient foods, harvest management, intra and inter-community networks, traditional food reciprocity, indigenous exchange, and adaptive support mechanisms.

Agriculture is a long-term commitment of knowledge, financial and human resources to the land. Amid this pandemic Covid-19 Fiji was hit by Category 4 cyclone Harold our economic front line was exposed lying bare the gaps our people and communities are falling through. The challenges of these twin disasters have a significant impact on our national job losses, the closure of businesses, food shortages and many more. The dre'e model and subsequent SOP will be a mechanism that should be implemented in agriculture development. The use of this model has demonstrated that the Traditional Knowledge of Kumala is a tool for Climate Smart Agriculture.

To summarize, it has been a true honour to hear the voices of these indigenous farmers in Ra. I had the opportunity to see how traditional knowledge serves as a safety net to support climate-smart agriculture while preserving kumala production in Fiji regardless of geographical location.

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Glossary

A

Au'vu .... *nature of relationship between vanua of Vanualevu & Ra.*

B

Balawa .... *totem plant*

Bati balavu .... *these are the warriors that protect the outer boundaries of the village and its chief.*

Bati leka................................*within the Vanua these are warriors that protect the inner boundaries of the village andits chief.*

Bula taucoko .... *the achievement of a state of completion.*

Bula vaka-vanua........................ *traditional Indigenous Fijian way of living, behaviour/life*

Bulu .... *underworld spirit.*

Bete .... *priest*

Bose ni vanua .... *village council or meeting*

Bure .... *traditional Fijian house.*

D

Dau ni vakasala .... *provides instructions and perceived to be full of wisdom.*

Dau/gonedau .... *traditional role as fisherman or sailor.*

Daunivucu .... *composer of meke or traditional Fijian dance.*

Dautawaqa/mataisau .... *traditional role as canoe builders.*

Dre'e .... *traditional woman basket for crops storage.*

I

I-Taukei..................................... *indigenous Fijians as owners of the land.*

i-tovo vakavanua....................... *protocols and cultural practices and processes with the Indigenous Fijian culture.i-*

Sevu .... *first fruit, formally presented*

K

Kava .... *yagona (*Piper *methysticum), a ceremonial drink.*

Kawa tamata............................. *race*

Kalougata .... *blessing*

Kakana dina .... *edible root crops (e.g., sweetpotato, taro & yams)*

Kerekere: .... *borrowing.*

Kocokoco ....greedy

Koro ....village

Koronivuli ....tertiary school.

*Kumala ....Sweetpotato (*Ipomoea batatas *(L.) Lam)*

L

Lagi ....heaven where God lives.

Loloma......................................the act of showing love and kindness to all

Lotu...religion or religious act.

Lolo ....house to store yams and kumala.

M

Marama-I-Taukei ....indigenous Fijian woman.

Matai....................................traditional role as carpenters within the village social structure.

Matanivanua............................traditional role as orator who speaks on behalf of a clan

Mataqali...................................sub- clan; sub-division of a yavusa.

Matanitu ....government institute.

Mana ....supernatural power.

Magiti ....food

N

Na i tovo vakaviti.......................Fijian way of life, involving customs and traditions.

Na kila vakayalomatua.............to have wisdom.

*Na noqu i noke ....fishing basket (noke) - added prefix **na noqu** means 'it*

Nai lavelave ....methods or instructions to do something.

Na mata ni civa ....pearl

O

O au sa'a...................................(Macuata dialect) a voice of respect and humility to acknowledge the space that I am speakingfrom and to those I am speaking to.

R

Ratu ....title prefixed to the name of a man of rank.

Roko Tui.....................................chiefly title, administrative head of a province

Rokola.......................................ancestral god of the carpenter (mataisau) clan.

S

Salusalu ....garland prepared using fresh fragrant flowers.

Sau .... *the spiritual power believed to have the ability to curse a person who is disrespectful. Sau is often associated withchiefs or chiefly families, their curse for a commoner.*

Sau tabu .... *burial site for indigenous Fijian chiefs.*

Sautu .... *wellbeing or the good quality life of the vanua or people.*

Sevusevu................................... *acknowledging entrance to the land or Vanua.*

Solesolevaki...........................*to work together to achieve a common purpose making mats, gardening.*

Su'e.......................................*traditional Fijian basket used by man for crop storage in Fiji.*

T

Tabua .... *polished tooth of a sperm whale, the most valuable item of Fijian property and used in exchange and ceremony.*

Talanoa .... *sharing of conversation and knowledge.*

Tali magimagi .... *used as a metaphor to talk about things in detail.*

Tanoa .... *bowl used to drink yaqona*

Tokatoka .... *the enlarged family unit.*

Tikina.. *district*

Turaga ni Koro.......................... *village headman*

Tuva kawa .... *to arrange the family tree*

V

Vakamarama .... *a female having characteristics and qualities that bestows respect.*

Vakaturaga .... *a male having characteristics and qualities that bestows respect; is said to bechieflike.*

Vakarau vakavanua .... *the practices of the land or Vanua.*

Vanua .... *the way of knowing, refers to 'a people, their chief, their defined territory, their waterways or fishing grounds, their environment, their spirituality, their history, their epistemology and culture.*

Vanua tabu............................... *scared place.*

Vasu...................................... *primarily defined as the village connection through the mother or the maternal links to a village.*

Varorogo .... *attentive and compliant.*

Vasili... *totem plant*

Veikauwaitaki........................... *thinking of others.*

Veidokai .... *respect-to show respect.*

Veisiko ....*to visit someone.*

Veiwasei ....*sharing with others.*

Veimaroroi................................*protectiveness*

Veivakatoroicaketaki................*enhancement/development*

Veidolei.....................................*exchange*

Veiwekani.................................*kinship*

Vinaka ....*good, thank you*

Vosota ....*patience*

Vucu..*Fijian chant*

Vula I Gasau ....*month of reeds*

Vulai keliekli ....*month of digging*

Vulagi ....*visitor, guest*

Vuravura...................................*physical world.*

Y

Yaqona ....*also known as kava or the traditional Fijian drink.*

Yavirau ....*a traditional fishing event, usually guided.*

Yavusa ....*group of families populating a village.*

Yalo...*spirit.*

Yasana......................................*province*

Yalomatua ....*considered wise.*

Appendices

Appendix 1: R Statistical analysis raw data of all kumala traits at the growth stage.

Soni_Raw Data

Soni

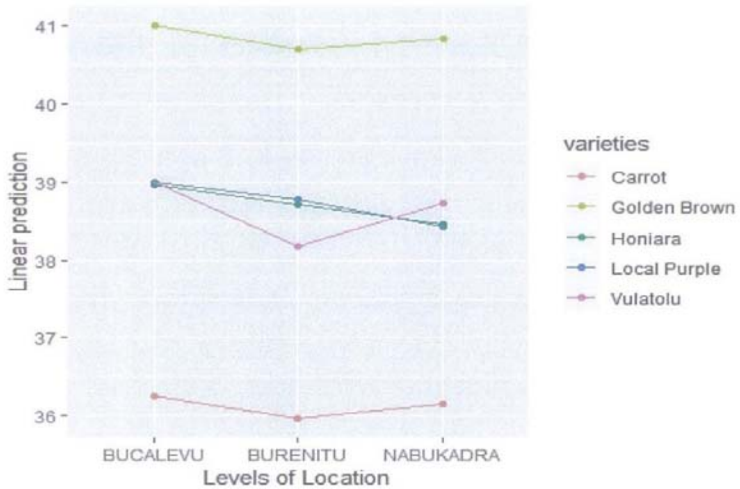
15 July 2019

```
library(emmeans)
library(tidyverse)

## Registered S3 methods overwritten by 'ggplot2':
##   method         from
##   [.quosures     rlang
##   c.quosures     rlang
##   print.quosures rlang

## Registered S3 method overwritten by 'rvest':
##   method            from
##   read_xml.response xml2

## -- Attaching packages --------------------------- tidyverse 1.2.1 --

## v ggplot2 3.1.1       v purrr   0.3.2
## v tibble  2.1.1       v dplyr   0.8.0.1
## v tidyr   0.8.3       v stringr 1.4.0
## v readr   1.3.1       v forcats 0.4.0

## -- Conflicts ------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(ggplot2)
library(sjPlot)
library(dplyr)
library(snakecase)
library(lme4)

## Loading required package: Matrix

##
## Attaching package: 'Matrix'

## The following object is masked from 'package:tidyr':
##
##     expand

library(nlme)

##
## Attaching package: 'nlme'

## The following object is masked from 'package:lme4':
##
##     lmList

## The following object is masked from 'package:dplyr':
##
##     collapse

soni_raw <- read.csv("soni_raw.csv", header = TRUE, sep = ",")
soni_raw$id <- as.factor(soni_raw$id)
soni_raw$dap <- as.factor(soni_raw$dap)

Chlorophyll.lme <- lme(Chlorophyll ~ Location*dap*varieties, random=~1 | id,
method="ML", data=soni_raw)
anova(Chlorophyll.lme)

##                        numDF denDF  F-value p-value
## (Intercept)                1   765 778788.7  <.0001
## Location                   2    45      7.1  0.0020
## dap                       17   765    851.1  <.0001
## varieties                  4    45    291.8  <.0001
## Location:dap              34   765      2.3  0.0001
## Location:varieties         8    45      1.4  0.2306
## dap:varieties             68   765      5.3  <.0001
## Location:dap:varieties   136   765      1.3  0.0095

CLD(emmeans(Chlorophyll.lme, "varieties"), Letters = letters)

## NOTE: Results may be misleading due to involvement in interactions

##  varieties    emmean      SE df lower.CL upper.CL .group
##  Carrot        36.13 0.09783 45    35.93    36.33  a
##  Vulatolu      38.64 0.09783 45    38.44    38.83  b
##  Honiara       38.71 0.09783 45    38.51    38.91  b
##  Local Purple  38.73 0.09783 45    38.53    38.93  b
##  Golden Brown  40.84 0.09783 45    40.65    41.04  c
##
## Results are averaged over the levels of: Location, dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05

CLD(emmeans(Chlorophyll.lme, "Location"), Letters = letters)

## NOTE: Results may be misleading due to involvement in interactions

##  Location  emmean      SE df lower.CL upper.CL .group
##  BURENITU   38.47 0.07578 45    38.31    38.62  a
##  NABUKADRA  38.52 0.07578 45    38.37    38.67  a
##  BUCALEVU   38.84 0.07578 45    38.69    38.99  b
##
```

```
## Results are averaged over the levels of: dap, varieties
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 3 estimates
## significance level used: alpha = 0.05
```

```
emmip(Chlorophyll.lme, varieties~Location)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```



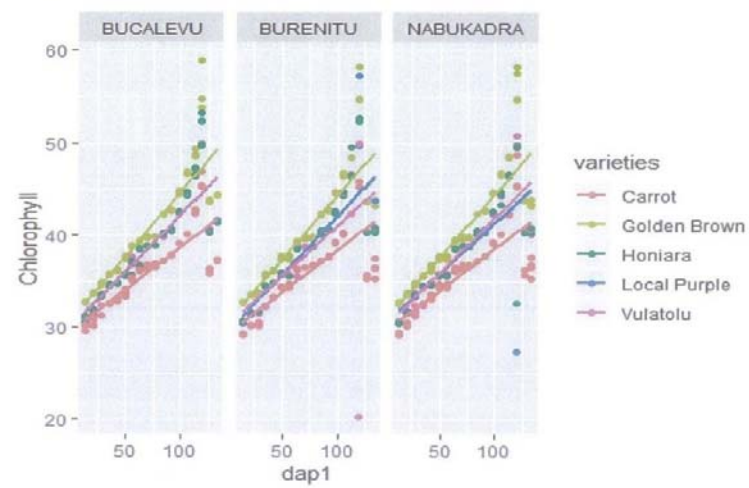

```
CLD(emmeans(Chlorophyll.lme, pairwise~varieties|Location), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
## Warning in CLD.emm_list(emmeans(Chlorophyll.lme, pairwise ~ varieties | :
## `CLD()` called with a list of 2 objects. Only the first one was used.
```

```
## Location = BUCALEVU:
##  varieties     emmean    SE df lower.CL upper.CL .group
##  Carrot          36.3 0.169 59     35.9     36.6  a
##  Honiara         39.0 0.169 45     38.6     39.3   b
##  Local Purple    39.0 0.169 45     38.7     39.3   b
##  Vulatolu        39.0 0.169 45     38.7     39.3   b
##  Golden Brown    41.0 0.169 45     40.7     41.3    c
##
## Location = BURENITU:
##  varieties     emmean    SE df lower.CL upper.CL .group
##  Carrot          36.0 0.169 45     35.6     36.3  a
##  Vulatolu        38.2 0.169 45     37.8     38.5   b
##  Honiara         38.7 0.169 45     38.4     39.1   b
##  Local Purple    38.8 0.169 45     38.4     39.1   b
##  Golden Brown    40.7 0.169 45     40.4     41.0    c
##
## Location = NABUKADRA:
##  varieties     emmean    SE df lower.CL upper.CL .group
##  Carrot          36.2 0.169 45     35.8     36.5  a
##  Local Purple    38.4 0.169 45     38.1     38.8   b
##  Honiara         38.5 0.169 45     38.1     38.8   b
##  Vulatolu        38.7 0.169 45     38.4     39.1   b
##  Golden Brown    40.8 0.169 45     40.5     41.2    c
##
## Results are averaged over the levels of: dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

```
ggplot(soni_raw, aes(dap1, Chlorophyll, color=varieties)) +
  geom_point() +
  geom_smooth(method="lm", se= FALSE) +
  facet_wrap(~Location)
```




```
No_Runners.lme <- lme(No_Runners ~ Location*dap*varieties, random=~1 | id,
method="ML", data=soni_raw)
anova(No_Runners.lme)
```

```
##                       numDF denDF   F-value p-value
## (Intercept)               1   765 1565.1073  <.0001
## Location                  2    45   23.4525  <.0001
## dap                      17   765  640.8916  <.0001
## varieties                 4    45   21.2698  <.0001
## Location:dap             34   765  156.9348  <.0001
## Location:varieties        8    45    1.1109  0.3741
## dap:varieties            68   765    1.0161  0.4446
## Location:dap:varieties  136   765    0.6157  0.9997
```

```
CLD(emmeans(No_Runners.lme, "varieties"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Golden Brown   2.65 0.236 45     2.17     3.12  a
##  Honiara        4.01 0.236 45     3.53     4.48   b
##  Vulatolu       4.06 0.236 45     3.59     4.53   b
##  Local Purple   4.44 0.236 45     3.97     4.92   b
##  Carrot         5.69 0.236 45     5.21     6.16    c
##
## Results are averaged over the levels of: Location, dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

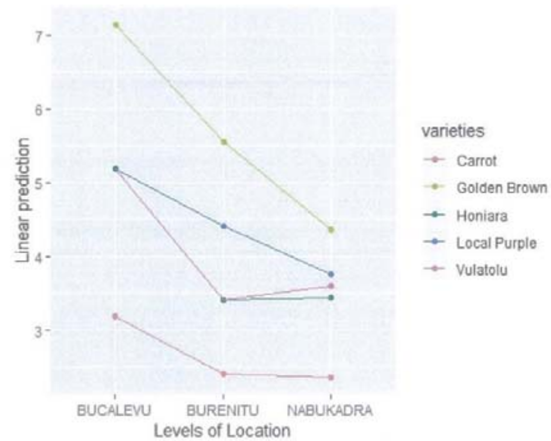
```
CLD(emmeans(No_Runners.lme, "Location"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
##  Location  emmean    SE df lower.CL upper.CL .group
##  NABUKADRA   3.50 0.183 45     3.14     3.87  a
##  BURENITU    3.83 0.183 45     3.47     4.20  a
##  BUCALEVU    5.17 0.183 45     4.80     5.54   b
##
## Results are averaged over the levels of: dap, varieties
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 3 estimates
## significance level used: alpha = 0.05
```

```
emmip(No_Runners.lme, varieties~Location)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```




```
CLD(emmeans(No_Runners.lme, pairwise~varieties|Location), Letters = letters)
```

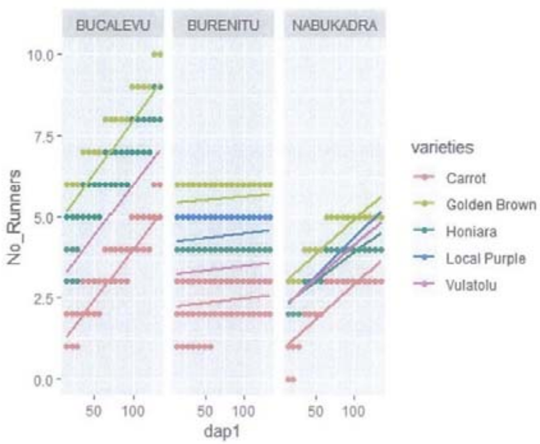
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
## Warning in CLD.emm_list(emmeans(No_Runners.lme, pairwise ~ varieties |
## Location), : `CLD()` called with a list of 2 objects. Only the first one
## was used.
```

```
## Location = BUCALEVU:
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Golden Brown   3.18 0.408 59     2.36     4.00  a
##  Vulatolu       5.18 0.408 45     4.36     6.00   b
##  Honiara        5.18 0.408 45     4.36     6.00   b
##  Local Purple   5.18 0.408 45     4.36     6.00   b
##  Carrot         7.14 0.408 45     6.32     7.96    c
##
## Location = BURENITU:
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Golden Brown   2.40 0.408 45     1.58     3.22  a
##  Vulatolu       3.40 0.408 45     2.58     4.22  ab
##  Honiara        3.40 0.408 45     2.58     4.22  ab
##  Local Purple   4.40 0.408 45     3.58     5.22   bc
##  Carrot         5.56 0.408 45     4.73     6.38    c
##
## Location = NABUKADRA:
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Golden Brown   2.36 0.408 45     1.54     3.18  a
```

```
## Honiara       3.44 0.408 45     2.62     4.27  ab
## Vulatolu      3.60 0.408 45     2.78     4.42  ab
## Local Purple  3.75 0.408 45     2.93     4.57  ab
## Carrot        4.36 0.408 45     3.54     5.18   b
##
## Results are averaged over the levels of: dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

```
ggplot(soni_raw, aes(dap1, No_Runners, color=varieties)) +
  geom_point() +
  geom_smooth(method="lm", se= FALSE) +
  facet_wrap(~Location)
```




```
R_Length.lme <- lme(R_Length ~ Location*dap*varieties, random=~1 | id,
method="ML", data=soni_raw)
anova(R_Length.lme)
```

```
##                        numDF denDF  F-value p-value
## (Intercept)                1   765 62379.17  <.0001
## Location                   2    45  1492.56  <.0001
## dap                       17   765 13614.64  <.0001
## varieties                  4    45   189.91  <.0001
## Location:dap              34   765   711.62  <.0001
## Location:varieties         8    45    22.00  <.0001
## dap:varieties             68   765    20.61  <.0001
## Location:dap:varieties   136   765    12.67  <.0001
```

```
CLD(emmeans(R_Length.lme, "varieties"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
##  varieties     emmean    SE df lower.CL upper.CL .group
##  Golden Brown    29.2 0.325 45     28.5     29.8  a
##  Vulatolu        36.7 0.325 45     36.0     37.3   b
##  Honiara         36.8 0.325 45     36.1     37.4   b
##  Local Purple    37.6 0.325 45     37.0     38.3   b
##  Carrot          41.5 0.325 45     40.9     42.2    c
##
## Results are averaged over the levels of: Location, dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

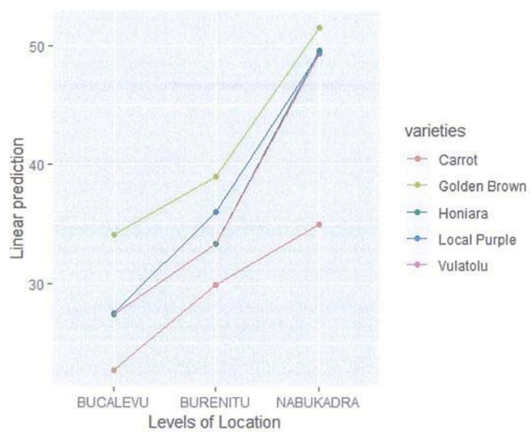
```
CLD(emmeans(R_Length.lme, "Location"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

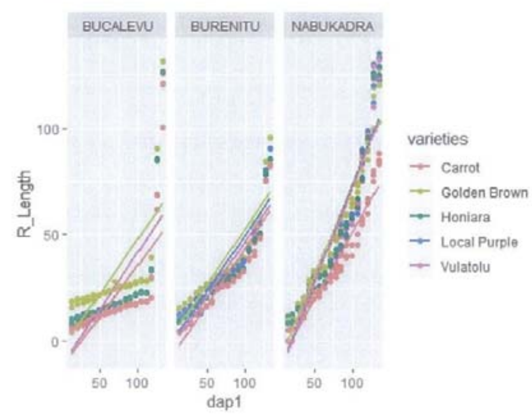
```
##  Location  emmean    SE df lower.CL upper.CL .group
##  BUCALEVU    27.8 0.252 45     27.3     28.3  a
##  BURENITU    34.3 0.252 45     33.8     34.8   b
##  NABUKADRA   47.0 0.252 45     46.4     47.5    c
##
## Results are averaged over the levels of: dap, varieties
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 3 estimates
## significance level used: alpha = 0.05
```

```
emmip(R_Length.lme, varieties~Location)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```




```
CLD(emmeans(R_Length.lme, pairwise~varieties|Location), Letters = letters)

## NOTE: Results may be misleading due to involvement in interactions

## Warning in CLD.emm_list(emmeans(R_Length.lme, pairwise ~ varieties |
## Location), : `CLD()` called with a list of 2 objects. Only the first one
## was used.

## Location = BUCALEVU:
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Golden Brown   22.7 0.564 59     21.6     23.8   a
##  Vulatolu       27.4 0.564 45     26.2     28.5   b
##  Honiara        27.4 0.564 45     26.2     28.5   b
##  Local Purple   27.4 0.564 45     26.3     28.6   b
##  Carrot         34.1 0.564 45     33.0     35.3   c
##
## Location = BURENITU:
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Golden Brown   29.9 0.564 45     28.7     31.0   a
##  Honiara        33.4 0.564 45     32.2     34.5   b
##  Vulatolu       33.4 0.564 45     32.2     34.5   b
##  Local Purple   36.0 0.564 45     34.9     37.1   c
##  Carrot         39.0 0.564 45     37.8     40.1   d
##
## Location = NABUKADRA:
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Golden Brown   34.9 0.564 45     33.8     36.0  a
##  Vulatolu       49.3 0.564 45     48.2     50.4   b
##  Local Purple   49.4 0.564 45     48.3     50.6   b
##  Honiara        49.6 0.564 45     48.5     50.7   b
##  Carrot         51.5 0.564 45     50.4     52.7   b
##
## Results are averaged over the levels of: dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05

ggplot(soni_raw, aes(dap1, R_Length, color=varieties)) +
  geom_point() +
  geom_smooth(method="lm", se= FALSE) +
  facet_wrap(~Location)
```




```
estab_rate_pc.lme <- lme(estab_rate_pc ~ Location*dap*varieties, random=~1 |
id, method="ML", data=soni_raw)
anova(estab_rate_pc.lme)

##                        numDF denDF  F-value p-value
## (Intercept)                1   765 41781.02  <.0001
## Location                   2    45    43.08  <.0001
## dap                       17   765     1.06  0.3937
## varieties                  4    45   122.38  <.0001
## Location:dap              34   765     0.90  0.6269
## Location:varieties         8    45     6.67  <.0001
```

```
## dap:varieties            68   765     1.06  0.3601
## Location:dap:varieties  136   765     0.90  0.7658
```

```
CLD(emmeans(estab_rate_pc.lme, "varieties"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
##  varieties    emmean SE df lower.CL upper.CL .group
##  Carrot         72.3  1 45     70.2     74.3  a
##  Honiara        94.4  1 45     92.4     96.5  b
##  Vulatolu       94.4  1 45     92.4     96.5  b
##  Local Purple   97.2  1 45     95.2     99.2  bc
##  Golden Brown  100.0  1 45     98.0    102.0  c
##
## Results are averaged over the levels of: Location, dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

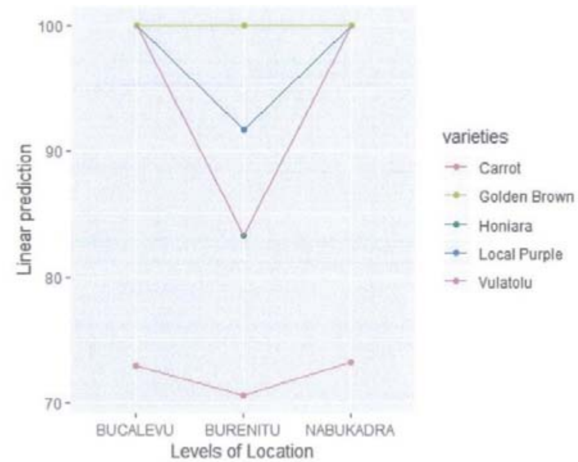
```
CLD(emmeans(estab_rate_pc.lme, "Location"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
##  Location  emmean    SE df lower.CL upper.CL .group
##  BURENITU    85.8 0.777 45     84.2     87.4  a
##  BUCALEVU    94.6 0.777 45     93.0     96.1  b
##  NABUKADRA   94.7 0.777 45     93.1     96.2  b
##
## Results are averaged over the levels of: dap, varieties
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 3 estimates
## significance level used: alpha = 0.05
```

```
emmip(estab_rate_pc.lme, varieties~Location)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```




```
CLD(emmeans(estab_rate_pc.lme, pairwise~varieties|Location), Letters =
letters)
```

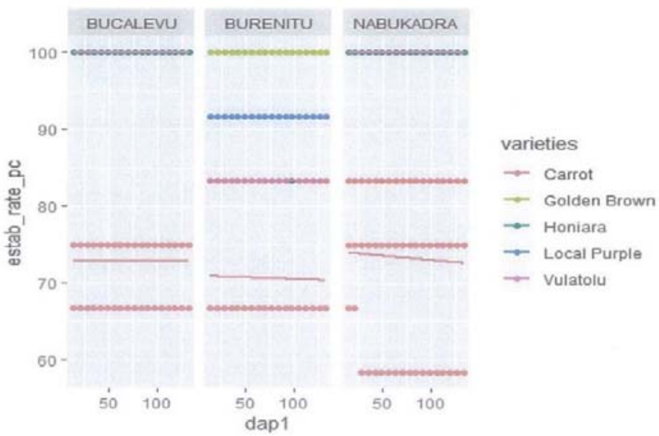
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
## Warning in CLD.emm_list(emmeans(estab_rate_pc.lme, pairwise ~ varieties |
:
## `CLD()` called with a list of 2 objects. Only the first one was used.
```

```
## Location = BUCALEVU:
##  varieties    emmean   SE df lower.CL upper.CL .group
##  Carrot         72.9 1.74 59     69.4     76.4  a
##  Golden Brown  100.0 1.74 45     96.5    103.5  b
##  Honiara       100.0 1.74 45     96.5    103.5  b
##  Vulatolu      100.0 1.74 45     96.5    103.5  b
##  Local Purple  100.0 1.74 45     96.5    103.5  b
##
## Location = BURENITU:
##  varieties    emmean   SE df lower.CL upper.CL .group
##  Carrot         70.6 1.74 45     67.1     74.1  a
##  Vulatolu       83.3 1.74 45     79.8     86.8  b
##  Honiara        83.3 1.74 45     79.8     86.8  b
##  Local Purple   91.7 1.74 45     88.2     95.2  c
##  Golden Brown  100.0 1.74 45     96.5    103.5  d
##
## Location = NABUKADRA:
##  varieties    emmean   SE df lower.CL upper.CL .group
```

```
##  Carrot        73.3 1.74 45     69.8     76.8   a
##  Golden Brown 100.0 1.74 45     96.5    103.5   b
##  Honiara      100.0 1.74 45     96.5    103.5   b
##  Vulatolu     100.0 1.74 45     96.5    103.5   b
##  Local Purple 100.0 1.74 45     96.5    103.5   b
##
## Results are averaged over the levels of: dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

```
ggplot(soni_raw, aes(dap1, estab_rate_pc, color=varieties)) +
  geom_point() +
  geom_smooth(method="lm", se= FALSE) +
  facet_wrap(~Location)
```




```
Leaf_No.lme <- lme(Leaf_No ~ Location*dap*varieties, random=~1 | id,
method="ML", data=soni_raw)
anova(Leaf_No.lme)
```

```
##                       numDF denDF  F-value p-value
## (Intercept)               1   765 3963.130  <.0001
## Location                  2    45  256.554  <.0001
## dap                      17   765 1311.656  <.0001
## varieties                 4    45    5.247  0.0015
## Location:dap             34   765  182.868  <.0001
## Location:varieties        8    45    7.857  <.0001
## dap:varieties            68   765   15.945  <.0001
## Location:dap:varieties  136   765   16.141  <.0001
```

```
CLD(emmeans(Leaf_No.lme, "varieties"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
##  varieties    emmean    SE df lower.CL upper.CL .group
##  Carrot         23.4 0.957 45     21.5     25.4  a
##  Golden Brown   26.2 0.957 45     24.3     28.1  ab
##  Vulatolu       28.1 0.957 45     26.2     30.0   b
##  Honiara        28.4 0.957 45     26.5     30.4   b
##  Local Purple   28.6 0.957 45     26.7     30.5   b
##
## Results are averaged over the levels of: Location, dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

```
CLD(emmeans(Leaf_No.lme, "Location"), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

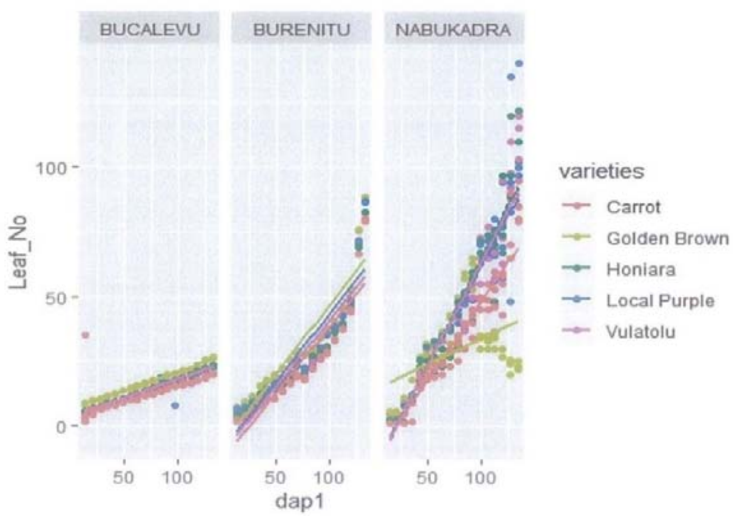
```
##  Location  emmean    SE df lower.CL upper.CL .group
##  BUCALEVU    14.4 0.741 45     12.9     15.9  a
##  BURENITU    28.4 0.741 45     26.9     29.9   b
##  NABUKADRA   38.0 0.741 45     36.5     39.5    c
##
## Results are averaged over the levels of: dap, varieties
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 3 estimates
## significance level used: alpha = 0.05
```

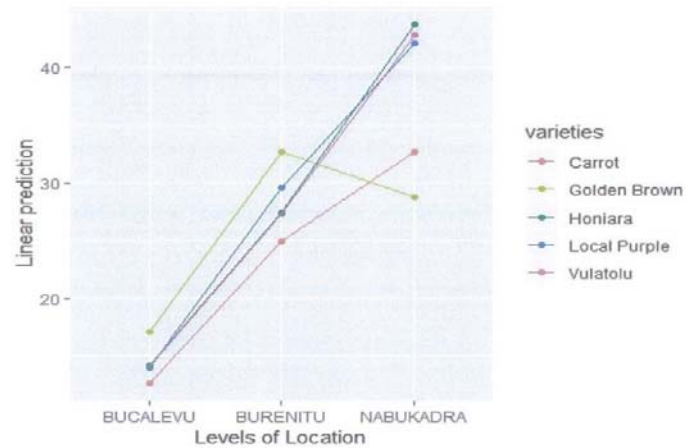
```
emmip(Leaf_No.lme, varieties~Location)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
## varieties    emmean   SE df lower.CL upper.CL .group
## Golden Brown   28.8 1.66 45    25.46     32.1  a
## Carrot         32.7 1.66 45    29.31     36.0  a
## Local Purple   42.1 1.66 45    38.80     45.5  b
## Vulatolu       42.8 1.66 45    39.43     46.1  b
## Honiara        43.8 1.66 45    40.42     47.1  b
##
## Results are averaged over the levels of: dap
## d.f. method: containment
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

```
ggplot(soni_raw, aes(dap1, Leaf_No, color=varieties)) +
  geom_point() +
  geom_smooth(method="lm", se= FALSE) +
  facet_wrap(~Location)
```






```
CLD(emmeans(Leaf_No.lme, pairwise~varieties|Location), Letters = letters)
```

```
## NOTE: Results may be misleading due to involvement in interactions

## Warning in CLD.emm_list(emmeans(Leaf_No.lme, pairwise ~ varieties |
## Location), : `CLD()` called with a list of 2 objects. Only the first one
## was used.

## Location = BUCALEVU:
##  varieties    emmean   SE df lower.CL upper.CL .group
##  Carrot         12.7 1.66 59     9.35     16.0  a
##  Local Purple   14.0 1.66 45    10.65     17.3  a
##  Vulatolu       14.1 1.66 45    10.81     17.5  a
##  Honiara        14.2 1.66 45    10.82     17.5  a
##  Golden Brown   17.1 1.66 45    13.74     20.4  a
##
## Location = BURENITU:
##  varieties    emmean   SE df lower.CL upper.CL .group
##  Carrot         25.0 1.66 45    21.61     28.3  a
##  Vulatolu       27.4 1.66 45    24.03     30.7  ab
##  Honiara        27.4 1.66 45    24.07     30.7  ab
##  Local Purple   29.6 1.66 45    26.27     33.0  ab
##  Golden Brown   32.7 1.66 45    29.33     36.0   b
##
## Location = NABUKADRA:
```

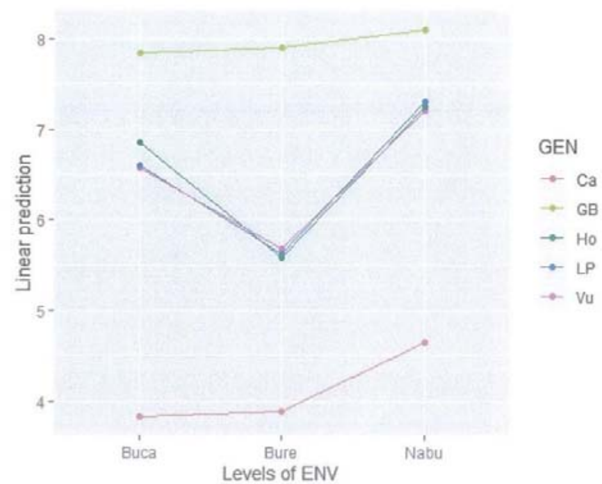
Appendix 2: R Statistical analysis raw data of all kumala traits harvest.

Harvest

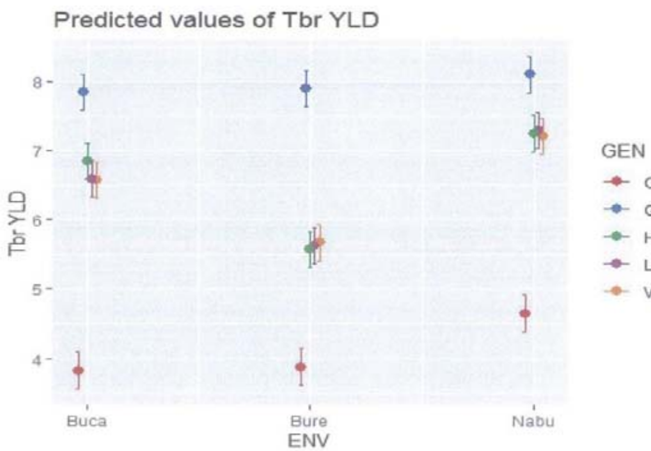
Soni

13 July 2019

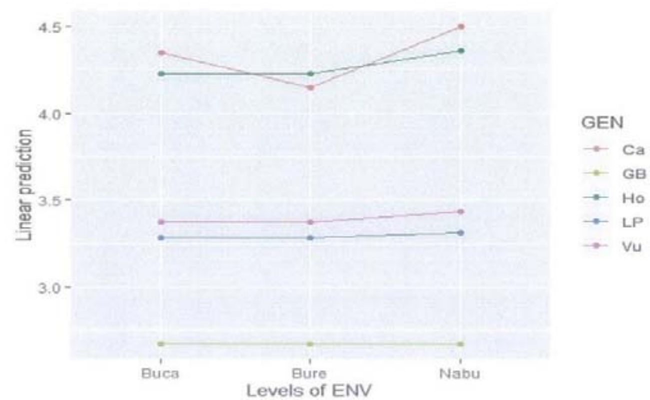
```
library(emmeans)
library(tidyverse)

## Registered S3 method overwritten by 'rvest':
##   method            from
##   read_xml.response xml2

## -- Attaching packages ----------------------- tidyverse 1.2.1 --

## v ggplot2 3.2.0       v purrr   0.3.2
## v tibble  2.1.1       v dplyr   0.8.0.1
## v tidyr   0.8.3       v stringr 1.4.0
## v readr   1.3.1       v forcats 0.4.0

## -- Conflicts -------------------------- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(ggplot2)
library(sjPlot)

## Learn more about sjPlot with 'browseVignettes("sjPlot")'.

library(dplyr)
library(snakecase)
library(arsenal)

## Warning: package 'arsenal' was built under R version 3.6.1

soni <- read.csv("soni.csv", header = TRUE, sep = ",")
head(soni)

##    ENV REP GEN Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM   Chl Leaf_No R_No R_Lgth
## 1 Nabu   1  GB     7.8    2.6  91.42   20.87 43.22      22    5    103
## 2 Nabu   1  LP     7.2    3.3  85.80   20.78 40.77     100    4    122
## 3 Nabu   1  Vu     7.3    3.4  71.31   23.04 40.12     115    4    124
## 4 Nabu   1  Ho     7.3    4.3  71.81   24.24 40.39     100    4    125
## 5 Nabu   1  Ca     4.6    4.5  63.30   24.31 35.23      80    3     85
## 6 Nabu   2  GB     8.1    2.7  84.80   20.13 43.19      23    5    121
##    estab
## 1 100.00
## 2 100.00
## 3 100.00
## 4 100.00
## 5  83.33
## 6 100.00

Tbr_YLD.lm <- lm(Tbr_YLD~ENV*GEN, data = soni)
anova(Tbr_YLD.lm)

## Analysis of Variance Table
##
## Response: Tbr_YLD
##           Df Sum Sq Mean Sq  F value    Pr(>F)
## ENV        2 13.755  6.8775  94.8808 < 2.2e-16 ***
## GEN        4 91.582 22.8955 315.8599 < 2.2e-16 ***
## ENV:GEN    8  4.654  0.5817   8.0251 1.183e-06 ***
## Residuals 45  3.262  0.0725
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

emmip(Tbr_YLD.lm, GEN~ENV)
```



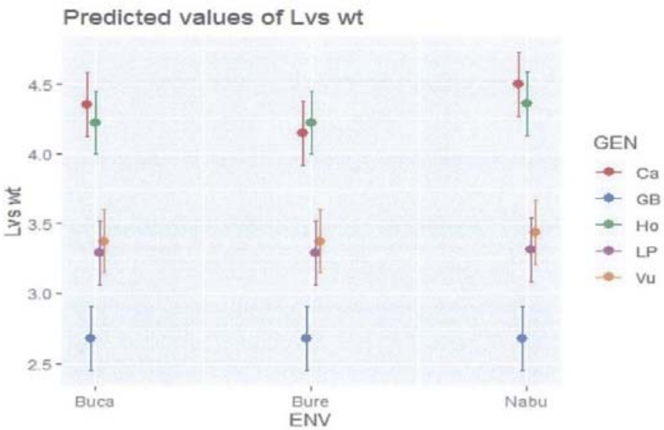

```
plot_model(Tbr_YLD.lm, "int")
```



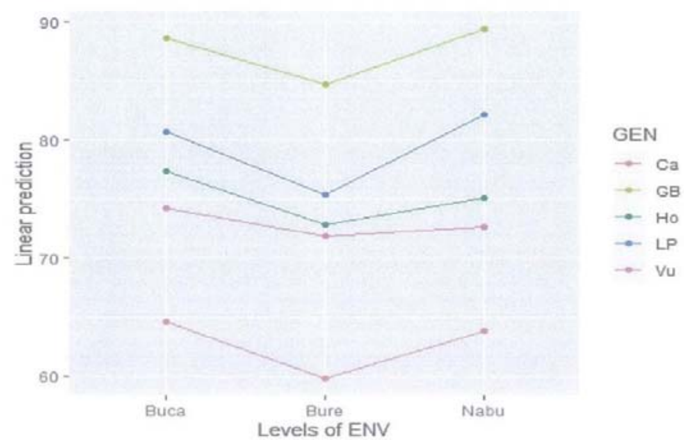

```
CLD(emmeans(Tbr_YLD.lm, pairwise~GEN|ENV), Letters = letters)

## Warning in CLD.emm_list(emmeans(Tbr_YLD.lm, pairwise ~ GEN | ENV), Letters
## = letters): `CLD()` called with a list of 2 objects. Only the first one
was
## used.

## ENV = Buca:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    3.83 0.135 45     3.55     4.10  a
##  Vu    6.58 0.135 45     6.30     6.85   b
##  LP    6.60 0.135 45     6.33     6.87   b
##  Ho    6.85 0.135 45     6.58     7.12   b
##  GB    7.85 0.135 45     7.58     8.12    c
##
## ENV = Bure:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    3.88 0.135 45     3.60     4.15  a
##  Ho    5.58 0.135 45     5.30     5.85   b
##  LP    5.62 0.135 45     5.35     5.90   b
##  Vu    5.67 0.135 45     5.40     5.95   b
##  GB    7.90 0.135 45     7.63     8.17    c
##
## ENV = Nabu:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    4.65 0.135 45     4.38     4.92  a
##  Vu    7.21 0.135 45     6.94     7.48   b
##  Ho    7.25 0.135 45     6.98     7.52   b
##  LP    7.30 0.135 45     7.03     7.57   b
##  GB    8.10 0.135 45     7.83     8.37    c
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05

Lvs_wt.lm <- lm(Lvs_wt~ENV*GEN, data = soni)
anova(Lvs_wt.lm)

## Analysis of Variance Table
##
## Response: Lvs_wt
##           Df  Sum Sq Mean Sq  F value Pr(>F)
## ENV        2  0.1363  0.0682   1.2666 0.2916
## GEN        4 23.7294  5.9324 110.2270 <2e-16 ***
## ENV:GEN    8  0.1728  0.0216   0.4014 0.9139
## Residuals 45  2.4219  0.0538
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

emmip(Lvs_wt.lm, GEN~ENV)
```



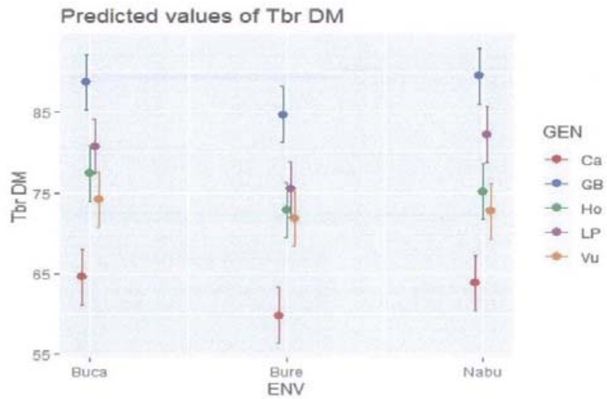

```
plot_model(Lvs_wt.lm, "int")
```



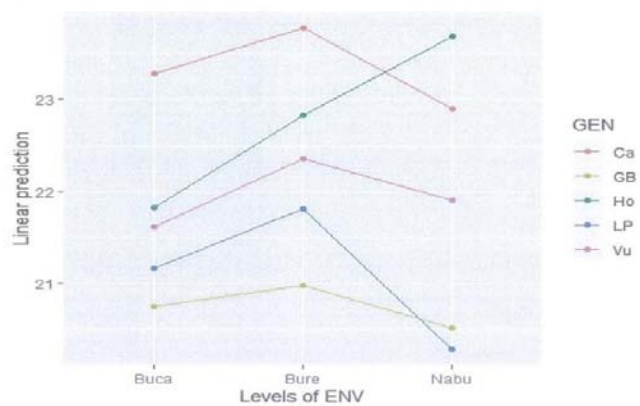

```
CLD(emmeans(Lvs_wt.lm, pairwise~GEN|ENV), Letters = letters)

## Warning in CLD.emm_list(emmeans(Lvs_wt.lm, pairwise ~ GEN | ENV), Letters
## = letters): `CLD()` called with a list of 2 objects. Only the first one
was
## used.

## ENV = Buca:
##  GEN emmean    SE df lower.CL upper.CL .group
##  GB    2.67 0.116 45     2.44     2.91  a
##  LP    3.29 0.116 45     3.05     3.52  b
##  Vu    3.38 0.116 45     3.14     3.61  b
##  Ho    4.22 0.116 45     3.99     4.46  c
##  Ca    4.35 0.116 45     4.12     4.58  c
##
## ENV = Bure:
##  GEN emmean    SE df lower.CL upper.CL .group
##  GB    2.67 0.116 45     2.44     2.91  a
##  LP    3.29 0.116 45     3.05     3.52  b
##  Vu    3.38 0.116 45     3.14     3.61  b
##  Ca    4.15 0.116 45     3.92     4.38  c
##  Ho    4.22 0.116 45     3.99     4.46  c
##
## ENV = Nabu:
##  GEN emmean    SE df lower.CL upper.CL .group
##  GB    2.67 0.116 45     2.44     2.91  a
##  LP    3.31 0.116 45     3.08     3.55  b
##  Vu    3.44 0.116 45     3.20     3.67  b
##  Ho    4.36 0.116 45     4.13     4.60  c
##  Ca    4.50 0.116 45     4.27     4.73  c
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05

Tbr_DM.lm <- lm(Tbr_DM ~ENV*GEN, data = soni)
anova(Tbr_DM.lm)

## Analysis of Variance Table
##
## Response: Tbr_DM
##           Df Sum Sq Mean Sq F value    Pr(>F)
## ENV        2  209.5  104.77  8.5149 0.0007307 ***
## GEN        4 3985.2  996.29 80.9744 < 2.2e-16 ***
## ENV:GEN    8   47.1    5.89  0.4788 0.8646938
## Residuals 45  553.7   12.30
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

emmip(Tbr_DM.lm, GEN~ENV)
```



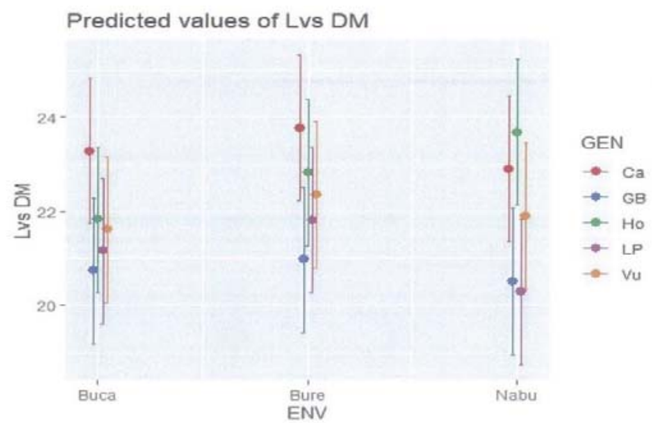

```
plot_model(Tbr_DM.lm, "int")
```




```
CLD(emmeans(Tbr_DM.lm, pairwise~GEN|ENV), Letters = letters)

## Warning in CLD.emm_list(emmeans(Tbr_DM.lm, pairwise ~ GEN | ENV), Letters
## = letters): `CLD()` called with a list of 2 objects. Only the first one
was
## used.

## ENV = Buca:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    64.5 1.75 45     61.0     68.1   a
##  Vu    74.2 1.75 45     70.7     77.7   b
##  Ho    77.4 1.75 45     73.9     80.9   b
##  LP    80.7 1.75 45     77.1     84.2   b
##  GB    88.7 1.75 45     85.2     92.2   c
##
## ENV = Bure:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    59.8 1.75 45     56.3     63.3   a
##  Vu    71.8 1.75 45     68.3     75.4   b
##  Ho    72.9 1.75 45     69.4     76.4   b
##  LP    75.4 1.75 45     71.9     79.0   b
##  GB    84.7 1.75 45     81.2     88.2   c
##
## ENV = Nabu:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    63.8 1.75 45     60.3     67.3   a
##  Vu    72.7 1.75 45     69.2     76.2   b
##  Ho    75.1 1.75 45     71.6     78.7   bc
##  LP    82.2 1.75 45     78.6     85.7    c
##  GB    89.4 1.75 45     85.9     93.0    d
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05

Lvs_.DM.lm <- lm(Lvs_.DM ~ENV*GEN, data = soni)
anova(Lvs_.DM.lm)

## Analysis of Variance Table
##
## Response: Lvs_.DM
##           Df  Sum Sq Mean Sq F value    Pr(>F)
## ENV        2   4.328  2.1642  0.8624 0.4290037
## GEN        4  57.299 14.3249  5.7083 0.0008376 ***
## ENV:GEN    8  10.425  1.3031  0.5193 0.8356184
## Residuals 45 112.927  2.5095
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

emmip(Lvs_.DM.lm, GEN~ENV)
```




```
plot_model(Lvs_.DM.lm, "int")
```



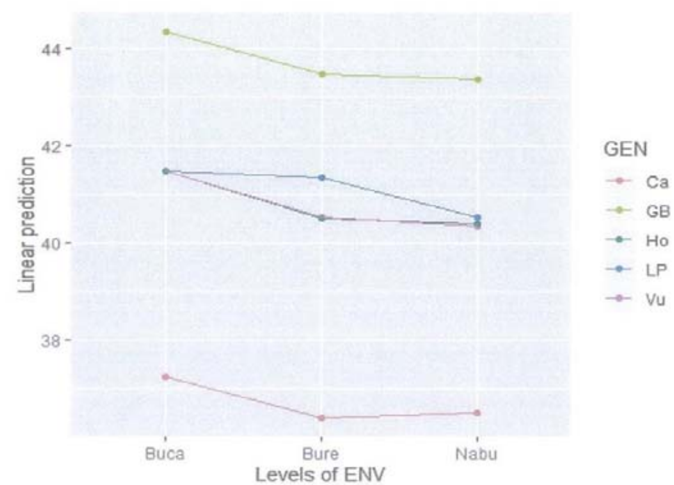

```
CLD(emmeans(Lvs_.DM.lm, pairwise~GEN|ENV), Letters = letters)
```

```
## Warning in CLD.emm_list(emmeans(Lvs_.DM.lm, pairwise ~ GEN | ENV), Letters
## = letters): `CLD()` called with a list of 2 objects. Only the first one
was
## used.

## ENV = Buca:
##  GEN emmean    SE df lower.CL upper.CL .group
##  GB    20.7 0.792 45     19.1     22.3  a
##  LP    21.2 0.792 45     19.6     22.8  a
##  Vu    21.6 0.792 45     20.0     23.2  a
##  Ho    21.8 0.792 45     20.2     23.4  a
##  Ca    23.3 0.792 45     21.7     24.9  a
##
## ENV = Bure:
##  GEN emmean    SE df lower.CL upper.CL .group
##  GB    21.0 0.792 45     19.4     22.6  a
##  LP    21.8 0.792 45     20.2     23.4  a
##  Vu    22.4 0.792 45     20.8     23.9  a
##  Ho    22.8 0.792 45     21.2     24.4  a
##  Ca    23.8 0.792 45     22.2     25.4  a
##
## ENV = Nabu:
##  GEN emmean    SE df lower.CL upper.CL .group
##  LP    20.3 0.792 45     18.7     21.9  a
##  GB    20.5 0.792 45     18.9     22.1  ab
##  Vu    21.9 0.792 45     20.3     23.5  ab
##  Ca    22.9 0.792 45     21.3     24.5  ab
##  Ho    23.7 0.792 45     22.1     25.3   b
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

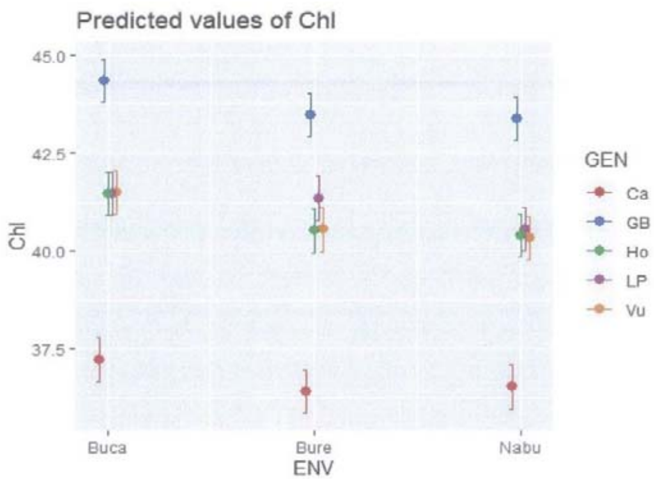
```
Chl.lm <- lm(Chl~ENV*GEN, data = soni)
anova(Chl.lm)
```

```
## Analysis of Variance Table
##
## Response: Chl
##           Df  Sum Sq Mean Sq  F value    Pr(>F)
## ENV        2  10.247   5.123  16.0820 5.376e-06 ***
## GEN        4 302.824  75.706 237.6353 < 2.2e-16 ***
## ENV:GEN    8   1.452   0.181   0.5696     0.797
## Residuals 45  14.336   0.319
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmip(Chl.lm, GEN~ENV)
```




```
plot_model(Chl.lm, "int")
```




```
CLD(emmeans(Chl.lm, pairwise~GEN|ENV), Letters = letters)
```

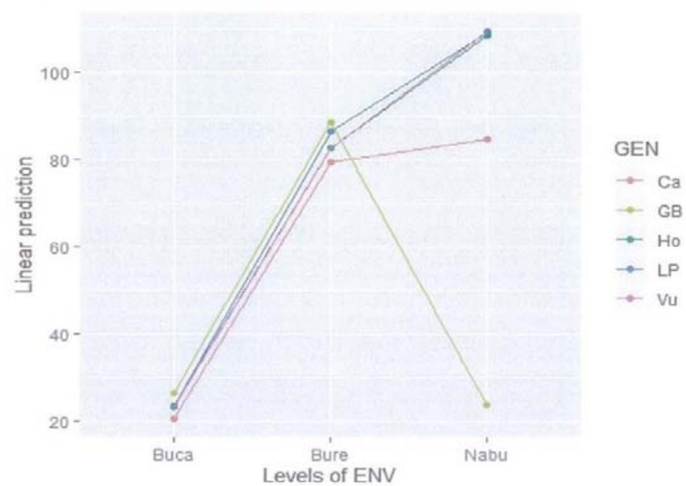
```
## Warning in CLD.emm_list(emmeans(Chl.lm, pairwise ~ GEN | ENV), Letters =
## letters): `CLD()` called with a list of 2 objects. Only the first one was
## used.
```

```
## ENV = Buca:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    37.2 0.282 45     36.7     37.8   a
##  LP    41.5 0.282 45     40.9     42.0   b
##  Ho    41.5 0.282 45     40.9     42.0   b
##  Vu    41.5 0.282 45     40.9     42.1   b
##  GB    44.3 0.282 45     43.8     44.9   c
##
## ENV = Bure:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    36.4 0.282 45     35.8     37.0   a
##  Ho    40.5 0.282 45     39.9     41.1   b
##  Vu    40.5 0.282 45     40.0     41.1   b
##  LP    41.3 0.282 45     40.8     41.9   b
##  GB    43.5 0.282 45     42.9     44.0   c
##
## ENV = Nabu:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    36.5 0.282 45     35.9     37.1  a
##  Vu    40.3 0.282 45     39.8     40.9   b
##  Ho    40.4 0.282 45     39.8     41.0   b
##  LP    40.5 0.282 45     40.0     41.1   b
##  GB    43.4 0.282 45     42.8     43.9   c
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

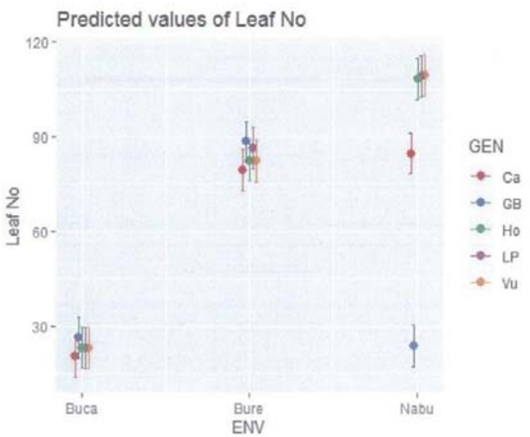
```
Leaf_No.lm <- lm(Leaf_No~ENV*GEN, data = soni)
anova(Leaf_No.lm)
```

```
## Analysis of Variance Table
##
## Response: Leaf_No
##           Df Sum Sq Mean Sq F value    Pr(>F)
## ENV        2  51669 25834.6 578.740 < 2.2e-16 ***
## GEN        4   6168  1541.9  34.542 3.449e-13 ***
## ENV:GEN    8  15983  1997.9  44.757 < 2.2e-16 ***
## Residuals 45   2009    44.6
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

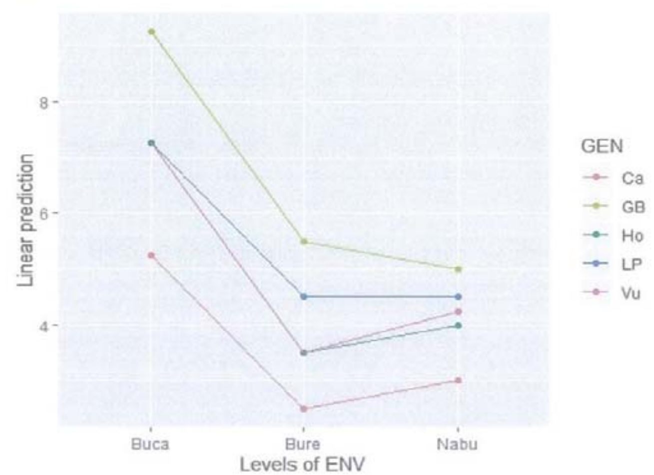
```
emmip(Leaf_No.lm, GEN~ENV)
```



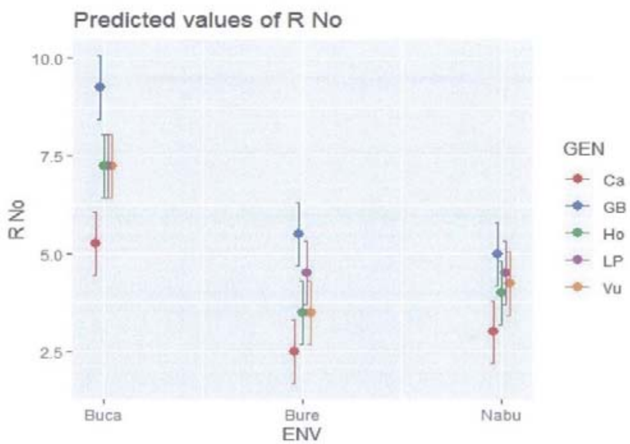

```
plot_model(Leaf_No.lm, "int")
```




```
CLD(emmeans(Leaf_No.lm, pairwise~GEN|ENV), Letters = letters)

## Warning in CLD.emm_list(emmeans(Leaf_No.lm, pairwise ~ GEN | ENV), Letters
## = letters): `CLD()` called with a list of 2 objects. Only the first one
was
## used.

## ENV = Buca:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    20.5 3.34 45     13.8     27.2  a
##  LP    23.2 3.34 45     16.4     29.9  a
##  Vu    23.2 3.34 45     16.5     30.0  a
##  Ho    23.3 3.34 45     16.5     30.0  a
##  GB    26.5 3.34 45     19.8     33.2  a
##
## ENV = Bure:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    79.5 3.34 45     72.8     86.2  a
##  Vu    82.5 3.34 45     75.8     89.3  a
##  Ho    82.5 3.34 45     75.8     89.3  a
##  LP    86.5 3.34 45     79.7     93.2  a
##  GB    88.5 3.34 45     81.7     95.2  a
##
## ENV = Nabu:
##  GEN emmean   SE df lower.CL upper.CL .group
##  GB    23.8 3.34 45     17.0     30.5   a
##  Ca    84.8 3.34 45     78.0     91.5   b
##  Ho   108.5 3.34 45    101.8    115.2    c
##  LP   109.2 3.34 45    102.5    116.0    c
##  Vu   109.5 3.34 45    102.8    116.2    c
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05

R_No.lm <- lm(R_No ~ENV*GEN, data = soni)
anova(R_No.lm)

## Analysis of Variance Table
##
## Response: R_No
##           Df  Sum Sq Mean Sq F value    Pr(>F)
## ENV        2 139.300  69.650 102.762 < 2.2e-16 ***
## GEN        4  55.733  13.933  20.557 1.085e-09 ***
## ENV:GEN    8   5.867   0.733   1.082    0.3929
## Residuals 45  30.500   0.678
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

emmip(R_No.lm, GEN~ENV)
```




```
plot_model(R_No.lm, "int")
```




```
CLD(emmeans(R_No.lm, pairwise~GEN|ENV), Letters = letters)
```

```
## Warning in CLD.emm_list(emmeans(R_No.lm, pairwise ~ GEN | ENV), Letters =
## letters): `CLD()` called with a list of 2 objects. Only the first one was
## used.
```

```
## ENV = Buca:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    5.25 0.412 45     4.42     6.08  a
##  LP    7.25 0.412 45     6.42     8.08  b
##  Ho    7.25 0.412 45     6.42     8.08  b
##  Vu    7.25 0.412 45     6.42     8.08  b
##  GB    9.25 0.412 45     8.42    10.08  c
##
## ENV = Bure:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    2.50 0.412 45     1.67     3.33  a
##  Vu    3.50 0.412 45     2.67     4.33  ab
##  Ho    3.50 0.412 45     2.67     4.33  ab
##  LP    4.50 0.412 45     3.67     5.33  bc
##  GB    5.50 0.412 45     4.67     6.33  c
##
## ENV = Nabu:
##  GEN emmean    SE df lower.CL upper.CL .group
##  Ca    3.00 0.412 45     2.17     3.83  a
##  Ho    4.00 0.412 45     3.17     4.83  ab
##  Vu    4.25 0.412 45     3.42     5.08  ab
##  LP    4.50 0.412 45     3.67     5.33  ab
##  GB    5.00 0.412 45     4.17     5.83   b
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

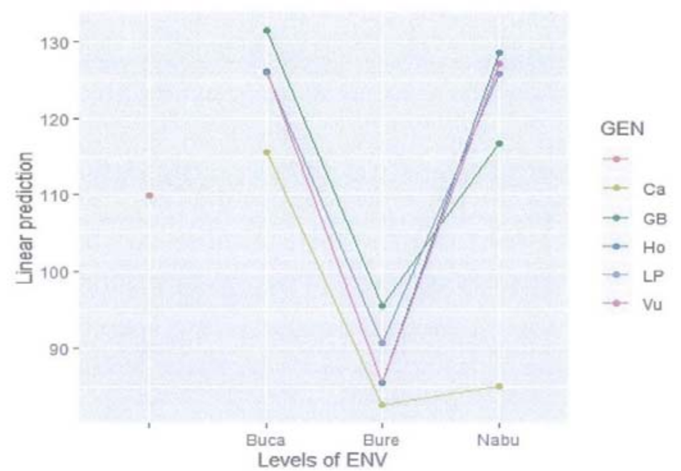
```
R_Lgth.lm <- lm(R_Lgth~ENV*GEN, data = soni)
anova(R_Lgth.lm)
```

```
## Analysis of Variance Table
##
## Response: R_Lgth
##           Df  Sum Sq Mean Sq F value    Pr(>F)
## ENV        3 15123.9  5041.3 294.099 < 2.2e-16 ***
## GEN        4  3605.5   901.4  52.585 < 2.2e-16 ***
## ENV:GEN    8  2674.2   334.3  19.501 2.815e-12 ***
## Residuals 45   771.4    17.1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmip(R_Lgth.lm, GEN~ENV)
```

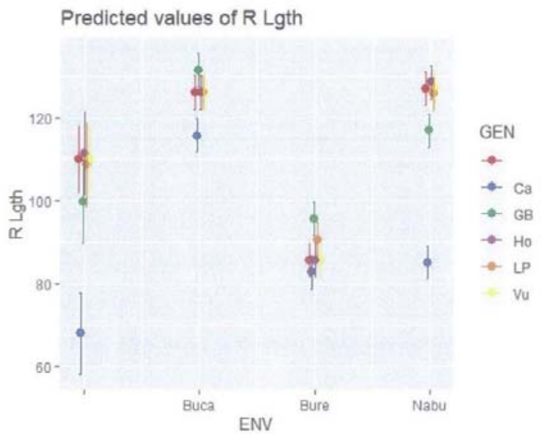
```
## Warning: Removed 8 rows containing missing values (geom_point).
```

```
## Warning: Removed 8 rows containing missing values (geom_path).
```



```
plot_model(R_Lgth.lm, "int")
```

```
## Warning in predict.lm(model, newdata = fitfram, type = "response", se.fit
=
## se, : prediction from a rank-deficient fit may be misleading
```




```
CLD(emmeans(R_Lgth.lm, pairwise~GEN|ENV), Letters = letters)
```

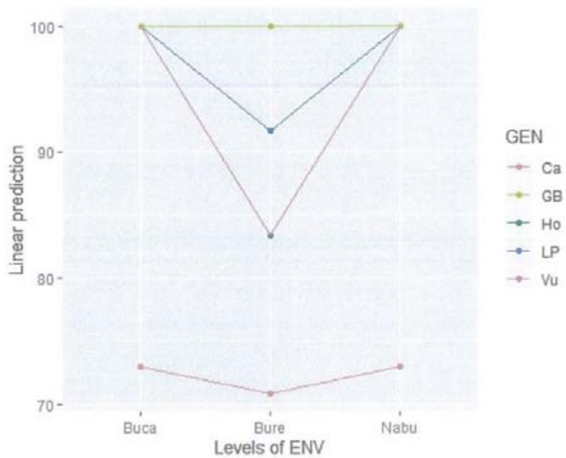
```
## Warning in CLD.emm_list(emmeans(R_Lgth.lm, pairwise ~ GEN | ENV), Letters
## = letters): `CLD()` called with a list of 2 objects. Only the first one
was
## used.
```

```
## ENV = :
##  GEN emmean   SE df lower.CL upper.CL .group
##       109.9 4.14 45    101.5    118.2  a
##  Ca  nonEst   NA NA       NA       NA
##  GB  nonEst   NA NA       NA       NA
##  Ho  nonEst   NA NA       NA       NA
##  LP  nonEst   NA NA       NA       NA
##  Vu  nonEst   NA NA       NA       NA
##
## ENV = Buca:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca   115.6 2.07 45    111.4    119.8   a
##  LP   126.0 2.07 45    121.8    130.2   b
##  Vu   126.0 2.07 45    121.9    130.2   b
##  Ho   126.1 2.07 45    121.9    130.2   b
##  GB   131.4 2.07 45    127.3    135.6   b
##      nonEst   NA NA       NA       NA
##
## ENV = Bure:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    82.6 2.07 45     78.4     86.8  a
##  Ho    85.5 2.07 45     81.3     89.7  a
##  Vu    85.5 2.07 45     81.3     89.7  a
##  LP    90.6 2.07 45     86.4     94.8  ab
##  GB    95.5 2.07 45     91.3     99.7   b
##      nonEst   NA NA       NA       NA
##
## ENV = Nabu:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    85.0 2.07 45     80.8     89.2   a
##  GB   116.8 2.07 45    112.6    120.9    b
##  LP   125.8 2.07 45    121.6    129.9    c
##  Vu   127.0 2.07 45    122.8    131.2    c
##  Ho   128.5 2.07 45    124.3    132.7    c
##      nonEst   NA NA       NA       NA
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 6 estimates
## significance level used: alpha = 0.05
```

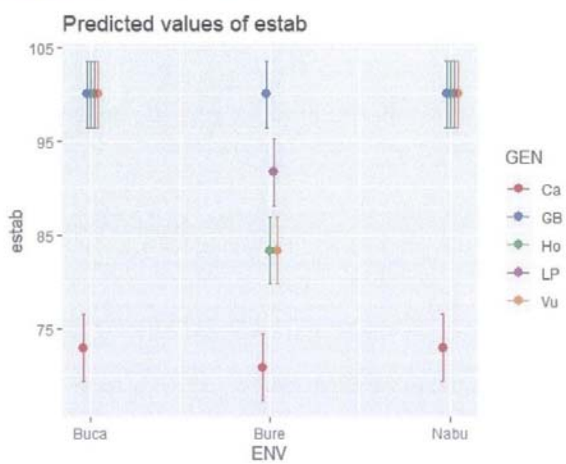
```
estab.lm <- lm(estab~ENV*GEN, data = soni)
anova(estab.lm)
```

```
## Analysis of Variance Table
##
## Response: estab
##           Df Sum Sq Mean Sq  F value    Pr(>F)
## ENV        2 1020.9  510.45  38.9259 1.535e-10 ***
## GEN        4 5925.8 1481.45 112.9733 < 2.2e-16 ***
## ENV:GEN    8  657.8   82.22   6.2701 1.935e-05 ***
## Residuals 45  590.1   13.11
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmip(estab.lm, GEN~ENV)
```




```r
plot_model(estab.lm, "int")
```




```r
CLD(emmeans(estab.lm, pairwise~GEN|ENV), Letters = letters)
```

```
## Warning in CLD.emm_list(emmeans(estab.lm, pairwise ~ GEN | ENV), Letters =
## letters): `CLD()` called with a list of 2 objects. Only the first one was
## used.

## ENV = Buca:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    72.9 1.81 45     69.3     76.6   a
##  LP   100.0 1.81 45     96.4    103.6   b
##  GB   100.0 1.81 45     96.4    103.6   b
##  Ho   100.0 1.81 45     96.4    103.6   b
##  Vu   100.0 1.81 45     96.4    103.6   b
##
## ENV = Bure:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    70.8 1.81 45     67.2     74.5   a
##  Ho    83.3 1.81 45     79.7     87.0   b
##  Vu    83.3 1.81 45     79.7     87.0   b
##  LP    91.7 1.81 45     88.0     95.3   c
##  GB   100.0 1.81 45     96.4    103.6   d
##
## ENV = Nabu:
##  GEN emmean   SE df lower.CL upper.CL .group
##  Ca    72.9 1.81 45     69.3     76.6   a
##  LP   100.0 1.81 45     96.4    103.6   b
##  Vu   100.0 1.81 45     96.4    103.6   b
##  Ho   100.0 1.81 45     96.4    103.6   b
##  GB   100.0 1.81 45     96.4    103.6   b
##
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 5 estimates
## significance level used: alpha = 0.05
```

Appendix 3: Statistical analysis of tuber dry matter correlation with other kumala traits

Tuber Dry Matter Correlation with other traits

Soni

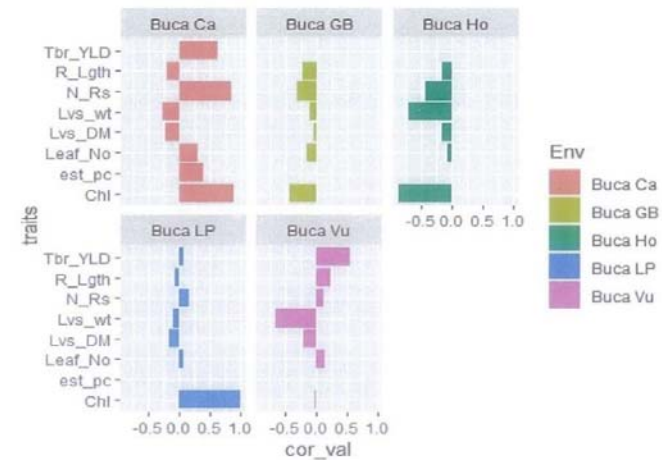
17 July 2019

```
library("PerformanceAnalytics")

## Warning: package 'PerformanceAnalytics' was built under R version 3.6.1

## Loading required package: xts

## Warning: package 'xts' was built under R version 3.6.1

## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric

## Registered S3 method overwritten by 'xts':
##   method     from
##   as.zoo.xts zoo

##
## Attaching package: 'PerformanceAnalytics'

## The following object is masked from 'package:graphics':
##
##     legend

library("corrplot")

## Warning: package 'corrplot' was built under R version 3.6.1

## corrplot 0.84 loaded

library(corrr)

## Warning: package 'corrr' was built under R version 3.6.1

## Registered S3 methods overwritten by 'ggplot2':
##   method         from
##   [.quosures     rlang
##   c.quosures     rlang
##   print.quosures rlang
```

```
library(MASS)
library(magrittr)
library(tidyverse)

## Registered S3 method overwritten by 'rvest':
##   method            from
##   read_xml.response xml2

## -- Attaching packages ---------------------------------------------------
--- tidyverse 1.2.1 --

## v ggplot2 3.1.1       v purrr   0.3.2
## v tibble  2.1.1       v dplyr   0.8.0.1
## v tidyr   0.8.3       v stringr 1.4.0
## v readr   1.3.1       v forcats 0.4.0

## -- Conflicts ----------------------------------------------------------
tidyverse_conflicts() --
## x tidyr::extract()   masks magrittr::extract()
## x dplyr::filter()    masks stats::filter()
## x dplyr::first()     masks xts::first()
## x dplyr::lag()       masks stats::lag()
## x dplyr::last()      masks xts::last()
## x dplyr::select()    masks MASS::select()
## x purrr::set_names() masks magrittr::set_names()

soni <- read.csv("soni.csv", header = TRUE, sep = ",")
soni$REP <- as.factor(soni$REP)
Buca_GB <- soni %>%
  filter(ENV=="Bucalevu"&Variety=="Golden Brown")
Buca_LP <- soni %>%
  filter(ENV=="Bucalevu"&Variety=="Local Purple")
Buca_Vu <- soni %>%
  filter(ENV=="Bucalevu"&Variety=="Vulatolu")
Buca_Ho <- soni %>%
  filter(ENV=="Bucalevu"&Variety=="Honiara")
Buca_Ca <- soni %>%
  filter(ENV=="Bucalevu"&Variety=="Carrot")

Bure_GB <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Golden Brown")
Bure_LP <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Local Purple")
Bure_Vu <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Vulatolu")
Bure_Ho <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Honiara")
Bure_Ca <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Carrot")
```

```
Nabu_GB <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Golden Brown")
Nabu_LP <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Local Purple")
Nabu_Vu <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Vulatolu")
Nabu_Ho <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Honiara")
Nabu_Ca <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Carrot")

Buca_GB <- Buca_GB[, sapply(Buca_GB, is.numeric)]
Buca_GB_corr <- correlate(Buca_GB)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Buca_GB_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .96
## 3  Tbr_DM     .00   -.10
## 4  Lvs_DM   -1.00   -.94   -.03
## 5     Chl     .35    .59   -.42   -.27
## 6 Leaf_No     .76    .91   -.16   -.70  .86
## 7    N_Rs     .51    .73   -.31   -.44  .98     .94
## 8  R_Lgth     .81    .94   -.23   -.76  .83     .99  .92
## 9  est_pc

tbr_dm_Buca_GB <- Buca_GB_corr %>%
  focus(Tbr_DM)

Buca_LP <- Buca_LP[, sapply(Buca_LP, is.numeric)]
Buca_LP_corr <- correlate(Buca_LP)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Buca_LP_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt    -.08
## 3  Tbr_DM     .06   -.09
## 4  Lvs_DM    -.94   -.23   -.16
## 5     Chl     .21   -.15    .99   -.28
## 6 Leaf_No     .85    .45    .05   -.97  .15
## 7    N_Rs     .89    .37    .15   -.99  .25     .99
## 8  R_Lgth     .84    .46   -.07   -.95  .03     .99  .97
## 9  est_pc

tbr_dm_Buca_LP <- Buca_LP_corr %>%
  focus(Tbr_DM)

Buca_Vu <- Buca_Vu[, sapply(Buca_Vu, is.numeric)]
Buca_Vu_corr <- correlate(Buca_Vu)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Buca_Vu_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .27
## 3  Tbr_DM     .55   -.65
## 4  Lvs_DM    -.93   -.61   -.19
## 5     Chl     .37    .28   -.01   -.48
## 6 Leaf_No     .79    .59    .14   -.84 -.07
## 7    N_Rs     .90    .67    .12   -.99  .42     .88
## 8  R_Lgth     .92    .58    .24   -.97  .24     .95  .98
## 9  est_pc

tbr_dm_Buca_Vu <- Buca_Vu_corr %>%
  focus(Tbr_DM)

Buca_Ho <- Buca_Ho[, sapply(Buca_Ho, is.numeric)]
Buca_Ho_corr <- correlate(Buca_Ho)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Buca_Ho_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .19
```

```
## 3  Tbr_DM    -.00   -.71
## 4  Lvs_DM    -.30   -.59   -.15
## 5      Chl   .38    .47   -.87    .32
## 6 Leaf_No    .55    .72   -.07   -.94  .00
## 7     N_Rs   .66    .85   -.44   -.70  .44      .90
## 8  R_Lgth    .65    .74   -.16   -.87  .15      .99  .95
## 9  est_pc

tbr_dm_Buca_Ho <- Buca_Ho_corr %>%
  focus(Tbr_DM)

Buca_Ca <- Buca_Ca[, sapply(Buca_Ca, is.numeric)]
Buca_Ca_corr <- correlate(Buca_Ca)

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Buca_Ca_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .54
## 3  Tbr_DM     .61   -.29
## 4  Lvs_DM    -.01    .51   -.24
## 5      Chl    .17   -.61    .87   -.11
## 6 Leaf_No     .93    .80    .29    .15 -.18
## 7     N_Rs    .95    .26    .83   -.14  .45      .77
## 8  R_Lgth     .58    .78   -.21   -.14 -.67      .78  .35
## 9  est_pc     .32    .26    .38    .81  .45      .26  .33    -.32

tbr_dm_Buca_Ca <- Buca_Ca_corr %>%
  focus(Tbr_DM)

Tbr_DM_Buca_cor <- cbind(tbr_dm_Buca_GB$rowname, tbr_dm_Buca_GB$Tbr_DM,
tbr_dm_Buca_LP$Tbr_DM, tbr_dm_Buca_Vu$Tbr_DM, tbr_dm_Buca_Ho$Tbr_DM,
tbr_dm_Buca_Ca$Tbr_DM)

colnames(Tbr_DM_Buca_cor) <- c( "traits" ,"Buca GB", "Buca LP","Buca Vu",
"Buca Ho", "Buca Ca")

Tbr_DM_Buca_cor <- as.data.frame(Tbr_DM_Buca_cor)

Tbr_DM_Buca_cor$"Buca GB" <-
round(as.numeric(as.character(Tbr_DM_Buca_cor$"Buca GB")), 2)
Tbr_DM_Buca_cor$"Buca LP" <-
round(as.numeric(as.character(Tbr_DM_Buca_cor$"Buca LP")), 2)
Tbr_DM_Buca_cor$"Buca Vu" <-
round(as.numeric(as.character(Tbr_DM_Buca_cor$"Buca Vu")), 2)
Tbr_DM_Buca_cor$"Buca Ho" <-
round(as.numeric(as.character(Tbr_DM_Buca_cor$"Buca Ho")), 2)
Tbr_DM_Buca_cor$"Buca Ca" <-
round(as.numeric(as.character(Tbr_DM_Buca_cor$"Buca Ca")), 2)

print(Tbr_DM_Buca_cor)

##    traits Buca GB Buca LP Buca Vu Buca Ho Buca Ca
## 1 Tbr_YLD    0.00    0.06    0.55    0.00    0.61
## 2  Lvs_wt   -0.10   -0.09   -0.65   -0.71   -0.29
## 3  Lvs_DM   -0.03   -0.16   -0.19   -0.15   -0.24
## 4     Chl   -0.42    0.99   -0.01   -0.87    0.87
## 5 Leaf_No   -0.16    0.05    0.14   -0.07    0.29
## 6    N_Rs   -0.31    0.15    0.12   -0.44    0.83
## 7  R_Lgth   -0.23   -0.07    0.24   -0.16   -0.21
## 8  est_pc      NA      NA      NA      NA    0.38

Tbr_DM_Buca_cor_long <- gather(Tbr_DM_Buca_cor, -traits, key="Env",
value="cor_val")
ggplot(Tbr_DM_Buca_cor_long, aes(x=traits, cor_val, fill=Env)) +
        geom_col() +
        coord_flip() +
        facet_wrap(~Env)

## Warning: Removed 4 rows containing missing values (position_stack).
```



```
Bure_GB <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Golden Brown")
Bure_LP <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Local Purple")
Bure_Vu <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Vulatolu")
Bure_Ho <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Honiara")
Bure_Ca <- soni %>%
  filter(ENV=="Burenitu"&Variety=="Carrot")

Bure_GB <- Bure_GB[, sapply(Bure_GB, is.numeric)]
Bure_GB_corr <- correlate(Bure_GB)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_GB_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .99
## 3  Tbr_DM    -.93   -.91
## 4  Lvs_DM     .06    .17   -.19
## 5     Chl     .66    .69   -.84    .66
## 6 Leaf_No     .66    .73   -.76    .78  .95
## 7    N_Rs     .64    .68   -.82    .70 1.00     .96
## 8  R_Lgth     .86    .91   -.87    .56  .89     .95  .89
## 9  est_pc

tbr_dm_Bure_GB <- Bure_GB_corr %>%
  focus(Tbr_DM)

Bure_LP <- Bure_LP[, sapply(Bure_LP, is.numeric)]
Bure_LP_corr <- correlate(Bure_LP)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_LP_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .06
## 3  Tbr_DM     .17    .86
## 4  Lvs_DM    -.60    .47    .03
## 5     Chl    -.44   -.22    .19   -.38
## 6 Leaf_No    -.56    .14    .46   -.08  .92
## 7    N_Rs    -.19    .60    .87   -.05  .64     .84
## 8  R_Lgth    -.60    .39    .60    .16  .78     .96  .89
## 9  est_pc

tbr_dm_Bure_LP <- Bure_LP_corr %>%
  focus(Tbr_DM)

Bure_Vu <- Bure_Vu[, sapply(Bure_Vu, is.numeric)]
Bure_Vu_corr <- correlate(Bure_Vu)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_Vu_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .76
## 3  Tbr_DM    -.53   -.67
## 4  Lvs_DM     .56   -.11   -.06
## 5     Chl    -.18    .50   -.21   -.92
## 6 Leaf_No     .63    .58    .17    .12  .13
## 7    N_Rs     .69    .85   -.18   -.09  .43     .91
## 8  R_Lgth     .72    .59    .10    .25  .02     .99  .89
## 9  est_pc

tbr_dm_Bure_Vu <- Bure_Vu_corr %>%
  focus(Tbr_DM)

Bure_Ho <- Bure_Ho[, sapply(Bure_Ho, is.numeric)]
Bure_Ho_corr <- correlate(Bure_Ho)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_Ho_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .78
```

```
## 3  Tbr_DM   -.81   -.47
## 4  Lvs_DM    .52    .18  -.92
## 5     Chl    .56    .52  -.85   .87
## 6 Leaf_No    .16    .69   .31  -.55 -.10
## 7    N_Rs    .58    .96  -.26   .01  .44     .83
## 8  R_Lgth    .26    .77   .19  -.44  .02     .99  .89
## 9  est_pc
```

```
tbr_dm_Bure_Ho <- Bure_Ho_corr %>%
  focus(Tbr_DM)

Bure_Ca <- Bure_Ca[, sapply(Bure_Ca, is.numeric)]
Bure_Ca_corr <- correlate(Bure_Ca)
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Bure_Ca_corr))
```

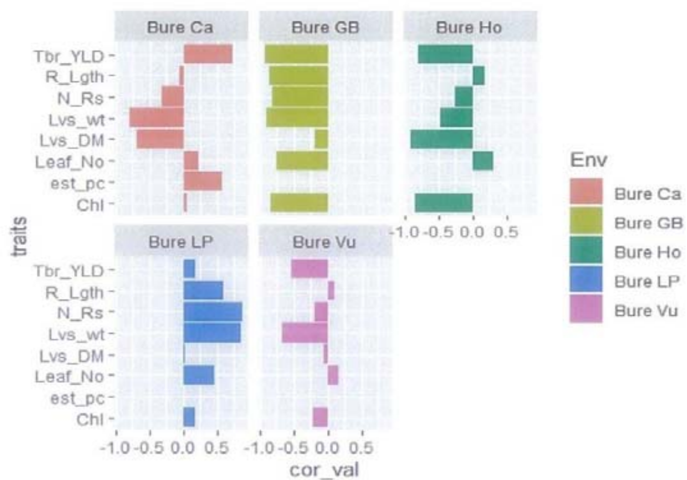
```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt    -.99
## 3  Tbr_DM     .73   -.80
## 4  Lvs_DM    -.01    .13   -.69
## 5     Chl     .67   -.56    .05    .66
## 6 Leaf_No     .82   -.73    .22    .56  .96
## 7    N_Rs     .39   -.30   -.33    .87  .75     .78
## 8  R_Lgth     .64   -.53   -.05    .76  .97     .96  .89
## 9  est_pc     .98   -.95    .57    .19  .77     .91  .58    .77
```

```
tbr_dm_Bure_Ca <- Bure_Ca_corr %>%
  focus(Tbr_DM)

Tbr_DM_Bure_cor <- cbind(tbr_dm_Bure_GB$rowname, tbr_dm_Bure_GB$Tbr_DM,
tbr_dm_Bure_LP$Tbr_DM, tbr_dm_Bure_Vu$Tbr_DM, tbr_dm_Bure_Ho$Tbr_DM,
tbr_dm_Bure_Ca$Tbr_DM)

colnames(Tbr_DM_Bure_cor) <- c( "traits" ,"Bure GB", "Bure LP","Bure Vu",
"Bure Ho", "Bure Ca")

Tbr_DM_Bure_cor <- as.data.frame(Tbr_DM_Bure_cor)

Tbr_DM_Bure_cor$"Bure GB" <-
round(as.numeric(as.character(Tbr_DM_Bure_cor$"Bure GB")), 2)
Tbr_DM_Bure_cor$"Bure LP" <-
round(as.numeric(as.character(Tbr_DM_Bure_cor$"Bure LP")), 2)
Tbr_DM_Bure_cor$"Bure Vu" <-
round(as.numeric(as.character(Tbr_DM_Bure_cor$"Bure Vu")), 2)
Tbr_DM_Bure_cor$"Bure Ho" <-
round(as.numeric(as.character(Tbr_DM_Bure_cor$"Bure Ho")), 2)
Tbr_DM_Bure_cor$"Bure Ca" <-
round(as.numeric(as.character(Tbr_DM_Bure_cor$"Bure Ca")), 2)

print(Tbr_DM_Bure_cor)
```

```
##    traits Bure GB Bure LP Bure Vu Bure Ho Bure Ca
## 1 Tbr_YLD   -0.93    0.17   -0.53   -0.81    0.73
## 2  Lvs_wt   -0.91    0.86   -0.67   -0.47   -0.80
## 3  Lvs_DM   -0.19    0.03   -0.06   -0.92   -0.69
## 4     Chl   -0.84    0.19   -0.21   -0.85    0.05
## 5 Leaf_No   -0.76    0.46    0.17    0.31    0.22
## 6    N_Rs   -0.82    0.87   -0.18   -0.26   -0.33
## 7  R_Lgth   -0.87    0.60    0.10    0.19   -0.05
## 8  est_pc      NA      NA      NA      NA    0.57
```

```
Tbr_DM_Bure_cor_long <- gather(Tbr_DM_Bure_cor, -traits, key="Env",
value="cor_val")
ggplot(Tbr_DM_Bure_cor_long, aes(x=traits, cor_val, fill=Env)) +
        geom_col() +
        coord_flip() +
        facet_wrap(~Env)
```

```
## Warning: Removed 4 rows containing missing values (position_stack).
```



```
Nabu_GB <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Golden Brown")
Nabu_LP <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Local Purple")
Nabu_Vu <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Vulatolu")
Nabu_Ho <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Honiara")
Nabu_Ca <- soni %>%
  filter(ENV=="Nabukadra"&Variety=="Carrot")

Nabu_GB <- Nabu_GB[, sapply(Nabu_GB, is.numeric)]
Nabu_GB_corr <- correlate(Nabu_GB)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_GB_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .37
## 3  Tbr_DM    -.09   -.06
## 4  Lvs_DM    -.54   -.16    .89
## 5     Chl     .69    .75    .42    .07
## 6 Leaf_No     .93    .16    .24   -.24  .69
## 7    N_Rs
## 8  R_Lgth     .90    .07   -.40   -.77  .30     .79
## 9  est_pc

tbr_dm_Nabu_GB <- Nabu_GB_corr %>%
  focus(Tbr_DM)

Nabu_LP <- Nabu_LP[, sapply(Nabu_LP, is.numeric)]
Nabu_LP_corr <- correlate(Nabu_LP)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_LP_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM   Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .86
## 3  Tbr_DM    -.04   -.15
## 4  Lvs_DM    -.31    .07    .55
## 5     Chl    -.78   -.77    .65    .53
## 6 Leaf_No    -.46   -.85    .36   -.32   .62
## 7    N_Rs     .82    .79   -.61   -.53 -1.00    -.60
## 8  R_Lgth    -.05   -.02   -.98   -.65  -.57    -.17  .52
## 9  est_pc

tbr_dm_Nabu_LP <- Nabu_LP_corr %>%
  focus(Tbr_DM)

Nabu_Vu <- Nabu_Vu[, sapply(Nabu_Vu, is.numeric)]
Nabu_Vu_corr <- correlate(Nabu_Vu)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_Vu_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt    -.24
## 3  Tbr_DM    -.94    .40
## 4  Lvs_DM     .53   -.92   -.59
## 5     Chl    -.82    .65    .77   -.89
## 6 Leaf_No     .01    .27   -.23   -.43  .43
## 7    N_Rs    -.13   -.84    .09    .75 -.44    -.66
## 8  R_Lgth    -.21   -.50    .32    .52 -.35    -.93  .87
## 9  est_pc

tbr_dm_Nabu_Vu <- Nabu_Vu_corr %>%
  focus(Tbr_DM)

Nabu_Ho <- Nabu_Ho[, sapply(Nabu_Ho, is.numeric)]
Nabu_Ho_corr <- correlate(Nabu_Ho)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_Ho_corr))

##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt     .84
```

```
## 3  Tbr_DM    -.43   -.29
## 4  Lvs_DM    -.36   -.50    .87
## 5     Chl    -.61   -.47   -.43   -.48
## 6 Leaf_No    -.32    .10   -.37   -.70  .77
## 7    N_Rs
## 8  R_Lgth    -.09    .07    .93    .75 -.67     -.42
## 9  est_pc
```

```
tbr_dm_Nabu_Ho <- Nabu_Ho_corr %>%
  focus(Tbr_DM)

Nabu_Ca <- Nabu_Ca[, sapply(Nabu_Ca, is.numeric)]
Nabu_Ca_corr <- correlate(Nabu_Ca)
```

```
## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Nabu_Ca_corr))
```

```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_DM  Chl Leaf_No N_Rs R_Lgth est_pc
## 1 Tbr_YLD
## 2  Lvs_wt    -.71
## 3  Tbr_DM     .00   -.32
## 4  Lvs_DM    -.93    .46    .34
## 5     Chl     .60   -.34    .65   -.40
## 6 Leaf_No     .35   -.56    .93   -.01  .81
## 7    N_Rs
## 8  R_Lgth     .27   -.76    .84    .11  .48     .89
## 9  est_pc    -.69    .65   -.72    .41 -.93    -.91         -.74
```

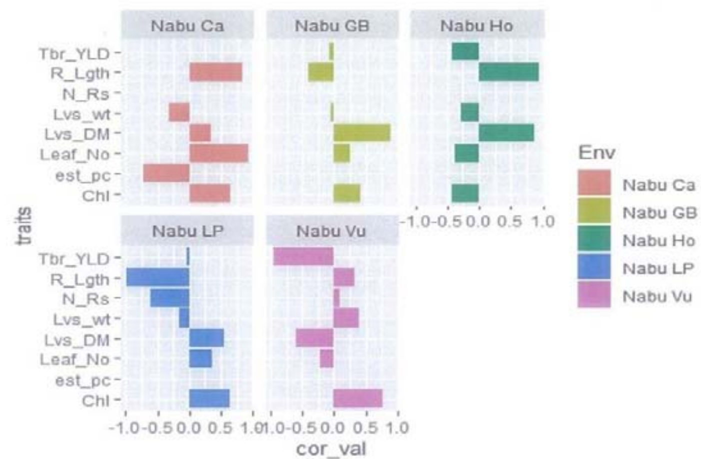
```
tbr_dm_Nabu_Ca <- Nabu_Ca_corr %>%
  focus(Tbr_DM)

Tbr_DM_Nabu_cor <- cbind(tbr_dm_Nabu_GB$rowname, tbr_dm_Nabu_GB$Tbr_DM,
tbr_dm_Nabu_LP$Tbr_DM, tbr_dm_Nabu_Vu$Tbr_DM, tbr_dm_Nabu_Ho$Tbr_DM,
tbr_dm_Nabu_Ca$Tbr_DM)

colnames(Tbr_DM_Nabu_cor) <- c( "traits" ,"Nabu GB", "Nabu LP","Nabu Vu",
"Nabu Ho", "Nabu Ca")

Tbr_DM_Nabu_cor <- as.data.frame(Tbr_DM_Nabu_cor)

Tbr_DM_Nabu_cor$"Nabu GB" <-
round(as.numeric(as.character(Tbr_DM_Nabu_cor$"Nabu GB")), 2)
Tbr_DM_Nabu_cor$"Nabu LP" <-
round(as.numeric(as.character(Tbr_DM_Nabu_cor$"Nabu LP")), 2)
Tbr_DM_Nabu_cor$"Nabu Vu" <-
round(as.numeric(as.character(Tbr_DM_Nabu_cor$"Nabu Vu")), 2)
Tbr_DM_Nabu_cor$"Nabu Ho" <-
round(as.numeric(as.character(Tbr_DM_Nabu_cor$"Nabu Ho")), 2)
Tbr_DM_Nabu_cor$"Nabu Ca" <-
round(as.numeric(as.character(Tbr_DM_Nabu_cor$"Nabu Ca")), 2)
```

```
print(Tbr_DM_Nabu_cor)
```

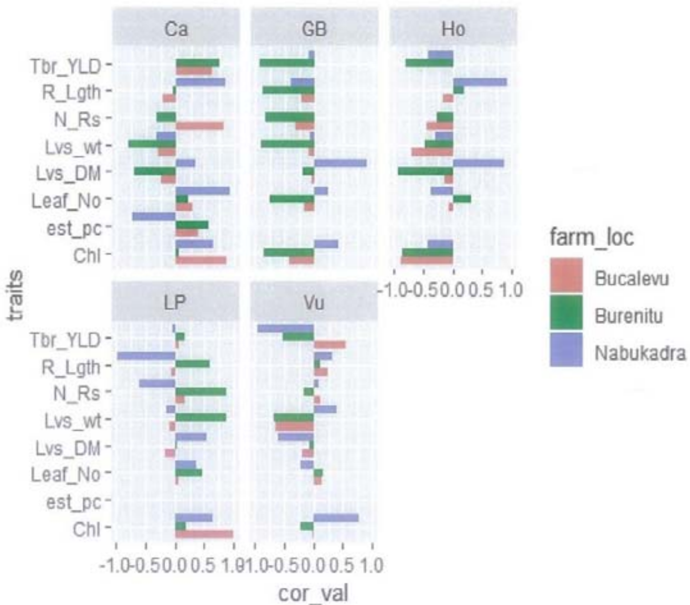
```
##    traits Nabu GB Nabu LP Nabu Vu Nabu Ho Nabu Ca
## 1 Tbr_YLD   -0.09   -0.04   -0.94   -0.43    0.00
## 2  Lvs_wt   -0.06   -0.15    0.40   -0.29   -0.32
## 3  Lvs_DM    0.89    0.55   -0.59    0.87    0.34
## 4     Chl    0.42    0.65    0.77   -0.43    0.65
## 5 Leaf_No    0.24    0.36   -0.23   -0.37    0.93
## 6    N_Rs      NA   -0.61    0.09      NA      NA
## 7  R_Lgth   -0.40   -0.98    0.32    0.93    0.84
## 8  est_pc      NA      NA      NA      NA   -0.72
```

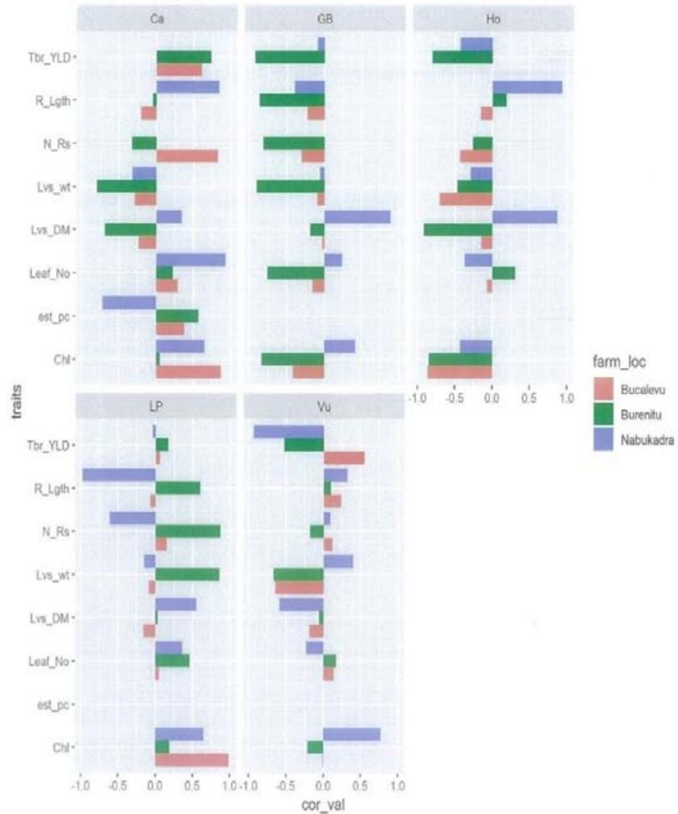
```
Tbr_DM_Nabu_cor_long <- gather(Tbr_DM_Nabu_cor, -traits, key="Env",
value="cor_val")
ggplot(Tbr_DM_Nabu_cor_long, aes(x=traits, cor_val, fill=Env)) +
        geom_col() +
        coord_flip() +
        facet_wrap(~Env)
```

```
## Warning: Removed 7 rows containing missing values (position_stack).
```



```
variety_env_cor_long <-
rbind(Tbr_DM_Buca_cor_long,Tbr_DM_Bure_cor_long,Tbr_DM_Nabu_cor_long)
farm_loc <- c(rep("Bucalevu",40),rep("Burenitu", 40), rep("Nabukadra", 40))
GEN <- rep(c(rep("GB",8),rep("LP", 8), rep("Vu", 8), rep("Ho", 8), rep("Ca",
8)),3)

variety_env_cor_long1 <- cbind(farm_loc, GEN, variety_env_cor_long)

ggplot(variety_env_cor_long1, aes(x=traits, cor_val, fill=farm_loc)) +
        geom_col(position = "dodge") +
        coord_flip() +
        facet_wrap(~GEN)

## Warning: Removed 15 rows containing missing values (geom_col).
```





Appendix 4: Kumala tuber yield correlation with other traits at harvest.

Tuber Yield Correlation with other traits

Soni

15 July 2019

```
library("PerformanceAnalytics")

## Warning: package 'PerformanceAnalytics' was built under R version 3.6.1

## Loading required package: xts

## Warning: package 'xts' was built under R version 3.6.1

## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric

## Registered S3 method overwritten by 'xts':
##   method     from
##   as.zoo.xts zoo

##
## Attaching package: 'PerformanceAnalytics'

## The following object is masked from 'package:graphics':
##
##     legend

library("corrplot")

## Warning: package 'corrplot' was built under R version 3.6.1

## corrplot 0.84 loaded

library(corrr)

## Warning: package 'corrr' was built under R version 3.6.1

library(MASS)
library(magrittr)
library(tidyverse)

## Registered S3 method overwritten by 'rvest':
##   method            from
##   read_xml.response xml2

## -- Attaching packages ---------------------- tidyverse 1.2.1 --

## v ggplot2 3.2.0      v purrr   0.3.2
## v tibble  2.1.1      v dplyr   0.8.0.1
## v tidyr   0.8.3      v stringr 1.4.0
## v readr   1.3.1      v forcats 0.4.0

## -- Conflicts ------------------------- tidyverse_conflicts() --
## x tidyr::extract()   masks magrittr::extract()
## x dplyr::filter()    masks stats::filter()
## x dplyr::first()     masks xts::first()
## x dplyr::lag()       masks stats::lag()
## x dplyr::last()      masks xts::last()
## x dplyr::select()    masks MASS::select()
## x purrr::set_names() masks magrittr::set_names()

soni <- read.csv("soni.csv", header = TRUE, sep = ",")
soni$REP <- as.factor(soni$REP)
Buca_GB <- soni %>%
  filter(ENV=="Buca"&GEN=="GB")
Buca_LP <- soni %>%
  filter(ENV=="Buca"&GEN=="LP")
Buca_Vu <- soni %>%
  filter(ENV=="Buca"&GEN=="Vu")
Buca_Ho <- soni %>%
  filter(ENV=="Buca"&GEN=="Ho")
Buca_Ca <- soni %>%
  filter(ENV=="Buca"&GEN=="Ca")

Bure_GB <- soni %>%
  filter(ENV=="Bure"&GEN=="GB")
Bure_LP <- soni %>%
  filter(ENV=="Bure"&GEN=="LP")
Bure_Vu <- soni %>%
  filter(ENV=="Bure"&GEN=="Vu")
Bure_Ho <- soni %>%
  filter(ENV=="Bure"&GEN=="Ho")
Bure_Ca <- soni %>%
  filter(ENV=="Bure"&GEN=="Ca")

Nabu_GB <- soni %>%
  filter(ENV=="Nabu"&GEN=="GB")
Nabu_LP <- soni %>%
  filter(ENV=="Nabu"&GEN=="LP")
Nabu_Vu <- soni %>%
  filter(ENV=="Nabu"&GEN=="Vu")
Nabu_Ho <- soni %>%
  filter(ENV=="Nabu"&GEN=="Ho")
Nabu_Ca <- soni %>%
  filter(ENV=="Nabu"&GEN=="Ca")
```

```
Buca_GB <- Buca_GB[, sapply(Buca_GB, is.numeric)]
Buca_GB_corr <- correlate(Buca_GB)
```

```
## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Buca_GB_corr))
```

```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .96
## 3  Tbr_DM     .00   -.10
## 4 Lvs_.DM   -1.00   -.94   -.03
## 5     Chl     .35    .59   -.42    -.27
## 6 Leaf_No     .76    .91   -.16    -.70  .86
## 7    R_No     .51    .73   -.31    -.44  .98     .94
## 8  R_Lgth     .81    .94   -.23    -.76  .83     .99  .92
## 9   estab
```

```
tbr_yld_Buca_GB <- Buca_GB_corr %>%
 focus(Tbr_YLD)
```

```
Buca_LP <- Buca_LP[, sapply(Buca_LP, is.numeric)]
Buca_LP_corr <- correlate(Buca_LP)
```

```
## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Buca_LP_corr))
```

```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt    -.08
## 3  Tbr_DM     .06   -.09
## 4 Lvs_.DM    -.94   -.23   -.16
## 5     Chl     .21   -.15    .99    -.28
## 6 Leaf_No     .85    .45    .05    -.97  .15
## 7    R_No     .89    .37    .15    -.99  .25     .99
## 8  R_Lgth     .84    .46   -.07    -.95  .03     .99  .97
## 9   estab
```

```
tbr_yld_Buca_LP <- Buca_LP_corr %>%
 focus(Tbr_YLD)
```

```
Buca_Vu <- Buca_Vu[, sapply(Buca_Vu, is.numeric)]
Buca_Vu_corr <- correlate(Buca_Vu)
```

```
## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Buca_Vu_corr))
```

```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .27
## 3  Tbr_DM     .55   -.65
## 4 Lvs_.DM    -.93   -.61   -.19
## 5     Chl     .37    .28   -.01    -.48
## 6 Leaf_No     .79    .59    .14    -.84 -.07
## 7    R_No     .90    .67    .12    -.99  .42     .88
## 8  R_Lgth     .92    .58    .24    -.97  .24     .95  .98
## 9   estab
```

```
tbr_yld_Buca_Vu <- Buca_Vu_corr %>%
 focus(Tbr_YLD)
```

```
Buca_Ho <- Buca_Ho[, sapply(Buca_Ho, is.numeric)]
Buca_Ho_corr <- correlate(Buca_Ho)
```

```
## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Buca_Ho_corr))
```

```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .19
## 3  Tbr_DM    -.00   -.71
## 4 Lvs_.DM    -.30   -.59   -.15
## 5     Chl     .38    .47   -.87     .32
## 6 Leaf_No     .55    .72   -.07    -.94  .00
## 7    R_No     .66    .85   -.44    -.70  .44     .90
## 8  R_Lgth     .65    .74   -.16    -.87  .15     .99  .95
## 9   estab
```

```
tbr_yld_Buca_Ho <- Buca_Ho_corr %>%
 focus(Tbr_YLD)
```

```
Buca_Ca <- Buca_Ca[, sapply(Buca_Ca, is.numeric)]
Buca_Ca_corr <- correlate(Buca_Ca)
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Buca_Ca_corr))
```

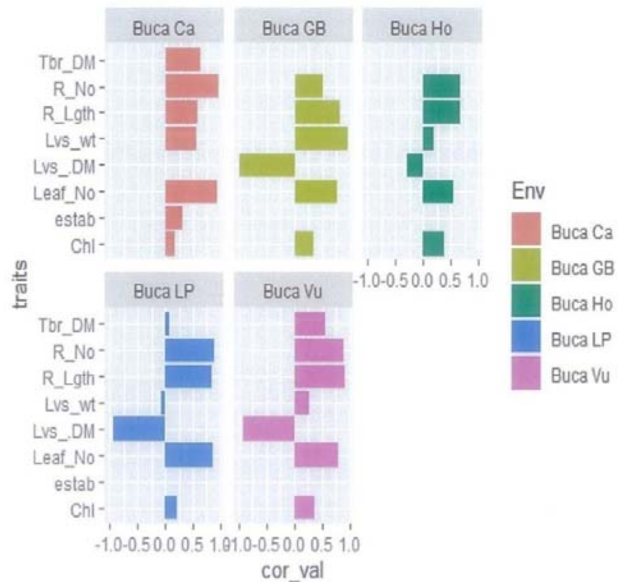
```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .54
## 3  Tbr_DM     .61   -.29
## 4 Lvs_.DM    -.01    .51   -.24
## 5     Chl     .17   -.61    .87    -.11
## 6 Leaf_No     .93    .80    .29     .15 -.18
## 7    R_No     .95    .26    .83    -.14  .45     .77
## 8  R_Lgth     .58    .78   -.21    -.14 -.67     .78  .35
## 9   estab     .32    .26    .38     .81  .45     .26  .33   -.32
```

```
tbr_yld_Buca_Ca <- Buca_Ca_corr %>%
 focus(Tbr_YLD)

tbr_yld_Buca_cor <- cbind(tbr_yld_Buca_GB$rowname, tbr_yld_Buca_GB$Tbr_YLD, t
br_yld_Buca_LP$Tbr_YLD, tbr_yld_Buca_Vu$Tbr_YLD, tbr_yld_Buca_Ho$Tbr_YLD, tbr
_yld_Buca_Ca$Tbr_YLD)

colnames(tbr_yld_Buca_cor) <- c( "traits" ,"Buca GB", "Buca LP","Buca Vu", "B
uca Ho", "Buca Ca")

tbr_yld_Buca_cor <- as.data.frame(tbr_yld_Buca_cor)

tbr_yld_Buca_cor$"Buca GB" <- round(as.numeric(as.character(tbr_yld_Buca_cor$
"Buca GB")), 2)
tbr_yld_Buca_cor$"Buca LP" <- round(as.numeric(as.character(tbr_yld_Buca_cor$
"Buca LP")), 2)
tbr_yld_Buca_cor$"Buca Vu" <- round(as.numeric(as.character(tbr_yld_Buca_cor$
"Buca Vu")), 2)
tbr_yld_Buca_cor$"Buca Ho" <- round(as.numeric(as.character(tbr_yld_Buca_cor$
"Buca Ho")), 2)
tbr_yld_Buca_cor$"Buca Ca" <- round(as.numeric(as.character(tbr_yld_Buca_cor$
"Buca Ca")), 2)


print(tbr_yld_Buca_cor)
```

```
##    traits Buca GB Buca LP Buca Vu Buca Ho Buca Ca
## 1  Lvs_wt    0.96   -0.08    0.27    0.19    0.54
## 2  Tbr_DM    0.00    0.06    0.55    0.00    0.61
## 3 Lvs_.DM   -1.00   -0.94   -0.93   -0.30   -0.01
## 4     Chl    0.35    0.21    0.37    0.38    0.17
## 5 Leaf_No    0.76    0.85    0.79    0.55    0.93
## 6    R_No    0.51    0.89    0.90    0.66    0.95
## 7  R_Lgth    0.81    0.84    0.92    0.65    0.58
## 8   estab      NA      NA      NA      NA    0.32
```

```
tbr_yld_Buca_cor_long <- gather(tbr_yld_Buca_cor, -traits, key="Env", value="
cor_val")
ggplot(tbr_yld_Buca_cor_long, aes(x=traits, cor_val, fill=Env)) +
        geom_col() +
        coord_flip() +
        facet_wrap(~Env)
```

```
## Warning: Removed 4 rows containing missing values (position_stack).
```



```r
Bure_GB <- soni %>%
  filter(ENV=="Bure"&GEN=="GB")
Bure_LP <- soni %>%
  filter(ENV=="Bure"&GEN=="LP")
Bure_Vu <- soni %>%
  filter(ENV=="Bure"&GEN=="Vu")
Bure_Ho <- soni %>%
  filter(ENV=="Bure"&GEN=="Ho")
Bure_Ca <- soni %>%
  filter(ENV=="Bure"&GEN=="Ca")

Bure_GB <- Bure_GB[, sapply(Bure_GB, is.numeric)]
Bure_GB_corr <- correlate(Bure_GB)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_GB_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .99
## 3  Tbr_DM    -.93   -.91
## 4 Lvs_.DM     .06    .17   -.19
## 5     Chl     .66    .69   -.84     .66
## 6 Leaf_No     .66    .73   -.76     .78  .95
## 7    R_No     .64    .68   -.82     .70 1.00     .96
## 8  R_Lgth     .86    .91   -.87     .56  .89     .95  .89
## 9   estab

tbr_yld_Bure_GB <- Bure_GB_corr %>%
 focus(Tbr_YLD)

Bure_LP <- Bure_LP[, sapply(Bure_LP, is.numeric)]
Bure_LP_corr <- correlate(Bure_LP)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_LP_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .06
```

```r
## 3  Tbr_DM     .17    .86
## 4 Lvs_.DM    -.60    .47    .03
## 5     Chl    -.44   -.22    .19    -.38
## 6 Leaf_No    -.56    .14    .46    -.08  .92
## 7    R_No    -.19    .60    .87    -.05  .64     .84
## 8  R_Lgth    -.60    .39    .60     .16  .78     .96  .89
## 9   estab

tbr_yld_Bure_LP <- Bure_LP_corr %>%
 focus(Tbr_YLD)

Bure_Vu <- Bure_Vu[, sapply(Bure_Vu, is.numeric)]
Bure_Vu_corr <- correlate(Bure_Vu)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_Vu_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .76
## 3  Tbr_DM    -.53   -.67
## 4 Lvs_.DM     .56   -.11   -.06
## 5     Chl    -.18    .50   -.21    -.92
## 6 Leaf_No     .63    .58    .17     .12  .13
## 7    R_No     .69    .85   -.18    -.09  .43     .91
## 8  R_Lgth     .72    .59    .10     .25  .02     .99  .89
## 9   estab

tbr_yld_Bure_Vu <- Bure_Vu_corr %>%
 focus(Tbr_YLD)

Bure_Ho <- Bure_Ho[, sapply(Bure_Ho, is.numeric)]
Bure_Ho_corr <- correlate(Bure_Ho)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Bure_Ho_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .78
```

```
## 3  Tbr_DM    -.81  -.47
## 4 Lvs_.DM     .52   .18  -.92
## 5     Chl     .56   .52  -.85    .87
## 6 Leaf_No     .16   .69   .31   -.55 -.10
## 7    R_No     .58   .96  -.26    .01  .44     .83
## 8  R_Lgth     .26   .77   .19   -.44  .02     .99  .89
## 9   estab
```

```
tbr_yld_Bure_Ho <- Bure_Ho_corr %>%
 focus(Tbr_YLD)

Bure_Ca <- Bure_Ca[, sapply(Bure_Ca, is.numeric)]
Bure_Ca_corr <- correlate(Bure_Ca)
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Bure_Ca_corr))
```

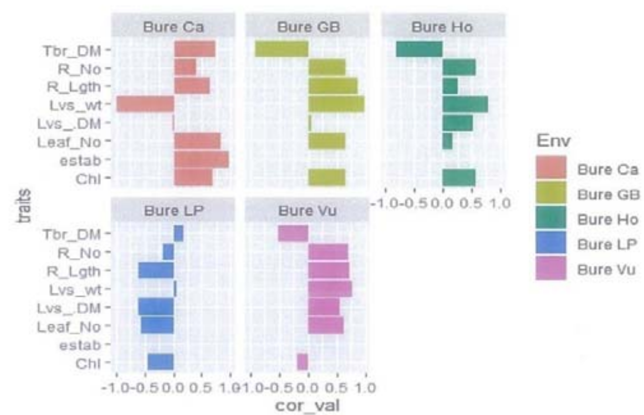
```
##    rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt    -.99
## 3  Tbr_DM     .73  -.80
## 4 Lvs_.DM    -.01   .13  -.69
## 5     Chl     .67  -.56   .05    .66
## 6 Leaf_No     .82  -.73   .22    .56  .96
## 7    R_No     .39  -.30  -.33    .87  .75     .78
## 8  R_Lgth     .64  -.53  -.05    .76  .97     .96  .89
## 9   estab     .98  -.95   .57    .19  .77     .91  .58    .77
```

```
tbr_yld_Bure_Ca <- Bure_Ca_corr %>%
 focus(Tbr_YLD)

tbr_yld_Bure_cor <- cbind(tbr_yld_Bure_GB$rowname, tbr_yld_Bure_GB$Tbr_YLD, t
br_yld_Bure_LP$Tbr_YLD, tbr_yld_Bure_Vu$Tbr_YLD, tbr_yld_Bure_Ho$Tbr_YLD, tbr
_yld_Bure_Ca$Tbr_YLD)

colnames(tbr_yld_Bure_cor) <- c( "traits" ,"Bure GB", "Bure LP","Bure Vu", "B
ure Ho", "Bure Ca")

tbr_yld_Bure_cor <- as.data.frame(tbr_yld_Bure_cor)

tbr_yld_Bure_cor$"Bure GB" <- round(as.numeric(as.character(tbr_yld_Bure_cor$
"Bure GB")), 2)
tbr_yld_Bure_cor$"Bure LP" <- round(as.numeric(as.character(tbr_yld_Bure_cor$
"Bure LP")), 2)
tbr_yld_Bure_cor$"Bure Vu" <- round(as.numeric(as.character(tbr_yld_Bure_cor$
"Bure Vu")), 2)
tbr_yld_Bure_cor$"Bure Ho" <- round(as.numeric(as.character(tbr_yld_Bure_cor$
"Bure Ho")), 2)
tbr_yld_Bure_cor$"Bure Ca" <- round(as.numeric(as.character(tbr_yld_Bure_cor$
"Bure Ca")), 2)

print(tbr_yld_Bure_cor)
```

```
##    traits Bure GB Bure LP Bure Vu Bure Ho Bure Ca
## 1  Lvs_wt    0.99    0.06    0.76    0.78   -0.99
## 2  Tbr_DM   -0.93    0.17   -0.53   -0.81    0.73
## 3 Lvs_.DM    0.06   -0.60    0.56    0.52   -0.01
## 4     Chl    0.66   -0.44   -0.18    0.56    0.67
## 5 Leaf_No    0.66   -0.56    0.63    0.16    0.82
## 6    R_No    0.64   -0.19    0.69    0.58    0.39
## 7  R_Lgth    0.86   -0.60    0.72    0.26    0.64
## 8   estab      NA      NA      NA      NA    0.98
```

```
tbr_yld_Bure_cor_long <- gather(tbr_yld_Bure_cor, -traits, key="Env", value="
cor_val")
ggplot(tbr_yld_Bure_cor_long, aes(x=traits, cor_val, fill=Env)) +
         geom_col() +
         coord_flip() +
         facet_wrap(~Env)
```

```
## Warning: Removed 4 rows containing missing values (position_stack).
```



```
Nabu_GB <- soni %>%
  filter(ENV=="Nabu"&GEN=="GB")
Nabu_LP <- soni %>%
  filter(ENV=="Nabu"&GEN=="LP")
Nabu_Vu <- soni %>%
  filter(ENV=="Nabu"&GEN=="Vu")
Nabu_Ho <- soni %>%
  filter(ENV=="Nabu"&GEN=="Ho")
Nabu_Ca <- soni %>%
  filter(ENV=="Nabu"&GEN=="Ca")

Nabu_GB <- Nabu_GB[, sapply(Nabu_GB, is.numeric)]
Nabu_GB_corr <- correlate(Nabu_GB)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_GB_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .37
## 3  Tbr_DM    -.09   -.06
## 4 Lvs_.DM    -.54   -.16    .89
## 5     Chl     .69    .75    .42     .07
## 6 Leaf_No     .93    .16    .24    -.24  .69
## 7    R_No
## 8  R_Lgth     .90    .07   -.40    -.77  .30     .79
## 9   estab

tbr_yld_Nabu_GB <- Nabu_GB_corr %>%
 focus(Tbr_YLD)

Nabu_LP <- Nabu_LP[, sapply(Nabu_LP, is.numeric)]
Nabu_LP_corr <- correlate(Nabu_LP)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_LP_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM   Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .86
## 3  Tbr_DM    -.04   -.15
## 4 Lvs_.DM    -.31    .07    .55
## 5     Chl    -.78   -.77    .65     .53
## 6 Leaf_No    -.46   -.85    .36    -.32   .62
## 7    R_No     .82    .79   -.61    -.53 -1.00    -.60
## 8  R_Lgth    -.05   -.02   -.98    -.65  -.57    -.17  .52
## 9   estab

tbr_yld_Nabu_LP <- Nabu_LP_corr %>%
 focus(Tbr_YLD)

Nabu_Vu <- Nabu_Vu[, sapply(Nabu_Vu, is.numeric)]
Nabu_Vu_corr <- correlate(Nabu_Vu)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_Vu_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt    -.24
## 3  Tbr_DM    -.94    .40
## 4 Lvs_.DM     .53   -.92   -.59
## 5     Chl    -.82    .65    .77    -.89
## 6 Leaf_No     .01    .27   -.23    -.43  .43
## 7    R_No    -.13   -.84    .09     .75 -.44    -.66
## 8  R_Lgth    -.21   -.50    .32     .52 -.35    -.93  .87
## 9   estab

tbr_yld_Nabu_Vu <- Nabu_Vu_corr %>%
 focus(Tbr_YLD)

Nabu_Ho <- Nabu_Ho[, sapply(Nabu_Ho, is.numeric)]
Nabu_Ho_corr <- correlate(Nabu_Ho)

## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero

##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'

fashion(shave(Nabu_Ho_corr))

##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt     .84
```

```
## 3  Tbr_DM    -.43   -.29
## 4 Lvs_.DM    -.36   -.50    .87
## 5      Chl    -.61   -.47   -.43     -.48
## 6 Leaf_No    -.32    .10   -.37     -.70  .77
## 7     R_No
## 8  R_Lgth    -.09    .07    .93      .75 -.67     -.42
## 9   estab
```

```
tbr_yld_Nabu_Ho <- Nabu_Ho_corr %>%
 focus(Tbr_YLD)
```

```
Nabu_Ca <- Nabu_Ca[, sapply(Nabu_Ca, is.numeric)]
Nabu_Ca_corr <- correlate(Nabu_Ca)
```

```
## Warning in stats::cor(x = x, y = y, use = use, method = method): the
## standard deviation is zero
```

```
##
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
fashion(shave(Nabu_Ca_corr))
```

```
##   rowname Tbr_YLD Lvs_wt Tbr_DM Lvs_.DM  Chl Leaf_No R_No R_Lgth estab
## 1 Tbr_YLD
## 2  Lvs_wt    -.71
## 3  Tbr_DM     .00   -.32
## 4 Lvs_.DM    -.93    .46    .34
## 5      Chl    .60   -.34    .65     -.40
## 6 Leaf_No     .35   -.56    .93     -.01  .81
## 7     R_No
## 8  R_Lgth     .27   -.76    .84      .11  .48      .89
## 9   estab    -.69    .65   -.72      .41 -.93     -.91         -.74
```

```
tbr_yld_Nabu_Ca <- Nabu_Ca_corr %>%
 focus(Tbr_YLD)
```

```
tbr_yld_Nabu_cor <- cbind(tbr_yld_Nabu_GB$rowname, tbr_yld_Nabu_GB$Tbr_YLD, t
br_yld_Nabu_LP$Tbr_YLD, tbr_yld_Nabu_Vu$Tbr_YLD, tbr_yld_Nabu_Ho$Tbr_YLD, tbr
_yld_Nabu_Ca$Tbr_YLD)
```

```
colnames(tbr_yld_Nabu_cor) <- c( "traits" ,"Nabu GB", "Nabu LP","Nabu Vu", "N
abu Ho", "Nabu Ca")
```

```
tbr_yld_Nabu_cor <- as.data.frame(tbr_yld_Nabu_cor)
```

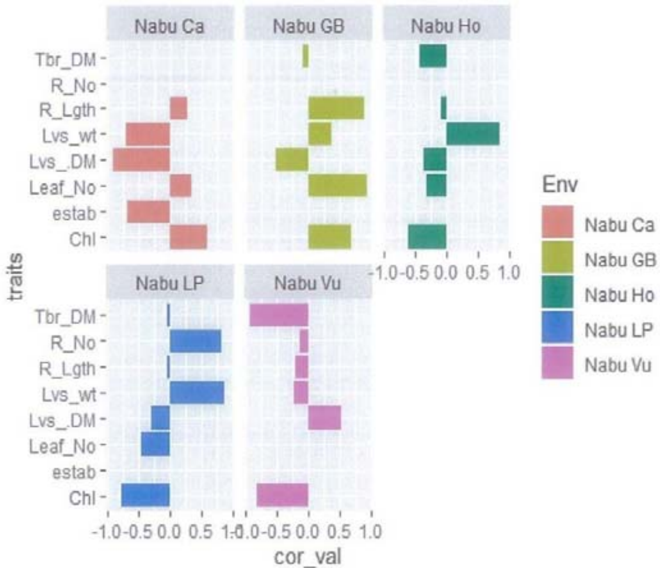
```
tbr_yld_Nabu_cor$"Nabu GB" <- round(as.numeric(as.character(tbr_yld_Nabu_cor$
"Nabu GB")), 2)
tbr_yld_Nabu_cor$"Nabu LP" <- round(as.numeric(as.character(tbr_yld_Nabu_cor$
"Nabu LP")), 2)
tbr_yld_Nabu_cor$"Nabu Vu" <- round(as.numeric(as.character(tbr_yld_Nabu_cor$
"Nabu Vu")), 2)
tbr_yld_Nabu_cor$"Nabu Ho" <- round(as.numeric(as.character(tbr_yld_Nabu_cor$
"Nabu Ho")), 2)
tbr_yld_Nabu_cor$"Nabu Ca" <- round(as.numeric(as.character(tbr_yld_Nabu_cor$
"Nabu Ca")), 2)
```

```
print(tbr_yld_Nabu_cor)
```

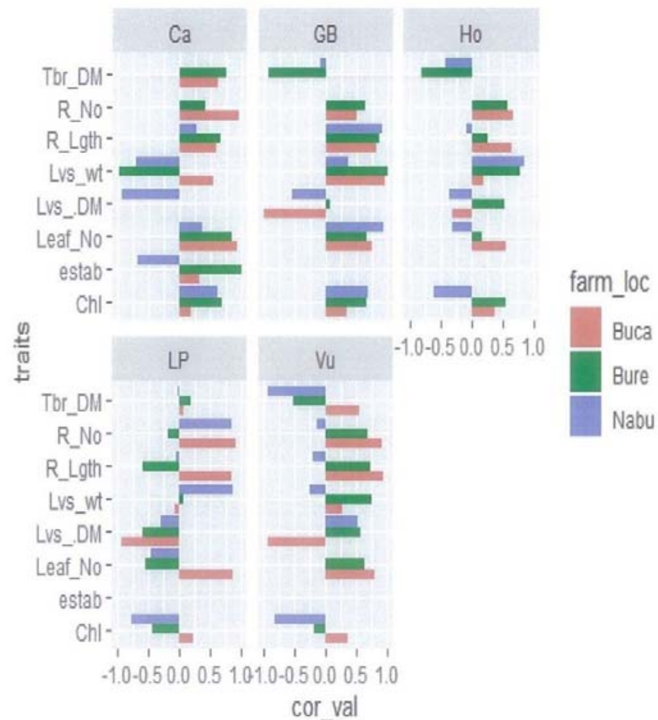
```
##    traits Nabu GB Nabu LP Nabu Vu Nabu Ho Nabu Ca
## 1  Lvs_wt    0.37    0.86   -0.24    0.84   -0.71
## 2  Tbr_DM   -0.09   -0.04   -0.94   -0.43    0.00
## 3 Lvs_.DM   -0.54   -0.31    0.53   -0.36   -0.93
## 4     Chl    0.69   -0.78   -0.82   -0.61    0.60
## 5 Leaf_No    0.93   -0.46    0.01   -0.32    0.35
## 6    R_No      NA    0.82   -0.13      NA      NA
## 7  R_Lgth    0.90   -0.05   -0.21   -0.09    0.27
## 8   estab      NA      NA      NA      NA   -0.69
```

```
tbr_yld_Nabu_cor_long <- gather(tbr_yld_Nabu_cor, -traits, key="Env", value="
cor_val")
ggplot(tbr_yld_Nabu_cor_long, aes(x=traits, cor_val, fill=Env)) +
        geom_col() +
        coord_flip() +
        facet_wrap(~Env)
```

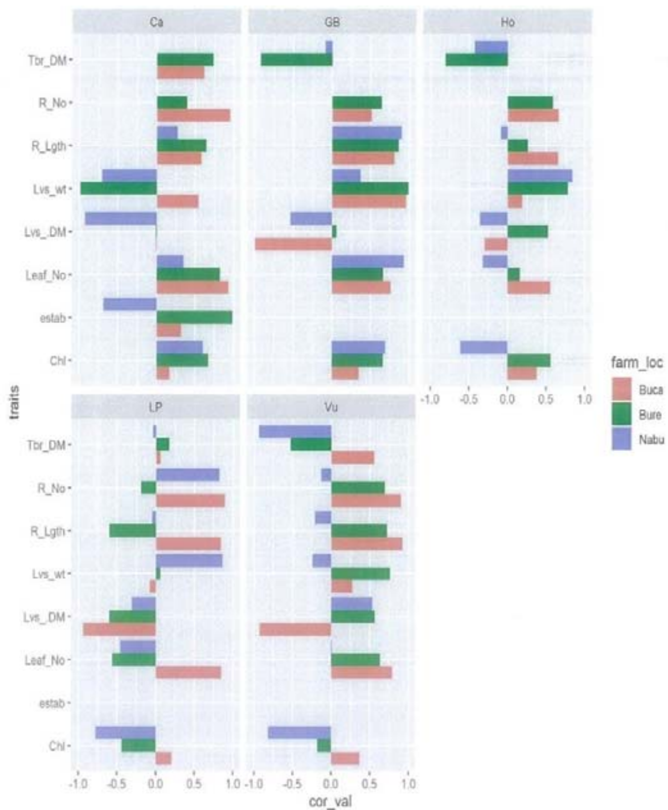
```
## Warning: Removed 7 rows containing missing values (position_stack).
```




```
GEN_env_cor_long <- rbind(tbr_yld_Buca_cor_long,tbr_yld_Bure_cor_long,tbr_yld
_Nabu_cor_long)
farm_loc <- c(rep("Buca",40),rep("Bure", 40), rep("Nabu", 40))
GEN <- rep(c(rep("GB",8),rep("LP", 8), rep("Vu", 8), rep("Ho", 8), rep("Ca",
8)),3)

GEN_env_cor_long1 <- cbind(farm_loc, GEN, GEN_env_cor_long)

ggplot(GEN_env_cor_long1, aes(x=traits, cor_val, fill=farm_loc)) +
        geom_col(position = "dodge") +
        coord_flip() +
        facet_wrap(~GEN)

## Warning: Removed 15 rows containing missing values (geom_col).
```

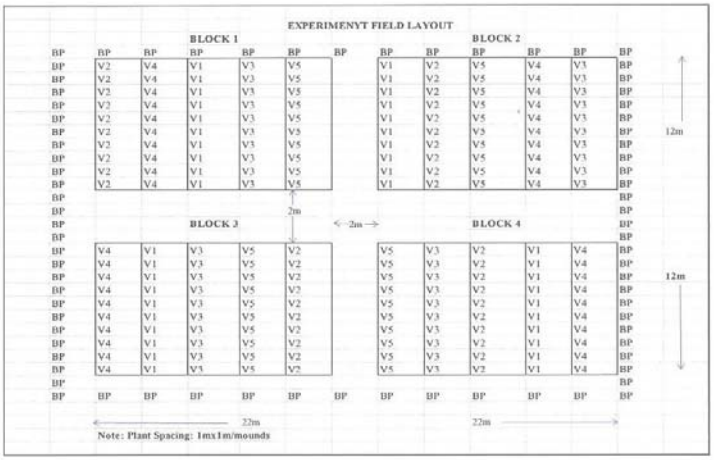



```
ggsave("GEN_env_cor_long1.jpg", width = 20, height = 20, units = "cm")

## Warning: Removed 15 rows containing missing values (geom_col).
```

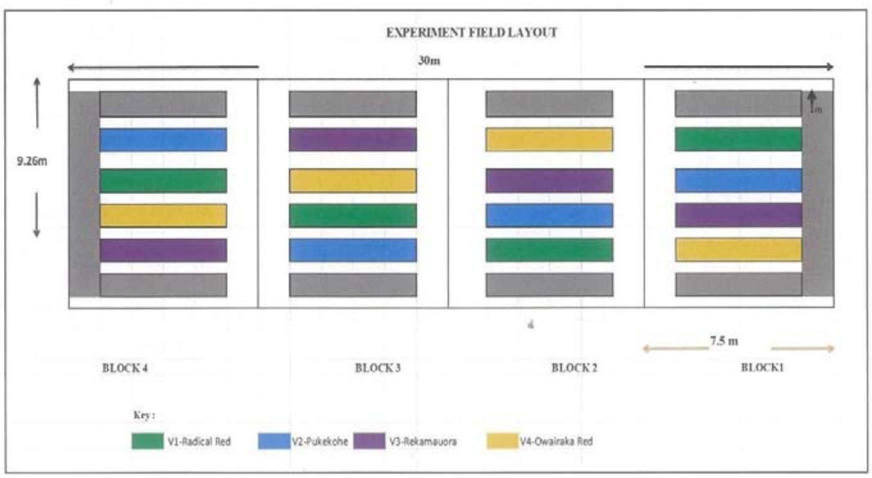


Ca
GB
Ho
LP
Vu
Tbr_DM
R_No
R_Lgth
Lvs_wt
Lvs_DM
Leaf_No
estab
Chl
traits
cor_val
-1.0
-0.5
0.0
0.5
1.0
farm_loc
Buca
Bure
Nabu

Appendix 5: Field Layout of the research trial in Ra and Massey University



Field Layout at Nabukadra, Burenitu and Bucalevu village in Ra



Field Layout designed at Massey University Field.

Appendix 6: Approval letter to research Ministry of I-Taukei Affairs.

MINISTRY OF ITAUKEI AFFAIRS
ITAUKEI TRUST FUND BUILDING COMPLEX
87 QUEEN ELIZABETH DRIVE, SUVA
P.O.BOX 2100, GOVERNMENT BUILDING, SUVA, FIJI.

TELEPHONE: (679) 3100 909 **FAX: (679) 3317 077**

Reference: MTA – 4/99/8-2 13th July 2018

Mr. Ilisoni Leweniqila
P O Box 5909
Valelevu

Re: Research Request - Letter of Support

In response to your request dated 3rd July 2018, this is a support letter by the Ministry of iTaukei Affairs (MTA) for you to carry out Free Prior and Informed Consent sessions with the community prior to carrying out your field research. The villages of interest are tabulated below:

No.	Village	Tikina	Province
1	Nabukadra	Kavula	Ra
2	Burenitu	Nalawa	"
3	Soa	Bureivanua	"

It is noted that your research project is titled, *"NA MATA NI CIVA AU A VAKAWALETAKA: an indigenous case study on the potential of kumala (Ipomoea batatas) to achieve Climate Smart Agriculture in Ra".*

Mandated to oversee the welfare and good governance of the iTaukei community under the iTaukei Affairs Act 1945, this letter is granted on the condition that the following will be undertaken:-

i. Roko Tui responsible for the proposed site(s) be informed of the research objectives and the communities that will be impacted in the process;
ii. Free Prior Informed Consent (FPIC) guideline Principle is obtained by researcher and evidence of this provided with a copy of final report;
iii. Individuals/communities that participate in the research are appropriately informed of the objectives and duration of the research;
iv. Cultural sensitivity and traditional protocols are observed;
v. All fieldwork and research activity is to be put on hold on Sunday; that Sundays' be respected as a day of rest;

vi. Status update(s) of the ongoing fieldwork be submitted at regular intervals to the Ra Provincial Council office and the designated MTA desk officer; and

vii. A copy of the finalized research findings report document and corresponding evidences of Free Prior Informed Consent (FPIC) is submitted to the community, Ministry of iTaukei Affairs, and the Ra Provincial Council office.

Kindly be advised that this support letter is also based on you meeting institutional requirements from other line Ministries / Government Departments that are directly/indirectly linked to your area of research interest.

The designated officers, as point of contact with regards to reporting and other necessary issues is Peni Torawale on email: peni.torawale@govnet.gov.fj telephone: 3100909 (ext 1029) or noa.bale@govnet.gov.fj ; telephone: 3100 909 (ext 1026).

You are advised to liaise with the Roko Tui upon arrival, for further assistance.

....
Naipote Katonitabua
Permanent Secretary for iTaukei Affairs

cc: **DCEO, TAB**
Roko Tui Ra

Appendix 7: Permit for research application.

MASSEY UNIVERSITY

COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

School of Agriculture & Environment
Maori & Pacific Agriculture Group
Rm 1.04, Fruit Crops Building
Batchelars Road, Palmerston North.
Private Bag 11222, Palmerston North 4440
NEW ZEALAND

Ph +64 6 9517876
Mob +64 27 2066850
Email: N.Roskruge@massey.ac.nz

2 July 2018

To whom it may concern

Re: Ilisoni Leweniqia – PhD project

Bula vinaka
This letter of support is given for Ilisoni Leweniqila, a current NZAid scholar from Fiji who is presently enrolled in Doctor of Philosophy (PhD) programme in Horticultural Science here at Massey University, Palmerston North, New Zealand. Ilisoni has recently completed his confirmation year in the programme (early June 2018) and is ready to commence the next phase of his research for the remaining two years of the programme. The doctoral course is taught through our School of Agriculture & Environment within the university's College of Sciences.

Ilisoni's project is firstly titled: *NA MATA NI CIVA AU A VAKAWALETAKA: an indigenous case study on the potential of kumala (Ipomoea batatas) to achieve Climate Smart Agriculture in Ra, Fiji*. He has a team of supervisors for which I am the primary supervisor alongside three others including Dr Litea Meo-Sewabu at USP in Suva. My own background is as an ethnobotanist and horticulturist specialising in root crops, especially through production and indigenous systems. I have worked globally including in Peru, Chile, Cornell (New York State) with the American Indian programme, Samoa, Papua New Guinea, Niue and also currently in Fiji in the KANA programme with farmer training. Ilisoni has the benefit of being able to access this wide network of practitioners and knowledge to support his own research.

With regard to Ilisoni's project, he will be looking to determine the most suitable cultivars of kumala for 'climate smart agriculture' in Fiji, especially to achieve food security in these emerging times of climate uncertainty as well as economic development for the local i-taukei communities. The project will require several crop cycle events on location at different altitudes in Ra district for him to measure their success (or otherwise) and be able to determine the value of each kumala variety, and associated knowledge, for future uptake. We value the additional support and recognition he can gain from your department and also appreciate the opportunity the project gives to the student and communities he will interact with..

If you need any further reference in regard to Ilisoni or his project please feel free to contact me as indicated above.Kei te mihi atu

Nikorima (Nick) Rahiri Roskruge (PhD) JP
Associate Professor in Horticulture and Maori Resource Development
Maori and Pacific Agriculture Group

Appendix 8: Research ethics notification.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Date: 14 September 2017

Dear Soni Leweniqila

Re: Ethics Notification - **4000018428 - "NA MATA NI CIVA AU A VAKAWALETAKA"**

Fijian parable "the pearl has been neglected" meaning that their purpose has not been recognised.

An indigenous case study on the potential of kumala (Ipomoea batatas) to achieve Climate Smart Agriculture in Ra, Fiji

Thank you for your notification which you have assessed as Low Risk.

Your project has been recorded in our system which is reported in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

If situations subsequently occur which cause you to reconsider your ethical analysis, please contact a Research Ethics Administrator.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

Human Ethics Low Risk notification

A reminder to include the following statement on all public documents:
"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director - Ethics, telephone 06 3569099 ext 86015, email humanethics@massey.ac.nz. "

Please note, if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to complete the application form again, answering "yes" to the publication question to provide more information for one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

B J Finch.

Dr Brian Finch
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)

Appendix 9: Participation information sheet.

MASSEY UNIVERSITY

Participant information sheet: ***An indigenous case study on the potential of kumala* (Ipomoea batatas) *to achieve Climate Smart Agriculture in Ra, Fiji***

Research Title: "Na mata ni Civa au a vakawaletaka". *An indigenous case study on the potential of kumala* (Ipomoea batatas) *to achieve Climate Smart Agriculture in Ra, Fiji.*

Invitation: Being invited to participate in this research project. It is important that you understand what the research is and why you were nominated to participate. Please read this information sheet carefully, and seek for assistances if it may needed or if you are comfortable to discuss with others feel free to do so. Thank you.

What is the project's purpose?
This research project seeks determine the most suitable cultivars of kumala for 'climate smart agriculture' in Fiji, especially to achieve food security in these emerging times of climate uncertainty as well as economic development for the local i-taukei communities in Ra.

Why am I being invited to participate?
You are being asked to take part because you have been identified by our Ministry (MPI) as a sweetpotato farmer in your community.

Do I have to take part in this research?
If you agree to take part we duly appreciate that, you may decline our request if you decide to and may withdraw from the research at any time.

What will happen if I agree to participate?
If you agree to participate, we will ask you questions about question of how do i-Taukei people in Ra conceptualise kumala as a potential crop for i-Taukei people in their community. We expect this conversation to take around 60 minutes. Your verbal consent will be recorded and you will be provided with a copy of this information sheet for your reference.

What are the risks of taking part?
We do not anticipate any risks beyond the risks you encounter in your everyday life.

What are the benefits of taking part?

It provides an exploration of the cultural constructs of traditional knowledge (TK) on production system and historical context of sweetpotato production in Fiji as perceived by i-Taukei people living in Ra. The research will also provide some context on how and why TK on kumala production has lost it importance within Fijian society. The findings of this research will allow for better recommendations that would assist farmers to enhance food security and create economic opportunities.

Research Time Frame expected?
Six months – End date December

What if something goes wrong?
If you have any complaints about the project please contact the principal researcher (contact information below). If, after contacting the lead researcher, your complaint has not been addressed to your satisfaction, please contact the Massey University Ethics Committee (contact information below).

Will my taking part in this research be kept confidential?
Your personal information will be kept strictly confidential.

Will I be recorded? What will happen to the recording?
With your permission, we will make an audio recording of our conversation. Audio recordings will be confidential.

What information will I be asked to share, and why do you need it for this research?
You will be asked about your tradition i-taukei knowledge on kumala and its history backgrounds.

What will happen to the results of this research project?
The results of this research will be presented at academic conferences and published in academic journals. Summary of our research findings will be shared with you.

Who is organizing and funding the research?
The research is funded by the Ministry of Foreign Affairs and Trade, New Zealand.

Who has ethically reviewed the project?
The project has been ethically reviewed and approved by Ethics Committee at Massey University, Palmerston North, New Zealand.

Contact information:

Ilisoni Leweniqila - Principle Researcher Massey University. Email: leweniqila.soni@gmail.com. Mobile: 9371587

Associate Professor Nikorima (Nick) Rahiri Roskruge (PhD) JP. Massey University. Email: N.Roskruge@massey.ac.nz. Mobile: +642272066850

Dr Huub Kerckhoffs. Masey University, Palmerston North, New Zealand. Email: h.kerckhoffs@massey.ac.nz

Dr Svetla Sofkova-Bobcheva. Massey University, Palmerston North, New Zealand. Email: s.sofkova-bobcheva@massey.ac.nz

Dr Litea Meo, University of the South Pacific. Email: litea.meosewabu@usp.ac.fj Mobile: 9360547.

Nicola Duffin, Doctoral Research Committee Massey University. Email: n.duffin@massey.ac.nz

Thank you for agreeing to participate in this research project.

Appendix 10: Participant consent form.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

FPIC: An indigenous case study on the potential of kumala (**Ipomoea batatas**) *to achieve Climate Smart Agriculture in Ra, Fiji.*

FREE, PRIOR AND INFORMED CONSENT FORM

We, the undersigned, consent to partake in the research project entitled **"Na mata ni Civa au a vakawaletaka".** *An indigenous case study on the potential of kumala* (Ipomoea batatas) *to achieve Climate Smart Agriculture in Ra, Fiji* sponsored by the NzAid (MFAT) in representation of the community name:

____

(*Provide community name*)

We have agreed on the basis of the information provided to me by the Principal Researcher of this research project, which we have read and understood, and in consultation with our community in a culturally manner.

We understand that participation in this research is entirely voluntary

We understand the purpose of this research and information provided will be confidential.

It's conceived that questions about the research project or queries on the use of any data or information which we have provided, or if we have any complaints or concerns relating to the research, we may contact the Principal Researcher, In the event that the Principal Researcher fails to address our questions or concerns to our satisfaction, we may contact the Massey University Ethics Committee.

____

(*Participant Name*)

are authorised to provide data and information to the Principal Researcher with this FPIC Form.

________________	________________	__________
Turaga ni Koro	*Signature*	*Date*

A copy of this consent form will be left with the community and a digital copy will be kept on a secure server at the MASSEY University.

Appendix 11: Results of soil samples on three research sites in Ra.

M E M O R A N D U M

From: Principal Research Officer - Chemistry

To: Sairusi Wara

Job No.: **1218093**

Date: 26 September 2018

Subject: **ANALYSIS RESULT**

Attached are the analysis results for **Soil** samples submitted on 21 August 2018.

To facilitate and expedite the processing of samples submitted to the laboratory a period of three months is allowed for the retention of samples in the laboratory after the dispatch of the results from FACL.

Any query regarding the attached results is to be addressed to the PRO (Chemistry) within this period for further action.

FIJI AGRICULTURAL LABORATORY, RESEARCH DIVISION
PRINCIPAL RESEARCH OFFICER

Ami C Sharma
Principal Research Officer (Chemistry)

FIJI AGRICULTURAL CHEMISTRY LABORATORY
Koronivia Research Station. P O Box 77, Nausori. Phone: +679-3477044 Fax: +679-3400262/3477546
Ministry of Agriculture

SOIL ANALYSIS RESULTS

Sairusi Wara
MoA
Dobuilevu Research Station

Job No.:	**1218093**
Sample Delivery Mode:	**Hand Delivered**
Date Received:	**21/08/2018**
Date Completed:	**26/09/2018**

Client ID	Lab ID	pH	Electrical Conductivity (mS/cm)	Total Organic Carbon (%)	Total Nitrogen (%)	Olsen Available Phosphorus (mg/kg)
Ilisoni Leweniqila (Nabukadra Field)	21810598	6.0	0.09	2.4	0.28	6
Ilisoni Leweniqila (Burenitu Field)	21810599	5.7	0.08	3.6	0.26	5

Note:
Results are reported oven dried basis.
Refer attached sheet (ideal values) to compare test values of soil samples.

Comments
Fairly good soil with
average soil fertility level.
Recommendations.
(1) Apply Triple superphosphate
180kg/ha as Basal
(2) 240 kg/ha Urea in
two split applications.
(3) 300 kg/ha K (Muriate of
potash
(4) Organic manure 10 t/ha
during land preparation

FIJI AGRICULTURAL LABORATORY, RESEARCH DIVISION, DEPARTMENT OF AGRICULTURE MINISTRY OF ... INDUSTRIES
PRINCIPAL RESEARCH OFFICER
Ami Chand Sharma
Principal Research Officer – Chemistry

MEMORANDUM

From: Principal Research Officer - Chemistry

To: Sairusi Wara

Job No.: **1218096**

Date: 20 September,2018

Subject: **ANALYSIS RESULT**

Attached are the analysis results for **Soil** samples submitted on 06 September, 2018.

To facilitate and expedite the processing of samples submitted to the laboratory a period of three months is allowed for the retention of samples in the laboratory after the dispatch of the results from FACL.

Any query regarding the attached results is to be addressed to the PRO (Chemistry) within this period for further action.

FIJI AGRICULTURAL LABORATORY, RESEARCH DIVISION
PRINCIPAL RESEARCH OFFICER

Ami C Sharma
Principal Research Officer (Chemistry)

FIJI AGRICULTURAL CHEMISTRY LABORATORY

Koronivia Research Station. P O Box 77, Nausori. Phone: +679-3477044 Fax: +679-3400262/3477546

Ministry of Agriculture

SOIL ANALYSIS RESULTS

Sainisi Wara		Job No.:	1218096
MoA		Sample Delivery Mode:	Hand Delivered
Dobuilevu Research Station		Date Received:	06/09/2018
Ra		Date Completed:	20/09/2018

Client ID	Lab ID	pH (H_2O)	Electrical Conductivity (mS/cm)	Total Organic Carbon (%)	Total Nitrogen (%)	Olsen Available Phosphorus (mg/kg)
Sairusi Wara [Bucalevu Field],Ra	21810615	6.2	0.03	2.3	0.2	6
Isikeli Raisuri [Lau Settlement],Ra	21810616	4.7	0.07	1.2	0.1	2

Note:
Results are reported oven dried basis.
Refer attached sheet (ideal values) to compare test values of soil samples

FIJI AGRICULTURAL LABORATORY, RESEARCH DIVISION
PRINCIPAL RESEARCH OFFICER
AGRICULTURE, MINISTRY OF PRIMARY INDUSTRIES

Ami Chand Sharma
Principal Research Officer – Chemistry

Notes

- *Ideal values*

Parameters	Values
pH (1:5 water)	5.6 – 6.6
EC (1:5 water)	0.4 – 0.8mS/cm
Olsen Available Phosphorus	20 – 30mg/kg
Calcium (Ca)	2.0 – 10 me/100g
Potassium (K)	0.3 – 0.6 me/100g
Magnesium (Mg)	1.0 – 3.0 me/100g
Sodium (Na)	0.3 – 0.7 me/100g

Parameters	Values
Carbon	4 – 10%
Nitrogen	0.3 – 0.6%
C:N ratio	10:12
Iron (Fe)	> 4.5 mg/kg
Manganese (Mn)	> 1.0 mg/kg
Copper (Cu)	> 0.2 mg/kg
Zinc (Zn)	> 1.2 mg/kg

- Comments

Sample 21810616 – Acidic Soil.

Recommendations

(1) Apply 6-7kg/ha Agricultural Lime during land preparation (for sample 21810616)

(2) Apply 240kg/ha Urea, split application is recommended for BSR samples.

(3) 200 – 180kg/ha Triple Super phosphate to samples 21810616 and 21810615 respectively. and this has to be applied as Basal

(4.) Apply 350 kg/ha Muriate of Potash.

(5) 10t/ha poultry manure or any organic materials

PRINCIPAL RESEARCH OFFICER
AGRICULTURAL LABORATORY, RESEARCH DIVISION
DEPARTMENT OF AGRICULTURE MINISTRY OF PRIMARY INDUSTRIES

Name: ________ Signature: ________ Date: ___/___/___

Appendix 12: Results of weather data in Ra district from 1938 – 2018.

FIJI METEOROLOGICAL SERVICE
PRIVATE MAIL BAG (NAP 0351)
NADI AIRPORT, FIJI

Telephone: 679 - 6724888 Facsimile: 679 - 6720430 (HQ), 6720190 (NWFC), 6724050 (Climate Services)
Email: fms@met.gov.fj ; Web Site: www.met.gov.fj

Information Sheet No. 82, Revision 3, 23 August, 2016

CLIMATOLOGICAL SUMMARY FOR DOBUILEVU, FIJI

Latitude: 17°33'36''S **Longitude: 178°14'47''E** **Height above MSL: 72.5m** **Station ID: V78521**

The Dobuilevu climate station is about forty kilometres due south of Penang Mill and about 117 kilometres from Suva on the King's Road. This station is situated on a small ridge rising to fifty-eight meters above mean sea level and surrounded by hills. The knoll rising to the east affects the early morning sunshine recordings; otherwise, the station is reasonably well exposed. The station was opened as a rainfall station in 1937 and then upgraded to climatological station in 1964. There has been no change to the site since its establishment. A telemetric tipping bucket rain gauge, measuring rainfall at 5 minute intervals, was installed within the enclosure on 15 December 2008.

RAINFALL TOTALS - millimetres (1938 - 2015)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Total Rainfall	385	345	394	284	134	102	65	82	121	151	217	272	2553
Highest Recorded	1176	1080	1081	1063	380	386	239	390	511	472	817	739	3723
Lowest Recorded	44	48	56	40	5	6	0	3	9	10	9	49	1437
Highest 1-Day[A]	360.0	415.0	349.2	257.0	177.0	200.3	110.0	215.9	370.0	195.3	281.1	318.0	415.0
Date of Highest	10/09	08/65	22/64	17/86	17/14	09/90	31/96	07/59	25/80	24/72	17/71	17/12	08/2/65

Percentiles ("p" percent of the years have rainfalls equal to or less than R (p) mm) (1938 - 2015)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
P = 5 R(p)=	78	140	158	93	32	11	9	16	16	18	24	82	1517
P=10	104	151	177	117	45	15	13	21	21	23	59	93	1804
P=20	207	194	237	154	57	27	21	29	40	54	84	146	2058
P=30	279	229	257	170	69	41	31	37	56	76	120	205	2226
P=40	316	269	300	189	82	55	39	55	85	117	141	219	2321
P=50	343	334	350	241	95	84	62	75	113	146	165	241	2443
P=60	410	352	395	296	138	101	68	84	129	173	204	268	2624
P=70	467	393	438	305	187	129	89	94	153	196	257	309	2824
P=80	559	473	524	389	213	151	104	116	176	235	318	394	2934
P=90	688	520	672	468	257	218	127	163	243	305	503	531	3297
P=95	815	729	874	603	289	327	142	212	337	365	571	598	3429

Mean No. of Days with Rainfall (1944 - 2015)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
>=0.1 mm	17	17	17	15	10	8	7	8	9	10	12	14	144
>=0.5 mm	17	17	17	14	10	8	7	7	8	9	12	14	140
>=1.0mm	16	16	17	14	9	7	6	7	8	9	12	13	134
>=5.0mm	12	12	12	9	5	4	3	4	5	5	8	10	89
>=10.0mm	9	9	9	6	3	2	2	2	3	3	5	7	60
>=20.0mm	6	5	6	4	2	1	1	1	2	2	3	4	37
>=50.0mm	2	2	2	1	1	1	0	0	1	1	1	1	13

Air Temperature - ° Celsius (1965 - 2015)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Daily Max[B]	31.1	31.3	31.2	30.1	28.9	28.0	27.2	27.5	28.3	29.1	30.0	30.8	29.5
Mean Daily Min[C]	22.3	22.3	22.3	21.5	20.0	19.3	18.2	18.0	18.8	19.8	20.7	21.6	20.4
Mean Daily Range[D]	8.8	9.0	8.9	8.6	8.9	8.7	9.0	9.5	9.5	9.3	9.3	9.2	9.1
Mean Daily Mean	26.7	26.8	26.8	25.8	24.5	23.7	22.7	22.8	23.6	24.5	25.4	26.2	25.0
Highest Max. Temp.	35.1	36.0	35.0	36.0	35.0	33.2	32.9	35.5	35.5	35.4	34.8	35.5	36.0
Date of Highest Max	01/12	15/15	11/99	19/96	25/08	18/95	18/98	29/07	23/89	26/05	30/13	15/15	15/2/15
Lowest Min. Temp.	13.0	12.2	15.5	11.0	11.6	11.0	8.5	9.8	9.0	10.0	12.0	12.1	8.5
Date of Lowest Min	1,2/74	29/08	6/83	29/08	2/08	12/72	18/86	04/86	1/77	17/77	6/77	16,17/08	18/7/86

Daily Dry & Wet Bulb Temperatures at 0900hrs - ° Celsius (1972 - 2015)													
Mean Daily Dry	27.4	27.2	26.9	26.0	24.5	23.5	22.6	23.0	24.0	25.4	26.5	27.3	25.4
Mean Daily Wet	25.2	25.3	25.1	24.3	23.0	22.0	21.1	21.3	21.8	22.8	24.0	24.7	23.4

Soil Temperatures at 0900hrs[E] - ° Celsius													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean at 10cm (1980–2015)	27.8	27.9	27.9	26.9	25.4	24.2	23.0	23.0	23.4	24.9	26.5	27.8	25.7
Mean at 30cm (2000–2015)	29.0	28.8	28.8	28.1	27.0	25.7	24.9	25.0	25.8	26.7	27.8	28.3	27.2

Relative Humidity at 0900hrs - Percent (1972 - 2015)													
Mean Daily RH	83	85	86	86	87	88	86	85	81	80	80	80	84

Sunshine Hours (1972 - 2015)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Sunshine	167	137	149	140	145	131	137	152	139	151	142	138
Highest Recorded	245	208	194	218	183	160	190	212	192	205	187	190
Lowest Recorded	119	64	91	79	82	83	67	92	87	57	98	76

Meteorological Elements	Monthly Normals* (1971-2000)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Maximum Temp (°C)	30.9	31.2	30.9	29.9	28.6	27.9	27.2	27.4	28.1	29.0	29.9	30.6	29.3
Minimum Temp (°C)	22.2	22.4	22.2	21.5	20.1	19.2	18.1	18.1	18.8	19.7	20.9	21.6	20.4
Mean Temp (°C)	26.6	26.8	26.6	25.7	24.4	23.6	22.7	22.7	23.5	24.4	25.4	26.1	24.9
Rainfall (mm)	395.4	333.8	429.3	288.7	130.3	101.4	56.1	80.5	119.1	153.1	225.6	271.4	2584.7

[A] Daily rainfall is recorded over a 24-hour period (9 am to 9am).
[B] Average daily maximum temperature recorded each day over 24-hour period (9am to 9am).
[C] Average daily minimum temperature recorded each day over 24-hour period (9am to 9am).
[D] Is the difference between the average maximum and the average minimum daily temperature for each month (Av Max - Av Min)
[E] The 9am temperature is not representative of the 24-hour temperature, especially at the shallower depths where the diurnal variations are high.
* Normals are referred to WMO standard long-term averages based on the period 1971-2000.

Revised by: Climate Services Division
Revision 1: 25th August,1982
Revision 2: 23rd November, 2001

For further information, please contact: The Director, Fiji Meteorological Service, Private Mail Bag NAP0351, Nadi Airport, Fiji Islands. Phone: (679) 6724888, Fax: (679) 6720430, E-mail: fms@met.gov.fj; URL: http://www.met.gov.fj

Monthly data for Dobuilevu Research Station

2016 to 2018

Data Quality: **All** Unit: **metric**

Site Name: **Dobuilevu Research Station** Site Number: **V78521**

Latitude: **-17.550000** Longitude: **178.233300** Elevation: **73.0 m**

Commenced: **Jul 1937** Status: **Open**

Rainfall (mm) Max Temp (°C) Min Temp (°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	142.6	M	135.8	613.2	26.5	103.0	M	M	M	123.9	197.1	M
	33.2	M	32.2	29.1	29.6	29.2	M	M	M	30.6	31.8	M
	21.1	M	23.4	22.5	20.2	19.1	M	M	M	20.4	21.4	M
2017	344.0	411.8	336.0	78.0	142.1	59.0	20.9	98.3	91.8	41.8	435.3	194.2
	32.2	30.9	30.8	31.4	29.2	27.7	27.3	28.1	28.9	30.5	30.5	30.6
	21.6	23.3	23.2	22.1	21.8	20.4	18.1	18.8	20.2	20.7	22.2	22.0
2018	M	354.8	690.2	604.0	120.8	58.0	4.0	0.0	81.2	430.3	122.2	246.6
	M	31.0	31.6	30.4	28.7	28.3	27.9	28.6	29.5	29.0	31.1	31.2
	M	23.2	22.7	22.0	20.2	20.9	18.5	17.5	21.0	21.9	21.6	22.8

Appendix 13: Guiding questions for *talanoa* and semi structured interview

SURVEY QUESTIONNAIRE FOR FARMERS

DISCLAIMER:

As part of my PhD research thesis at the Massey University, Manawatu Campus. I am conducting a survey which involves questionnaire on *"How do i-Taukei people in Ra conceptualise Kumala?" It provides an exploration of the cultural constructs of Traditional Knowledge on Production System and historical context of sweet potato production in Fiji as perceived by i-Taukei people living in Ra and contextualise the loss of importance within society.* This study is an endeavour to understand how indigenous Fijians people in Ra conceptualise Kumala in respond to challenges Fiji is facing such, and create opportunities that occur as a result of agricultural development and to further knowledge on the processes of change and adaptation experienced by these communities. The purpose of this study is to therefore broaden our understanding of the social-ecological systems of indigenous Fijian communities and shed light on the exploits, opportunities and changes endured as a result of agriculture development in Ra. This research will also explore indigenous knowledge to find out the historical context of sweet potato production in Fiji and contextualise the loss of importance within society. There is also a need to recover traditional knowledge in regards to their production, harvest and storage which can then be restored and implemented by i-Taukei farmers in the village. This will contribute to food security through access to knowledge and Kumala planting materials and allow for better recommendations to assist farmers with variety selection and economic wellbeing or sustainable living. Any information obtained in connection with this study that can be identified with you will remain confidential.

CONSENT:

I have read and understood all the information written above. My participation in this survey is voluntary and I am willing to share necessary information for this survey and reclaim the status of kumala to my society.

a. Survey No: ____________ c. Date: ____________
b. Village ____________ d. District ____________

Personal Information

1. Name: ____________
2. Age: ____________
3. Contact Number: ____________
4. Gender:
   a) Male ☐ b) Female ☐
5. Marital status
   a) Married ☐ b) Unmarried ☐
6. Nature of Job
   a) Permanent ☐ b) Part-time ☐
7. No of years in Agriculture Business: ________
8. Educational Qualification:
   a) None ☐ b) Primary ☐ c) Secondary ☐ d) Tertiary ☐

Land Tenure

9. Which type of Land you are farming
   a) I-Taukei ☐ b) Freehold ☐ c) Mataqali ☐ d) Crown land ☐
10. Total acre of land: ________
11. No. of years using this land ________

General Information

12. What crops do you grow?

Crops	Acres

13. What do you use these crops for?

Crops	Purpose

14. What are the farming systems that you practise?
    a) Subsistence Farming b) Semi-commercial Farming c) Commercial Farming
15. Why did you choose this practise?
16. Do you use Machinery for ploughing?
17. If "YES", why?

Sweet Potato production and cultivars

18. How long you have been cultivating sweetpotato?

19. How many cultivars of sweetpotato do you cultivate (acre)?

20. Where do you source these sweet potato cultivars?

21. Name the cultivars and describe their characteristics

Sweet Potato Cultivar	Characteristics

Traditional Cultivation and Storage of Sweet Potato

22. Is sweet Potato are traditional crop cultivated from the past?
    a) Yes ☐ b) No ☐

23. What about now?
    a) Yes ☐ b) No ☐

24. If "NO", why it has been forgotten?

25. List the traditional tools that you use in planting Sweet potato?

26. Do you use a traditional calendar to plant sweetpotato?

27. Identify and explain indicators of this traditional calendar?

28. When is the best month to plant sweetpotato?

29. Explain if there's any traditional planting method of sweetpotato stating reasons for this method?

30. Do you store sweetpotato for other purposes?

    a) Yes ☐ b) No ☐

31. List the purpose of storing sweetpotato?

32. What are the advantage and disadvantages of this method?

25. List the traditional tools that you use in planting Sweet potato?

26. Do you use a traditional calendar to plant sweetpotato?

27. Identify and explain indicators of this traditional calendar?

28. When is the best month to plant sweetpotato?

29. Explain if there's any traditional planting method of sweetpotato stating reasons for this method?

30. Do you store sweetpotato for other purposes?

a) Yes ☐ b) No ☐

31. List the purpose of storing sweetpotato?

32. What are the advantage and disadvantages of this method?

Traditional Practices of Kumala during Climate Change Challenges

33. What challenges do you face?

34. How often does it occur?

35. How do you manage your sweetpotato during this challenges?

36. Do you think that sweetpotato will sustain to this challenges? If "Yes", how?

37. What are some activities that you do in preparing for a drought and cyclones?

38. Which crop do you prefer is the best crop for rehabilitation programmes and explain why?

39. From your experience, can sweetpotato sustain you during these extreme weather events?

40. Do you prefer that Sweetpotato is the suitable crop for food security in your society? If "Yes", Why?

Extending Traditional Knowledge

41. Do some of the traditional knowledge of sweetpotato still been practised today?

42. Name some of this knowledge and give reasons to the answer above?

43. What could be done to extend this traditional knowledge?

Traditional Knowledges contribution to sustainable livelihood.

44. Can traditional knowledge of sweetpotato sustain your livelihood?

45. What are the ways that traditional knowledge can sustain your livelihood?

46. Name other activities that you used to sustain your livelihoods?

Agriculture Services from the MPI

47. Does the MPI provide sweetpotato planting material to your society?

48. How often?

49. Do they provide food security programmes or workshop awareness in your society to promote the value of cultivating sweetpotato?

50. If "Yes", how often?

51. What have you learnt from this awareness on the value of sweetpotato?