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Evaluation of soil nutrient management practices of taro farmers' in Taveuni, Fiji[+]

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Abstract

There is evidence that the soil health in Taveuni, Fiji is deteriorating over time threatening livelihoods of taro producers. The present study was conducted to understand the soil nutrient management practices followed by taro farmers in Taveuni. The study revealed that the farmers in Taveuni use various organic and chemical fertilizers and various other soil fertility management practices such as mulching, crop rotation with legumes, yagona and agroforestry. The quantity of nitrogen, phosphorous and potash (NPK) applied to taro crop on different types of soils was meager. The study further revealed that there was imbalanced and insufficient use of chemical fertilizers and organic sources of soil nutrients. The main cause of low use of fertilizers was that the farmers in Taveuni do not know the fertility status of their farms as no soil testing was ever done and majority of them are also not fully aware of various low-cost organic methods of maintaining soil fertility of farms.

Keywords: *Soil nutrient, Soil health, Soil fertility, Soil management, Taro cultivation*

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1. Introduction

The greatest natural resource of any country is the soil (Brady, 1984; DAC, 2011). It is the medium from which majority of the food is produced either directly or indirectly. The soil quality defines quantity and quality i.e. nutritional value and safety of the foods grown (Colin *et al*., 2005; Rosegrant and Cline, 2003; Yong-Guan, 2009). Since food which plays an important life-sustaining role, is generated from the soil, it is extremely essential to maintain the capacity of the soil to sustain productivity, environmental quality and the human health (Bennett *et al*., 1999). Poor soil management practices and intensive cultivation of land causing soil degradation has become a global concern as it is a major contributing factor to soil erosion, soil acidification and losses of soil organic matters (SOM) and soil nutrients (Adesanwo, 2009). On the whole, it decreases the agricultural production capacity, food security and livelihoods. The problem of degrading soil is aggravated by the need to reduce poverty and unsustainable farming practices (Colin *et al*., 2005; Sanchez *et al*., 1997).

The depletion of soil fertility is a major environmental and economic issue in developing countries like Fiji. Evidence suggests that the land degradation problem in Fiji is not improving in spite awareness of the numerous environmental issues. In Fiji, the primary form of land degradation is the soil fertility degradation (Asafu-Adjaye, 2008). In many parts of the country, the loss of the soil chemical fertility due to nutrient depletion is becoming an increasingly serious problem (Prasad, 2006). Fiji's soils including those of Taveuni have been reported to be deficient of many essential nutrients. Reports by Duncan, suggested that the problem of declining soil fertility is threatening taro producers in Fiji (Duncan, 2010). Therefore, soil testing and fertilizer trials should be conducted to determine whether the plant nutrition problem was due to lack of macronutrients or micronutrients in the soil (Duncan, 2010).

The study undertaken by the Australian Centre for International Agricultural Research (ACIAR) has also confirmed the declining trend in the soil fertility on the island of Taveuni, Fiji (Smith, 2011). This study showed that in some of the taro production areas on Taveuni, there are visible impacts of deteriorating the soil health and thus, agricultural growth has slowed down, causing unsustainable taro production (Smith, 2011). This situation has challenged the farmers in Taveuni in trying to reach their planned harvesting goal and led to constant search for new fertile land and hence, the need to clear extensive areas of forest land for taro planting. As a result, Taveuni island has had the highest rate of deforestation in Fiji in recent years (Panapasa, 2012). Since Taveuni is the major producer of taro crop in Fiji, declining soil fertility in that island has posed threat to food and income security for the country due to poor crop yields and low profit margins (Panapasa, 2012).

Moreover, due to an increase in food demand for domestic and export market, the traditional shifting cultivation system is also slowly replaced by continuous mono cropping system in Fiji. Hence, as a result of this frequent cultivation of land, the soil nutrients are lost and sufficient time is not given for the soil nutrient replenishment to be achieved (Panapasa, 2012). This happens because plant tissues are composed of carbon and certain essential nutrients which cause nutrients to be removed from the soil during crop harvest (Nash *et al*., 2014; Yong-Guan, 2009). Therefore, when land is intensively used with no appropriate replenishment of plant nutrients, the soil nutrients get exhausted and thus the soil fertility declines. Hence, to ensure sustainable soil environment and crop production, the nutrients removed from the soil must be equal to the nutrient replenished (Jahiruddin and Satter, 2010). The nutrients in the soil should be replaced with sources of nutrients such as synthetic fertilizers, manures, municipal wastes, etc. (Havlin *et al*., 2005; Masikati *et al*., 2014; Mbah and Onweremadu, 2009; Wivstad *et al*., 2005).

The cultivation of agricultural land also alters the total physical, chemical and biological aspects of the soil that contribute to its structure, porosity and availability of the soil nutrients (Colin *et al*., 2005). According to Johnson (1992) and Mann (1986), cultivation usually decreases the organic matter (OM) content of the soil. Moreover, long-term application of fertilizers can result in accumulation of their residues in the soils (Marrs, 1993). For example, Compton and Boone (2000), Koerner *et al*. (1997) and Richter *et al*. (2000) have reported increased nitrogn (N) content in the soil in New England and France while, Kalisz (1986) found that phosphorous (P) content was lowered in Eastern Kentucky. Moreover, increased potassium (K), calcium (Ca) and magnesium (Mg) contents and higher pH was also reported (Kalisz, 1986; Koerner *et al*., 1997). Hence, these results consistently suggest that prolonged agricultural use of the soil has a long-term effect on the soil properties (Antti and Hytonen, 2005; Adesanwo *et al*., 2009; Bhat *et al*., 2012).

For good quality product with high yield, taro crop needs to be grown in rotation and grown on the land that has been left fallow for quite some time (Robin and Pilgrim, 2003; McGregor, 2011). Studies have shown that this is not the case in commercial taro production areas of Taveuni (Robin, 2006; McGregor, 2011). Due to land constraints in some parts of Taveuni, taro has been cultivated on the same piece of land for up to 15 years or at most left a piece of land fallow for two years (Robin, 2006; McGregor, 2011). Soil fertility measures such as green manure, longer fallow period and organic fertilizers as well as good quality planting materials are now under trial to improve the production and quality of taro in Taveuni (Robin, 2006; McGregor, 2011).

In light of the above backgrounds, this study was undertaken in Taveuni island of Fiji with the aim to evaluate the current soil nutrient management practices followed by taro producers and to make suggestions for improving the soil chemical balance of farms for achieving long-term sustainable agricultural growth.

2. Methodology

The study was conducted in Taveuni island of Fiji during 2013. A random sample of fifty farmers was randomly selected for the study from four different locations namely: Matei, Mua, Vione and Delaivuna. Required information pertaining to the years 2010-2012 about various types and quantity of fertilizers used on farms as well as other soil fertility measures used by the farmers was obtained on a structured questionnaire by personal interview method. Ideas were also gathered about the problems that the farmers in Taveuni were facing in following proper soil fertility management practices. The data obtained from the questionnaire survey was classified according to the soil types. An attempt was made to identify the trend in the taro production in Taveuni for the past three years. The descriptive statistics based on survey data are presented in tabular form and bar diagrams. The data obtained in the structured questionnaire were statistically analyzed.

3. Results and Discussion

3.1. General Information about Sample Taro Farms and Crop Outputs

The data obtained from the questionnaire survey on crop output was classified according to the soil types, number of farms, average size of the farms and the average taro yield during 2010-2012. The number of farms and taro yields on farms having clay soil, clay loam soil, loam soil and sandy soil is given in Table 1. The data shows that the highest taro production was on the farms having loam soil.

Table 1. Characteristics of sample farms and average taro yields during 2010-2012.

Soil type of farms	Number of farms	Average size of farm (acres)	Average taro yield during 2010-2012 (kg/acre)
Clay	1	1.0	766.7
Clay loam	34	2.2	1233.3
Loam	11	1.9	2256.8
Sandy loam	4	3.0	1279.9

An attempt was made to identify the annual variations in the taro production in Taveuni for the years 2010-2012. The annual variations in taro

production for farms having clay soil, clay loam soil, loam soil and sandy soil is shown in Figure 1, which clearly shows that there was a significant decline ($\rho < 0.01$) in the taro production on farms in all four types of the soil during the years 2010-2012.

3.2. Fertilizer Application by Farmers

Knowing the fertility status of the soil is useful in designing a balanced fertilizer application scheme (Bista *et al*., 2010). However, like many traditional farming systems, many farmers in Taveuni, rely on the soils' natural ability to provide essential nutrients to crops and apply some fertilizer (organic or chemical) without knowing the fertility status of their farms soil. The frequency of the soil tested on the farms and the fertilizers applied to the crops grown on different types of soils are shown in Table 2. The survey revealed that 94 % of the farmers interviewed never had the soil on their farm tested while the remaining 6 %, who had sent the soil samples for analysis, did not receive any feedback from the soil testing laboratories (or from the organization which took the soil samples) on the soil nutrient status of their farms. Hence, farmers applied fertilizers either based on traditional knowledge or on the availability of the fertilizers. The study showed that 4 % of the farmers did not apply any form of fertilizer on their farm. The majority (96 %) of the farmers applied either organic fertilizer, chemical fertilizer or a combination of fertilizers either at the time of crop planting (6 %), in the middle of the cropping cycle (82 %) or during both periods (8 %) (*cf.* Table 2).

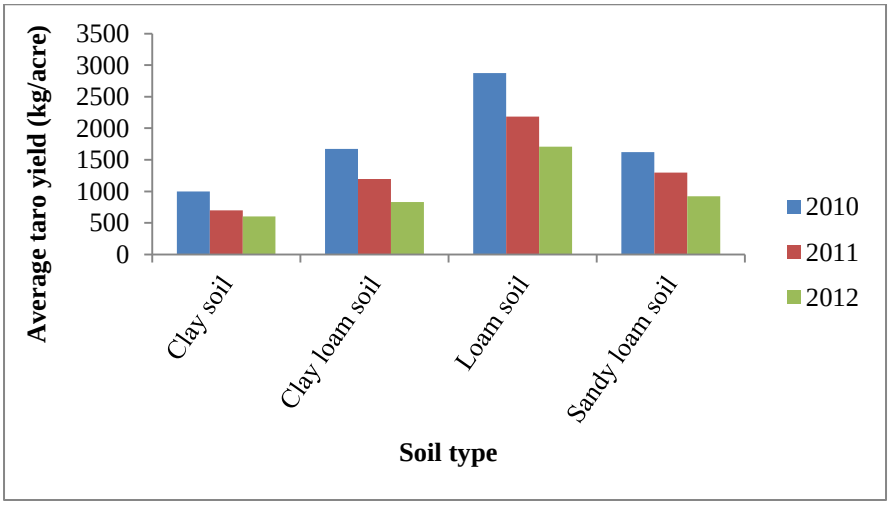

Figure 1. Taro yields on farms with different soil types during the years 2010 -2012.

Table 2. Frequency of the soil tested on the farms and fertilizers applied to crops.

Soil types	Sandy loam	Loam	Clay loam	Clay
Frequency of soil tested on the farms				
Never	4 (8)	11 (22)	31 (62)	1 (2)
Once every 5 years	--	--	--	--
Once every 2 years	--	--	--	--
Others (Once in 2012)	--	--	3 (6)	--
Frequency of fertilizers applied to crops				
Never	1 (2)	--	1 (2)	--
At the time of planting	--	2 (4)	1 (2)	--
Middle of cropping cycle	3 (6)	9 (18)	28 (56)	1 (2)
At the time of planting and in the middle of the cropping cycle	--	--	4 (8)	--

The figures in parenthesis denote percentage of farmers interviewed.

3.3. Use of Organic Fertilizers on Taro Farms

The number of farmers using different organic fertilizers and the average quantity of these fertilizers used on their farms is shown in Table 3. Mulching is the primary source of nutrients for the soil fertility management in Taveuni, Fiji. Mulching was used by 38 % of the sample farmers. The highest percentage of different types of fertilizers was used on farms with clay loam soil. Mulching was however, not used by farmers with sandy loam soils. Only 14 % of the farmers interviewed have been using fish meal as an organic source of the nutrients in their taro farms. Out of this, 12 % farmers applied on farms with clay loam soil and only 2 % of farmers on farms with loam soil. It was found that fish meal has not used on farms with clay and sandy loam soils (Table 3). In general, an average of 75 g/taro plant of fish meal have been used by these 14 % farmers during the years 2010-2012. Similarly, compost has been used by 16 % of the farmers but only to the farms having clay loam soil. The data presented clearly shows that an average of 112.5 g/taro plant of compost applied by the farmers who used compost as nutrients source. Moreover, 18 % of the farmers applied lime as a source of nutrients on their farms of which only 2 % farmers applied on the farms with loam soil while 16 % farmers applied on the farms with clay loam soil. For those using lime as a nutrient source on their farm, an average of 88.9 g/taro plant was used. Seaweed has also been used by a small group of the farmers (4 %) on their farms with an average of 50 g/taro plant.

Table 3. Quantity (grams/plant) of different organic and chemical fertilizers used by farmers on different type of soils.

Types of fertilizers used	Types of soil on farms			
	Sandy loam	Loam	Clay loam	Clay
Fish meal (gram/plant)	--	50.0 (2)	79.2 (12)	--
Compost	--	--	112.5 (16)	--
Lime	--	50.0 (2)	93.8 (16)	--
Seaweed	--	--	50.0 (4)	--
Mulching (% of farms)	--	12.0	24	2
Urea (45% N)	30.0 (2)	235.0 (4)	47.5 (8)	--
Hydro-complex (12:11:18)	--	235.0 (4)	30.0 (2)	--
Alroc (12:14:14)	26.7 (6)	--	53.3 (6)	--
NPK_1 (15:15:15)	30.0 (2)	112.0 (10)	38.8 (16)	--
NPK_2 (13:13:21)	--	42.5 (4)	41.1 (18)	--
NPK_3 (10:10:20)	30.0 (2)	--	--	--
Average N	10.2 (6)	51.9 (14)	10.2 (20)	--
Average P	6.2 (6)	21.0 (14)	6.3 (38)	--
Average K	7.2 (6)	23.2 (14)	8.0 (38)	--

The figures in parenthesis denote percentages of farmers using fertilizers.
N= Nitrogen, P = Phosphoric acid, and K = Potash.
The figures in the parenthesis with NPK fertilizer types denote the ratios of N:P:K in its composition.

Table 4. Percentage of farmers using different soil fertility measures on their farms with different soil type.

Soil fertility measures	Soil types				Total (%)
	Sandy loam	Loam	Clay loam	Clay	
Taro crop rotation with legumes	6	2	38	0	46
Taro crop rotation with yagona	4	4	18	0	26
Taro crop rotation with vegetables	0	0	2	0	2
Taro crop with raintrees	4	6	16	0	26
Taro crop with drala trees	6	6	36	0	48
Taro crop with coconut trees	2	0	2	0	4
Taro crop with pine trees	0	2	0	0	2
Taro crop with no fallowing	2	6	8	0	16
Taro with 3-6 months fallowing	2	6	8	2	18
Taro with 6-12 months fallowing	0	6	30	0	36
Taro with 1-2 years fallowing	0	4	22	4	30

3.4. Use of Chemical Fertilizers on Farms

The number of farmers using different chemical fertilizers on their farms and the average quantity of different chemical fertilizers used are shown in Table 3. The data in Table 3 reveals that in addition to organic fertilizers, some farmers have also used chemical fertilizers to supplement nutrient content in the soil of their farms. The common fertilizers used by these farmers include; urea, NPK, hydro-complex and alroc. The data analysis showed that the highest percentage of the chemical fertilizers (NPK) was used on farms with clay loam soil. Although, the farmers having clay loam soil on their farms made the use of chemical fertilizers, a higher quantity of the fertilizers was used on the farms having loam soil (*cf.* Table 3; column 3). Hence, a greater quantity of NPK fertilizer was supplemented into loam soil. It was also observed that the fertilizer NPK (15:15:15) was opted by the largest number of farmers (28 %) while the fertilizer NPK (10:10:20) was used by a very small percentage (2 %) of the farmers.

3.5. Other Soil Fertility Measures

A number of other soil fertility measures other than fertilizer use have been adopted by the farmers in the study area. The number of farmers using different soil fertility measures on their farms is presented in Table 4. Legumes were used by 46 % of the farmers on their farms of sandy loam, loam and clay loam soil but not at all by those farmers having clay soil. The common legumes used by these farmers include; mucuna beans, tokatolu, and long bean plants. On taro farms, legumes are mostly planted a number of months prior to taro planting, after which the plants are sprayed and cleared before taro is planted. Some farmers have also implemented the crop rotation technique on their farms. The common crops rotated with taro crop farming include yagona (26 %) and vegetables (2 %). Agroforestry practices were also commonly used by the farmers in the study area. Twenty six percent of the farmers have planted raintree on their taro farms while 48 % of the farmers have planted drala trees. A small percent of the farmers have also planted coconut trees (4 %) and pine trees (2 %) on their farms together with taro plants.

Another soil fertility management practice is fallowing i.e. leaving the fields unused for a certain period of time. The number of farmers using fallowing technique is shown in Table 4. Fallowing practice was used by majority (84 %) of farmers surveyed. These farmers fallow their arable land for a certain period of time to allow for soil nutrient replenishment before re-planting taro on that piece of land. Sixteen percent of the farmers however do not practice fallowing. This is mainly because the sizes of the farms owned by these farmers are relatively small; hence it becomes difficult for them to practice fallowing. About 18 % of the farmers fallow their taro farm for 3 to 6 months, 36 % for 6 to 12 months while 30 % of them leave their taro plots fallow for 1 to 2 years. The results show that the farmers with clay loam soil keep their farms fallow for the longest period of time (*cf.* Table 4; column 4).

3.6. Constraints in Organic Fertilizers Usage

The farmers' responses on the constraints for insufficient use of organic sources of nutrients are shown in Table 5. A significant number of farmers do not use organic sources of plant nutrients on their farms while those who use, are not using sufficient quantity of it. A number of constraints were mentioned by the farmers that hindered them from using sufficient amounts of organic fertilizers. The study also revealed that majority (60 %) of the farmers were not aware about the various organic sources of soil the nutrients and their benefits. Some farmers (32 %) face shortage of organic fertilizers while others (40 %) do not have sufficient time to prepare them. A major influencing factor was the lack of awareness (80 %) on the fertility status of the soil on their farms.

Table 5. Reasons for insufficient use of organic sources of nutrients.

Constraints	Farmers (%)
Insufficient supply	32
Lack of knowledge on organic sources of nutrients	50
Lack of knowledge on the fertility status of the soil	80
Lack of knowledge on its benefits	60
Lack of time to prepare organic fertilizers	40

For a sustainable soil management, nutrient loss should be equal to nutrient replacement (Havlin *et al*., 2005; Jahiruddin and Satter, 2010; Mbah and Onweremadu, 2009). Organic nutrients sources are often seen as substitutions to chemical fertilizers. However, the organic inputs such as compost, crop residues, animal manure, lime, etc. cannot fulfill crop nutrients demand over large areas due to limited quantities of organic input available, their low nutrients content and the high labor demands needed for processing and application (Jate, 2012; Palm, 1997). Conversely, abundant supply of chemical fertilizers in some countries has changed farmers' perception and appreciation of organic sources of nutrients such as manure (Schroder, 2005). It has also been reported that a combined input of both organic and chemical fertilizers have shown increased intensity and enhanced synchronization of nutrient release and uptake by crops causing improved yields (Mbah and Onweremadu, 2009; Kunzova, 2013; Rezig *et al*., 2013). Therefore, the challenge is to combine the right proportion and type of different qualities of organic nutrient inputs with chemical fertilizers to optimize nutrient availability to taro plants (Jate, 2012; Palm, 1997).

While the interest of any nation should be to maximize crop yield and the interest of any farmer should be to achieve profitable yield, this should not be at the cost of putting the soil health at any risk. However, the study conducted on the island of Taveuni, Fiji revealed that continuous planting has exhausted the soils nutrient reserves, thereby causing the deterioration of soil health (Panapasa, 2012; Prasad, 2006). The taro production data obtained through the questionnaire survey showed that the annual variation generally declining over the years (Figure 1). This study clearly implicated that the farmers on the island of Taveuni, Fiji are adding imbalanced or insufficient nutrients to the soil to replenish those lost through leaching or removed by the taro cultivation. The study also confirmed that due to the continuous taro cultivation the soil nutrients continue to decline even though many farmers practiced some form of the soil fertility management techniques.

It is also understood that due to an inadequate soil testing facilities, many farmers in Taveuni, Fiji were unaware about the nutrients availability in their farm soils. This has surely led to the failure in correcting the soil health problems or in applying balanced and sufficient quantities of fertilizers (Horneck, *et al*., 2011; Yost and Uchida, 2000). Moreover, the results of the survey showed that very few types of organic fertilizers were used by the farmers in Taveuni, Fiji and those who used organic fertilizers were quite a small percentage of the farmers. The farmers who participated in this study suggested a number of constraining factors that hindered them from using sufficient quantities of organic fertilizers. Similarly, only a small percentage of the farmers who were interviewed used chemical fertilizers on their farms. The farmers who used chemical nutrients sources were also mostly unaware about the balanced plant nutrition and the fertility status of the soil in their farms. However, a substantial percentage of the farmers have incorporated other soil fertility measures on their farms such as planting legumes, crop rotation, agroforestry and fallowing (*cf*. Section 3.5, Table 4).

4. Conclusion and Recommendations

The study showed that taro yields declined over time. It was mainly due to deterioration in the soil health in Taveuni, Fiji. This type of variation would make livelihood systems of taro producers unsustainable. Only a limited number of taro farmers are using various organic and chemical fertilizers on their farms. The quantities of N, P and K nutrients applied to taro farms were meager, imbalanced and insufficient. Other soil fertility management practices, such as mulching, crop rotation with legumes, yagona and agroforestry were also not very popular among the farmers. The main cause of not managing the soil health properly was that farmers do not know the soil chemical balance and the soil fertility status of their farm lands. Majority of farmers also do not know about various low-cost organic methods of the soil fertility management.

To reverse the declining trend of the soil fertility and to improve the quality and quantity of the taro production in Taveuni, Fiji, there is an urgent need to improve awareness among the farmers about the soil fertility management practices. More research experiments should be carried out on farmers' fields with combined efforts of both the farmers and researchers, to ensure that the researchers are able to combine farmers' traditional knowledge and experience into their modern research techniques to evolve the best farm management practices. Most importantly, some provision should be made to ensure that the farmers' soils are tested and test results are conveyed to them

with advice about how to improve soil health of their farms.

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