ECOLOGICAL SUSTAINABILITY OF RUBBER-BASED AGROFORESTRY SYSTEMS IN THE PHILIPPINES

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Abstract — The rubber agroforestry system (RAS) was developed for small landholder farmers with inadequate resources as an alternative to the rubber monoculture system. The study was conducted on the RAS farms in North Cotabato, Philippines, considered one of the country's best rubber-producing areas. Research methods used include observations and field measurements while review of existing documents was used in securing secondary data.

This study aimed to determine the ecological sustainability of rubber agroforestry farms in the study sites. Specifically, it aimed to determine the following ecological soundness indicators based on farm diversification, soil fertility status and management, as well as pest and weed disease management. The study showed that the ecological sustainability of a rubber-based agroforestry system in North Cotabato is moderately sustainable based on ecological soundness criteria. Although RAS has its good environmental merits, farmers' dependency on chemicals for pests, weeds and disease management and use of inorganic fertilizers affect its ecological sustainability.

Keywords — **Farm diversification, fertility status and management, pest and weed disease management, and rubber agroforestry system**

INTRODUCTION

In an attempt to increase the country's natural rubber production, the Department of Agriculture (DA) is currently implementing the National Rubber Development Program (NRDP), which intends to gradually increase the country's rubber tree plantations. Specifically, it aims to increase the national average yield from 1 ton per hectare to 2 tons per ha, improve the quality of rubber production towards meeting world standards for competitiveness and increase investments in the rubber industry. Furthermore, the creation of Republic Act No. 10089 or the "Philippine Rubber Research Institute Act of 2010" signifies the intention of the country to strengthen its rubber industry. As of 2010, there are about 138,710 hectares of rubber tree plantations in the country which are mostly concentrated in the island of Mindanao, particularly in the provinces of Zamboanga Sibugay, North Cotabato, and Basilan (BAS, 2010).

A large part of these rubber production areas is traditional monoculture plantations which were established in our country since the early 1900s. On the other hand, there are other rubber-based farming systems existing in Mindanao that are being practiced mostly by smallholder farmers which are characterized by intercropping rubber with other crops. This rubber-based intercropping system may be classified as Rubber Agroforestry System (RAS).

The RAS technology, which is also known in other countries as "Jungle Rubber", was conceptualized as an alternative to the usual rubber monoculture. It was developed for small-landholder farmers with inadequate resources. Amidst its multiple economic and environmental functions, it can be inferred that RAS cannot compete on the quantity and quality of rubber produced in rubber monoculture plantations because of its small-scale production. Therefore, improved versions of the technology are developed to suit smallholder farmers.

This study aimed to determine the ecological sustainability of rubber agroforestry farms in the study sites. Specifically, it aimed to determine the following ecological soundness indicators based on farm diversification, soil fertility status and management, as well as pest and weed disease management.

METHODOLOGY

The study was conducted in three selected rubber-producing areas in North Cotabato, Philippines namely the municipalities of Makilala, Kabacan and the City of Kidapawan. The ecological sustainability of RAS was evaluated by its ecological soundness. Rasul & Thapa (2003) described ecological soundness as the preservation and improvement of the natural environment. Indicators used in assessing the ecological soundness of RAS were farm diversification, soil fertility status, soil fertility management, and pest, weeds and diseases management. Altieri (1995), Edwards & Grove (1991), and Hossain & Kashem (1997) as cited by Rasul & Thapa (2003) all agreed that there is a higher chance of agricultural sustainability with increasing crop diversification, mixed cropping, and use of organic fertilizers.

Farm Diversification. There is no established ideal number of crops that can be grown with rubber since the effect of intercropping to the main crop will be dependent on several factors such as planting design, nature of the intercrop, and others. This study assumed that intercrops do not have an allelopathic effect on the rest of the crops in RAS, hence, eliciting positive effects on the farm such as promoting biodiversity, better soil nutrient utilization, and others. The author proposed the range or limit in this study and was based on the actual number of crops grown simultaneously with rubber. One (1) crop grown at the time, like in the case of Taungya was considered unsustainable and given a score of 1. Two to three crops grown simultaneously was given a score of 2 or moderately sustainable and farms with more than 3 crops grown simultaneously is considered highly sustainable and given a score of 3.

Soil Fertility Status. Nitrogen (N) and potassium (K) are given higher point allocations than other soil nutrients since both play a crucial role in rubber development. Nitrogen is essential in the overall development of the tree, while potassium plays a vital role in rubber latex flow (Mandal et al. 2015).

Soil Fertility Management. The author proposed the range or limit used in this study for this parameter. Many kinds of literature attested to the long-term environmental benefits of using organic fertilizers. Using that statement as a basis, the farms in the study areas that used organic fertilizer (compost, vermicast, farm yard manure, and mulch crop residues) are considered highly sustainable and were given a rating score of 3. The farmers using inorganic or synthetic fertilizers were given a rating of 1 (low sustainability) due to the long-term negative effect of inorganic fertilizers in the environment. The use of organic and inorganic fertilizers combination was given a rating of 2 (moderately sustainable).

Pest, Weeds and Disease Management. As proposed by the author, the use of biological and/or physical means in pest, weeds and disease management was considered highly sustainable.

Table 1. Sustainability parameters and range.

PARAMETERS	HIGHLY SUSTAINABLE (RATING=3)	MODERATELY SUSTAINABLE (RATING=2)	LOW/ UNSUSTAINABLE (RATING=1)	SOURCE
Farm Diversification	>3 crops grown simultaneously	2 to 3 crops grown simultaneously	1 crop	*
Soil Fertility Status				
a) pH	5.5 to 6.0	6.0 to 7.5	>7.5	Legada, 1998 as cited by Barcellano, 2005
b) OM (%)	>4.5	3.6 to 4.5	0 to 3.5	USM, Kabacan using Walkley-Black Method
c) N (%)	>0.75	0.21 to 0.75	<0.21	CSR/FAO Staff, 1983) as cited by Barcellano, 2005
d) P (ppm)	>16	11 to 15	0 to 10	USM, Kabacan using Olsen's
e) K (ppm)	<150	114 to 150	0 to 113	USM, Kabacan using Hot H2SO4
Soil Fertility Management	Use of organic fertilizers only	Use of combined organic and inorganic fertilizer	Use of inorganic fertilizers only	*
Pest, Weeds and Diseases Management	Use of biological and/or mechanical only	Use of biological and/ or mechanical + chemical	Use of chemical only	*

Table 1 describes the range used to determine low, moderate and high sustainability.

The use of chemicals or pesticides is considered unsustainable in the long run due to its negative effect on the environment and was given a score of 1. In contrast, using a combination of biological/ physical with chemical is considered moderately sustainable. The parameters used for ecological soundness are farm diversification, soil fertility status, soil fertility management and pest, weeds, and disease management. Percentage allocation is equally distributed to the aforementioned parameters. The ecological sustainability of RAS was determined using the equations:

SES = 25% (SI for Farm Diversification) + 25% (SI for Soil Fertility Status) + 25% (SI for Soil Fertility Management) + 25% (SI for Pest, Weeds, and Disease Management)

ASSFS = 10% (SI for soil pH) + 10% (SI for soil OM) + 35% (SI for Nitrogen) + 10% (SI for Phosphorus) + 35% (SI for Potassium)

Where:

SES = sustainability rating for ecological soundness
SI = sustainability index
ASSFS = average sustainability rating for soil fertility status

RESULTS AND DISCUSSION

Farm Diversification

Table 2 summarizes the list of crops grown in the RAS farms of Makilala, Kidapawan, and Kabacan. Noted is a high crop diversification in RAS than pure rubber plantations, the latter being a monoculture. On the average, the most common intercrop grown with rubber is coconut, followed by banana, and poultry. The number of crops in RAS farms ranges from a minimum of two (e.g. Rubber + banana) to six (e.g. Rubber

Table 2. Types of agricultural crops and animals in RAS farms.

TYPE	SITE			TOTAL
	MAK	KID	KAB	
Coconut	77	65	5	147
Banana	13	28	17	58
Poultry	15	9	4	28
-Native				
-Duck				
-Turkey				
Fruit Trees	12	5	25	25
-Durian				
-Mangosteen				
-Mango				
-Lanzones				
-Rambutan, etc.				
Grains	6	3	9	9
-Rice				
-Corn				
Small ruminant	5	3	1	9
Swine	0	5	2	7
Cut flowers	6	0	0	6
Beverage	1	2	1	4
-Coffee				
-Cacao				
Root crops	3	0	0	3
Aquaculture (Tilapia)	2	1	0	3
Multipurpose Trees and Shrubs	0	2	0	2
-Yemane				
-Mahogany				
-Ipil Ipil				
-Madre Cacao				

Legend: MAK - Makilala; **KID** - Kidapawan; **KAB** - Kabacan

+ banana + corn + native chicken + duck + goat). The average number of crops in RAS farms is 3. Crop diversification on a farm not only encourages better soil nutrient utilization, it also promotes biodiversity and reduces the risk of crop failure, thereby making the farms less vulnerable to food shortage (Rasul and Thapa 2003).

Soil Fertility Status

For farmers and landowners of rubber farmlands, an understanding of the numerous soil parameters affecting the growth and performance of the said tree is paramount to properly manage the farm and ultimately increase yield. Another reason why proper management is needed is that according to Damrongrak and his colleagues in 2015, humid tropical soils like those found in the country have inherently low fertility.

The soil chemically contains, in different proportions, nutrients that are necessary for the growth of rubber trees. Some of these important nutrients including organic matter (OM), Nitrogen (N), Potassium (K) and Phosphorus (P) concentrations in the soil are presented in Table 3. Organic matter and nitrogen are expressed in % while potassium and phosphorus are presented in parts per million (ppm). The data were gathered from three municipalities namely: Makilala, Kidapawan, and Kabacan. Specifically, it indicates the mean value for each parameter for two different types of farms, one utilizing a rubber monoculture type of farm and the other employing rubber-based agroforestry stands in the acreage/ land area.

For the interest of this study i.e., rubber productivity, both the chemical and physical aspects of soil fertility are considered and discussed briefly in the succeeding paragraphs. The sole physical parameter presented in Table 3 will be discussed first. For the chemical characteristics tested, soil reaction or soil pH is discussed first as it directly affects nutrient availability in the soil strata and all the major nutrients needed will follow.

The soil is generally made up of three major components in different proportions. Soil texture refers to the relative amounts of these components namely sand, clay, and silt (Samarappuli, 2010). There are two types of soil texture that have been observed in the three barangays. The first, sandy loam, was observed solely in the rubber-based agroforestry farms of Makilala. A sandy loam soil texture according to Hoanh and Natividad in 1987 is a light soil with low nutrient storage capacity and low available water storage. This can mean that nutrients are easily leached out from the soil when water passes through the soil matrix. However, relative to all other farms in the three municipalities, this farm has a better soil quality in some parameters than most of the others. The second type of soil texture that was observed and considered as the major soil type of the acreage, is the sandy clay loam texture. In the soil class provided by Hoanh and Natividad (1987), this is considered medium soil. Contrary to the sandy loam soils of Makilala mixed agroforestry farms, this type is characterized as having medium nutrient storage capacity and medium to high available water storage. This means that nutrients are better retained in this type of soil texture and are not easily leached by via liquid runoffs.

Better growth and establishment of rubber trees are obtained on clayey than sandy soils (Samarappuli, 2010). The reason is simple and expected—clay characteristics give it the capacity to retain nutrients and water better. In soils where water storage availability is low, water can be a limiting factor. When water becomes limiting, the yield can also be lower for rubber trees (Samarappuli, 2010). Finally, Samarappuli (2010) suggested that a soil texture with “sufficient clay at a minimum amount of 35% to retain adequate moisture and nutrients and about 50% sand to allow the expression of good physical soil

Table 3. Average soil chemical and physical properties at pure rubber stand and rubber with agroforestry stand.

	Stand	Organic Matter (%)	Nitrogen (%)	Potassium (ppm)	Phosphorus (ppm)	pH	Soil Texture
MAK	Pure Rubber	3.94	0.24	696	10.85	4.28	Sandy Clay Loam
	RAS	4.63	0.25	499	11.31	4.65	Sandy Loam
KID	Pure Rubber	2.47	0.15	1187	1.52	4.16	Sandy Clay Loam
	RAS	2.47	0.15	666	4.07	4.22	Sandy Clay Loam
KAB	Pure Rubber	1.87	0.11	608	2.57	4.22	Sandy Clay Loam
	RAS	1.56	0.09	471	1.60	4.38	Sandy Clay Loam

Legend: MAK -Makilala; **KID** - Kidapawan; **KAB** - Kabacan

properties" is considered as desirable for the optimum cultivation of rubber.

Soil pH

For the chemical parameters, one routine work is to determine soil pH especially when plant nutrition and nutrient availability is of particular interest. Knowledge on soil acidity is useful as it directly exerts a very strong effect on the solubility and availability of nutrient elements. Indirectly, it influences nutrient uptake and root growth and to some extent influences the presence and activity of many microorganisms. The State University of New York College of Environmental Science and Forestry has provided descriptive terms for the pH ranges of soil. A soil pH value of less than 4.5 is described as being extremely acidic while those ranging from 4.5 to 5.0 are very strongly acidic. Hoanh and Natividad (1987) has provided the descriptive term for soil quality based on their acidity. A soil pH ranging from 4.5-5.5 is considered as very poor soil. From these two literatures, the soil from the RAS farms and rubber monoculture farms of the three barangays are described in terms of acidity and quality.

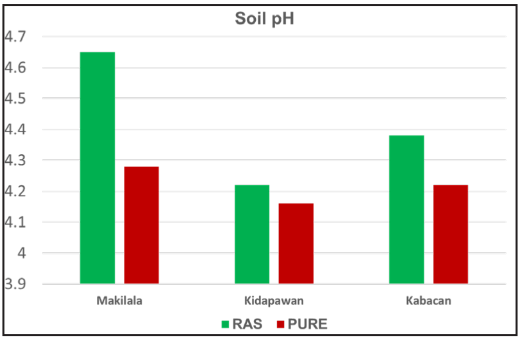

Figure 1. Soil pH of RAS and pure rubber farms in Makilala, Kidapawan, and Kabacan.

As seen in Figure 1, the soil pH, considering all three municipalities and either of the two farm types employed, does not vary that much with each other i.e., all have low pH values recorded. It can be observed however that rubber monoculture farms' soils are more acidic compared to their RAS counterpart. This is true for all three municipalities. Pure rubber farm soil from Kidapawan is most acidic with a pH of 4.16 while RAS farm soils in Makilala are least acidic with a pH of 4.65. All soil types are described as extremely acidic with the exemption of the soil pH of RAS in Makilala which is very strongly acidic. Furthermore, all are considered as very poor soil in terms of soil reaction/pH. A study by Samarappuli in 2010 also showed similar results, possibly suggesting that rubber soils are acidified soils as well. In the study, it was determined that rubber growing soils are of low pH with values also ranging from 4 to 5.

Rubber trees tolerate and grow in a vast majority of acidic soils in the humid tropics (Akamigbo and Asadu, 1983 as cited by Orimoloye et al, 2010; Samarappuli, 2000). Still, it should be noted that extreme pH conditions are not favorable for the good performance of rubber trees (Samarappuli, 2010). In fact, some nutrients are unavailable with acidic soils. Plant nutrients are available within 6.5 to 7.5 pH range. Specifically, strongly acidic soils are characterized as having low Ca, Mg, K and P and too much Fe and Mn (Waizah et al., 2011, Oku et al., 2012 and Suchartgul et al., 2012 all as cited by Damrongrak et al., 2015).

Percent Organic Matter (% OM)

Aside from providing the descriptive terms for the quality of soil in terms of soil pH, Hoanh and Natividad (1987) also provided soil classes/descriptive terms for a particular range of values for the parameters of % organic matter, % nitrogen and phosphorus concentration in ppm and these descriptive terms are used in this discussion. According to these authors, having a % organic matter of less than 2% means that the soil contains very low organic matter. On the other hand, % organic matter from 2-4% means having low organic matter and 4-10% means the soil contains medium organic matter. Figure 2 shows that among the three municipalities, Kabacan has soils with the least organic matter. Specifically, the soil in monoculture farms of Kabacan contains 1.87% organic matter while RAS farms contain 1.56% organic matter. The measurement of the % organic matter for Kidapawan, on the other hand, yielded the same value at 2.47%. Makilala has a % organic matter with 3.94% and 4.63% in pure rubber stand and with rubber-based agroforestry, respectively. It is in this area where the % organic matter is highest, albeit still being described as having low organic matter for monoculture plantations and medium organic matter for RAS stands. The stand with agroforestry species has a higher % organic matter because it was influenced by vegetation cover having intercropped with agroforestry species. This cover provides the soil with fallen leaves and twigs which when decomposed releases organic substances in the soil to be used again by the plants. Agroforestry species such as different livestock also contribute to the addition of organic matter through their deposition of fecal matter and excretory wastes. During decomposition, organic matter is recycled. Moreover, additional crops provide land cover and help reduce surface runoff thus contributing further to the fertility of the soil.

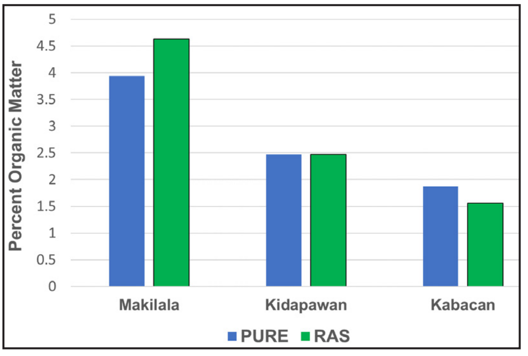

Figure 2. The percent organic matter (%OM) of PURE and RAS farms.

Percent Nitrogen (% N)

The soil from all three sites regardless of the farm type contains very low nitrogen since % nitrogen is < 0.30%. It can be observed from that the difference between the % nitrogen of the two farm types from a barangay does not differ greatly. The same can be said when comparing % nitrogen between study areas. The % nitrogen in the soil in Kidapawan is measured at 0.15% for both rubber monoculture and Rubber-based agroforestry stands. For Makilala, % nitrogen is slightly higher in mixed stands than pure (0.25% nitrogen versus 0.24% nitrogen, respectively) while the opposite can be said true for Kabacan. This is because, in Kabacan, the % nitrogen for monoculture rubbers stands is measured at 0.11 % versus the 0.09% measured for their rubber-based agroforestry stands. Because of these observations, a clear relationship cannot be established. Nonetheless, one source of nitrogen in these soils would be the excretory urine from livestock in silvopastoral and agrisilvopastoral utilized rubber-based agroforestry techniques which can contribute greatly to the total nitrogen in the soil. There is also a need to consider subjecting to statistical analysis the difference between the two farm techniques in order to determine whether the observed differences are significant or not.

Finally, the state of the soil in the three municipalities based on the levels of N in the soil can be problematic as it may hinder having more yield from tapping rubber trees as Nitrogen nutrition could be the most limiting factor for the growth of rubber trees (Pongwichian et al., 2010).

Figure 3 shows the percent organic Nitrogen in pure rubber farms and RAS.

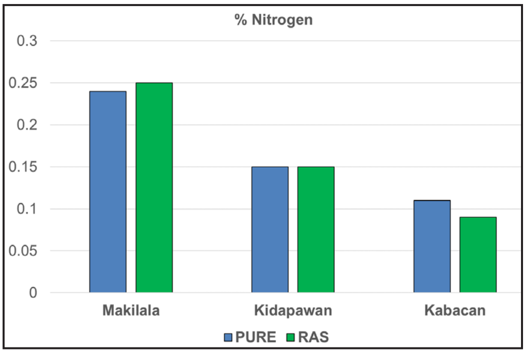

Figure 3. The percent organic Nitrogen (%N) of PURE and RAS farms of Makilala, Kidapawan and Kabacan.

Potassium

According to Mandal et al. (2015), potassium plays a significant role in rubber latex flow of the tree. Figure 4 shows the potassium concentrations in the soil of the three sites. It is easily observable from this figure that pure rubber stands have more potassium than their rubber-based agroforestry stand counterpart. Among the pure stands, the one in Kidapawan has the highest value with 1187 ppm followed by that in Makilala at a value of 696 ppm while Kabacan soil contains 608 ppm. On the other hand, the potassium concentration for the agroforestry farms in Kidapawan has the highest concentration at 666 ppm. Meanwhile, the farms in Makilala and Kabacan have also similar potassium content in the soil measured at 499 ppm and 471 ppm respectively.

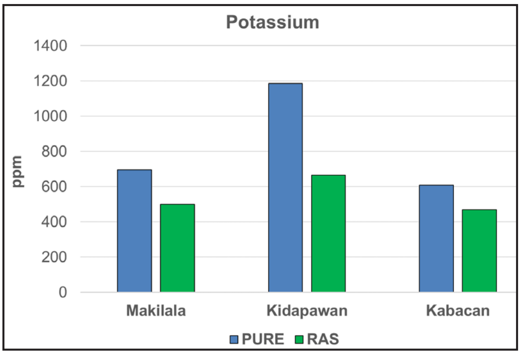

Figure 4. The potassium concentration (ppm) in the soils of PURE and RAS farms of Makilala, Kidapawan and Kabacan.

Phosphorus

At less than four ppm, soil is considered to have a very low phosphorus content while from four to six ppm and from seven to 20 ppm, soils contain low and medium phosphorus respectively. Only soils with at least 21 ppm of phosphorus can be considered as having a high content of the said nutrient in the soil. Based on Figure 5, it can be said that the phosphorus content ranges from very low to medium in the study areas. Specifically, only the soils of Makilala have medium phosphorus content. In this site, the rubber-based agroforestry stand soil has a slightly higher phosphorus content at 11.31 ppm compared to the monoculture stand with 10.85 ppm. For Kidapawan, the rubber-based agroforestry farm soil has low phosphorus content at 4.07 ppm while pure rubber stands have very low content at only 1.52 ppm. For both Makilala and Kidapawan, the mixed culture stands have higher phosphorus content. The opposite is observed for Kabacan. Still, both farm soils have very low content of the said nutrient with only 2.57 ppm and 1.60 ppm Phosphorus for pure rubber and rubber-based agroforestry stands respectively.

The observations that phosphorus is very low to low in some sites is possibly explained by going back to soil reaction/ pH. Phosphorous is optimally available in the range of 6.5 to 6.8. In fact, it has also been proven in the literature that the results of Phosphorus and Total N possess low soil fertility for rubber plantations (Orimoloye, 2010).

In general, the nutrient content of the soil ranges from very low to medium. It can thus be said that major soil nutrients like Nitrogen, Phosphorus and Potassium must be supplemented in this farmland. According to Alle et al. (2014), high doses of phosphatised, nitrogenous and potassic fertilizers causes degradation of sand and increase in clay and silt while favoring litter decomposition in the soil as well. From the discussions on soil texture, it has been proven that sand particles/ soil rich in sand have very low nutrient availability because nutrients are easily leached. Farmers must also note that regardless of the high dose inputs of both nitrogen and phosphorus, these nutrients undergo significant losses in rubber plantations (Alle et al., 2014). As with any plant, the performance and economic viability of rubber trees can be restricted severely when limiting factors for a soil parameter such as nutrient availability is present. To achieve a high yield of rubber latex, good variety, high fertility of the soil and appropriate cultural management both in immature and tapping stage are important (Damrongrak et al., 2015). Based on the results of soil analysis, the two study site, Kidapawan & Kabacan, show poor soil fertility status with low levels of % organic matter, % nitrogen and Phosphorous. It can be said that in general, the best soil relatively is found in Makilala especially in the aspect of soil fertility. In terms of stability, Makilala site with agroforestry reigns with a high % organic matter. It is an indication that RAS improves soil structure, maintain tilth and minimize erosion (Parthasarathy, 2008).

Figure 5 shows the phosphorus concentrations in the soil of the three sites.

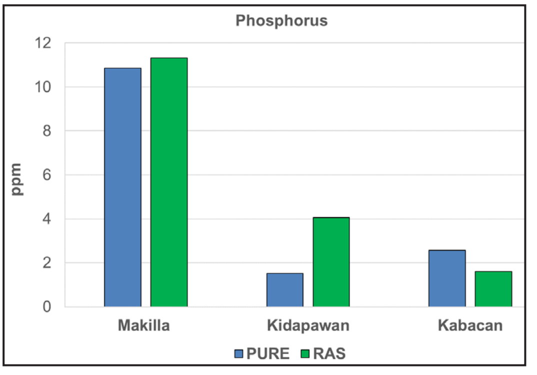

Figure 5. The phosphorus concentration (ppm) in the soils of rubber monoculture and rubber-based agroforestry farms.

Soil Fertility Management

As summarized in Table 4, the fertility management of the respondents from the RAS and PURE groups were established. In particular, it shows the kind of fertilizer applied by the farmers. Particulars include organic and commercially available inorganic fertilizer. Organic fertilizers are ameliorating substances prepared by the farmers while inorganic fertilizers are those bought from the market. Respondents were grouped as to those using organic fertilizers, inorganic fertilizer or a combination of both.

Table 4. Use of Organic and Inorganic Fertilizers by Rubber Farmers.

PARTICULARS	RAS								PURE								TOTAL	
	MAK (n=93)		KID (n=76)		KAB (n=20)		Subtotal (N1=189)		MAK (n=92)		KID (n=76)		KAB (n=27)		Subtotal (N2=195)		(N=384)	
	F	%	F	%	F	%	F	%	F	%	F	%	F	%	F	%	F	%
Organic																		
- Compost	8	8.60	3	3.95	-	0.00	11	5.82	-	0.00	-	0.00	-	0.00	-	0.00	11	2.86
- Vermicast	1	1.08	-	0.00	-	0.00	1	0.53	-	0.00	-	0.00	-	0.00	-	0.00	1	0.26
- Farm Yard Manure (FYM)	5	5.38	6	7.89	-	0.00	11	5.82	-	0.00	-	0.00	-	0.00	-	0.00	11	2.86
- Mulch crop residues	16	17.20	14	18.42	1	5.00	31	16.40	2	2.17	-	0.00	-	0.00	2	1.03	33	8.59
Inorganic	48	51.61	45	59.21	2	85.00	110	58.20	84	91.30	67	88.16	27	100	178	91.28	288	75.00
Organic + Inorganic	15	16.13	8	10.53	15	10.00	25	13.23	6	6.52	9	11.84	-	0.00	15	7.69	40	10.42
Total	**93**	**100**	**76**	**100**	**20**	**100**	**189**	**100**	**92**	**100**	**76**	**100**	**27**	**100**	**195**	**100**	**384**	**100**

Legend: MAK - Makilala; **KID** - Kidapawan; **KAB** - Kabacan

The low number of farmers using farm manure as fertilizer could be attributable to the inability to aggregate free-ranging farm animals such as native chicken to amass their wastes as well as the pungent smell of the manure that they could not tolerate to process. In addition, farmers in the study areas avoid large ruminants such as cattle to roam freely since it could topple the harvested latex while grazing. Another important factor, according to the farmers that decrease the likelihood of their preference of FYM as fertilizer is the limited sources of the organic fertilizer components as poultries (i.e. chicken, duck, and turkey) in the community are very few, hence collected dung for fertilizer is unsustainable. Only one farmer from Makilala cultures African night crawler (*Eudrilus eugeniae*) and applies the vermicast to enhance the growth and development of the fruit trees in his farm.

Respondents from the RAS group had a total of 54 organic fertilizer and 110 inorganic fertilizer users for ameliorating the nutrient deficiency in their farm for increase yield and better quality of the harvest. There are also 25 farmers that combine the use of organic and inorganic fertilizers to their farms. The low number of farmers that are practicing the application of organic fertilizer can be attributed to the limited sources of its components as well as the farmers' limited knowledge of how to produce them. Meanwhile, the majority are using inorganic fertilizers as they are readily available in the market. However, this kind of ameliorating substances can be costly, hence reducing the profit derivable from their production, and can adversely impact the surrounding ecosystem and biological and non-biological resources.

Looking into the PURE group, it was found out that vast majority are using commercial inorganic fertilizer alone (MAK: F=84; KID: F=67; KAB: F=27). Unlike in the RAS group, none of the farmers in the PURE group are solely using inorganic fertilizers to their farms, instead, some farmers (MAK: F=6; KID: F=9) practiced the combination of organic and inorganic fertilizers. The same attributions, namely, difficulty in amassing components and the limited number of sources within the community for producing organic fertilizer could explain this practice.

A total of 178 farmers uses inorganic fertilizer while only 2 farmers apply its counterpart with 15 using the combination of organic and inorganic fertilizers in the PURE group. This could imply that the practice of commercially available ameliorating substances is preferred by the farmers in the PURE group. High availability of inorganic fertilizers in the market and conventionality could be the factors contributing to such practice. However, cost and adverse impact on the environment, specifically to the biotic components of the soil could be few of the repercussions of using commercial fertilizers.

Generally, the majority (75%) of the farmers are into the use of organic fertilizers albeit there is a big difference in percentage between RAS and PURE groups. More than half (58.2%) of the farmers in RAS are using inorganic fertilizers compared to 91.28% in PURE. The difference could be caused by the frequent use of low-cost organic fertilizers to non-rubber crops in RAS farms. The dependency in inorganic fertilizer by the majority of the farmers in both groups could be attributed to its high availability and accessibility in the market and convenience of usage.

Pest, Weeds, and Disease Management

Table 5 summarized the pest, weeds, and disease management that the farmers use on their farms. Managements applied by the respondents are grouped as: biological wherein they use other plants with properties that could attack the pathogens, mechanical which refers to the physical/manual removal of pests/weeds, or chemical which is the use of pesticides/herbicides.

Table 5. Pest, Weeds and Disease Management.

PARTICULARS	RAS								PURE								TOTAL	
	MAK (n=93)		KID (n=76)		KAB (n=20)		Subtotal (N1=189)		MAK (n=92)		KID (n=76)		KAB (n=27)		Subtotal (N2=195)		(N=384)	
	F	%	F	%	F	%	F	%	F	%	F	%	F	%	F	%	F	%
Biological	4	4.30	3	3.95	0	0.00	7	3.70	0	0.00	0	0.00	0	0.00	0	0.00	7	1.82
Mechanical	12	12.90	9	11.84	2	10.00	23	12.17	5	5.43	2	2.63	0	0.00	7	3.59	30	7.81
Chemical	27	29.03	32	42.11	14	70.00	73	38.62	68	73.91	53	69.74	17	62.96	138	70.77	211	54.95
Biological and Mechanical	15	16.13	6	7.89	0	0.00	21	11.11	0	0.00	0	0.00	0	0.00	0	0.00	21	5.47
Biological and Chemical	0	0.00	5	6.58	0	0.00	5	2.65	0	0.00	0	0.00	0	0.00	0	0.00	5	1.30
Mechanical and Chemical	27	29.03	14	18.42	4	20.00	45	23.81	19	20.65	21	27.63	10	37.04	50	25.64	95	24.74
Biological, Mechanical and Chemical	8	8.60	7	9.21	0	0.00	15	7.94	0	0.00	0	0.00	0	0.00	0	0.00	15	3.91
Total	**93**	**100**	**76**	**100**	**20**	**100**	**189**	**100**	**92**	**100**	**76**	**100**	**27**	**100**	**195**	**100**	**384**	**100**

Legend: MAK - Makilala; **KID** - Kidapawan; **KAB** - Kabacan

Majority of the respondents in RAS (F=73, 38.62%) and PURE (F=138, 70.37%) chemically manage pest, weeds, and diseases in their rubber farms. The RAS group alone (F=7) accounting for only 1.82% of the total respondents uses biological control as their only means to address concerns about pest, weeds, and diseases. The second most preferred method in addressing this concern was through the use of chemical and mechanical combination.

This implies the dependency of the farmers on chemicals in addressing this problem. This may be due to the convenience of use and easy access to this type of method. Farmers tend to ignore the disadvantage of using chemicals and inorganic stuff on their farms than to reap the long-term benefit of being organic and using natural methods.

Sustainability Rating for Ecological Soundness

Results of the analysis as summarized in Table 6 showed that sustainability rating for ecological soundness is 2.03 or moderately sustainable. Among the parameters, soil fertility status got the highest rating at 2.39. On the contrary, soil fertility management got the lowest score at 1.70. This can be attributed to the large number of farmers that are using chemicals in order to arrest the occurrence of pests, weeds, and diseases. Use of chemicals, in the long run, will have a negative effect on the environment affecting the sustainability of the system.

Table 6. Sustainability rating for ecological soundness.

SUSTAINABILITY PARAMETER	WEIGHT	SI
Farm Diversification	25%	2.31
Soil Fertility Status	25%	2.39
pH (10%)		
OM (20%)		
N (20%)		
P (10%)		
K (40%)		
Soil Fertility Management	25%	1.70
Pest, Weeds and Disease Management	25%	1.74
SES	2.03	
Description	Moderately Sustainable	

CONCLUSION

The study focused on the sustainability of RAS models among rubber farmers in the municipalities of Makilala, Kidapawan, and Kabacan in Mindanao. Physico-chemical soil analyses were conducted in the rubber farms of the respondents in order to determine ecological soundness. Two types of soil are observed in the studied barangays – sandy loam and sandy clay loam soil. Of the three study areas, sandy clay loam, which is considered better at nutrient retention only exists in two areas and is not observed in the rubber agroforestry farms in MAK. In terms of soil acidity, pure rubber farms appear to have more acidic soil as compared to RAS farms. Though rubber trees survive in a wide range of acidity levels, it must still be noted that highly acidic soil is not apt for any type of vegetation. Considering nutrient content (Nitrogen, Phosphorus, Potassium), it can be said that the levels in all three areas range from very low to medium with the RAS farm in Makilala being observed as the one with the most optimum soil properties for growing rubber.

Aside from assessing soil properties, the farmers were also assessed regarding their soil fertility management practices, specifically their use of organic and inorganic fertilizers. Despite the majority in both RAS and PURE groups registering use of organic fertilizers, there is a huge disparity in the two with regards to using inorganic fertilizers with the former group registering only a little more than half of its population as compared to almost the whole PURE group (91%). This suggests that access to organic fertilizer may be harder to come by for farmers of the PURE group explaining their high reliance on the inorganic variants. The situation in PURE farms can be problematic in the long-run as inorganic fertilizers, despite their easier way of application, can be costly reducing the profit of PURE rubber farmers as well as damaging to the surrounding ecosystems; chemical runoff from rubber plantations causing unfavorable biotic repercussions.

In terms of the use of chemical substances, the majority of the farmers in both RAS and PURE groups resort to chemical means in dealing with pests, weeds, and diseases citing ease of acquisition and application. Despite the negative repercussions of chemical runoff, the respondents prefer this practice due to its effectiveness and efficiency in dealing with the problem as compared to the more time-consuming alternatives of manual removal of pests and weeds or the production of organic pesticides and herbicides.

The study showed that the ecological sustainability of rubber-based agroforestry system in North Cotabato based on ecological soundness criteria is moderately sustainable. Albeit RAS has its good environmental merits, the dependency of farmers on chemicals for pest, weeds and disease management and use of inorganic fertilizers affect its ecological sustainability.

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