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EVALUATE THE COMPETITIVE INTERACTIONS AMONG COMPONENT CROPS IN CASSAVA-LEGUME-BASED INTERCROPPING SYSTEMS

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ABSTRACT

Competition among component crops in an intercropping system is an important factor that influences productivity. To realize the benefit of intercropping in terms of higher productivity per unit area, the competitive behaviour of component crops needs to be quantified. As such, an experiment was conducted to determine the competitive behaviour of component crops in cassava-legume-based intercropping systems. The experiment was a factorial randomized complete design with three replications. The treatments consisted of seven cropping associations and two spatial arrangements. The result shows that both land equivalent ratio and area time equivalent ratio was greater than one and was higher for the cassava-soybean system compared to the other cropping systems. In general, the land equivalent ratio was higher than the area time equivalent ratio across the three agro-climatic zones. In the case for the competitive ratio and the relative crowding coefficient, both indices were higher for cassava compared to the legumes and were also higher for the cassava-soybean system compared to the other cropping systems. Also, both indices were on average higher when the legumes were intercropped with cassava using the 2 m x 0.5 m spatial arrangement. The result further shows a higher monetary advantage index for all cropping systems compared to monocropping. In conclusion, it was shown that, cassava-legume-based intercropping systems were advantageous in terms of both competitive and economic indices.

Contribution/Originality: This study contributes to the existing literature, as the results of the study agree with the findings of several authors that, cassava legume intercropping systems utilize environmental sources more efficiently and were more profitable compared to the sole cropping.

1. INTRODUCTION

Intercropping is one of the sustainable agricultural methods defined as the growing of two or more crops on the same piece of land within the same year to promote their interaction. This cropping system results in the enhancement of crop productivity and improves soil organic matter and soil fertility through nitrogen fixation [1].

Cassava (*Manihot esculenta* Crantz) is grown widely in the tropics as a food security crop and as a cash crop. In Sierra Leone, it is the second staple food after rice. Intercropping cassava with other food crops is a common form of cropping system practiced by small-scale farmers in the humid and sub-humid tropics. It has been estimated that 50% of the cassava grown in tropical Africa is intercropped with cereals, grain legumes, and leafy vegetables [2].

Intercropping of cassava with grain legumes has been popular in tropical environments [3, 4] because legumes have the potential for biological nitrogen fixation which could be an important factor in soil nitrogen conservation. Furthermore, intercropping cassava with grain legumes has the potential to increase the land equivalent ratio compared to the pure stand [5].

Several factors can affect the growth and productivity of species in intercropping particularly planting ratio, spatial arrangement, plant density, cultivar, and competition [6-8]. Competition is one of the main factors that influence the growth rate and yield of plant species used in intercropping Caballero, et al. [6]. Willey [9] reported that, higher performance in intercropping systems could be achieved when interspecific competition between intercropping components is lower than intraspecific competition. To obtain the benefit of intercropping in terms of higher productivity and economic benefit, the competitive behaviour of component crops in an intercropping system needs to be identified and quantified [10]. To this end, indices such as land equivalent ratio [11], area time equivalent ratio, relative crowding coefficient, competitive ratio [7], and monetary advantage index [12] have been proposed to describe competition within and economic advantages of intercropping systems over sole cropping. The objective was to evaluate the effect of cropping systems and spatial arrangement on some competitive and economic indices of cassava intercropped with grain legumes.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out in 2015/2016 and 2016/2017 cropping seasons in three agro-climatic zones namely: Sumbuya representing the transitional rain forest, Makeni representing the savannah woodland, and Segbwema representing the rain forest zone.

2.2. Plant Material

The planting materials were obtained from the research station at Njala. The cassava variety used was slicass 6 whilst, the grain legumes used were slipea 5 (cowpea), Slibean 2 (Soybean), and slinut 1 (groundnut).

2.3. Experimental Design and Treatment

The experiment was a factorial randomized complete block design (RCBD) with three replications. The treatments consisted of seven cropping associations (sole cassava, sole groundnut, sole cowpea, sole soybean, cassava + cowpea, cassava + groundnut, and cassava + soybean) and two spatial arrangements of cassava (1 m x 1 m and 2 m x 0.5 m). The plot size was 7 m x 6 m.

Cassava was planted at the spacing of 1 m x 1 m (1:1) and 2 m x 0.5 m (1:3) respectively; whilst cowpea and groundnut were planted at the spacing of 50 cm x 20 cm with two seeds per hole for cowpea and one seed per hole for groundnut. On the other hand, soybean was planted at the spacing of 50 cm x 10 cm with two seeds per hole. The legumes were introduced in between the rows of the cassava. Weeding was done with a hoe at one, three, and six months after planting. Cassava was harvested at 12 months after planting whilst the three grain legumes were harvested at their different maturity dates [13].

2.4. Determination of Competitive Indices and Monetary Advantage Index

2.4.1. Land Equivalent Ratio

The land equivalent ratio (LER) was used as a basis for comparing the efficiency of the intercropping systems in using the environmental resources with monoculture systems [14]. When the value of LER is greater than one, shows that intercropping favours the growth and yield of the species. On the other hand, when LER is lower than one, indicates that intercropping negatively affects the growth and yield of crops grown in the mixture [6]. According to Willey and Rao [15], the land equivalent ratio can be calculated as follows:

LER= {La+Lb}

La = (Yab/Yaa)

Lb = (Yba/Ybb) [16].

Where La and Lb are the LERs for the individual crops, Yab and Yba are the individual crop yields in intercropping, and Yaa and Ybb are the individual crop yields in sole cropping.

2.4.2. Area time Equivalent Ratio

The area time equivalent ratio (ATER) gives a more realistic comparison of the yield advantage of intercropping over sole cropping was calculated using the following formula:

Area time equivalent ratio (ATER) = (ATER main crop + ATER intercrop)

$$\text{ATER main crop} = \frac{Yab}{Yaa} \times \frac{Tm}{Ta}$$

$$\text{ATER intercrop} = \frac{Yba}{Ybb} \times \frac{Tb}{Ta}$$

Where Yab was the yield of the main crop (cassava) as intercrop, Yaa was the yield of the main crop (cassava) as sole, Yba as yield of the intercrops, Ybb as yield of intercrops as sole, Tm is the duration of the growth cycle of the main crop (cassava), Tb is the duration of the growth cycle of the intercrops, and Ta is the duration in days of the component crop with the longest growing period.

2.4.3. Relative Crowding Coefficient

The relative crowding coefficient (RCC or K) is the measure of the relative dominance of one species over the other in intercropping [17].

The K was calculated as:

K = (K main crop x K intercrop) K main crop ={Yab Zba} / { (Yaa – Yab) Zab } K intercrop = (Yba Zab) /{ (Ybb – Yba)Zba}

Where Zab was the sown proportion of the main crop (cassava) in intercropping, Zba was the sown proportion of the intercrop, Yab was the yield of the main crop (cassava) in intercropping, Yba was the yield of the intercrop, Yaa was the yield of the main crop (cassava) as monocrop, and Ybb was the yield of the intercrops in intercropping. In general, when the product of the two coefficients (K main crop x K intercrop) is greater than, equal to, or less than unity means that, the given crop is more, equal, or less competitive than its associated crop [15].

2.4.4. Competitive Ratio

Competitive ratio (CR) is the measure of the competitive ability of the two crops grown in the intercropping system over the other [18]. It represents simply the ratio of individual land equivalent ratios of the two-component crops and takes into account the proportion of the crops in which they were initially sown [19].

The competitive ratio was calculated according to the following formula:

$$\text{CR main crop} = \frac{\text{LER main crop}}{\text{LER intercrops}} \times \frac{Zba}{Zab}$$

$$\text{CR intercrops} = \frac{\text{LER intercrops}}{\text{LER main crop}} \times \frac{Zab}{Zba}$$

Where LER main crop and LER intercrop are the land equivalent ratios of the main crop (cassava) and intercrop respectively, Zab and Zba are the sown proportions of the main crop and intercrop respectively. When CR is greater than one, indicates that one crop is more competitive than the other whilst if CR is less than one shows that, the other crop is less competitive than the other.

2.4.5. Monetary Advantage Index

The monetary advantage index (MAI) is an important index in determining the economic viability of intercropping. It was calculated using the formula:

$$\text{Monetary advantage index (MAI)} = \frac{(\text{value of combined intercrops}) \times (\text{LER} - 1)}{\text{LER}}$$

As the value of the monetary advantage index increases the higher the profitability of the cropping system [14].

2.5. Data Collection

2.5.1. Cassava

Root yield was determined by harvesting all the cassava plants within the net plot followed by the detachment of all the storage roots from the stump and weighing using a salter scale. Root yield was expressed in t/ha.

2.5.2. Legumes

The grain legumes were harvested at maturity (3-4 months after planting). Matured dried pods were harvested from the net plot. The grains were weighed on a sensitive balance and the weights obtained extrapolated to Kg/ha.

2.6. Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using the SAS statistical package [20] and the differences between treatment means were separated using the Student Newman-Keuls Test (SNK) at a 0.05 level of significance.

3. RESULTS

3.1. Competitive and Economic Functions of Cassava and Component Crops

3.1.1. Land Equivalent Ratio

The partial land equivalent ratio with respect to the cropping systems for both cassava and the legumes was above 0.5 across the three agro-climatic zones (Table 1). Also, the partial land equivalent ratio for cassava was higher than the legumes for all the cropping systems except for the cassava-cowpea system at Sumbuya representing the transitional rain forest zone where the partial land equivalent ratio for cowpea was higher than cassava. The total land equivalent ratios across the agro-climatic zones were not significantly different ($F = 1.16$, $P = .340$) although a higher value was recorded in Makeni in the savannah woodland (1.98) followed by Segbwema (1.74) and Sumbuya (1.72) in the rain forest and transitional rain forest respectively (Table 1). The total land equivalent ratios across the cropping systems in the three agro-climatic zones were greater than one (1) and on average ranged between 1.72-1.98. In addition, there were significant differences ($F = 27.80$, $P < .001$) in the total land equivalent ratio among cropping systems with the cassava-soybean system recording the highest in the three agro-climatic zones. The total land equivalent ratio for the cropping systems across the three agro-climatic zones ranged between 1.92-2.14, 1.58-2.07, and 1.48-1.66 for the cassava-soybean, cassava-groundnut, and cassava-cowpea systems respectively (Table 1).

Concerning spatial arrangement, the partial land equivalent ratio for both cassava and the legumes was also above 0.5 across the three agro-climatic zones (Table 1). The total land equivalent ratio was on average higher for the 2 m x 0.5 m spatial arrangement than the 1 m x 1 m spatial arrangement among the zones and cropping systems. The total land equivalent ratio across the cropping systems and the zones ranged between 1.66-1.99 and 1.55-1.72 for the 2 m x 0.5 m and 1 m x 1 m spatial arrangements respectively. Furthermore, the total land equivalent ratios were all above one (1) for both spatial arrangements and ranged between 1.63–1.89 for all the cropping systems and the agro-climatic zones (Table 1). For the three zones, the cassava-soybean cropping system was observed to have recorded the highest land equivalent ratio.

Table 1. Land equivalent ratio of cassava and component crops as influenced by cropping system and spatial arrangement.

Land Equivalent Ratio (LER)									
Treatments	Agro-climatic zones								
	Savanna woodland (Makeni)			Rain forest (Segbwema)			Transitional rain forest (Sumbuya)		
	Cassava	Legume	Total	Cassava	Legume	Total	Cassava	Legume	Total
Cropping system									
Cassava - groundnut	1.16	0.91	2.07 a	0.94	0.77	1.71 b	0.94	0.64	1.58 b
Cassava-cowpea	0.86	0.72	1.58 b	0.77	0.71	1.48 c	0.70	0.96	1.66 ab
Cassava-soybean	1.26	0.88	2.14 a	1.14	0.90	2.04 a	1.21	0.71	1.92 a
Mean			1.98 a			1.74 a			1.72 a
Spatial arrangement									
Cassava-groundnut									
1m x 1m	0.76	0.70	1.46 b	0.80	0.63	1.43 a	0.73	0.70	1.43 b
2m x 0.5m	1.20	0.92	2.12 a	0.86	0.73	1.59 a	1.03	0.89	1.92 a
Mean			1.84 a			1.51 a			1.68 a
Cassava -cowpea									
1m x 1m	0.75	0.52	1.27 b	0.77	0.59	1.36 b	0.60	0.55	1.15 a
2m x 0.5m	0.98	0.81	1.76 a	0.81	0.75	1.56 a	0.56	0.62	1.16 a
Mean			1.52 a			1.46 a			1.50 a
Cassava-soybean									
1m x 1m	1.41	0.67	2.08 b	1.37	0.75	2.12 a	1.57	0.80	2.37 a
2m x 0.5m	1.66	0.67	2.33 a	0.97	0.77	1.74 b	1.41	0.82	2.23 a
Mean			2.21 a			1.93 a			2.30 a

Note: Means in column with the same letter are not significantly different at P > 0.05 (SNK).

3.1.2. Area Time Equivalent Ratio

In the case of the area time equivalent ratio, the partial area time equivalent ratio for cassava among the cropping systems was greater than 0.5 in the three zones; however, it was less than 0.5 for the legumes. In addition, the partial area time equivalent ratio for cassava for the three zones was higher than the legumes (Table 2). There were significant differences ($F = 26.53$, $P < .001$)) in the total area time equivalent ratio among the cropping systems with the cassava-soybean cropping system recording the highest followed by the cassava-ground and the cassava-cowpea system. The total area time equivalent ratio was greater than one (1) for the cassava-soybean and the cassava-groundnut systems across the three agro-climatic zones (Table 2). Furthermore, there were no significant differences ($F = 1.20$, $P = 0.29$) in the total area time equivalent ratio with respect to the agro-climatic zones. In addition, the area time equivalent ratio was less than the land equivalent ratio across the cropping systems and agro-climatic zones. Relating to the spatial arrangement, the partial area time equivalent ratios recorded for cassava were higher than the legumes across the cropping systems and agro-climatic zones (Table 2).

In Makeni representing the savannah woodland, the partial area time equivalent ratio was on average higher for the 2 m x 0.5 m spatial arrangement than the 1 m x 1 m spatial arrangement across the cropping systems. In addition, the total area time equivalent was greater than one (1) for the cassava-groundnut and cassava-soybean systems (Table 2).

Similarly, the partial area time equivalent ratio in Segbwema representing the rain forest was higher for the 2 m x 0.5 m spatial arrangement concerning the cassava-groundnut and cassava-cowpea systems. For the soybean system, the 1 m x 1 m spatial arrangement recorded a higher area time equivalent ratio than the 2 m x 0.5 m spatial arrangement (Table 2). In addition, the total area time equivalent ratio was greater than one (1) for the cassava-groundnut and cassava-soybean systems.

In the case of Sumbuya representing the transitional rain forest, the partial area time equivalent ratio for cassava was higher for the 1 m x 1 m spatial arrangement concerning the cassava-cowpea and cassava-soybean systems. The total area time equivalent ratio was higher for the cassava-soybean system (1.73) followed by the cassava-groundnut (1.08) whilst the cassava-cowpea system recorded the least (0.71) (Table 2). In addition, the total area time equivalent ratio was greater than 1 (one) for the cassava-soybean and cassava-groundnut systems.

Table 2. Area time equivalent ratio of cassava and component crops as influenced by cropping system and spatial arrangement.

Area Time Equivalent Ratio (ATER)									
Treatments	**Agro-climatic zones**								
	Savannah woodland (Makeni)			**Rain forest (Segbwema)**			**Transitional rain forest (Sumbuya)**		
	Cassava	**Legume**	**Total**	**Cassava**	**Legume**	**Total**	**Cassava**	**Legume**	**Total**
Cropping system									
Cassava - groundnut	1.16	0.23	1.39 b	0.94	0.19	1.13 b	0.94	0.16	1.10 b
Cassava-cowpea	0.86	0.14	1.00 c	0.77	0.14	0.91 c	0.70	0.19	0.89 c
Cassava-soybean	1.21	0.29	1.50 a	1.14	0.30	1.44 a	1.21	0.24	1.45 a
Mean			1.30 a			1.16 a			1.15 a
Spatial arrangement									
Cassava-groundnut									
1m x 1m	0.76	0.18	0.94 b	0.80	0.16	0.96 a	0.73	0.18	0.91 b
2m x 0.5m	1.20	0.23	1.43 a	0.86	0.18	1.04 a	1.03	0.22	1.25 a
Mean			1.19 a			1.00 a			1.08 a
Cassava -cowpea									
1m x 1m	0.75	0.10	0.85 b	0.77	0.11	0.88 a	0.60	0.11	0.71 a
2m x 0.5m	0.98	0.15	1.13 a	0.81	0.14	0.95 a	0.56	0.12	0.70 a
Mean			0.99 a			0.92 a			0.71 a
Cassava-soybean									
1m x 1m	1.41	0.22	1.68 a	1.37	0.25	1.62 a	1.57	0.27	1.77 a
2m x 0.5m	1.66	0.22	1.86 a	0.97	0.26	1.23 b	1.41	0.27	1.68 b
Mean			1.77a			1.43 b			1.73 a

Note: Means in column with the same letter are not significantly different at P > 0.05 (SNK).

3.1.3. Competitive Ratio (CR)

The competitive ratio for cassava concerning the cropping systems was higher than the legumes and was greater than one (1) across the three agro-climatic zones (Table 3). There were significant differences (F= 7.99, *P* = .005) in the mean competitive ratio concerning the cropping systems across the agro-climatic zones with the cassava-soybean system recording the highest followed by the cassava-groundnut whilst the cassava-cowpea system recorded the least (Table 3). Furthermore, significant differences in the competitive ratio were also recorded concerning the agro-climatic zones with Sumbuya in the transitional rain forest registering the highest (3.91) followed by Makeni (3.71) and Segbwema (3.51) in the savannah woodland and rain forest respectively. Concerning spatial arrangement, higher CR values were also recorded for cassava compared to the legumes. In addition, all the CR values for cassava were greater than one (1) across the three agro-climatic zones and cropping systems (Table 3). In Makeni, significant differences (F = 4.75, P = .030) were recorded in the mean completive ratio regarding cassava-groundnut and cassava-soybean systems with higher CR values recorded for the 2 m x 0.5 m spatial arrangement compared to the 1 m x 1 m spatial arrangement. There were however no significant differences (F =

1.70, P = 0.102) in the CR values for the cassava-cowpea system although slightly higher values were recorded for the 2 m x 0.5 m spatial arrangement compared to the 1 m x 1 m spatial arrangement (Table 3).

In Segbwema, significant differences (F = 1.12, *P* = 0.909) were not recorded in the CR values with respect to cassava-groundnut and cassava-cowpea systems although slightly higher CR values were recorded with respect to the 1 m x 1 m spatial arrangement compared to the 2 m x 0.5 m spatial arrangement of cassava (Table 3). Significant differences were however recorded with respect to the cassava-soybean system with the 2 m x 0.5 m spatial arrangement recording significantly higher values compared to the 1 m x 1 m spatial arrangement (Table 3).

In the case of Sumbuya, significant differences (F = 1.40, *P* = 0.268) were also recorded in the CR values pertaining to the cassava-groundnut and cassava-soybean systems with the 2 m x 0.5 m spatial arrangement of cassava registering significantly higher CR values compared to the 1 m x 1 m spatial arrangement. There were however, no significant differences in the CR values concerning the cassava-cowpea system although a slightly higher value was recorded with respect to the 1 m x 1 m spatial arrangement compared to the 2 m x 0.5 m spatial arrangement of cassava (Table 3).

Table 3. Competitive ratio of cassava and component crops as influenced by cropping system and spatial arrangement.

Competitive Ratio (CR)									
Treatments	**Agro-climatic zones**								
	Savannah woodland (Makeni)			**Rain forest (Segbwema)**			**Transitional rain forest (Sumbuya)**		
	CR Cassava	**CR Legume**	**Mean**	**CR Cassava**	**CR Legume**	**Mean**	**CR Cassava**	**CR Legume**	**Mean**
Cropping system									
Cassava - groundnut	5.25	0.19	2.72 b	5.51	0.18	2.85 b	6.11	0.16	3.14 b
Cassava-cowpea	4.98	0.28	2.63 b	4.52	0.22	2.37 b	3.04	0.33	1.69 c
Cassava-soybean	11.45	0.11	5.78 a	10.55	0.09	5.32 a	14.20	0.07	7.13 a
Mean			3.71 ab			3.51b			3.98 a
Spatial arrangement									
Cassava-groundnut									
1m x 1m	4.52	0.22	2.37 b	5.29	0.19	2.74 a	4.35	0.23	2.29 b
2m x 0.5m	6.52	0.15	3.34 a	4.66	0.21	2.44 a	7.90	0.17	4.04 a
Mean			2.86 b			2.59 c			3.17 a
Cassava -cowpea									
1m x 1m	6.01	0.16	3.09 a	5.44	0.18	2.81 a	4.55	0.22	2.39 a
2m x 0.5m	6.05	0.17	3.11a	5.40	0.19	2.80 a	4.52	0.22	2.37 a
Mean			3.10 a			2.81 b			2.38 c
Cassava-soybean									
1m x 1m	13.97	0.07	7.02 b	15.22	0.06	7.64 b	16.35	0.06	8.20 b
2m x 0.5m	24.78	0.04	12.41 a	17.59	0.06	8.33 a	17.19	0.05	8.62 a
Mean			9.71 a			7.98 c			8.41 b

Note: Means in column with the same letter are not significantly different at P>0.05 (SNK).

3.1.4. Relative Crowding Coefficient (RCC or K)

The partial relative crowding coefficient with respect to cropping system was higher for cassava than the legumes, and was also greater than one (1) in the three agro-climatic zones except for the cassava-groundnut system in Makeni in the savannah woodland where the partial relative crowding coefficient for groundnut was greater than one (1) (Table 4). There were significant differences (F = 7.05, *P* = 0.012) in the product of the relative crowding coefficient with respect to the cropping system at Makeni and Segbwema with the cassava-soybean system recording the highest followed by cassava-groundnut and cassava-cowpea systems (Table 4). In Sumbuya, there were also significant differences (F = 8.67, P = 0.007) across the cropping systems but the cassava-groundnut system was observed to have recorded the highest relative crowding coefficient followed by the cassava-soybean and the cassava-cowpea systems (Table 4). Furthermore, there were significant differences in the product of the relative crowding coefficients among the zones with Segbwema (31.86) recording the highest followed by Makeni (28.92) whilst Sumbuya recorded the least (17.08) (Table 4).

Concerning spatial arrangement, higher partial relative crowding coefficients were also recorded for cassava compared to the legumes across the zones. In addition, all the partial relative crowding coefficients for cassava were greater than one (1). For the legumes, the partial relative crowding coefficient was only greater than one (1) at Sumbuya for the cassava-groundnut system using the 2 m x 0.5 m spatial arrangement of cassava (Table 4).

For the cassava-groundnut and cassava-cowpea systems, the 2 m x 0.5 m spatial arrangement recorded a significantly higher product of the relative crowding coefficient compared to the 1 m x 1 m spatial arrangement across all the zones (Table 4). The values for the product of the relative crowding coefficient for both spatial arrangements were above one (1). For the cassava-soybean cropping system, significant differences in the spatial arrangement were also recorded in Segbwema and Sumbuya representing the rain forest and the transitional rain forest respectively, with the 2 m x 0.5 m arrangement recording the highest compared to the 1 m x 1 m arrangement. However, there were no significant differences in Makeni where the 1 m x 1 m spatial arrangement recorded a slightly higher value compared to the 2 m x 0.5 m spatial arrangement (Table 4).

Table 4. Relative crowding coefficient of cassava and component crops as influenced by cropping system and spatial arrangement.

Relative crowding coefficient (RCC or K)									
	Agro-climatic zones								
Treatments	**Savannah woodland (Makeni)**			**Rain forest (Segbwema)**			**Transitional rain forest (Sumbuya)**		
	K Cassava	**K Legume**	**K (kc x kl)**	**Cassava**	**Legume**	**K (kc x kl)**	**Cassava**	**Legume**	**K (kc x kl)**
Cropping system									
Cassava - groundnut	15.70	1.64	25.74 c	16.08	0.80	12.86 c	68.19	0.42	28.63 a
Cassava-cowpea	27.31	0.63	18.57 c	14.32	0.60	8.59 c	9.90	0.90	8.91 b
Cassava-soybean	49.96	0.85	42.47 a	67.38	1.10	74.12 a	47.95	0.29	13.91 b
Mean			28.92 b			31.86 a			17.08 c
Spatial arrangement									
Cassava-groundnut									
1m x 1m	13.32	0.57	7.59 b	16.52	0.35	5.78 b	11.26	0.56	6.31 b
2m x 0.5m	28.80	2.37	68.25 a	31.21	0.47	14.66 a	148.52	1.68	249.51 a
Mean			37.91 b			10.22 c			127.91 a
Cassava -cowpea									
1m x 1m	12.80	0.26	3.33 b	14.33	0.34	4.87 b	6.37	0.30	1.91 a
2m x 0.5m	454.00	0.84	381.36 a	27.72	0.58	16.07 a	6.79	0.33	2.24 a
Mean			192.34 a			10.47 b			2.08 c
Cassava-soybean									
1m x 1m	28.64	0.24	6.87 a	31.08	0.37	11.49 b	22.94	0.48	11.01 b
2m x 0.5m	25.06	0.25	6.27 a	379.56	0.34	129.05 a	34.47	0.46	15.85 a
Mean			6.57			70.27			13.43

Note: Means in column with the same letter are not significantly different at P > 0.05 (SNK).

3.1.5. Monetary Advantage Index (MAI)

The monetary advantage index was highly significant (F = 11.05, P < 0.0001) concerning the cropping system with the cassava-soybean system recording the highest value followed by the cassava-groundnut system whilst the cassava-cowpea system recorded the least across the three zones (Table 5). The mean monetary advantage index recorded concerning the cassava-soybean cropping system across the three agro-climatic zones was 26.27% and 47.03% higher than the cassava-groundnut and cassava-cowpea systems respectively (Table 5). In addition, there were significant differences with respect to the agro-climatic zones with Segbwema (1,277.19) in the forest zone recording the highest followed by Makeni (979.93) and Sumbuya (952.61) in the savannah woodland and the transitional rain forest respectively. The monetary advantage index recorded in Segbwema was 23.27% and 25.41% higher than Makeni and Sumbuya respectively (Table 5).

Relating to spatial arrangement, significant differences (F = 6.81, *P* = 0.001) were recorded concerning cassava-groundnut and cassava-cowpea systems with the 2 m x 0.5 m spatial arrangement recording significantly higher values compared to the 1 m x1 m spatial arrangement across the three agro-climatic zones (Table 5). For the cassava-soybean system, significant differences were also recorded at Segbwema and Sumbuya with the 1 m x 1 m spatial arrangement recording the highest value compared to the 2 m x 0.5 m spatial arrangement. However, in Makeni, the 2 m x 0.5 m spatial arrangement recorded the highest monetary advantage index compared to the 1 m x 1 m spatial arrangement (Table 5).

Table 5. Monetary advantage index of cassava and component crops as influenced by cropping system and spatial arrangement.

Agro-climatic zones			
Treatments	**Savannah woodland (Makeni)**	**Rain forest (Segbwema)**	**Transitional rain forest (Sumbuya)**
	Monetary Advantage Index (MAI)	**Monetary Advantage Index (MAI)**	**Monetary Advantage Index (MAI)**
Cropping system			
Cassava -groundnut	1,087.00b	1,223.65 b	815.75 b
Cassava-cowpea	628.01c	1,001.17 c	625.59 c
Cassava-soybean	1,224.8 a	1,606.74 a	1,416.48 a
Mean	979.93 b	1,277.19 a	952.61 b
Spatial arrangement			
Cassava-groundnut			
1m x 1m	476.58 b	1,022.55 b	528.48 b
2m x 0.5m	1,201.20 a	1,365.30 a	1,177.63a
Mean	838.89 c	1,193.93 a	885.056 b
Cassava -cowpea			
1m x 1m	361.83 b	871.03 b	220.00 a
2m x 0.5m	1,022.79 a	1,652.76 a	239.18 a
Mean	692.37 b	1,261.90 a	229.59 c
Cassava -soybean			
1m x 1m	1,476.95 b	3,089.84 a	2,051.77 a
2m x 0.5m	1,642.74 a	1,856.96 b	1,815.77 b
Mean	1,559.84 c	2,473.40 a	1,933.77 b

Note: Means in column with the same letter are no significantly different at P> 0.05 (SNK).

4. DISCUSSION

Intercropping may result in either interspecific competition or facilitation between the component crops [21]. Competition is one of the most important factors that significantly influence the rate of growth and yields of component crops in intercropping systems compared with sole cropping [6].

The land equivalent ratio is an effective and widely used index for comparing intercropping systems due to different species growing on the same piece of land [22]. It reflects the extra advantage of intercropping systems over sole cropping systems.

The partial land equivalent ratios for both cassava and the legumes across the cropping systems were all above 0.5 indicating an advantage for intercropping both cassava and the legumes. In addition, on average, the partial land equivalent ratio for cassava was greater than the legumes across all the cropping systems, which shows that cassava contributed more to the total yield compared to the legumes. In addition, it also shows that cassava was more competitive than the legumes and that it utilizes the nitrogen that was fixed by the legumes for better growth and yield. Furthermore, the total land equivalent ratio concerning cropping systems was above one (1). This indicates an advantage of intercropping over sole cropping in terms of the use of environmental resources for plant growth. Also, it shows that interspecific interaction or complementarity was greater than competition as such, intercropping resulted in greater land-use efficiency. It further shows that 0.72ha. and 0.92ha of more land will be required by the sole cropping system to produce the same yield as in the intercropping system.

This result is similar to that reported by Yayeh, et al. [22] in which he reported values of land equivalent ratio of above one (1) in wheat-lupine and barley intercropping systems. In addition, values of land equivalent ratio greater than one (1) have been reported for sorghum-bottle gourd intercropping [23], cassava-legumes intercropping [4, 24, 25], and for cassava-maize-egusi melon intercropping systems [26].

The result further shows a higher total land equivalent ratio for the cassava-soybean cropping system indicating that higher productivity per unit area was achieved in intercropping cassava with soybean than sole cropping and the other intercropping systems. This result conforms to the findings of Mbah, et al. [27]. These authors reported yield advantages in cassava-soybean mixtures compared to other cropping systems. The reason for the yield advantage in intercropping systems is because component crops have different growth pattern and maturity period and thus, made demands on resources at different times, which leads to better temporal use of growth resources [3].

Concerning spatial arrangement, the total land equivalent ratio ranged from 1.46-2.30 between the two spatial arrangements, which show that the idea of intercropping cassava with cowpea, soybean, and groundnut was highly productive in terms of environmental resource utilization relative to sole cropping. In addition, the higher land equivalent ratio reported with respect to the 2 m x 0.5 m (1 C: 3 L) spatial arrangement indicates higher productivity under this arrangement resulting from the efficient utilization of environmental resources compared to the 1 m x 1 m (1 C: 1 L) spatial arrangement. This finding also indicates that, interspecific competition was reduced with increasing row distance between cassava and legumes.

In all the treatments, the area time equivalent ratios were lower than the land equivalent ratio indicating over-estimation of resource utilization by the land equivalent ratio. This result agrees with the findings of Hiebsch and McCollum [28] who reported the likelihood of over-estimation of the advantages of intercropping by using land equivalent ratio when component crops differs in growth duration. Awal, et al. [29] also reported the superiority of area time equivalent ratio over land equivalent ratio in situations when the land coverage time by intercrop component is different.

The study further shows significant differences in terms of the area used and time when cassava was intercropped with cowpea, soybean, and groundnut across the three agro-climatic zones. The area time equivalent ratio for the cassava-soybean and cassava-groundnut was greater than one (1) which indicates yield advantage of intercropping over monocropping [30]. Similar reports indicating better environmental resource utilization in intercropping have also been reported by Aasim [31] and Uddin, et al. [32] for cotton intercropped with cowpea and wheat intercropped with peanut, respectively. The Results also indicate that among the crops studied, the cassava-soybean system was more efficient in the utilization of both area and time compared to the other cropping systems.

Furthermore, the higher mean area time equivalent ratio recorded for the 2 m x 0.5 m (1 C: 3 L) spatial arrangement shows that this spatial arrangement is superior in terms of utilizing the environmental resources for the growth and productivity of the component crops compared to the 1 m x 1 m (1 C: 1 L) spatial arrangement.

The Competitive ratio is an important index that determines the extent to which one crop competes with the other. It gives a better measure of the competitive ability of component crops in a polyculture and is a better index compared to relative crowding index (K) and aggressively (A) [15].

In the current study, the competitive ratio (CR) recorded among the intercropping systems in the three agro-climatic zones shows that, cassava was more competitive than the three legumes in the association. The greater competitiveness of cassava in the intercropping system compared to the legumes might be attributed to the shading effect by the tall cassava plant, which could affect the amount of sunlight that is intercepted by the legumes. This result agrees with the findings of Oroka [33] who reported that cassava was the dominant species in the cassava-groundnut intercropping systems. Ogola, et al. [34] have also reported a higher competitive ratio for cassava than the legumes. In addition, Amanullah, et al. [35] have reported the advantages accrued from the cassava-legume intercropping system. Furthermore, among the cropping systems, the cassava-soybean system was highly competitive compared to the other cropping systems. Studies have revealed that such competition may lead to decrease in survival, growth or reproduction of at least one of the species [36].

In addition, the Competitive ratio for the intercropped cassava with the three legumes was higher in the 2 m x 0.5 m (1 C: 3 L) spatial arrangement compared to the 1 m x1 m (1 C: 1 L) spatial arrangement because of the increasing row distance between the cassava and the legumes. This finding shows that, interspecific competition was reduced with increasing row distance between the cassava and the legumes and the competitive ability of intercropped legumes were improved.

The relative crowding coefficient was another index used to determine the relative dominance of one species over the other [17]. The relative crowding coefficient (K) was significantly different when cassava was intercropped with the grain legumes. The recorded values of the partial relative crowding coefficient indicate that cassava was highly dominant in all the intercropping systems as it recorded higher values of relative crowding coefficient compared to the component crops. In addition, it can be inferred that cassava utilizes resources more competitively than the legumes and hence was more dominant. This result agrees with the findings of Khan, et al. [37] who reported a higher partial K value for cotton intercropped with legumes. In addition, the partial relative coefficient values for cowpea across the three locations were higher than soybean and groundnut indicating that cowpea was more competitive in the cassava-legume mixture. In addition, the fact that the product of the relative crowding coefficient of component crops in the cropping system was greater than one (1) indicates that, intercropping systems had yield advantages. Additionally, the higher values for the product of the relative crowding coefficient reported for the cassava-soybean system at Makeni and Sumbuya show that the system was highly dominant over the other cropping systems in these zones and that it utilizes growth resources more competitively compared to the other cropping systems.

Furthermore, because the product of the relative crowding coefficient of the component crops in the 1 m x 1 m and the 2 m x 0.5m spatial arrangements were greater than one (1) across cropping systems, implies that, both spatial arrangements had yield advantages. In addition, because cassava recorded a higher competitive advantage in the 2 m x 0.5 m spatial arrangement over the 1m x 1m arrangement implies that, cassava will be getting the bulk of the growth resources across cropping systems for higher root yield.

The monetary advantage index takes into account both the economic and absolute yield advantage of intercropping systems over sole cropping [22, 38]. The study demonstrates that intercropping cassava with grain legumes significantly affects the monetary advantage index across cropping systems among the three zones. The monetary advantage indices were positive in all the cropping systems and were higher than one (1) which indicates that the intercropping systems were more economically feasible and profitable compared to the sole cropping. This result corroborates with the findings of Dutta, et al. [39] on maize-rape seed system. The higher monetary advantage index recorded for the cassava-soybean system shows that the cropping system was more profitable compared to the other cropping systems across the three zones. Furthermore, the higher monetary advantage index value recorded at Segbwema indicates a high feasibility and profitability of the cropping systems at this zone. In addition, the higher monetary advantage index value recorded across cropping systems and agro-climatic zones could be related to the higher land equivalent ratios and relative crowding coefficient values across cropping systems and agro-climatic zones. The above observation is in accordance with Dhima, et al. [7] who also related higher monetary advantage index with higher land equivalent ratio and relative crowding coefficient values. These results also conform to the findings of Ghosh [12] who also reported a significant, direct, and positive relationship between higher values of land equivalent ratio, relative crowding coefficient, and monetary advantage index.

Furthermore, a higher and positive monetary advantage index was recorded for all the intercropping combinations with respect to spatial arrangement; this indicates a yield advantage of intercropping systems over sole cropping. The higher monetary advantage index obtained for the 2 m x 0.5 m spatial arrangement with respect to cassava-groundnut and cassava-cowpea systems indicate that this spatial arrangement was economically viable compared to the 1 m x 1m spatial arrangement. This result contradicts with the findings of Khonde, et al. [40] and Kheroar and Patra [41] who reported a higher and positive monetary advantage index in maize-groundnut intercropping system using the 1 m x 1 m spatial arrangement. However, for the cassava-soybean system, higher monetary advantage index values were recorded at Segbwema and Sumbuya for the 1 m x 1 m spatial arrangement.

5. CONCLUSIONS

Results from the competitive and economic indices show that cassava legume intercropping systems utilize environmental sources more efficiently and was more profitable compared to the sole cropping. The total land equivalent ratio across cropping systems and spatial arrangements were all greater than one (1). The competitive ratio and relative crowding index show that intercropping systems utilize environmental resources more competitively especially when the 2 m x 0.5 m spatial arrangement of cassava was used. In addition, cassava appeared to be the most dominant crop compared to the legumes as shown by its higher values for competitive ratio and relative crowding coefficient. The result obtained for the monetary advantage index shows that all intercropping systems were feasible and profitable.

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