JOURNAL OF METEOROLOGY AND CLIMATE SCIENCE
J. Met & Clim. Sci. 18(1): 78-88 (March, 2020)

N.Met.S
Nigerian Meteorological Society

Utilization of Maize–Millet-Okra Intercropping Systems in Western Nigeria

Lugard Nwamini[1]*, Abayomi Eruola[1], Akeem Makinde[1], Jubril Soaga[2] and John Attah[1]

[1]*Department of Water Resources Management and Agrometeorology – Federal University of Agriculture, Abeokuta, Nigeria*
[2]*Department of Forestry and Wildlife Management – Federal University of Agriculture, Abeokuta, Nigeria*
**Corresponding author's email: donpasluggy@yahoo.com*

Abstract: *Utilization of Maize–Millet-Okra intercropping systems was investigated in Southwest, Nigeria. Yield attributes of each of the crops during the 2017 and 2018 growing seasons formed the basis for the investigation. Indices, such as water use efficiency (WUE), water equivalent ratio (WER) and land equivalent ratio (LER) were calculated to characterize the intercropping efficiency of land and water use compared to when in cropping. The results showed that WUE of crops in combination and intercrop ranged from 5.7 to 61.67 Kg/ha/mm, LER in combination and intercrop ranged from 0.57 to 1.46 and WER ranged from 1.00 to 2.04. Okra performed excellently well in WUE, WER and LER in its combination with maize and millet. 2-tier intercrop performed better than 3-tier intercrop irrespective of the crop combination. Land equivalent ratio consistently gave values of more than 1, indicating the superiority of intercropping over sole cropping. Crops in intercrop, irrespective of combination method utilized water effectively than in sole cropping. Though, water is not a limiting factor in the study area, intercropping utilized water more effectively when planted in row intercropping system.*

Key words: *WUE, WER, LER, intercrop, combination*

INTRODUCTION

Resources management in agriculture is fast becoming necessary for sustainable crop production particularly in this era of climate change. Globally, agricultural activities particularly crop production, dominate the use of land and freshwater (FAO 2012) as a result of increasing demand for food. However, in marked contrast to domestic and industrial fresh water withdrawals, most of the water withdrawn by agriculture is lost in evaporation and transpiration. Hence, an urgent improvement of productivity per unit of water consumed per area of land utilized in agriculture is needed. This can be achieved by developing crops that require less water and few land to produce sufficient yield, through understanding the physiological mechanisms that determine growth and water loss, and plant response to reduced water availability in little land area. Olasantan (2005) reported that one of the reasons majority of the traditional farmers in the tropics often practice intercropping system is to reduce evaporative water losses. Critchley and Siegert (1991) in their work further iterated that improved crop yields and water productivity can be accomplished through *in-situ* water management, and by managing soil evaporation. The advantage of Intercropping over mono-crop cultures have been discussed by Obadoni, Mensah and Emua (2010) and Ijoyah and Anyam (2013) among others. The major problem associated with intercropping is the concepts of theoretical ecology which deals with the competition for resource develops due to varying time of planting, root growth patterns, and/or different resource demands (Ijoyah and Anyam, 2013; Amujoyegbe and Elemo, 2013). In view of the difficulties of competition for water supply and space in intercropping system, planning crop combinations with effective use of available water and space is of great importance. To compare yields of mono-cropped and intercropped fields of crops in different combination, the land equivalent ratio (LER) and water equivalent ratio (WER) can be adopted.

Intercropping vegetable crop with cereals has been shown to give higher returns than sole cropping (Ren, Liu, Wang and Zhang, 2016). Thus, for sustainable agricultural production, researchers all over the world and in Nigeria in particular have not relented on their efforts at investigating both the positive and negative effects of intercropping. Millet cultivation and production is said to be suitable for the agronomic conditions in Nigeria (FAO, 2012) and it is gradually gaining relevance in the intercropping system in some part of the country because of its economic potential and role in the cereal industry (Kunchinda and Ogunwole, 2000). The usual time for planting millet in Nigeria coincides with that of maize, cowpea, sorghum, groundnut among others (Adeniyan, Akande, Balogun and Saka, 2015). However, because of its tolerance to difficult growing conditions, it can be grown where other cereals such as maize or wheat would not survive. Pearl millet responds well to management inputs, therefore it has high potential of becoming an important component of intensive agriculture especially in arid and semi-arid regions (Izge, 2006). Research into millet with other food crop has been extensive in Nigeria (Obilana, 2003, Dewey, Hanna, David, William and Jeffrey, 2012, Izge, 2006 and Agbaje, Saka, Adegbite and Adeyeye, 2016). However, there are few types of research on resources utilization in various intercropping using different crop combination currently. For these reasons, the objective of this research was to investigate resources utilization in maize-millet-okra intercropping systems and crop combination in order to determine the best maize-millet-okra combination.

MATERIALS AND METHODS

Description of study area

The research was conducted at the Research farm of Federal University of Agriculture along Alabata road, Abeokuta (7° 15'N, 3°25'E) in Odeda Local Government Area of Ogun State, South Western Nigeria (Fig 1) during the 2017 and 2018 growing seasons. The experiment comprising of 3 different intercropping systems (row, strip and mixed) and 5 different combinations of maize-millet-okra (sole, maize-millet, maize-okra, millet-okra and maize-millet-okra) was laid out in a factorial arrangement fitted in a randomized complete block design (RCBD) replicated thrice. The study area is characterized by a tropical climate with distinct wet and dry seasons with bimodal rainfall pattern and mean annual air temperature of about 30°C (Makinde *et al.*, 2017). The actual rainfall totals during the 2017 and 2018 growing season were 1202 and 1256.6 mm, respectively. However, the area is characterized by rainfall variability which is not limited to seasonal fluctuations but also includes year to year variability in the onset, cessation and duration of the rains which are also characterized by dry spells of unpredictable magnitude which may last from a few days to more than three weeks. The soil at the experimental site was categorized as a well-drained tropical ferruginous soil (A horizon of an Oxic Paleudulf of Iwo series) with 83% sand, 5% silt and 12 % clay with a pH of 6 (Olasantan, 2005).

EXPERIMENTAL DESIGN AND FIELD MEASUREMENT

Figure 2 shows the arrangement of the different intercropping systems used. The experiment comprises a total of 15 plots (treatments) replicated three times, giving a total of 45 plots covering a land extent of 67 m × 14 m. Each plot measures 4 m × 4 m in size with a walk-path of 1 m for inter-row and 0.5 m for intra-row. The experimental site was cleared, stumped and ridged manually with the use of cutlass and hoe during the late April for both experiment. This time marked the early growing seasons in the study area. One cultivar of pearl millet (Ex-Bornu), maize (Downy Mildew Resistant- Late Streak virus Resistant – Yellow DMR-LSR-Y) and okra (Louisiana green velvet- LGV) were sown per hole in their respective plots with four seeds of millet and maize, two seeds of okra dibbled in each plot at an average depth of 0.15 m. The seedlings were thinned to one plant per stand at 20 days after sowing. Crops were spaced following recommended spacing reported by researchers; 0.75 m × 0.25 m for maize and millet (Michael, Ishaya and Richard 2015; Sani, Danmowa, Sani and Jaliya 2011), while spacing for okra was 0.80 m × 0.30 m (Ijoyah, Atanu and Ojo 2010). Insecticide was applied at the rate of 2 ml/L on equal basis and all plots were regularly weeded using traditional hoe and NPK 20-10-10 fertilizer at the rate of 40 kg/ha was applied four (4) weeks after planting to the experimental sites.

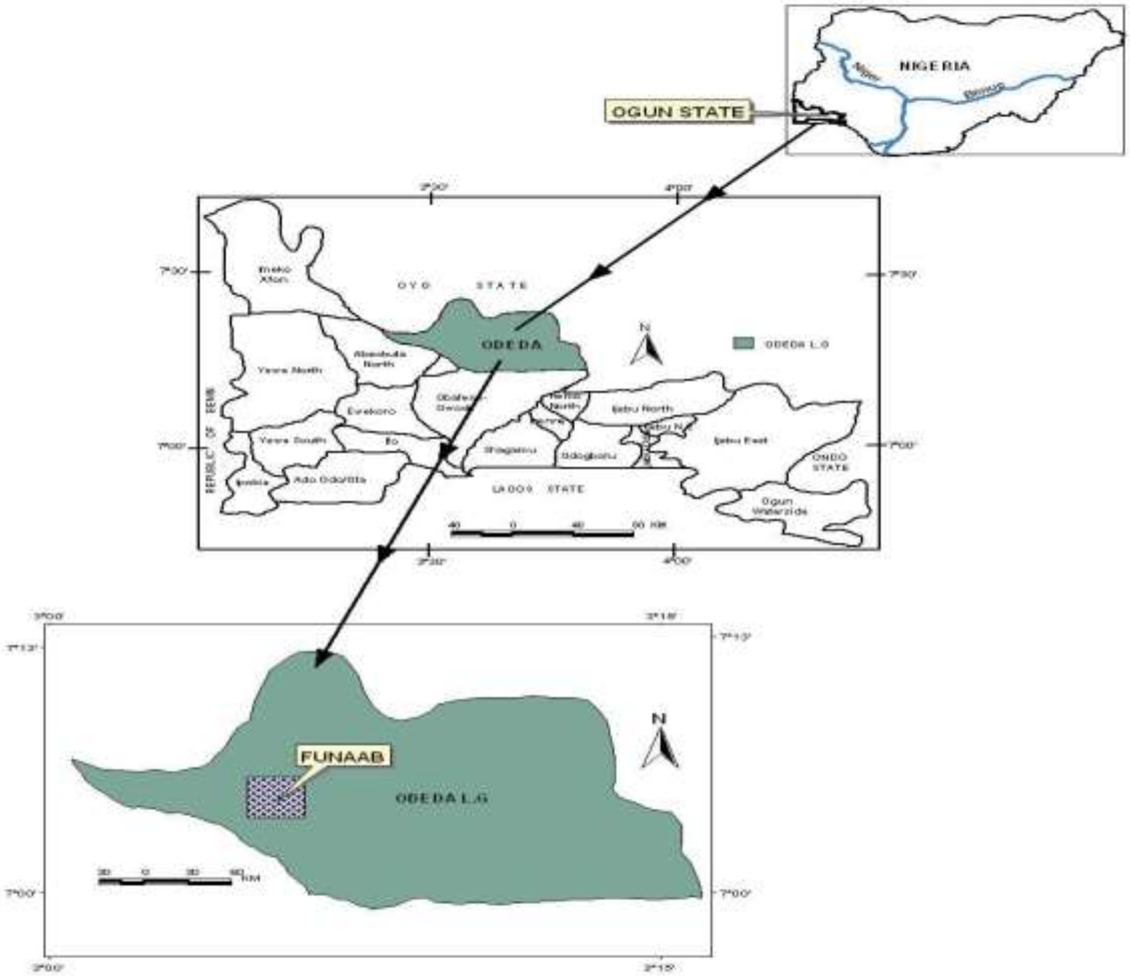

Fig 1: Location of University of Agriculture, Abeokuta within Odeda Local Government Area in Ogun State, Southwestern Nigeria

The crops were harvested at their various physiological maturities. During each of the growth stages, weekly observation of soil temperature (°C) and soil moisture at varying depths (5, 10 and 20 cm) was done in-situ while rainfall amount (mm) was collected at weather station adjacent to the experimental field. Consumptive water used by the crop (ET_a) in mm was measured using soil water balance computation throughout the growing season (Ghiberto, Libardi, Brito, and Trivelin, 2011). The soil water balance equation is given as:

$$ET = IR + ER + \Delta S + GW \quad (1)$$

In the formula, IR and ER are irrigation water and effective rainfall (mm), while ΔS and GW are change in soil moisture content and ground water contribution (mm). The sum of IR and GW during the period of this experiment was assumed to be zero. For practical purposes, the GW was taken as zero when the ground water table is 3 m below the soil surface (Zhang *et al.*, 2007). Depth of water table in the study area has been reported to be between 35 to 70 m (Badmus and Olatinsu, 2010). Irrigation was not applied throughout the course of the experiments. The Soil moisture content was determined using the TDR (TDR 100) method mentioned in Wojciech, Andrzej, Agnieszka, Cezary and Krzysztof 2012. The TDR contains two long probes which are buried into the soil to determine the instantaneous soil water content. Perforated PVC pipe access tubes measuring 4 inches in diameter was inserted to depths of 15 cm per plot for easy access of TDR.

Effective rainfall (ER) is that part of rainfall that is added and stored in the soil root zone and can be utilized by crops (Farmwest, 2013). This was estimated using FAO/AGLW method as given below:

ER = 0.6 × monthly rainfall – 10 (when rainfall is < 70mm) (2)

ER = 0.8 × monthly rainfall – 24 (when rainfall is > 70mm) (3)

Viets (1962) defined water use efficiency (WUE in kg/ha/mm) as the ratio of crop production to that of evapotranspiration. WUE is represented mathematically as:

$$\text{WUE} = {}^{Y}/_{ET} \qquad (4)$$

Where the grain yield (Y) is measured in kg/ha

The assessment of water utilization efficiency of the intercropping population was achieved following the method of Mao *et al.* (2012) for the determination of Water Equivalent Ratio (WER) as shown:

$$\text{WER} = \text{WER}_{(A)} + \text{WER}_{(B)} = \frac{WUE(int.A)}{WUE(mono.A)} + \frac{WUE(int.B)}{WUE(mono.B)} \qquad (5)$$

Where:

$\text{WER}_{(A)}$ and $\text{WER}_{(B)}$ = Water Equivalent Ratio of crop A and B

$\text{WUE}_{(int.\ A)}$ and $\text{WUE}_{(int.\ B)}$ = Water Use Efficiencies of crop A and B in intercrop

$\text{WUE}_{(mono.\ A)}$ and $\text{WUE}_{(mono.\ B)}$ = Water Use Efficiencies of monocrop of crop A and B.

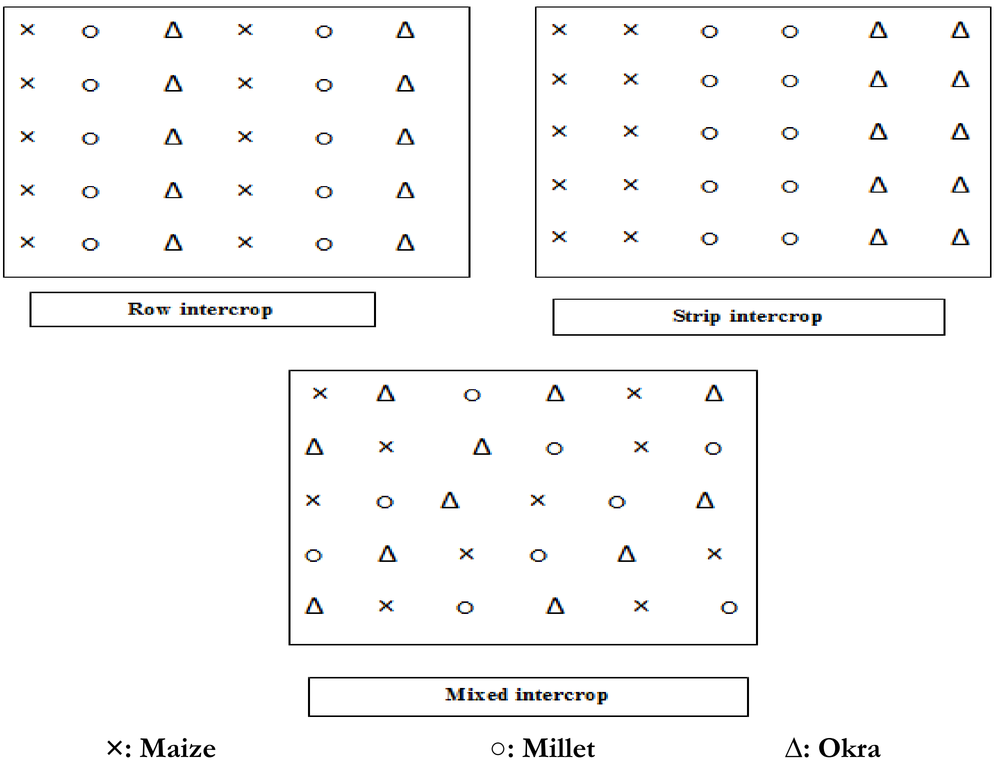

Fig. 2: Schematic diagram of the different intercropping systems used

The WER quantifies the amount of water that would be needed in single crops to achieve the same yield as produced with one unit of water in intercrop. If the $WER > 1$, it suggests that the water utilization efficiency of intercropping is higher than that of monoculture. If $WER < 1$, it shows that water utilization efficiency of intercropping is lower than that of monoculture.

Furthermore, Land Equivalent Ratio (LER) was calculated according to Mead and Willey, (1980) as follows:

$$\text{LER} = \frac{Y_A}{S_A} + \frac{Y_B}{S_B} + \frac{Y_C}{S_C} \qquad (6)$$

Where;

Y_A, Y_B and Y_C = individual crop yield in intercropping

S_A, S_B and S_C = yield of the respective crops in sole (monocrop)

According to Amanullah, Haji, Abbas and Ghaffar (2016) and Suliman (2012), LER is a standardized index that is defined as the relative area required by sole crops to produce the same yield as intercrops. LER value greater than 1 shows that intercropping has a yield advantage over sole cropping, while LER value less than 1 indicates that intercropping has no advantage over sole cropping and when LER = 1, there is no advantage to intercropping.

RESULTS AND DISCUSSION

Intercropping is critical to resources conservation and utilization efficiency in particular land and water (Feike *et al*., 2010). This is because water supply and space utilization significantly influence crop developmental rates and yield (Nortes, Gonzalez-Real, Egea, and Baille 2009). Ijoyah and Anyam (2013) and others have documented that major arable crops in humid, sub-humid and semi-arid regions are produced under mix-intercropping with poor WUE, but widely popularized. Among such are cassava/maize/egusi-melon and sorghum/maize/okra.

From the present study on the potential of water use and productivity of maize in performance with intercrop of millet-okra during the 2017 and 2018 growing seasons (Table 1). It was observed that the WUE of maize in sole significantly ($p \leq 0.05$) enhanced the utilization of water effectively than in intercrop, irrespective of planting combination having the highest WUE of 17.5 Kg/ha/mm and 18.2 Kg/ha/mm in 2017 and 2018 growing seasons respectively. reported that grain yield of sorghum reduced significantly in intercropped treatment as compared to sole crop. There was also marked difference in the yield of 2-tier and 3-tier combination systems.

Furthermore, it was observed that though no significant ($p>0.05$) differences in WUE, WER and LER in the intercrops systems which resulted to an insignificant ($p>0.05$) differences in the yield components (days to However, when in intercrop, the WUE were not significantly ($p>0.05$) different. Furthermore, it was obvious that the WUE in 2-tier (maize/ millet and maize/okra) were better than 3 tier (maize-millet-okra). It was also observed that the WER and LER varies in combination of crops indicating that crops in combination proved to make better use of water and land resources in time and space than in mono-crop since the LER and WER were greater than 1. This finding agrees with the works of Tsubo and Walker, (2002), Awal, Koshi, and Ikeda (2006) and Zhang *et al*., (2007). Natarajan and Willey (1980) and Ong, Black, Marshall, and Corlett (1996) in their study also claimed that though soil water use by various intercropping systems were found to be similar compared to monoculture, however, intercropping utilizes soil water more efficiently.

Generally, higher yield was observed in mono-cropping than the crops in combination. The higher yield recorded in mono-cropping system could be attributed to competition-free environment and high plant density of individual crop in sole than in combination with other.

Grain yield of maize in sole was 55.61, 47.81 and 90.13% higher than when in Mz/Mil, Mz/Ok and Mz/Mil/Ok respectively in 2017 and 23.87, 21.01 and 69.48% higher than when in Mz/Mil, Mz/Ok and Mz/Mil/Ok respectively in 2018 growing season. Mahakulkar, Wanjari, Otdykhe, Shekar, and Ingle 1995 reported higher grain yield of sorghum in sole cropping as compared to intercropping sorghum with maize and okra. Also, Anil 2007 and Adeniyan *et al.* (2015) 1% tasseling, days to 50% tasseling, cob weight and 500 seed weights). Significant ($p \leq 0.05$) higher grain yield were observed in maize in row and strip cropping system than the mixed cropping. It was also observed that, maize irrespective of intercropping system utilizes water effectively producing WER of greater than 1 but, failed in its space management of land by producing LER of less than 1.

Table 1: Maize performance in maize-millet-okra intercrop and combination

Treatment	WUE Kg/ha mm	Water Equivalent Ratio (WER)	Land Equivalent Ratio (LER)	Days to 1% tasseling	Days to 50% tasseling	Cob weight (kg)	500-seed weight (g)	Grain yield (kg/ha)
				2017				
CB								
Maize	17.5[a]	0	0	44.67[a]	53.00[a]	0.31[a]	70[a]	3296.62[a]
Mz/Mil	8.5[b]	1.00[c]	0.95[b]	47.56[a]	55.44[a]	0.32[a]	70[a]	1862.12[b]
Mz/Mil/Ok	5.7[c]	1.24[b]	1.31[a]	47.67[a]	55.44[a]	0.33[a]	70[a]	1248.38[c]
Mz/Ok	10.9[b]	1.52[a]	1.27[a]	47.11[a]	54.11[a]	0.35[a]	80[a]	2024.63[b]
INTS								
Mixed	9.7[a]	1.26[a]	0.83[a]	46.92[a]	54.5[a]	0.31[a]	70[a]	1964.16[b]
Row	10.3[a]	1.12[a]	0.87[a]	46.92[a]	54.83[a]	0.34[a]	80[a]	2082.94[ab]
Strip	11.2[a]	1.62[a]	0.95[a]	46.42[a]	54.17[a]	0.32[a]	80[a]	2277.47[a]
				2018				
CB								
Maize	18.2[a]	0	0	43.14[a]	51.10[a]	0.21[a]	60[a]	2423.04[a]
Mz/Mil	7.8[b]	1.36[c]	1.03[b]	48.02[a]	54.23[a]	0.36[a]	70[a]	1906.24[b]
Mz/Mil/Ok	8.3[b]	1.64[b]	1.52[a]	48.84[a]	56.34[a]	0.41[a]	60[a]	1173.51[c]
Mz/Ok	9.4[b]	1.09[a]	1.06[a]	45.62[a]	53.25[a]	0.38[a]	70[a]	1962.38[b]
INTS								
Mixed	10.4[a]	1.48[a]	0.96[a]	47.62[a]	54.8[a]	0.29[a]	80[a]	1795.72[b]
Row	12.2[a]	1.56[a]	0.88[a]	46.24[a]	53.42[a]	0.31[a]	70[a]	1939.35[a]
Strip	10.6[a]	1.14[a]	0.97[a]	46.86[a]	55.35[a]	0.30[a]	80[a]	1903.86[ab]

Means with same letter along the column are not significantly different at ($p>0.05$)

The water use and land utilization efficiency of millet in intercrop with maize and okra was also assessed during the 2017 and 2018 growing season (Table 2). Generally, mean WUE of millet in combinations with maize and/or okra was 31.48% higher than when in sole in 2017 and 21.85% higher than in sole in 2018 growing season thereby, making millet in cereal combination enhancing the utilization efficiency of water better than in sole cropping. This might be attributed to more water consumed in cereals (millet and maize) both in mono-crop and in combination as a result of growth length (119 days for millet, 83 days for maize and 71 days for okra) of the cereals which allows more interception and capturing of precipitation and the subsequent uptake and utilization of water. This is in accordance with the work of Zhang, Li, Huang, Huang and Chai (2002) that growth stages of crops when on the field for long, uptake and utilizes more soil nutrients than short duration crops thereby resulting in better growth and higher yields.

Millet in combination and intercropping consistently showed advantage of improving the water and land utilization efficiency since both WER and LER were greater than 1 except for the intercrop of millet in the 2017 growing season. This indicated that the combination and intercropping patterns had same functions and effects in the aspect of water utilization efficiency and of land use, implying that millet performance in intercrop and combination with maize and okra had the potential to increase the utilization of water and land in large extent, compared with the single crops. It was further observed that millet performed better in sole cropping producing higher yield (5920.83 kg/ha in 2017 and 4751.34 kg/ha in 2018) than when in combination with maize and/or okra. Though, better grain components were observed in combination than in sole millet.

Table 2: Millet performance in maize-millet-okra intercrop and combination

Treatment	WUE Kg/ha mm	Water Equivalent Ratio (WER)	Land Equivalent Ratio (LER)	Days to panicle initiation	Days to panicle formation	Grain yield (kg/ha)
			2017			
CB						
Millet	27.17^{c}	0	0	57.67^{b}	67.00^{b}	5920.83^{a}
Mil/Okr	14.09^{d}	1.28^{b}	1.11^{b}	62.44^{a}	70.67^{a}	2834.03^{b}
Mil/Mz	57.77^{a}	1.00^{c}	0.95^{c}	60.78^{ab}	70.33^{a}	2258.33^{c}
Mil/Mz/Okr	40.59^{b}	2.04^{a}	1.31^{a}	61.67^{a}	71.44^{a}	1672.92^{d}
INTS						
Mixed	32.33^{a}	1.68^{b}	0.79^{a}	59.92^{a}	69.25^{a}	3148.44^{a}
Row	35.99^{a}	1.43^{a}	0.84^{a}	60.92^{a}	70.08^{a}	3187.50^{a}
Strip	36.39^{a}	1.34^{b}	0.90^{a}	61.08^{a}	70.25^{a}	3178.65^{a}
			2018			
CB						
Millet	24.62^{c}	0	0	56.06^{b}	65.42^{b}	4751.34^{a}
Mil/Okr	21.26^{d}	1.41^{b}	1.04^{b}	60.14^{a}	68.73^{a}	2609.56^{b}
Mil/Mz	34.81^{b}	1.36^{c}	1.17^{c}	59.52^{ab}	68.24^{a}	2045.67^{c}
Mil/Mz/Okr	35.93^{a}	1.48^{a}	1.26^{a}	62.16^{a}	72.06^{a}	1747.53^{d}
INTS						
Mixed	34.82^{a}	1.68^{a}	0.57^{a}	61.34^{a}	70.74^{a}	2941.75^{a}
Row	36.74^{a}	1.43^{b}	1.31^{a}	61.08^{a}	69.26^{a}	3083.62^{a}
Strip	35.92^{a}	1.34^{b}	1.46^{a}	62.17^{a}	2885.62^{a}	

Means with same letter along the column are not significantly different at ($p>0.05$)

Okra in intercrop with maize and millet was assessed for water and land utilization efficiency during the 2017 and 2018 growing (Table 3). Okra performed excellently well in WUE, WER and LER in its intercrop with maize and millet. This could be a result of least competition by okra because of its early maturity and senescence. However, it was obvious that Ok/Mz combination utilizes water and land effectively but gave lesser yield as compared to its sole cropping. Ok/Mz combination had highest WUE of 61.67 kg/ha/mm in 2017 and 46.21 kg/ha/mm in 2018, LER of 1.27 in 2017 and 1.14 in 2018 and best yield in the intercropping systems (261.46 kg/ha in 2017 and 306.48 kg/ha in 2018) though not significant. This indicated that okra performed well in intercropping and in mono-cropping, though better off in mono-cropping. The higher productivity in mono-crop over combinations with Maize and/or Millet can be attributed to lower population density of Okra in intercrop (Jestinos and Eastonce 2016).

Table 3: Okra performance in maize-millet-okra intercrop and combination

Treatment	WUE Kg/ha mm	Water Equivalent Ratio (WER)	Land Equivalent Ratio (LER)	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Pod yield (kg/ha)
			2017				
CB							
Okra	12.6[d]	0	0	8.00[a]	2.73[a]	26[a]	425.83[a]
Ok/Mil	14.1[c]	1.02[a]	1.11[a]	6.32[b]	2.51[ab]	22[b]	253.33[b]
Ok/Mz/Mil	40.59[b]	1.04[b]	1.31[a]	6.00[b]	2.36[b]	21[b]	247.05[b]
Ok/Mz	61.67[a]	1.52[a]	1.27[a]	6.63[b]	2.44[ab]	24[b]	261.46[b]
INTS							
Mixed	27.46[a]	1.64[a]	0.87[a]	6.59[a]	2.46[a]	23[a]	291.04[a]
Row	29.09[a]	1.83[a]	0.89[a]	6.89[a]	2.52[a]	22[a]	293.23[a]
Strip	32.66[a]	1.32[a]	1.01[a]	6.73[a]	2.56[a]	22[a]	306.48[a]
			2018				
CB							
Okra	13.26[d]	0	0	10.21[a]	3.06[a]	33[a]	512.22[a]
Ok/Mil	18.04[c]	1.24[b]	1.25[a]	7.43[ab]	2.92[ab]	24[b]	324.14[b]
Ok/Mz/Mil	38.24[b]	1.37[b]	1.42[a]	6.54[b]	2.42[b]	25[b]	288.51[b]
Ok/Mz	46.21[a]	1.84[a]	1.14[a]	5.84[b]	3.02[ab]	31[ab]	302.31[b]
INTS							
Mixed	29.54[a]	1.52[a]	1.06[a]	5.86[a]	2.37[b]	22[a]	308.42[a]
Row	29.75[a]	1.49[a]	1.31[a]	6.42[a]	2.86[a]	27[a]	314.05[a]
Strip	28.43[a]	1.27[a]	0.86[a]	5.51[a]	3.23[a]	31[a]	294.34[a]

Means with same letter along the column are not significantly different at (p>0.05)

CONCLUSION

From this study, it is obvious that knowledge of soil-water and plant conditions under different crop combination and intercropping systems can allow us develop agricultural management strategy capable of improving food safety in forest-savanna transition zone of Nigeria.

Generally, results suggest that Maize-Millet-Okra intercropping effectively use water and land resources. The various intercropping systems used in the trial consistently gave an LER greater than 1, implying efficient use of natural resources over sole cropping. Though water is not a limiting factor in the study area, crops in intercrop, irrespective of the crop combination method utilized water effectively than in sole cropping.

Based on the findings from this study, it is recommended that, row intercropping system should be encouraged amongst farmers as it has proven to make effective use of resources (LER), in particular available soil water than in other intercropping systems.

Each intercropping system described in the study, especially, row intercropping system has shown to increase water use, water efficiency, growth and yield of crops. Finally, the study revealed that Maize-Millet-Okra in row intercropping system performed better in growth, yield and effectively utilizes soil water, though not significantly (p>0.05) different from Maize-Millet-Okra in strip and mixed intercropping systems.

REFERENCES

A. B. Obilana. Overview: Importance of millets in Africa. -in: AFRIPRO Proceedings of workshop on the Proteins of Sorghum and Millets: *Enhancing Nutritional and Functional Properties for Africa*. Pretoria, South Africa. 26–43, 2003.

A. M. Suliman. Assessing the Land Equivalent Ratio (LER) of Two Leguminous Pastures (CLITORIA and

SIRATRO) Intercropping at Various Cultural Practicesand Fencing atZALINGEI –Western Darfur State – Sudan. *ARPN Journal of Science and Technology* VOL. 2, NO. 11, Dec 2012.

A. U. Izge. Combining ability and heterosis of grain yield components among pearl millet (Pennisetum glaucum L. R. Br) in breds?. PhD Thesis, Federal University of Technology, Yola, Nigeria pp. 148 2006.

B. J. Amujoyegbe and K. Elemo. Productivity of maize/cowpea intercrop as influenced by time of introducing cowpea and nitrogen fertilizer rates in southwestern Nigeria. *Agricultural Science Research Journal, 3*(7): 186 – 193 2013.

B. M. Sani, N. M. Danmowa, Y. A. Sani and M. M. Jaliya. Growth, Yield and Water Use Efficiency of Maize-Sorghum Intercrop at Samaru, Northern Guinea Savannah, Nigeria. *Nigerian Journal of Basic and Applied Science*, 19 (2): 253-259, 2011.

B. O. Obadoni, J. K. Mensah and S. A. Emua. Productivity of intercropping systems using *Amaranthus cruentus* L and *Abelmoschus esculentus* (Moench) in Edo State, Nigeria. *World Rural Observations*, *2*(2): 53 – 60, 2010.

B. S. Badmus and O. B. Olatinsu. Aquifer characteristics and groundwater recharge pattern in a typical basement complex, Southwestern Nigeria. *African Journal of Environmental Science and Technology* Vol. 4 (6), pp. 328-342, June, 2010. ISSN 1991-637X © 2010 Academic Journals.

B. V. Mahakulkar, S. S. P. Wanjari, N. R. Otdykhe, V. B. Shekar and R. W. Ingle. Productivity of newly evolved sorghum (*Sorghum bicolor*) genotypes-based intercropping systems. *Indian Journal of Agronomy, 40*(2): 169 – 171, 1995.

B. Z. Zhang, S. Z. Kang, L. Zhang, T. S. Du, S. E. Li and X. Y. Yang. Estimation of seasonal crop water consumption in a vineyard using Bowen ratio-energy balance method. *Hydrological Processes* **21**: 3635–3641, 2007.

C. K. Ong, C. R. Black, F. M. Marshall and J. E. Corlett. Principles of resource capture and utilisation of light and water. In: Ong, C. K., Huxley, P. A. _Eds.., Tree crop Interactions a Physiological Approach. CAB International, 1996.

E. Zhang, L. Li, G. Huang, P. Huang and Q. Chai. Regulation of fertilizer application on yield and root growth of spring wheat–faba bean intercropping system. *Journal of Applied Ecol*ogy 13: 839–842, 2002.

F. G. Jr. Viets. Fertilizers and the efficient use of water. *Advances in Agronomy* 14: 223-264, 1962.

F. K. Amanullah, M. Haji, U. Abbas and A. Ghaffar. Land Equivalent Ratio, Growth, Yield and Yield Components Response of Mono-cropped vs. Inter-cropped Common Bean and Maize With and Without Compost Application.*Agric. Biol. J. N. Am., 7(2):40-49* 2016.

F. Liangshan, S. Zhanxiang, Muzi, Zheng, M. Mwangi, Z. Jiaming, Y. Ning, B. Wei, F. Chen, Z. Zhe, C. Qian and Z. Dongsheng, Productivity enhancement and water use efficiency of peanut-millet intercropping. *Pak. J. Bot.*, 48(4): 1459-1466, 2016.

F. O. Olasantan. Cassava cultivation management for sustainable vegetable production in intercropping with okra. *J. Sustain. Agric. 27*(2): 53 – 68, 2005.

FAO. 2012. FAOSTAT – FAO Statistical Databases. Retrieved from http://faostat.fao.org/. Date assessed September 2018

Farmwest. Effective precipitation: (22. 3. 2013).http://www.farmwest.com/node/934 Date assessed September 2018

G. O. Agbaje, J. O. Saka, A. A. Adegbite and O. O. Adeyeye. Influence of agronomic practices on yield and profitability in kenaf (*Hibiscus cannabinus* L.) fibre cultivation. *African Journal of Biotechnology*, Vol.7(5): 565 - 574 2016.

K. Anil. Effects of legumes on growth, yield and quality of pop sorghum in inter and mixed cropping system

(Unpublished Master's Thesis). University of Agricultural Sciences, Dharwad 2007.

L. Dewey, W. G. Hanna, B. David, D. William and P. W. Jeffrey. Pearl millet for Grain, CAES Publications, London, Pp. 76 2012.

L. L. Mao, L. Z. Zhang, W. W. Li, W. V. D. Werf, J. H. Sun, H. Spiertz and L. Li. Yield advantage and water saving in maize/pea intercrop. *Field Crops Research*, 138: 11-20, 2012.

L. Li, J. Sun, F. Zhang, T. Guo, X. Bao, A. Smith and S. E. Smith. Root distribution and interactions between intercropped species. *Oecologia* 147: 280–290 2006.

L. S. Feng, M. Z. Zheng, Z. X. Sun, J. M. Zheng, L. Yang and Y. Ning. Water consumption and use efficiency of major crops in southern kerqin sandy land. *J. Agri. Biotech. & Ecol.,* 3(2): 252-262 2010.

M. A. Awal, H. Koshi and T. Ikeda. Radiation interception and use by maize/peanut intercrop canopy. *Agricultural and Forest Meteorology*. 139, 74–83 2006.

M. Jestinos, and T. G. Eastonce. Analysis of Soil Profile Water Storage under Sunflower × Cowpea Intercrop in the Limpopo Province of South Africa. http://dx.doi.org/10.5772/62764 2016. Date assessed February 2019.

M. Natarajan and R. W. Willey. Sorghum-pigeonpea intercropping and the effects of plant population density. 2. Resource use. *The Journal of Agricultural Science*, 95 (1). pp. 59-65, 1980.

M. O. Ijoyah and H. H. Anyam. Evaluation of okra-soybean based cropping system as influenced by sowing densities of okra in a Southern Guinea savannah location, Nigeria. *International Journal of Current Science, 6*: 147 -152 2013.

M. O. Ijoyah, S. O. Atanu and S. Ojo. Productivity of okra (*Abelmoschus esculentus* L. Moench) at varying sowing dates in Makurdi, Nigeria. *Journal of Applied Biosciences* 32 2015-2019 2010.

M. Tsubo and S. Walker. A model of radiation interception and use by a maize–bean intercrop canopy. *Agricultural and Forest Meteorol*ogy 110: 203–215, 2002.

N. C. Kunchinda and J. O. Ogunwole. Effect of dates and row arrangement on crop growth yield in kenaf/ maize mixture in the northern guinea savanna of Nigeria. *Journal of Sustainable Agric. Environ*. 2: 251-256 2000.

O. I. Michael, K. H. Ishaya and T. G. Richard. Effects of Intra-Row Spacing of Pearl Millet (*Pennisetum glaucum* (L.) R. Br) and Cropping Systems on the Productivity of Soybean-Pearl Millet Intercropping System in a Southern Guinea Savanna Location, Nigeria. *World Scientific News 18 (2015) 35-48*.

O. N. Adeniyan, S. R. Akande, M. O. Balogun, and J. O. Saka. Evaluation of crop yield of African yam bean, maize and kenaf under intercropping systems. *American –Eurasian Journal of Agriculture and Environmental Science*. 2(1: 99-102.) 2015.

P. A. Nortes, M. M. Gonzalez-Real, G. Egea and A. Baille. Seasonal effects of deficit irrigation on leaf photosynthetic traits of fruiting and non-fruiting shoots in almond trees. *Tree Physiology*, *29*: 375 – 388, 2009.

P. J. Ghiberto, P. L. Libardi, A. S. Brito and P. C. Trivelin. Components of the water balance in soil with sugarcane crops. *Agricultural Water Management* 102 (2011) 1–7.

R. Mead and R. W. Willey.The concept of aland equivalent ratio and advantages. *Experimental Agriculture*.16: 217- 226, 1980.

S. Wojciech, W. Andrzej, S. Agnieszka, S. Cezary and L. Krzysztof. A TDR-Based soil moisture monitoring system with simultaneous measurement of soil temperature and electrical conductivity. *Sensors 12*: 13545-13566, 2012.

T. Feike, Q. Chen, J. Penning, S. Graeff-Hönninger, G. Zühlke and W. Claupein. How to overcome the slow death of intercropping in China? In: (Eds.): Darnhofer, I & M. Grötzer. Building Sustainable Rural Futures.

Proceedings of the 9th European IFSA Symposium. pp: 2149-2158 2010.

T. Weldeslassie, R. P. Tripathi and W. Ogbazghi. Optimizing tillage and irrigation requirements of sorghum in sorghum-pigeonpea intercrop in hamelmalo region of eritrea. *J. Geosci. & Environ. Prot.,* 4(4): 63, 2016.

V. Makinde, O. O. Adeleke, A. Eruola, Okeyode, I. C., Akinboro, F. G., O. O. Alatise, and O. F. Dada. Impact of Climate Change on Groundwater Resources in Odeda Local Government Area, Ogun State, Southwest Nigeria. *The African Review of Physics (2017)* ***12***: Special Issue on Applied Physics in Africa 0001.

W. Critchley and K. Siegert. A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production.17/1991*FAO Corporate Document Repository* 1991.

Y. Gao, A. Duan, X. Qiu, Z. Liu, J. Sun, J. Zhang and H. Wang. Distribution of roots and root length density in a maize/soybean strip intercropping system. *Agri. Water Manag.*, 98(1): 199-212 2010.

Y. Ren, J. Liu, Z. Wang and S. Zhang. Planting density and sowing proportions of maize–soybean intercrops affected competitive interactions and water-use efficiencies on the Loess Plateau, China. *Eur. J. Agron.,* 72: 70-79, 2016.

