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Modified Sloping Agricultural Land Technology Using *Pennisetum Purpureum* Hedgerows: Yield Gap Analysis In Cocoyam Production.

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Abstract

An on-farm study was conducted on a marginal, sloping, non-arable Class VI land at Umudike, Ikwuano Local Government Area (LGA), Abia State, using a modified sloping agricultural land technology (SALT), where cocoyam (cv NXs 001) was planted in alleys between *Pennisetum purpureum* hedgerows. A yield gap analysis was conducted to assess technological gap (TG), extension gap (EG) and technology index (TI). Results showed that the modified SALT demonstration resulted in 32.7 - 84.7 % increase in cocoyam yield over standard yield, represented by farmer's practice. The TG and EP ranged from 2.56 - 4.4, 2 and 1.46 - 3.32 t ha^{-1}, respectively, while TI ranged from 14.9 - 33.9 %. It was concluded that full technological gap existed in adoption of SALT in the area because the farmers were unaware of the technology. We, therefore, recommend awareness campaign, training of the farmers and participatory on-farm demonstrations of SALT, to enhance its adoption as an improved land management technology, to reduce yield gaps, and technology index and sustain cocoyam production on marginal sloping lands.

Keywords: Cocoyam, extension gap, SALT, technology gap and technology index.

Introduction: Soil erosion in agricultural systems is a contemporary issue. According to the Economics of Land Degradation (ELD) Initiative (2015), soil erosion accounts for 75 billion tons of soil loss annually from arable land, resulting in a median productivity loss of 0.3 % of crop yield annually (FAO 2015). Limited space for agricultural expansion has resulted in the expansion of agricultural cropland into marginal and highly erodible landscapes (Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M, 2011) and re-expansion into erodible agricultural landscapes that were previously taken out of production (Bigelow, D., Claassen, R., Hellerstein, D., Breneman, V., Williams, R., You, C, 2020), and the conversion of less productive land into cropland. Foley, *et al.* (2011), reported that between 1985 and 2005 there was a global net increase of 2.41 % of cropland area into these highly erodible landscapes. It is expected that within this context of agricultural land scarcity and the demand for agricultural products, estimated to double by 2050 (Foley, 2011), soil erosion, agricultural production, and sustainable land management will continue to be a critical global, regional and local issue throughout the 21st century.

Consequently, increasing demographic pressure, and the quest to obtain both food and money in the limited land resource of southeastern Nigeria, exert remarkable pressure on the environment. Increasing urban and rural development results in many infrastructural projects being sited on best agricultural lands. In Ikwuano LGA, the establishment of National Root Crops Research Institute (NRCRI) Umudike, which started as a Provincial Experimental Farm in January, 1923 and Michael Okpara University of Agriculture Umudike (MOUAU), formerly Federal University of Agriculture, Umudike, established in November 1992, further enhanced scarcity of good agricultural land in surrounding communities. Consequently, many rural farmers in Umudike, Umuariaga, Amaba communities, etc, are forced to cultivate marginal sloping landscapes, belonging to class VI land, classified as non-arable (Chukwu, G. O, Madu, T. U, Chinaka, E. C and Anyaegbunam, H. N, 2013). Unfortunately, research interest on marginal lands, has not received encouragement from research scientists, leading to a deficit in both knowledge production and knowledge dissemination and utilization of marginal lands, for sustainable arable crop production.

Sloping agricultural land technology (SALT) is a soil conservation agro-forestry system developed by the Mindano Baptist Rural Life Church, Philippines, to sustain crop and animal production on degraded uplands (Tacio, 1991). The technology is environmentally sound, technically simple and socially appropriate. Its success depends on the use of double hedgerows of N-fixing trees and shrubs like *Leucaena leucocephala,* spaced 4 - 6 m apart between alleys, to control erosion, and planted with arable and tree crops. The trees and shrubs are pruned when they are 1.5 - 2 m high to about 0.5 m. The prunings are spread on the alleys as mulch to improve soil fertility. Unfortunately, *Leucaena leucocephala,* on which SALT was developed, does not tolerate acid soils. Consequently, Chukwu, G. O, Okafor, C. N, and Odika, F. O. (2006) suggested that the tree shrubs could be replaced with *Pennisetum purpureum*, a multi-purpose grass in the area that is commonly planted and maintained within the homestead farms (Figure 1). The grass is used as a fodder for livestock, in erosion control, as vegetable (the succulent tillers), while the matured stems serve as fuel wood (FAO, 2013; Kabirizi, J., Muyekho, F, Mulaa, M, Msangi, R, Pallangyo, B, Kawube, G, Zziwa, E, Mugerwa, S, Ajanga, S, and Lukwago, G, 2015). Igwe *et al*., (2017) recommended adaptive soil erosion management techniques, based on indigenous knowledge of the affected people and landholders, as a pragmatic strategy to reduce the severity of soil erosion. We, therefore, modified the SALT technology by using *Pennisetum purpureum* instead of *Leucaena leucocephala* used when SALT was developed.

Figure 1. Shows *Pennisetum purpureum* commonly cultivated within homestead farms.

Technology Gap, Extension Gap and Technology Index: An investment in cocoyam research and production could significantly contribute to its large scale production, higher physical availability and removal of its orphan status. Like other crops grown in sub-Saharan Africa (SSA), the yield potential of cocoyam is seldom realized, mainly because of a lack of knowledge regarding sustainable soil management, pest and disease control and other yield limiting factors. This creates a technology gap, defined by Yadav, D. B, Kamboj, B. K. and Garg, R. B. (2004), as the difference between potential yield and demonstration yield. When technology gap is low or nil, it implies that there is no adoption of the technology, when it is medium, there is partial adoption while high technology gap indicates a state of full adoption of the technology (Singh, R., Dogra, R., Sarkar, A., Saxena, A and Singh, B, 2018). The yield gap of cocoyam is the difference between the yields farmers commonly obtain and what they might obtain under optimal management and the use of improved varieties, and it varies between 40 - 60 % (Benny, D., Benson, J., Ivekolia, M., Jmol, M K., and Ovah, R., 2022). Potential yield is the yield of a crop cultivar or variety when grown with water and nutrients that are sufficient enough not to limit crop growth and yield reducing factors (Benny *et al.*, 2022). The yield is considered to be the absolute maximum production of the crop possible in the given environment, which is attained by the best available methods and with the maximum inputs in trials on the experiment station in a given season. Potential yield is location specific and it varies with agro-climatic zones, which control conditions that influence crop growth and yield, such as such as climate, soil types, etc. In Asia, Lebot (2009) reported a potential yield of cocoyam in traditional cropping systems ranging between 60 - 110 t ha^{-1}. However, in Ghana, the average on-farm cocoyam yield is between 4.0 and 4.7 t ha^{-1} while the potential yield is estimated at 7.6 - 10 t ha^{-1} (Omenyo, E. L., Moses, E., Asumadu, H., Ankoma, A. A, 2014). In Nigeria, the productivity of cocoyam from 2015 - 2020 ranged from 3.75 - 4. 09 t ha^{-1} (FAOSTAT, 2022) with a mean of 3.92 t ha^{-1} giving a potential yield ranging from 6.53 - 9.38 t ha^{-1}. The extension gap is defined as the difference between demonstration yield and the yield of farmers' practice (Meena, M. S., Singh, S. K., Meena, H. N., Meena, R. K., and Choudhary, A, 2021). The present study was targeted to generate information on yield gap analysis of cocoyam cultivated in alleys of *Pennisetum purpureum* hedgerows on marginal sloping lands and how to reduce the extension gaps to encourage cocoyam production on such non-arable lands.

Materials and Methods: The Study Area: The study was conducted on a non-arable Class VI land at Umudike, Ikwuano Local Government Area (LGA) (5° 24′ - 5° 30′ N; 7° 32′ -7° 37′ E (Figure 2), Abia State, using a modified sloping agricultural land technology (SALT). The soils were Haplic Acrisols, typical of Ahiara series with an isohyperthermic temperature and udic moisture regimes (Chukwu *et al.,* 2013). The climate is typical of the humid tropics with distinct rainy and dry seasons. The mean annual minimum and maximum rainfall is 1,200 mm and 2,000 mm, spread between April and early November. The mean minimum and maximum temperatures were 22 and 30 °C, respectively. Relative humidity varied from 90.2 to 52.5 % (National Root Crops Research Institute {NRCRI}, 2022). The vegetation is typical of the degraded humid tropical rainforest zone of southeast agro-ecological zone of Nigeria.The original vegetation has been greatly altered by human activities due to demographic pressure, wild forestry fires and ecological problems of soil erosion, leading to dominance of secondary forests. Land use is predominantly arable crop production with some oil palm plantations. The predominant farming system is intercropping and agro-forestry system.

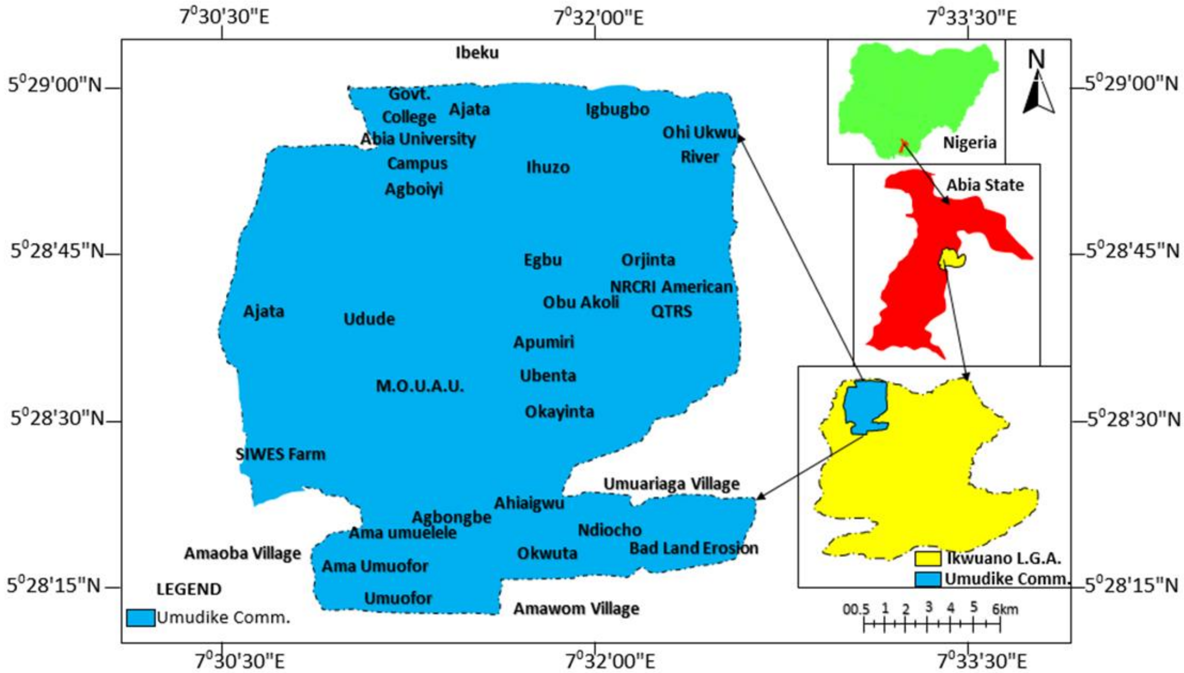

Figure 2. Map of Ikwuano showing study area (Umudike).

The study was a participatory on-farm research, involving scientists and farmers, using a randomized complete block design with three replications. Two farmers participated but three farms were used. One farmer had two farms. Each farm represented a replicate. Treatments comprised four (0, 2, 3 and 4 rows) hedgerows of local *P. purpureum*. Test crop was cocoyam landrace (NXs 001) of *Xanthosoma mafafa* species. Land preparation was based on the farmers' practice. It involved clearing, burning and mound making. However, the mounds were spaced 100 m x 100 m per plot of 5 m x 4 m. Pre-cropping composite soil samples were collected at 0 - 15 cm depth plot^{-1}. Undisturbed adjacent soil samples were collected at 0 - 10 cm depth using soil cores. Cocoyam planting materials were weighed plot^{-1} before planting in April, 2022. Two setts (cut cocoyam) of 50 g each, were planted at 0 -15 cm depth per mound to have a plant density of 40 plants plot^{-1}, equivalent to 20,000 plants ha^{-1}. *Pennisetum purpureem* shoots of 20 cm long were planted in slanting position at 20 cm x 20 cm inter and intra row spacing, to form 2, 3 and 4 rows hedgerows, with plant densities of 50, 75 and 100 plants hedgerow^{-1} for 2, 3 and 4 hedgerows, respectively. The control plot had no *Pennisetum purpureem* shoots. Poultry manure was applied after planting, at 4 t ha^{-1} by controlled broadcasting, in shallow groves made on the mounds. NPK fertilizer 15 15 15 was applied at six weeks after planting, immediately after weeding, at the rate of 400 kg ha^{-1} by side band method.

Yield Gap, Extension Gap and Technology Index: Yield of the SALT plots and potential yield of cocoyam were compared to estimate the yield gaps, which were further categorized into extension gap and technology index following the formulae used by Samui *et al*. (2000) and Yadv *et al*. (2004)), thus:

Technology gap = Pi (Potential yield) - Di (Demonstration yield) … (i)

Extension gap = Di (Demonstration Yield) - Fi (Farmers yield) … (ii)

$$\text{Technology index} = \frac{\text{Technology gap}}{\text{Potential yield}} \times \frac{100}{1} \quad \ldots \text{(iii)}$$

Adoption gap analysis was computed following the procedure of Singh *et al.* (2018**).** They categorized adoption gap into low or no technological category to represent a situation where there was full gap and no adoption of a technology. Medium category gap, explains a situation of partial but not full adoption of the technology while in a high category gap, all the gaps are filled and there is full adoption of the technology. Data generated were analysed using descriptive statistics.

Results and Discussion : Yield Gap and Technology Index: Table 1 shows cocoyam yield in relation to hedgerow, standard yield or farmer's yield practice, yield increase over standard practice, and potential yield. The table also shows that cocoyam yield increased directly with hedgerows, from the control (0 hedgerow) 5.78 t ha^{-1} to four rows hedgerows (7.24 t ha^{-1}). The yield gap is represented by increase in yield over standard or farmer's practice, by the potential yield (Benny *et al*., 2022). It was 5.88 t ha^{-1}, equivalent to 150 % increase. However, when the demonstrated modified SALT technology yields were compared with the standard yield, the differences ranged from 1.86 - 3.32 t ha^{-1}, equivalent to 32.7 - 84.7 %, respectively. It is envisaged that the wide gap in yield between standard yield and demonstrated SALT plots can be narrowed with the adoption of SALT as an improved land management technology.

Productivity of crops can be very low due to poor transfer of technology from the points of its development to the points of its utilization, and only a little new knowledge percolates to the farmers' fields. Hence, a vast gap will exit between knowledge production and knowledge utilization (Kumar, 2014).

Table 1. Comparing experimental yield with standard yield.

***Pennisetum* hedgerows**	**Cocoyam yield (t ha^{-1})**	**Standard yield practice (t ha^{-1})**	**Yield increase over standard yield (t ha^{-1})**	**Yield increase over standard yield (%)**	**Potential yield (t ha^{-1})**	**Yield gap (t ha^{-1})**	**(%)**
Control (0)	5.78	3.92	1.86	47.4	9.80	5.88	150
2	6.53	3.92	2.61	66.6	9.80	5.88	150
3	6.90	3.92	2.68	6.4	9.80	5.88	150
4	7.24	3.92	3.32	84.7	9.80	5.88	150
Mean	6.53	3.92	2.62	66.8	9.80	5.88	150

Technology Yield Gap and Extension Yield Gap: Table 2 shows technological yield gap and extension yield gap and technological index. Technology yield gap which represents the difference between SALT demonstration and potential yield, decreased from the control (4.02 t ha^{-1}) to four hedgerows (2.56 t ha^{-1}) with a mean of 3.17 t ha^{-1} and coefficient variation of 20.1 %. Technology index followed the same trend as technology yield gap, ranging from 14.9 % in the control to 33.9 % in four rows hedgerow. This gap indicated what might be achieved by adoption of SALT over the standard or farmer's practices. The extension yield gap ranged from 1.86 - 3.32 t ha^{-1} and represented the difference between yield from SALT plots and the standard yield (Meena *et al.*, 2021).

Table 2. Technology gap, extension gap and technological index.

***Pennisetum* hedgerows**	**Technology yield gap (t ha^{-1})**	**Extension yield gap (t ha^{-1})**	**Technology index (%)**
0	4.02	1.86	41.0
2	3.27	2.61	33.4
3	2.90	2.98	29.6
4	2.56	3.32	26.1
Mean	3.17	2.71	32.5
CV (%)	20.1	23.5	35.7
SD	0.64	0.64	9.45

Adoption gap: Table 3 revealed that none of the participant farmers ever practiced planting cocoyam in alleys of about 4 m apart on marginal sloping land. Similarly, neither of the farmers ever heard of SALT nor planted cocoyam in alleys between *Pennisetum purpureum* hedgerows on sloping lands. The results indicated nil extent of adoption of alleys of 4 m in cocoyam production and planting in alleys of *Pennisetum purpureum* of sloping land. The result corroborated the observation of Singh *et al*. (2018) who reported full technological gap in the adoption of high yielding varieties of chickpea and barley in district of Rajasthan.

Table 3. Adoption gap between modified SALT and farmer's practice in cocoyam production.

Technological intervention	**Farmer's Practice**	**Gap**

Planting cocoyam in alleys 4 m apart in sloping land	Planting cocoyam in sloping land without short alleys of 4 m apart.	0 (Full gap)
Planting cocoyam in alleys of *Pennisetum* hedgerows	Planting cocoyam in sloping land without *Pennisetum* hedgerows	0 (Full gap)

Conclusion and Recommendations: It was concluded that full technological gap existed in adoption of SALT in the area because the farmers were unaware of the technology. This could be attributed to a deficit in both knowledge production and knowledge dissemination and utilization of SALT among the farmers who cultivate marginal sloping lands in Ikwuano LGA, Abia State. Adoption gap between SALT and farmer's practices in cocoyam production can be narrowed by awareness campaign, training, participatory, on-farm demonstration of the technology, and motivation of the farmers to adopt the SALT technology.

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NB: Figure 1 does not show cocoyam. It shows *Pennisetum purpureum* commonly grown at homestead farms, which was used to form the hedgerows.