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Empirical analysis on effectiveness of soil and water conservation techniques for sustainable agriculture

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Abstract
Sustainable agricultural food production depends on the effective conservation techniques that improve and sustain adequate soil nutrients that support plant growth and productivity. Therefore, this study saddled empirically to analyse the effectiveness of soil and water conservation techniques for sustainable agriculture. Five sample areas were randomly selected in Girie LGA, of Adamawa State (Modirre, Jera-Bakari, Damare, Dakri and Jera-Bonyo) that adopted soil and water conservation techniques. Three indices were chosen as conservation index namely; soil fertility improvement techniques, soil erosion control techniques and water infiltration techniques respectively. Data collected were statistically analysed and compared using 4-poits Likert scaling test. The result revealed that organic manure was the most highly effective and adopted techniques towards soil fertility improvement in the area while construction of water ways and sand bags were found to be highly effective than the other techniques employed by the farmers which might be linked to the ease of construction. Similarly, for improving water infiltration techniques, tillage and vegetative barriers were more effective compared with the other techniques in the farm locations of the study area. The study revealed that the less effective techniques was as a result of inadequate skills and training among the farmers which consequently reducing their output per unit area. It is therefore recommends that intensive sensitization and training on the integrated modern conservation techniques should be employ to the peasant farmers in the area with the aim of realizing optimum food production that will sustain the growing population in the area from starvation.

Keywords: agriculture, conservation, soil, sustainable, techniques and water

1. Introduction

Water, land and other natural resources are the basis for humans to generate income and produce consumable goods and services [1]. Nevertheless, their availability is limited in space and time, and this influences livelihoods, especially of the rural poor who directly depend on them [2].Thus, these resources are not static in nature therefore are prone to deprivation over time. Reference [3] explained that land degradation by accelerated soil erosion remains one of the biggest environmental problems worldwide, threatening both developed and developing countries. Similarly, Soil degradation problems are a preoccupation of countries all over the world [4, 5]. Research results confirmed that soil nutrient depletion caused by erosion is the major cause for decline of agricultural production [6, 7]. According to Reference [8] the crop yield reduction due to soil erosion by the year 2020 is estimated to reach 16.5 % for the African continent and about 14.5 % for sub-Saharan Africa. Generally, some researchers have argued that a significant area of land now being cultivated may be rendered economically unproductive if erosion continues unabated [9; 10; 11; 12]. Consequently, the protection of the soil resources for the future generations is their main challenge [13; 14].

In West Africa, soil erosion gulps about 10-21 tons of top soils per ha on nearly gentle slopes of 0.4 - 0.8% and up to 30 - 35 tons on 1-2% slopes [15]. In Nigeria, it has been reported that over 25 million tons of valuable top soils are lost annually to erosion [16]. Farmers' decisions to conserve natural resources in general, and soil and water in particular are largely determined by their knowledge of the problems and perceived benefits of conservation [17]. Similarly, agricultural land in Nigeria is often results in the degradation of natural soil fertility and reduced productivity [18]. In Adamawa state, soil degradation is quite glaring and felt through on-field observation conducted by the authors these factors includes development of erosions on farmlands (sheet to gully), deforestation practices which gradually manifest to desert encroachment, overgrazing effects on soil structure, industrialization and urbanization of buildings on fertile agricultural lands due to increase in population rate [19].

In view of this, the severe degradation of the land resources has necessitated several soil and water conservation techniques by the farmers to reverse the trend. The situation in Sub-Saharan Africa SSA calls for more sustainable farming systems as a means of restoring the productivity of eroded soils in the region. For some time now, the challenge has been on how to accommodate better conservation practices to reduce the problem of soil erosion in SSA for improved productivity and people's livelihood [20]. Hence, conservation farming techniques such as hillside terraces, stone-lines and bunds, trash-lines, sand-bag lines, earth-contour bunds, crop rotation, rice-bran mulch, vegetation-barriers and organic manuring utilize natural ecological processes to conserve moisture, improve soil structure, curtail soil erosion and enhance soil fertility [21]. Thus, intensification of agriculture has also led to the degradation and exhaustion of soil and land [22].

Reference [23] explained that over the centuries, intensive systems of soil and water conservation have been developed

and practiced by local farmers settling around the adjacent plains of the Mandara Mountains of Northern Nigeria. Similarly, In recent years, intensive system of cultural soil conservation techniques have been developed by local farmers most especially those settling around the floodplains in the North central region of Nigeria, which improved their production and sustained the inherent fertility of the soil [24].

In Adamawa State, farmers were well known of the devastating effects of soil degradation on yield reduction and conversely the impact of conservation techniques towards yield improvement in the region. As a consequence, small scale farmers engaged exhaustively in restoring the soil fertility decline on their farms through adoption of some conservation techniques which includes hillside terracing, organic manure, shifting cultivation, crop rotation, earth contouring, sand bag barriers, stone bunds, vegetative barriers, mulching, cover cropping, mixed cropping and bush fallowing in the North-eastern region of the Nigeria [25].

Geire LGA of Adamawa state is one of the areas where farming activities are intensively carried out throughout the year (both irrigation and rainy farming). Consequently, the intensive farming activities in the area has led to utilization of the marginal land by the farmers which gradually exposed the soil to erosion, poor structure, high infiltration rate which resulted to loss of inherent fertility and subsequently reduced the size of the farmlands thereby diminished the annual crop yield in the area. Thus, intensification of agriculture has also led to the degradation and exhaustion of soil and land. However, the farmers embarked on some soil conservation techniques on their farms through adoption of contour bands, sands bags, terracing, mulching, cover cropping, organic manure among others with the aim of improving and sustaining the soil and water indices for profitable production. However, there is still a paucity of knowledge between the recognition of indigenous SWC practices and their effective use. Moreover, indigenous technologies have remained traditional for decades with limited scientific interventions for improvements to sustain crop production. Therefore, assessment of agronomic practices of conserving and preventing soil and water from degradation in the study is highly imperative and timely to address the menace for maximum food production to meet up the growing population. To this ardent need, this study aimed at analyzing the effectiveness of agronomic soil and water conservation techniques in Girei LGA, of Adamawa state, Nigeria.

2. Study Area

Girei Local Government Area of Adamawa State is located between Latitude 9^0 11 and 9^0 39 North and Longitude 12^0 11 and 12^o 49 East of the equator [26]. The area has land mass of about 2186sqkm and has a population of 129,995 people [27]. It shares common boundaries with Song Local Government to the north, Fufore Local Government to the east, and Yola North, Demsa and Yola South Local Governments to the south. The area has a tropical climate marked by distinct rainy and dry seasons. The average rainfall is about 792mm [26]. The vegetation of the area is Sudan Savannah characterized by light forest in the area. The main occupation of the people in the area is farming and animal rearing. There are also civil servants and small scale traders. The major ethnic groups found in the area are Fulani, Hausa and Bata. Its closeness to the state capital provides advantage of market for agricultural produce. The major crops cultivated in the area are sorghum, maize, cowpea, rice and groundnut.

3. Materials and Method

Multi-stage random sampling technique was used in selecting respondents for the study. First stage sampling involved the random selection of five (5) out of the ten (10) wards in the Local Government Area. From each of the selected wards, two (2) villages were randomly selected. A total number of 30 questionnaires were administered to each of the sampled areas making a total of one hundred and fifty (150) questionnaires. Field data were purposively sampled through on-farm oral using structured questionnaires among farmer population practicing local conservation methods in the selected five sites of the study area. Other information on the subject was sourced from existing relevant literatures.

4. Data Analysis

The effectiveness of the techniques adopted by the small scale farmers in the study area was analyzed using a 4-point Likert scaling test by [28] expressed as:

$$\mathbf{ETV} = \frac{\mathbf{\Sigma\ Scale\text{-}grade \times Corresponding\ Responses}}{\mathbf{Total\ Number\ of\ Questionnaires}} \quad \mathbf{\ldots\ldots\ldots Eq\ (1)}$$

Where: **ETV**= Effectiveness Test Value and **Σ**=summation.

The scale-grades were; 1=Not effective (NE); 2=less effective (LE); 3=moderately effective (ME), 4= highly effective (HE). The Effectiveness Test Value (ETV) of < 2.0 was taken as the benchmark, below it any of the conservation techniques was considered as not effective (NE) within a given effective period (EP)

5. Result and Discussion

5.1 The Effectiveness of Soil fertility Improvement.

The data on the soil fertility improvement effectiveness practices were presented on table 1 below where the following discussions were considered.

Table 1: Effectiveness of Soil Fertility Improvement

Farm locations	Moddire,			Jera-Bakari			Damare.			Dakri			Jera-Bonyo,		
C.T	ETV	ER	EP	ETV	ER	EP	ETV	ER	EP	ETV	ER	EP	ETV	ER	EP
Cover cropping	3.0	ME	4	3.8	HE	7	1.7	NE	-	3.3	ME	3	3.95	ME	9
Organic manure	3.2	ME	5	3.67	HE	6	3	ME	4	3.80	HE	7	3.91	HE	5
Recycling of crop residues	1.3	NE	-	3.1	ME	3	3.3	ME	3	1.0	NE	-	2.1	LE	-
Crop rotation	1.8	NE	-	3.4	ME	4.0	3.73	HE	6	1.5	NE	-	3.2	ME	4
Agroforestry	2.0	LE	-	3.1	ME	5	1.7	NE	-	3.4	ME	2	1.4	NE	-

Source: Field Survey, 2019 C.T; Conservation Techniques

5.1.1 Cover cropping

Cover crops most especially the legumes are very important practices in restoring the nutrients loses in the soil. This is because of their ability to fix large amounts of biological N. From the result obtained in table 1 above it was investigated that the use of cover cropping as soil fertility improvement was rated highly effective in Jera-Bonyo and Jera-Bakari (3.95 and 3.8) within the period of 7-9 years practices while in Moddirie and Dakri was moderately effective within an adopted period of 3-4 years respectively. This result concords with the finding of [29] on an Alfison in Nigeria which showed that cover crops can be used to improve SOM, total N, CEC, infiltration rate and water retention capacity. Conversely, the practice was less effective (1.7) in Damare area. Similar result was reported by [30], in areas of Digil, Njairi and Lamorde of Mubi region it was revealed that use of cover crops was effective and its efficacy was significant most especially in maintaining water infiltration in the area. Basically, cover crops provides a protective cover against soil erosion and also helps in reducing the rate of soil moisture loss through reduced evaporation from soil surfaces [31].

5.1.2 Organic manure

Organic manure comprises of wastes from both plants and animals, whether composted or fresh, but intended for use as a fertilizer which is often brought into the field to improve the soil physical and chemical properties [32]. The extent to which manure can enhance soil nutrient content and soil physical properties depends on the source and quantity of organic matter added. The main source of organic manure used in the study area was cowdung manure (see fig 1 below) due to the presence of pastoral farmers in most of the villages. It was investigated from this study that the application of organic manure in Jera-Bakari Dakri and Jera-Bonyo (3.67, 3.8 and 3.91) were found to be highly effective within an effective period of 5-7 years as shown in table 1 above. This is because the cowdung manure contains a significant quantity of nitrogen which releases slowly through mineralization process. According Ref [33] observed that animal manure is a source of all plant nutrients including nitrogen, calcium, magnesium, potassium and sodium. Thus, Organic manures check erosion, leaching of nutrients, evaporation losses and remain longer in soil and releases nutrients slowly making it available to plants [34; 35; 36; 37]. However, the organic manure most especially cowdung manure which is the most adopted in the area was not adequate to applied on all the farms coupled with an intensive work associated with its application. Reference [31] reported that organic manure incorporation is an intensive practice that is commonly done under continuous cultivation on farmlands around homes and market places. Generally, in Sub-Saharan Africa, it has been reported that the majority of soil fertility indicators were significantly higher in soils that received organic manure than in soils that did not [38].

Fig 1: Shows the application of organic manure on farmlands

5.1.3 Recycling of crop residues

Crop residues can be recycled either by composting, or by much or direct incorporation in the soil to improve the fertility status of the soil for sustainable food production (see fig 2 below). Thus, that the role of crop residues in maintaining SOM under tropical and sub-tropical soil conditions needs no emphasis [39]. From the result obtained (table 1) it was observed that only areas of Damare and Jera-Bakari crop residues recycling techniques was moderately effective within a period of 3 years (rated as 3.3 and 3.1) on their farmlands while the remaining areas the practice was less or not effective respectively. The less adoption of this technique may be linked to over utilization of the crop residues by the farmers in feeding their animals or they prefer to sell them to the pastoral farmers. Reference [25], reported recently in Yola South LGA where crop residues recycling techniques received 19 % of the farmers adopted because the amount of crop residues after harvest are extensively utilized for many purposes such as fencing, housing, fodder (hay), and fueling (fire wood) at the expense of soil surface degradation in the area. Therefore, farmers are advised to conserve these manure resources and suggest proper methods of utilizing crop residues [39].

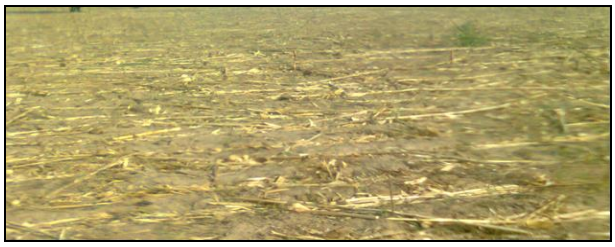

Fig 2: Shows the incorporation of maize residues on farmlands

5.1.4 Crop rotation

Crop rotation is also a farming system that improves soil nutrient accumulation [32]. Crop rotation involves growing of different crops on the same piece of land over successive years in a definite sequence or cycles with the aim of restoring the nutrient decline. For crop rotation techniques

result presented on table 1 shows that Damare farm location was rated highly effective rated as 3.73 within effective period of 6 years while Jera-Banyo and Jera-Bakari were considered as moderately effective (3.2 and 3.4). Conversely, in Dakri and Moddire areas was less effective. This might be linked to inadequate knowledge by the majority of the farmers on the techniques towards sustaining and improving the nutrients status of the soil. While some farmers are more concern on the cultivation of maize as the major crop than any other crop that will favour rotation.

5.1.5 Agroforestry

Agroforestry is a technique of land use in which trees are combined with crops or pastures or both [40]. The aim of this farming system is to maintain higher productivity over a long period of time. It was investigated that only Dakri and Jera-Bakari that agroforestry cultivation was glared to be moderately effective (3.4 and 3.1) within a period 2-3 years among the farmers. Thus, agroforestry is an important component of farming systems in the humid tropics, not only in terms of nutrient recycling and soil conservation, but also in supplying food and fire woods to farmers and ensuring the overall sustainability of crop production [41]. Conversely, farmers in most of the study areas were not adopting the techniques due to excessive deforestation in the area in search of agricultural land and for economic purposes. Hence, deforestation and conversion of marginal land to agriculture has been followed by severe soil erosion that has caused crop production losses, which in turn result in economic losses [42]. This practice is shown in figure 3 below.

Fig 3: Shows the of agroforestry practice in the study area.

5.2 The effectiveness of soil erosion control techniques.

The data on the soil erosion control techniques effectiveness Practices were presented on table 2 above where the following discussions were considered.

Table 2: Effectiveness of Soil Erosion Control Techniques

Farm locations	Moddire,			Jera-Bakari			Damare.			Dakri			Jera-Bonyo,		
C.T	ETV	ER	EP	ETV	ER	EP	ETV	ER	EP	ETV	ER	EP	ETV	ER	EP
Vegetaative barriers	1.1	NE	-	3.0	ME	4	3.7	HE	5	1.3	NE	-	3.88	HE	6
Contour bunds	1.7	NE	-	3.3	ME	2	1.3	NE	-	3.0	ME	3	1.4	NE	-
Water ways	3.89	HE	6	3.95	HE	8	3.0	ME	3	3.77	HE	7	3.2	ME	5
Bench /Hill terracing	3.2	ME	5	2.4	LE	-	2.3	LE	-	3.95	HE	7	3.2	ME	4
Sand bags	3.90	HE	7	2.4	LE	-	3.8	HE	5	3.93	HE	7	2.33	LE	-

Source: Field Survey, 2019 **C.T;** Conservation Techniques

5.2.1 Vegetative barriers.

Vegetative barriers encompasses plantation of grasses and shrubs side by side the erosion banks with the aim of minimizing the vulnerability extent of the erosion. Result on table 2 above revealed that in Modirre and Dakri areas the adoption of vegetative barriers as techniques of erosion control was not effective (1.1 and 1.3). However, the techniques appeared to be moderately effective in Jera-Bakari while Damare and Jera-Bonyo was highly effective with a rated value of 3.7and 3.88 within an effective period of 5-6 years respectively. Similar findings was reported by Ref. [43] who found that the barriers could be effective in controlling soil erosion on relatively gentle slopes of up to about 14%. In addition, Ref. [44] also reported that the vegetative barrier reduces soil erosion rates.

5.2.2 Contour bunds

Contour bunds or contour banks are small bunds usually of 20 - 45 cm high and built along a contour with the aim of catching and retaining the runoff water to infiltrate slowly into the soil thereby reducing the erosivity index and improving the erodibility index of soil. Contour bunds are the uncommonly adopted techniques geared towards erosion control in the study area. This might be attributed to labour intensiveness that is associated with the techniques coupled with inadequate information on its effectiveness. It was only in Dakri and Jera-Bakari (3.0 and 3.3) where the techniques assessed to be moderately effective techniques within a period of 2-3 years as depicted on table 2 above. Reference [30] previously reported that, contour bunds practice was found to be less adopted by the farmers in Mubi area towards maintaining soil erosion and water infiltration.

5.2.3 Water ways.

Construction of water ways was the common most adopted techniques by the peasant farmers in the area where highly effectiveness of the techniques was observed in Dakri, modirre and Jera-Bakari with rated values of 3.77, 3.89 and 3.95 with effective periods of 6-9 years respectively. This shows that most farmer prefer water ways techniques for the

control of erosion in their farmlands, which may not be unconnected with its ease of construction as depicted in figure 4 below. The result in Jera-Bonyo and Damare areas were rated moderately effective on controlling the erosion for sustainable food production as depicted on table 2 above. According to Reference [24], in overall, most farmers (38%) adopted water ways erosion control method in Giwa area of Kaduna State, Nigeria

Fig 4: Shows the adoption of ways towards controlling the soil ersiion on farmlands

5.2.4 Bench / Hillside Terraces

A bench terrace is a piece of sloped plane that has been cut into a series of successively receding flat surfaces or platforms, which resemble steps, for the purposes of more effective farming. It is designed as a method of soil conservation to slow or prevent the rapid surface runoff of rainwater and irrigation [45]. From this study it was discovered that the adoption of the techniques was moderately effective among the small scale farmers in the areas of Moddirre and Jera-Bonyo within a period of 4-5 years (see fig 5) while in Dakri area it appeared highly effective with a rated value of 3.95 respectively (table 2). This result agreed with the findings of [46] who reported that in Gikuuri, Embu district in the central highlands of Kenya *Fanya Juu* terraces are found to effectively control soil loss by 57 % and bench terraces by 44 % as compared with cropped land without soil conservation measures. Similarly, Reference [30], concluded that hillside-terraces proved glaring effectiveness in conserving soils of Duda, Hurida, Gella and Yelwa within the period of 10 to 14 year. Conversely, less effectiveness of the techniques was recorded in Jera-Bakari and Damare areas. This might be connected to absence or few hills in most farmlands of the villages with gentle slopes. Generally, Reference [47] stated that Bench/ hills terraces are effective soil conservation measures used on slope lands for crop production.

Fig 5: Shows the terracing techniques on farmland in the area.

5.2.5 Sand Bags.

The techniques involves filling of sands with some gravels and placed at the prevailing erosion site as described in figure 6 below. This techniques was highly effective in Damare, Moddire and Dakri areas (3.8, 3.90 and 3.93) within 5-7 years effectiveness period and moderately effective only in Damare while Jera-Bakari and Jera-Bonyo areas were rated less effective (table 2). This technique was among the oldest of which the farmers adopted in the area. Thus, it is easier to make and require less technical experience. In similar findings of Ref [24]. reported that a large proportion of the farmers (47%) practiced sand bags as a means of controling eerosion, infiltration rate and reducing run-off of water on farmlands in Giwa LGA of Kaduna State, Nigeria.

Fig 6: Shows the adoption of sand bags techniques on controlling soil erosion

5.3 The Effectiveness of Soil Infiltration Techniques.

The data on the soil infiltration techniques effectiveness practices were presented on table 3 below where the following discussions were considered.

Table 3: Effectiveness of Water Infiltration Techniques

Farm locations	Moddire,			Jera-Bakari			Damare.			Dakri			Jera-Bonyo,		
Conservation Techniques	**ETV**	**ER**	**EP**	**ETV**	**ER**	**EP**	**ETV**	**ER**	**EP**	**ETV**	**ER**	**EP**	**ETV**	**ER**	**EP**
Tillage	3.86	HE	7	3.3	ME	5	3.7	HE	7	3.0	ME	4	3.5	HE	4
Rice-bran mulching	2.2	LE	2	3.3	ME	4	3	ME	5	3.4	ME	6	1.8	NE	-
Contour bunds	2.0	LE	3	3.71	HE	6	2.3	LE	1	3.86	HE	5	1.5	NE	-
Vegetative covers	3.1	ME	5	3.88	HE	6	2	LE	3	3.5	HE	8	3.7	HE	6
Sand bags.	3.78	HE	6	1.0	NE	-	3.3	ME	5	3.4	ME	3	3.88	HE	5

Source: Field Survey, 2019 C.T; Conservation Techniques

5.3.1 Tillage techniques

Reference [48], defined tillage as physical, chemical, or biological soil manipulation to optimize conditions for seed germination, emergence and seedling establishment Soil compaction induces changes in soil fertility status, and the changes may be manifested in good or poor performance of crops. The result on table 3 revealed that tillage is the most employed techniques in all the study areas as techniques of improving infiltration rate. It was investigated to be highly effective in Damare, Jera-Bonyo and Moddire farm locations with a rated value of 3.5, 3.7 and 3.86 within 4-7 years effectiveness periods respectively (see fig 7). This is because tillage practices improve the soil structure, reduce the soil compactibility thereby allowing root penetration and mining up the nutrients to the surface layers. Similarly, Ref. [48], also found that the organic carbon of tropical soils decreased less when no tillage practices were used than when the soils were ploughed. Nevertheless, deep and excess tillage is not advisable in agriculture because it losses the soil surface, and destroys soil aggregates, leading to soil crusting eventually predispose the soil to erosion especially in Savanna soils. In proving this, study by Ref. [49] in Nigeria showed that runoff was highest on bare fallow plowed plots than on plots under traditional mounds and lowest on untilled plots. Except for the no tillage system, erosion was reduced on the plots which were cultivated across slopes. Therefore, tillage practices should be adopted with caution considering the soil properties which might have direct effect on them.

Fig 7: Shows tillage system used to loosen or create favorable soil conditions for plant growth

5.3.2 Rice-bran mulching

Mulching involves the use of organic or artificial materials to cover the soil, when crops have been planted. This technique was not effective in Jera-Bonyo farm location and less effective in Moderre while the moderate effectiveness was recorded in Damare, Jera-Bakari, and Dakri areas with corresponding rated values of 3.0, 3.3 and 3.4 as depicted in table 3 above. According to Reference [50] who reported that *Tithonia diversifolia* mulching was effective in reducing runoff, soil and nutrient losses at the same time is a good green manure. Basically, the main advantages of mulching practices are reduction in the rate of soil water evaporation, reduced impact of solar energy (temperature moderation), smothers weed growth and competition with crops, and as well as playing an important role in soil conservation and maintenance of soil fertility [31, 51]. The efficacy of rice bran stubble mulching in soil conservation involves protecting both sheet and gully erosion, trapped soil/sediment, improving soil moisture, reducing the rate of soil water evaporation and increasing soil nutrient thereby sustaining the inherent fertility of the soil for optimum food production [52].

5.3.3 Contour bunds.

Soil contour bunds are ridges and ditches made of soil, dug across the slope along the contour. They are used to prevent run-off and to conserve soil and water [53]. Among the water infiltration techniques the use of contour bunds was not effective in Jera-Bonnyo area while the less effectiveness was observed at Moddirre and Damare farm locations except in Jera-Bakari and Dakri where it revealed highly effective within a period of 6-5 years effective period as portrayed in table 3 accordingly. Even though, Farmers can build contour bunds themselves without external assistance [54]. But still in the area the techniques appeared less in adoption among the farmers which might be connected to lack of technical support and training on the application. Thus, for greater effectiveness, contour banks are sometimes combined with contour cultivation, the latter helps to reduce the quantity of runoff [32]. In addition, contour bunds are appropriate for fields with permeable soils of gentle to moderate slopes [55]. Thus, they reduce soil erosion and increase the amount of water the soil can hold. The technique is shown in figure 8 below.

Figure 8. Shows the contour bunds/ ridging techniques on improving rate of soil infiltration on farms

5.3.4 Vegetative covers.

In terms of improving water infiltration rate the use of vegetative barriers was the second most adopted techniques in the area. In Dakri, Jera-Bonyo and Jera-Bakari areas the practice was found to be highly effective (3.5, 3.7 and 3.88) within the effective period of 6-8 years. While Damare area was moderately effective with rated value of 3.1 and the less effectiveness was recorded in Damare farmland locations. Conversely, in Giwa area of Kaduna Sate it was reported that use of vegetative covers was not effective and less adopted by majority of the farmers as means of water infiltration techniques [34].

5.3.5 Sand bags

Sand bags techniques were highly effective in Modirrre and Jera-Bonyo with rated values of 3.78 and 3.88 within 5-6 years conservation effective period with aim of sustainable food production for the growing population. This result concord with the recent findings of Ref. [25] sand bags revealed to had mostly adopted physical soil and water conservation techniques of about 30 % in Wuro-chekke farm location of Yola South LGA, Adamawa Sate Nigeria of the respondents this practiced was adopted to reduce the rate of water run-off out of the farms. Moreover, in Damare and Dakri the techniques was moderately effective (3.3 and 3.4) while the exceptionality was found in Jera-Bakari where it was not effective.

6. Conclusion

In an effort to reduce degradation and restore the degraded lands, soil and water conservation (SWC) measures have played a considerable role in Nigeria particularly in some areas in the northern part of the country. However, the adoption of various SWC techniques by the small scale farmers will not provide optimum productivity without identifying the level of effectiveness of each adopted technique. Because is not all the techniques are effective on their farmlands. To achieve this, the empirical analysis on effectiveness of soil and water conservation techniques for sustainable agriculture was conducted in the study area. The study provided tangible evidence on the effectiveness of SWC, on the three major indispensable techniques of conservation namely, soil fertility improvement, soil erosion and infiltration techniques respectively. The result revealed that most of the farmers in the area are employing various SWC techniques towards improving soil nutrients and preventing it from degradation towards realizing sustainable food production. The most effective techniques towards soil fertility improvement was revealed to be application of organic manure which has long effects on soil system while construction of water ways and sand bags were the most effective on erosion control and for water infiltration rate the adoption of tillage techniques and vegetative barriers were more effective than the other techniques.

Recommendations

The effectiveness of SWC practices towards improving the soil quality and thereby sustainable agricultural productivity cannot be overemphasized. Based on the findings obtained from this research, the following recommendations are made;

1. The farmers are advised to adopt combine or multiple techniques as integrated strategies depending on slope level and erosivity level of the farm locations for optimum sustainability of soil resources.
2. To enhance the adoption of SWC techniques, the study recommends farmers sensitization and technical support for the efficient use of SWC techniques.
3. Intensive training should be giving to the farmers by the extension workers and soil scientist on the new effective innovations of conservation practices that will suit their cultural operation and soil characteristics.
4. There is a need to conduct further research on analyzing the cost effectiveness of recommended SWC techniques on soil fertility and yield of various food crops production.

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