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ANALYSIS OF ADOPTION OF REGENERATIVE AGRICULTURAL TECHNOLOGIES AMONG FARMERS IN BENUE STATE, NIGERIA

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Abstract

The study analysed adoption of regenerative agricultural technologies among rural farmers in Benue State, Nigeria. A sample size if 185 respondents was selected for the study. Data were collected using a structured questionnaire, data collected were analysed using both descriptive and inferential statistics. The findings revealed that majority (71.4%)s of the respondents were males, 39.5% were age between 31 −40years, 80%were married and 54.6% obtained secondary education. About 76% of the respondents had farm size of at least 4 hectares and 54.6% had household size of between 1−10 members. About 40% of the respondents had annual income between ₦200,000 −₦500,000, 40.5% had farming experience of 10 years, and 94.1% were not members of any association. In the Eastern zone, crop rotation (96.7%) and zero/minimum tillage (93.4%) among others were adopted. Zero/minimum tillage (97.5%) and planting of cover crops (90.1%) were adopted in the Northern zone and in the central zone use of herbicides only when necessary (86.0%) and bush fallowing (83.7%) were adopted. Education (4.863) and farming experience (8.021) have significant effect on adoption of regenerative agricultural technologies at 5% and 1% level of probability, respectively.The study concluded that regenerative agricultural technologies were adopted among farmers across the three agro-ecological zones in the study area.

Keywords: *Adoption, Regenerative, Agriculture, Technologies, Farmers*

1.0 Introduction

Agriculture is a net producer of greenhouse gas emissions both directly through conventional farming practices that deplete soil carbon stocks, while emitting nitrous oxide and indirectly through land-use change (Lal *et al*., 2004a). Since the dawn of

farming, most agricultural soils have lost from 30 to 75 percent of their original soil organic carbon (Lal *et al*., 2007). Adoption of regenerative agricultural technologies have the potential to both reduce net greenhouse gas emissions and act as a direct carbon dioxide sink (Lal *et al*., 2004b; Smith *et al*., 2008). Moving agriculture from a source of carbon pollution to a potential carbon sink is in everyone's best interest. Agriculture that sequesters carbon is also agriculture that addresses planetary water crisis, extreme poverty and food insecurity, while protecting and enhancing the environment now and for future generations [United Nations Conference on Trade and Development (UNCTAD, 2013)]. Regenerative agriculture is the key to this shift and it is the climate change solution ready for widespread adoption.

Regenerative systems can provide the nitrogen needed for soil carbon sequestration by including nitrogen-fixing legumes and/or trees in the farm plan, making synthetic nitrogen fertilization unnecessary. Legumes planted as cover crops, forage or cash crops in regenerative systems work with rhizobium, a soil bacterium to fix atmospheric nitrogen which feeds plants and microorganisms. This nitrogen fixing relationship supports carbon storage, while reducing nitrogen losses and environmental damage that comes with synthetic fertilization (Jensen *et al*., 2012).

Regenerative agriculture is defined as farming technologies that replenish the functional capacities of the land. It restores the complex soil ecosystem and improves its ability to produce food. In the process, it offers a suite of benefits including reduced input costs, stabilized or increased crop yields, carbon sequestration, soil organic matter increase, pollution reduction, and food security. These benefits can make farming and ranching more profitable (Giller *et al*., 2021). Regenerative agriculture revitalizes land, is a system approach where farmers work with nature, not against it. It is a biological model based on principles of ecology. With the farmer's help, farm and rangeland can lock carbon underground, thereby restoring degraded soils, addressing food insecurity and mitigating the impacts of the climate crisis on food production. It also enables a quick drawdown of atmospheric carbon dioxide (Lal, 2004a). Solving the long-term climate problem means getting to a zero carbon economy devoid of fossil fuels. It is widely acknowledged that we are not going to arrive at a new low-carbon economy any time soon; the technologies, markets, political and social structures needed to shift the world's economies are not materializing quickly enough [United Nations Environment

Programme (UNEP, 2013)].

Agriculture as practiced across the world is part of solution for food production on one hand and is part of the problem on another hand as it is a net producer of greenhouse gas emissions both directly through conventional industrial farming practices, and indirectly through land-use change and the greater food system (Khan *et al.,* 2007). Agricultural production accounts for around 10 percent of annual emissions 6.2 gigatonnes of carbon dioxide equivalent (Lal *et al*., 2007). The food system at large, including fertilizer and pesticide manufacturing, processing, transportation, refrigeration and waste disposal, accounts for 30 percent or more of total annual emissions, (Lal *et al*., 2007).

The globally connected food and farming system succeeded in producing an enormous oversupply of foodstuffs unimaginable to our great-grandparents because they focused on calorie yields. It is not a surprise to anyone paying attention that this carbohydrate abundance comes at a high price: widespread degradation of land, water and air; biodiversity and ecosystem losses; continued hunger and nutritional deficiencies paired with a rapid rise in obesity and related diseases; and destruction of rural communities and farmers livelihoods around the world [International Panel of Experts on Sustainable (IPES, 2016)]. A decade ago, it was observed that the world needed to limit greenhouse gas emissions to 44 gigatons of carbon dioxide equivalent by 2020 (Lal, 2020).

Globally, soil organic matter contains three to four times as much carbon as either the atmosphere or terrestrial vegetation (Lal, 2020; Schmidt *et al*., 2011). Even small changes in soil carbon can lead to large changes in the atmospheric concentration of carbon dioxide, either for better or for worse (Lal, 2020). In order to close the emissions gap, land use must be converted from being a net source of emissions to a net sink. On this basis, regenerative agriculture and its technologies are the outstanding solution to close this emissions gap (UNEP, 2019).

In reduction of agrochemical fertilizer, nitrogen loss is also reduced. Less than half of the 109 million metric tonns of fossil-fuel-based nitrogen fertilizer used each year is assimilated into crops, the rest is either leached into groundwater creating marine dead zones or lost as potent nitrous oxide greenhouse gas emissions (Peoples *et al*., 2019). In addition, the industrial production of nitrogen fertilizer directly contributes two to three

percent of all global greenhouse gas emissions, and the acidification of agricultural soils due to synthetic nitrogen also contributes another two to three percent of emissions (Zamanian *et al*., 2018). It has become necessary to look out for adoption of regenerative agricultural technologies.

2.0 Objectives of the study

The broad objective of this study was to analyze adoption of regenerative agricultural technologies among farmers in Benue State, Nigeria. The specific objectives were to:

i. describe the socio-economic characteristics of the respondents;
ii. identify regenerative agricultural technologies adopted across the three agro-ecological zones by the respondents;

Statement of Hypotheses

i. Socio-economic characteristics of the respondents have no significant effect on adoption of regenerative agricultural technologies.

3.0 Methodology

The study was conducted in Benue State, Nigeria. The State drives its name from River Benue, one of the longest rivers in the country. Benue State is one of the 36 States in Nigeria. The State lies between longitudes $6^0 35'$ E and $8^0 10'$ E of the Greenwich Meridian and latitudes $6^0 30'$ N and $8^0 10'$ N of the equator at an elevation of 97m above sea level in southern guinea Savannah agro ecological zone [National Population Census (NPC, 2006)]. The State has 23 Local Government Areas (LGAs), 423 council wards and three agro-ecological zones (North-East, North-West and Southern zones) with administrative headquarters at Makurdi. The State covers landmass of 32,518 Km^2 with a projected population of 6,286,170 people (World Bank, 2022). It lies in the North-Central region of Nigeria and shares boundaries with five other states; Nassarawa to the North, Taraba to the east, Cross-River to the south, Enugu to the Southeast and Kogi State to the West. The State also shares a common boundary with the Republic of Cameroon in the south-east [Benue State Agricultural Rural Development Authority (BNARDA, 2010)].

The State experiences tropical climate with two distinct seasons, the rainy season and dry seasons, The State is made up of several ethnic groups including Tiv, Idoma and Igede. Others are Jukun, Etulo, Abakpa, Akyeya, Hausa, Igbo and Igala, among others. The State is estimated to have 75% of her population engaged in subsistence farming that

is purely rainfed (BNARDA, 2010). The state is a major producer of food and cash crops such as cassava, yams, rice, groundnut, melon and maize. Others includes sweet potato, millet, sorghum, sesame and wide range of others like soya bean, sugarcane, oil palm, mango, tomato, citrus and banana (BNARDA, 2010). Benue State is blessed with abundant mineral resources. Limestone at Tse-Kucha near Gboko and kaolinite at Otukpo are being commercially exploited. Other mineral deposits include baryte, gypsum, feldspar, wolframite, mineral salts and gemstones (BNARDA, 2010).

The population of the study comprised all farmers in Benue State, Nigeria. A sample size of 185 respondents was selected using multi-stage and simple random sampling techniques. In the first stage, the population of the study was stratified into three already existing Agricultural Zones of Eastern, Northern and Central. The second stage involved purposive selection of one LGA from each Agricultural Zone based on soil nutrient depletion and the need to manage the soil nutrients for agricultural production: from North Eastern zone Vandeikya LGA, North Western zone Tarka LGA and Central zone Okpokwu LGA were selected. The third stage involved purposive selection of three rural communities from each LGA; In Vandeikya LGA Mbadede, Mbakaange and Mbagbera were selected. In Tarka LGA Tongov, Mbaigba and Mbaayo. and from Okpokwu LGA Ugbokolo, Okpoga and Ojigo rural communities were selected respectively.

In the final stage, a sampling frame was developed for each of the rural communities and using a proportional allocation of 1.64 percent (0.0164) across board, a sample size of 185 respondents was selected for the study. Data for the study were collected from primary source, using structured questionnaire. Data were analyzed using descriptive and inferential statistics. Objectives i and ii were analysed using descriptive statistics such as frequency, percentages and mean. Hypothesis was tested using Logistic regression.

4.0 Result and Discussion

4.1 Socio-economic characteristics of the respondents

Table 1 shows that, 39.5% of the respondents were aged between 31- 40 years. The age between 41 −50years was 28.1%. This shows that a small portion of the respondents were matured enough to make decisions on regenerative agricultural technologies to be adopted and understand the consequences of a failed technology and

its implications on farmers and their families. Age play a vital role in adoption process, matured farmers might have gained much experience to enable them make a choice that is expected to be beneficial to them and their families. This result is similar to the findings of Olaniyi and Adewale (2010); Idrisa *et al.* (2012); Jamilu *et al.* (2014) and Issah *et al*. (2016) that farmers were between the ages of 30− 40 years and they were at their active age of production.

Table 1 also reveals that majority (71.4%) of the respondents were males and by implication, farming was dominated by males. The dominance of male folks among the respondents is common among farming communities in Africa. This finding is similar to Jost *et al.* (2016) that males dominate the farming population in the traditional African communities. An African community is commonly characterized by men domination in farming activities, which lead to adoption of regenerative agricultural technologies mainly by male folks.

It was found that, majority (80%) of the respondents were married and 14% single. Marriage confers people with responsibilities, making them to engage farming practices such as regenerative agricultural technologies to increase yields and improve their income. This implies that married people concentrate more on farming activities, probably to provide food for their family members. The finding is in agreement with Issa *et al.* (2016) and Umar *et al*. (2014) that farmers were married and engaged in farming activities to feed and provide the necessities of life for their families.

Table 1 reveals that 54.6% of the respondents had secondary education and 24.3% had non formal education. Education is one among the prerequisites that encourages adoption of technologies among farmers. Education illuminates the minds of the farmers and encourages decision that are born-out of knowledge and experience to improve the living standard of the farmers. The respondents had the basic education to understand the implications of adopting regenerative agricultural technologies. The finding is in tandem with Farid *et al.* (2015) and Issa *et al.* (2016) that education is a core prerequisite that guides decision making in regenerative agricultural technologies adoption process, since it facilitates reading and understanding about innovation.

Table 1 shows that majority (63.8%) of the respondents were farmers and 28% were civil servants. Farmers, farming is one of the occupation that has engaged many people. Some people engage in farming as a business, while others are engaged in farming

as a last resort. The finding is similar to Umar *et al*. (2014) that a greater percent of Nigerian population is into farming to feed and meet up with their family needs. The finding also corroborates with Kughur *et al.* (2017) that farming is the common occupation among rural dwellers and civil servants also do it on part-time basis to complement their earnings.

It was also found that majority (75.68%) of the respondents had at least 4 hectares. This implies that majority of the respondents were small-scale farmers and low income earners who find it difficult to adopt capital intensive farming technologies. Also, small scale farmers generally have a problem of land fragmentation that hinders them from adopting agricultural technologies that requires large portions of land. The finding is in line with Kughur *et al.* (2019) that respondents in the study were area small-scale farmers who lack the capital to invest in large-scale agricultural production, they make use of family labour.

Table 1 also shows that majority (54.6%) of the respondents had household size of 1-10 persons, while 44.3% had 11-20 persons. In the case of small-scale farmers, big household size positively impacts adoption of certain agricultural technologies by availability of labour. Large household size also provides labour to farmers; members of the family serving as labourers. The finding is in corroboration with Kughur *et al.* (2022) that in most farming communities large number of people in the household are very common among farming families and the people are used for family labour.

It was found that most (40%) of the respondents earned ₦200,001 – ₦500,000 while 23.8% earned ₦500,001 - ₦700,000. The result indicated that a reasonable proportion of the respondents earned between ₦200,000 –₦500,000. The implication is that the respondents were small scale farmers who earned relatively small annual income. Small scale farmers have a lot of limitations including, but not limited to inability to access formal credit, inadequate farm inputs and low or small annual income among others. The finding is in tandem with Kughur *et al.* (2019) who stated that annual income of a farmer determines the quality and quantity of farm enterprise he operated.

Table 1 also shows that 40.5% of respondents had at least 10 years of farming experience while 29.7% had 11-20 years considerate proportion of the respondents had experience of at least 10 years. Farmers with reasonable years of experience are expected to have understood how farm enterprise works, what to do and how to do it. It is expected

that they know certain innovations with perceived benefits but in the situation where farmers are inexperienced, the opposite is the case. The findings agrees with Nmadu (2015) who stated that farmers with short period of farming experience, could be disadvantageous in up-taking or adopting innovations and technologies.

Table 1 further reveals that majority (94.1%) of the respondents were not membership of farmers associations. This implies that a majority of the respondents were not members of farmers' associations. In rural community, farmers have associations that could enable them share information about technologies and it encourages adoption. This is in disagreement with Nmadu (2015) that social involvement of farmers through their participation in farmers' associations will enhance diffusion of information among the farmers. Also, it is essential that farmers be involved in social organizations as it will enhance their access to government assistance in form of loans and others.

It was found that majority (84.9%) of the respondents had no contact with extension agents in an interval of a year and 12.4% had contact with extension agent. This implies majority of the respondents had no contact with extension agents. Extension contact with farmers create avenue for farmers to learn about new technologies. Extension agent communicates to the farmers about the latest agricultural innovations in existence. The finding agrees with Ayoade and Akintunde (2012) who stated that inadequate extension visits limits farmers' participation and adoption of regenerative agricultural innovations.

Table 2: Distribution of Socio-Economic Characteristics of the Respondents (n=185)

Variable	Frequency	Percentage	Mean
Age (years)			**40.9**
31-40	73	39.5	
41-50	52	28.1	
21-30	28	15.1	
51 and above	21	11.4	
≤20	11	5.9	
Sex			
Male	132	71.4	
Female	53	28.6	
Marital Status			
Married	148	80.0	
Single	26	14.1	
Widow/widower	6	3.2	
Separated	3	1.6	
Divorced	2	1.1	
Education Qualification			
Secondary Education	101	54.6	
Non Formal Education	45	24.3	
Tertiary Education	31	16.8	
Primary Education	8	4.3	
Major occupation			
Farming	118	63.8	
Civil Service	28	15.1	
Retiree	19	10.3	
Fish Farming	6	3.2	
Petty Trading	6	3.2	
Artisan	4	2.2	
Student	4	2.2	
Farm size (Hectares)			**6.18**
≤ 4	140	75.68	
4.1-7	25	13.51	
7.1-10	15	8.11	
≥10.1	5	2.70	
Household Size (Persons)		**9.07**	
1-10	101	54.6	
11-20	82	44.3	
≥21	2	1.1	
Annual income (₦)			**616,978.38**
200,001 – 500,000	74	40.0	
500,001 – 700,000	44	23.8	
700,001 – 1,000,000	30	16.2	
≥1,000,000	24	13.0	
≤200,000	13	7.0	
Farming experience (years)			**16.11**
≤10	75	40.5	
11 – 20	55	29.7	
21 – 30	42	22.7	
≥31	13	7.0	
Membership farmers' association			
Not member	174	94.1	
Member	11	5.9	
Contact with extension agent			
Zero (0) time	157	84.9	
1 time	23	12.4	
2 times	5	2.7	

4.2. Regenerative Agricultural Technologies Adopted Across the Three Agro-Ecological Zones

Table 2 shows that North Eastern zone adopted crop rotation (96.7%) and zero/minimum tillage (93.4%). For North Western zone, zero minimum tillage (97.5%) and planting of cover crops (90.1%) were adopted. For Central zone, use of herbicides only when necessary (86.0%), bush fallowing (83.7%) and zero/minimum tillage (83.7%) were adopted. This implies that, regenerative agricultural technologies such as crop rotation and Zero or minimum tillage were highly adopted in the North eastern agricultural zone. Zero or minimum tillage (93.4%) and planting of cover crops (90.1%) were majorly adopted in the North Western agricultural zone and use of herbicides only when necessary, Zero or minimum tillage and bush fallowing were majority adopted recorded in the Central agricultural zone. The finding is in agreement with McGuire (2018) who stated that regenerative agricultural technologies such as cover crops, reduced or zero tillage, compost, mulching were adopted by farmers. These regenerative agricultural technologies help soil in regenerating the used resources. The finding is also, in corroboration with Chase (2022) who reported that, no till or reduced tillage, cover crops, mulching, bush fallowing and use of herbicides only when necessary were the regenerative agricultural technologies adopted by farmers.

Table 4: Regenerative Agricultural Technologies Adopted Across the Three Agro -Ecological Zones by the Respondents

Technologies	North Eastern zone	North Western zone	Central zone
Zero or minimum tillage	93.4	97.5	83.7
Planting of cover crops	82.0	90.1	81.4
bush fallowing	86.9	86.4	83.7
mulching	80.3	75.3	76.7
use of compost/manure	65.6	87.7	69.8
crop rotation	96.7	84.0	41.9
of animal dung	67.2	87.7	76.7
inter-cropping	85.2	61.7	69.8
Animal and crop integration	42.6	53.1	46.5
managed grazing	23.0	49.4	37.2
use of synthetic fertilizer only when necessary	23.0	58.0	76.7
application of pesticides only when necessary	27.9	56.8	69.8
use of herbicides only when necessary	24.6	21.0	86.0
Agroforestry	42.6	28.4	48.8
silvopasture	23.0	13.6	39.5

[3] **Multiple Responses**

4.3 Effects of Socio-Economic Characteristics of Farmers on Adoption of Regenerative Agricultural Technologies

Table 3 of binary logistic regression analysis shows that Chi-square statistic (X^2) value of regression model was 69.53 and significant at 1%. This implies that the socio-economic characteristics of the respondents have significant effect on adoption of regenerative agricultural technologies. The Cox and Snell R^2 value of the logistic regression model indicated that 28.0% of the variations of the dependent variable were explained by the logistic regression model. The result, also, shows that Nagelkerke R^2 for regression is 0.373 indicating that the variables tested accounted for only 37.3% of the variation of the dependent variables. The remaining 62.7% is attributed to the error term. This result rejects the null hypothesis which states that socio-economic characteristics of the respondents have no significant effect on adoption of regenerative agricultural technologies.

The coefficient of level of education 0.027(0.059) had positive and significant effect at 5% level of probability on adoption of regenerative agricultural technologies. This means that increase in level of education will also increase the level of adoption of regenerative agricultural technologies. This is in agreement with Ngema (2017) that increase in educational level will increase the level of adoption of regenerative agricultural technologies. The coefficient of farming experience 0.005 (0.084) had positive and significant effect at 1%, suggesting that a percentage increase in farming experience will increase the probability of adoption of regenerative agricultural technologies. Experience is very important in all ramifications and that of farming is also imperative to farmers. Experienced farmers might have experimented on certain farm practices for many years and have acquired certain farming skills and knowledge about such practices that can make them be more focused and careful in handling farm affairs than the inexperience ones. The finding corroborates with Ranganathan (2020) that increase in education level of a farmers will lead to an increase in adoption of regenerative agricultural technologies. Education play a vital role in adoption of regenerative agricultural technologies among farmers. Education enables one to read, understand and have accurate judgment about the technologies.

Table 3. Logistic Regression Analysis Showing the Effect of Selected Socio -economic Variables of Farmers on Adoption of Regenerative Agricultural Technologies

Variables	B	S.E	Wald	Sig.	Exp(B)
Age	-0.020	0.021	0.909	0.340	0.980
Education	0.059	0.043	4.863	0.027**	1.100
Household size	-0.044	0.070	0.389	0.533	0.957
Farming experience	0.084	0.030	8.021	0.005*	1.088
Farmers' association membership	0.338	0.904	0.140	0.708	1.402
Estimated annual Income	0.000	0.000	1.304	0.253	1.000
Contact with extension agent	0.106	0.426	0.062	0.803	1.112
Farm size	0.046	0.126	0.132	0.717	1.047
Marital status	0.382	0.257	2.204	0.138	1.465
Constant	-3.271	2.080	2.473	0.116	0.038
Log likelihood	**195.698**				
Cox and Snell R. Square	**0.280**				
Nagelkerke R. Square	**0.373**				
Chi-square	**69.53**	**0.000**			

Note: significant at 1% and 5% level of probability
1% = *, 5% = **

5.0 Conclusion and Recommendations

The study concluded that regenerative agricultural technologies were adopted among farmers across the three agro-ecological zones in the study area. It is recommended that government, non-governmental organizations and wealthy individuals should organize trainings to equip rural farmers with the technical known-how about regenerative agricultural technologies, extension workers should provide adequate information about regenerative agricultural technologies and encourage education of farmers.

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