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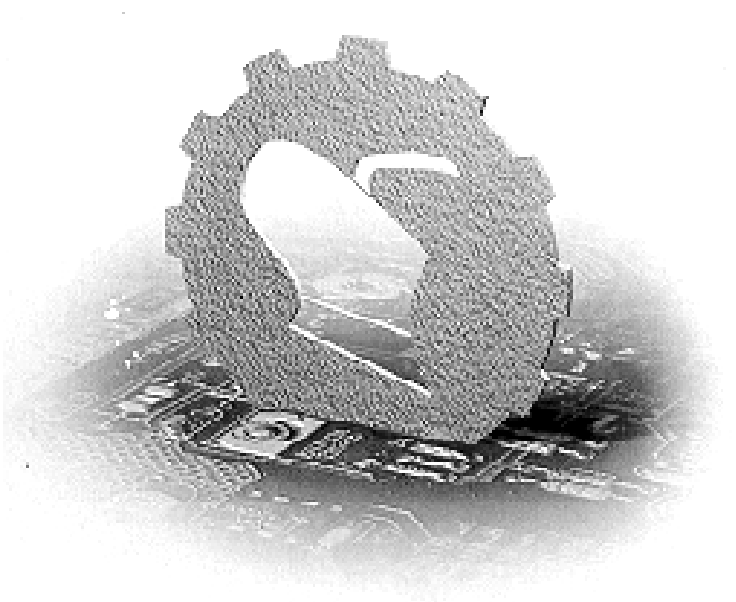

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DYNAMICS OF GLOBAL HARVEST AND PRODUCTION OF CEREALS: EXPLORING TRENDS FOR 30-YEAR PERIOD

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Abstract: Cereals are the world's largest crops and the key source of staple food for millions of people globally. In this study, we analyse the trends in the production and growth of the most important and widely grown types of cereals cultivated as grain globally: 1) maize (corn), 2) wheat, 3) rice; 4) barley; 5) sorghum; 6) oats; 7) millet; 8) rye. The dataset on the produced cereals was collected from the Food and Agriculture Organization (FAO). Methods include the analysis of geospatial and economic data on the agricultural production of cereals for the period 1993-2023 and relevant literature review. The results revealed major trends in the agriculture production harvest of cereals at the global scale: the increase in production and yield quantities was noted for 4 crop types: maize, rice, wheat, millet. In contrast, barley, sorghum, oats and rye shown decrease in harvest in recent 30 years. The study contributes to the analysis of food security and crop availability for sustainable agricultural development.

Key words*: food security, agriculture, statistical analysis, crop, sustainability*

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INTRODUCTION

Food security and agricultural safety are one of the most important global challenges that impact humanity.

In the future decades, agricultural sector will need to produce more food to sustain world population with minimized environmental risks [1-5]. Crop production has variations in increased and decreased harvest globally. The cycles of harvest strongly depend on the environmental sustainability (soil fertility, water availability and temperature) and anthropogenic efforts (increased fertilizer applications, improved agricultural techniques, optimized crop varieties and sustainable agronomic management) [6-8]. The development of precision farming techniques improves crop harvest since farm companies adopt novel practices for process optimization [9-12].

Optimized irrigation techniques improves yield of cereals through proper soil management. Such measures contribute to the sustainable agriculture and ensures food. These include, for instance, improved fertilizers, organic matter and high-quality pest-resistant seeds [13-14]. Other techniques are based on crop rotation for sustainability of soil [15]. Such measures significantly improve the yield quality and quantity through a comprehensive crop management plan and adapting to favorable weather conditions and climate settings. Techniques acceptable in agriculture to maximize yields include strategic cereal succession planting [16] and vertical growing of plants [17-18].

Assessment of the dynamics of cereals as food inputs in cropland helps efficiently monitor and control the distribution of cereals as major staple food source for humanity. Statistical analysis and spatial evaluation of trends in food security improves analysis of crop growth and environmental sustainability. To better understand the flow of the main cereal types, trends and balance in crop availability and the environmental impacts on eight main types of cereals (maize, wheat, rice, barley, sorghum, oats, millet and rye) this study presents the estimation of cropping systems globally from 1993 to 2023.

MATERIAL AND METHODS

The data were collected from the Food and Agriculture Organization (FAO) database on 8 major types of cereals used globally as staple food: 1) maize (corn), 2) wheat, 3) rice; 4) barley; 5) sorghum; 6) oats; 7) millet; 8) rye. The methods include spatial analysis through visualization of maps, statistical analysis graphs and pie charts. The review of the relevant literature has been done on current trends in agriculture research regarding the global dynamics of crops, environmental sustainability and cereal production. The improved techniques of crop harvest in the context of agricultural development were reviewed in published works.

First, recent trends in land preparation (plowing, harrowing, laser leveling for water conservation) are developed and reported in studies on wheat, maize, rice and millet [19]. The techniques of seed sowing are described [20] and include the improved tillage for cereals to transplantation methods. The reports on water management in tropical areas were analyzed to explain recent increase in rice growth globally. These include, for instance, studies on rice cultivation in tropical climate (China, India, Thailand, Indonesia) and specific relief (terraces with leveled steps on slopes) [21-24].

Analysis of water conservation practices was done to evaluate preventive measures against soil erosion [25]. Finally, we considered reports on recent trends in agricultural chemistry and biochemical techniques which address the issues of environmental impacts and improve crop harvest through novel chemical fertilizers. Novel synthetically manufactured substances enhance soil fertility, and support improving crop yields through adding depleted nutrients [26].
These measures contribute to the sustainability of agricultural practices and improve harvest efficiency. Hence, recent trends in the global dynamics of crop production were reviewed and analyzed.

RESULTS AND DISCUSSION

The global dynamics of the production and yield quantities of maize (*Zea may L.*), rice (*Oryza sativa L.*), wheat (*Triticum aestivum L.*) and millet (*Panicum miliaceum L.*) for the period 1993 – 202 is visualized in Figure 1.

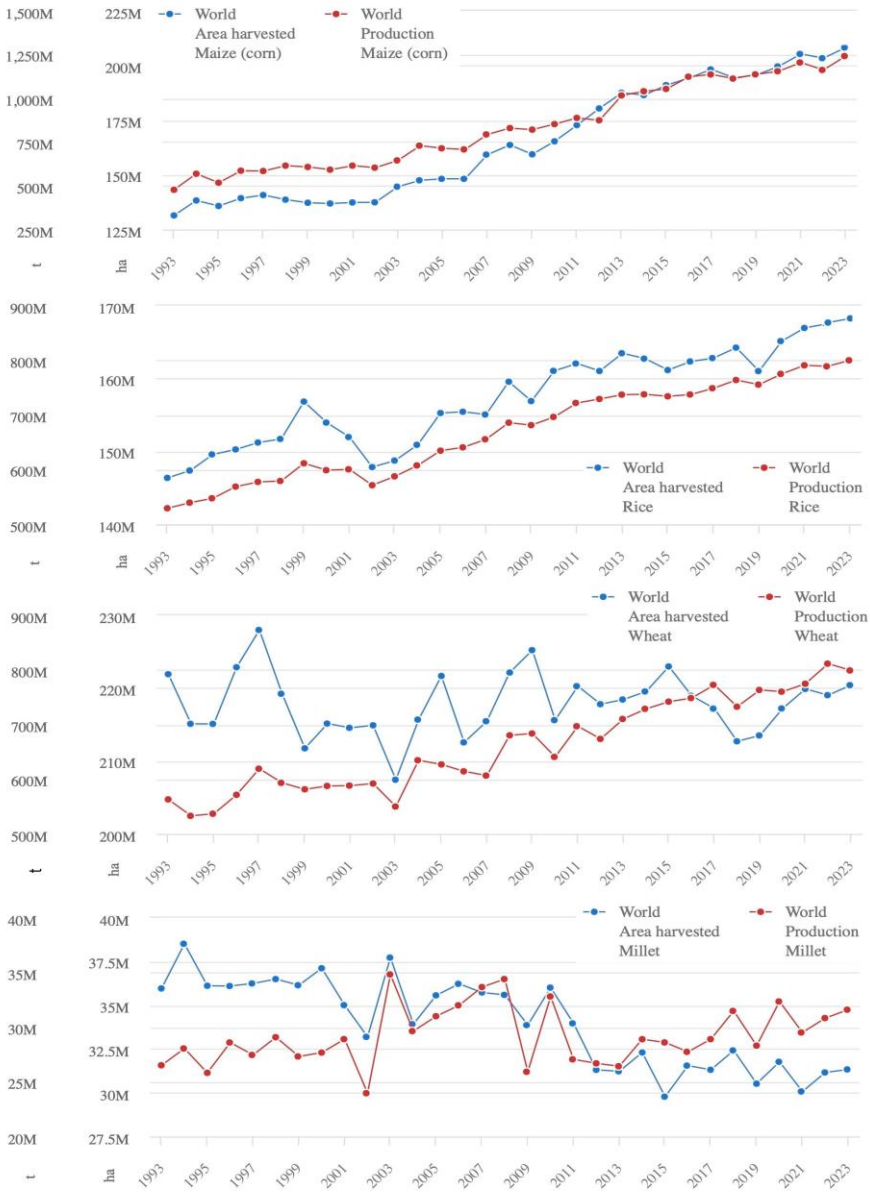

Figure 1. Increase in dynamics: cereals maize, rice, wheat, millet. Trends in production and yield quantities for the period 1993 – 2023. Data source: FAO. Compilation: author.

Over the past decades, the overall cereal food production in increased in maize, rice, wheat and millet increased. This is related to the increase in soil management practices, such as improved fertilizers and organic matter, optimizing irrigation techniques, and utilizing high-quality, pest-resistant seeds.

The maps in Figures 2–5 show the distribution of the production main cereals by countries: maize (Figure 2), rice (Figure 3), wheat (Figure 4) and millet (Figure 5) since 1993 to 2023. Globally, these cereal types are the world's most important staple food cereals.

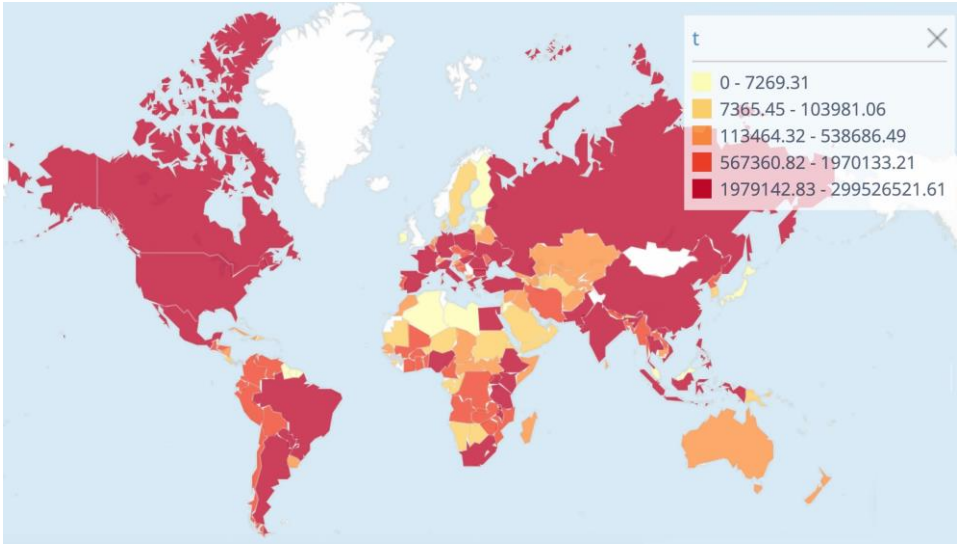

Figure 2. Maize: production quantities by country with average 1993 – 2023. Data: FAO.

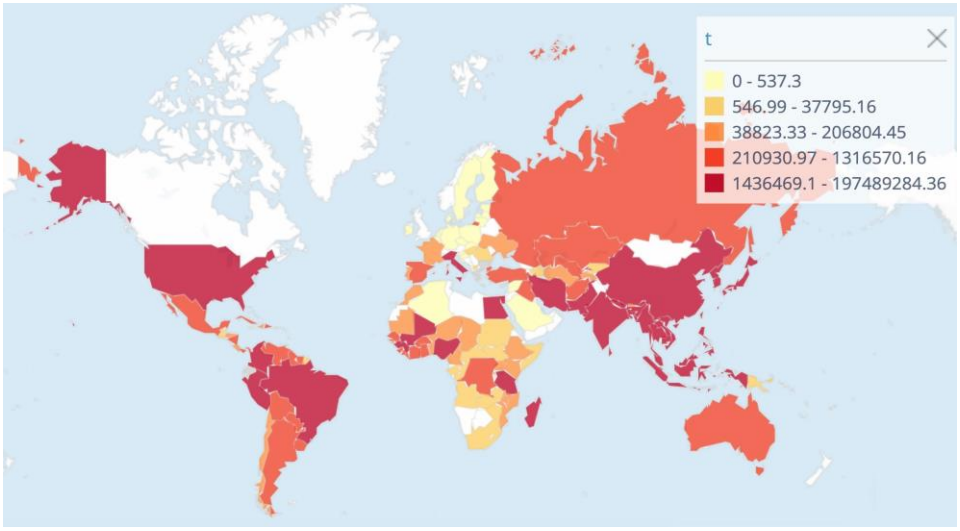

Figure 3. Rice: production quantities by country with average 1993 – 2023. Data: FAO.

Undoubtedly, the growth in these cereals is explained by the characteristics of these crops. Being versatile and adaptable to various weather conditions, these cereals are notable for high productivity which ensues large area of harvest globally. As a consequence, secured yields makes them crucial for global food security.

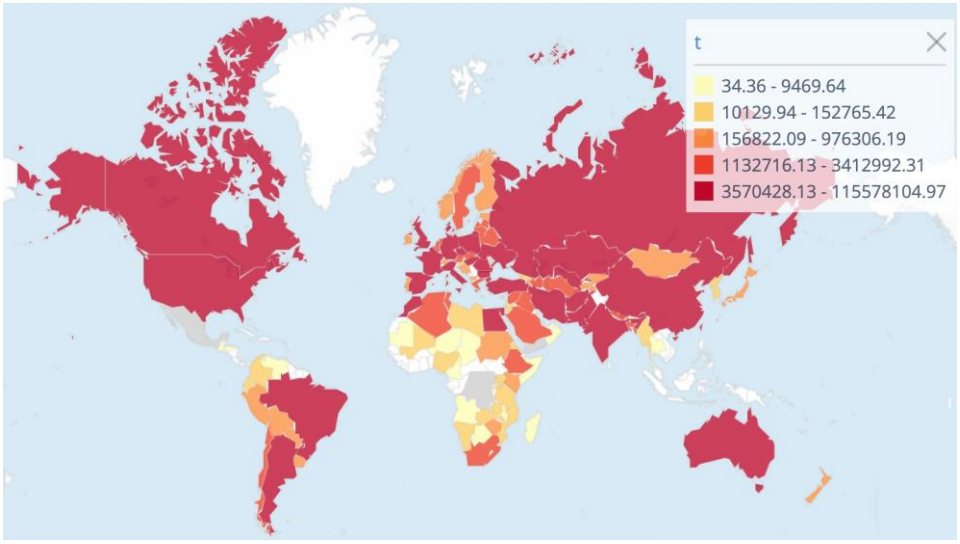

Figure 4. Wheat: production quantities by country with average 1993 – 2023. Data: FAO.

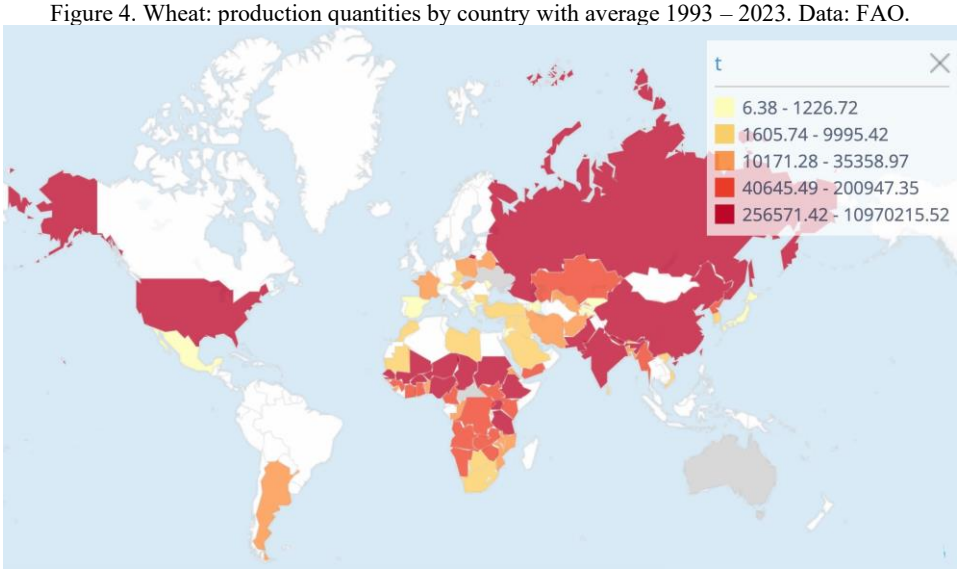

Figure 5. Millet: production quantities by country with average 1993 – 2023. Data: FAO.

High calories and quality of grains enable the use of these cereals as major staple food for humanity, but also additionally as a nourishment in livestock feed. Finally, these cereals can be stored for long periods due to resistivity to external storing conditions and properties of grain. The development of synthetic fertilizers in chemical agronomy along with the appropriate management and balanced applications contributed to the increase of crop yields. This has significantly improved cereals production with most popular types, such as wheat and maize and reduced yield gaps in the recent decades.

In contrast, recent trends show the decrease in the global production of the cereal's rye, barley, oats and sorghum, Figure 6.

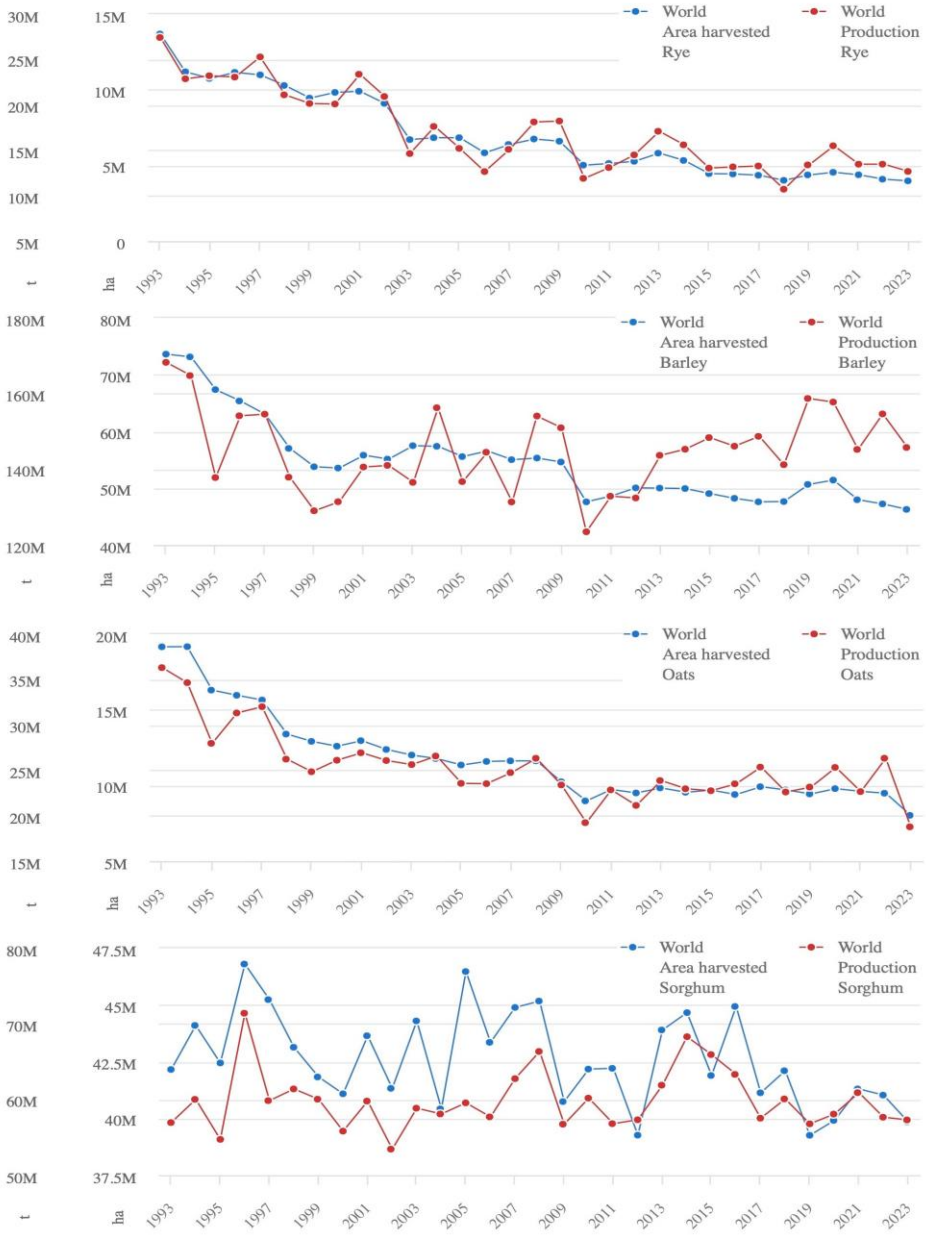

Figure 6. Decrease in dynamics: rye, barley, oats and sorghum. Trends for production and yield quantities of cereals for the period 1993 – 2023. Data source: FAO. Compilation: author.

Figure 7–10 show the distribution of the minor crop cereals globally: rye (Figure 7), barley (Figure 8), oats (Figure 9) and sorghum (Figure 10).

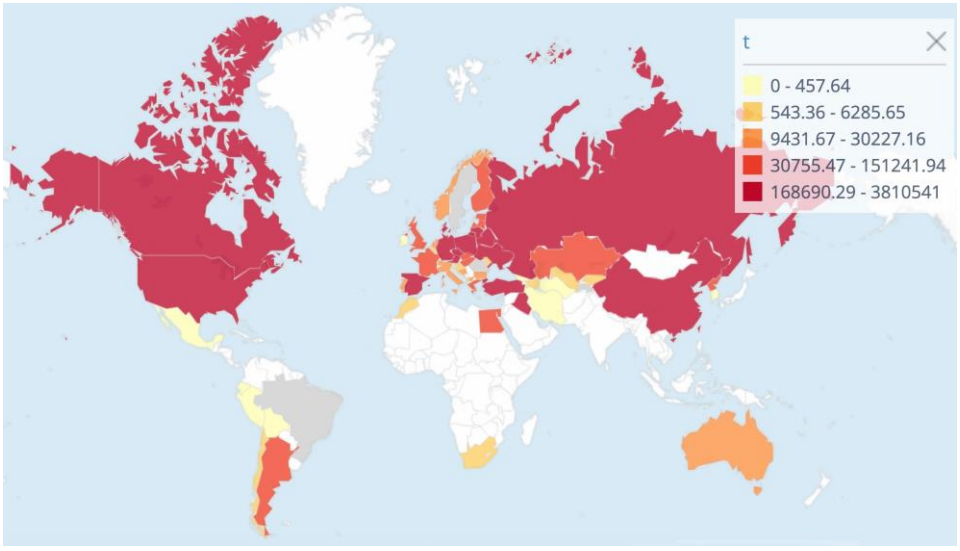

Figure 7. Rye: production quantities by country with average 1993 – 2023. Data: FAO.

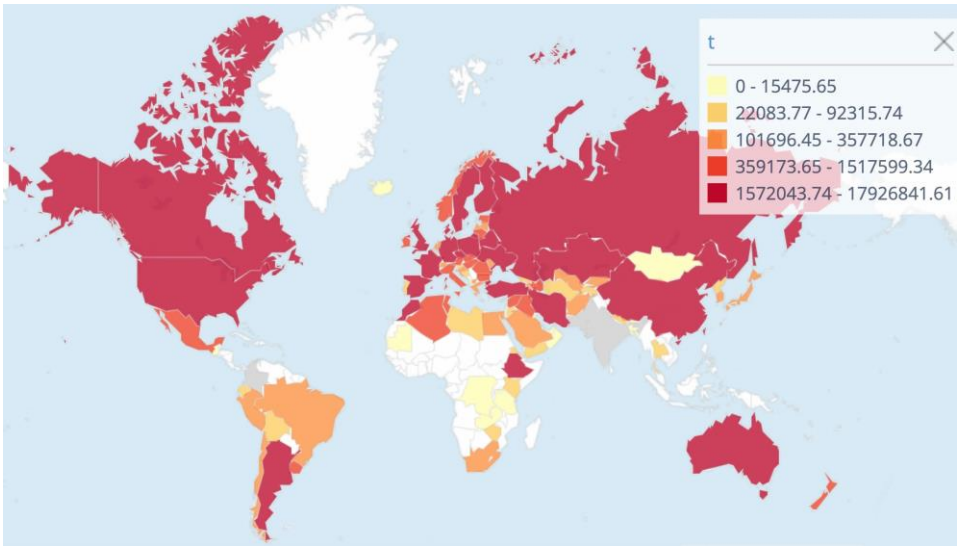

Figure 8. Barley: production quantities by country with average 1993 – 2023. Data: FAO.

Major reason for the decline in production of minor cereals is explained by the change in land use patterns toward major cereals (rice, maize, wheat and millet) as well as slower demand growth for these minor cereals (rye, barley, oats and sorghum) in important applications, such as animal feed and biofuels.

Besides, certain substantial effects originate from the climate change and weather events such as temperature warming, extreme heat and repetitive droughts, which negatively affects the yields.

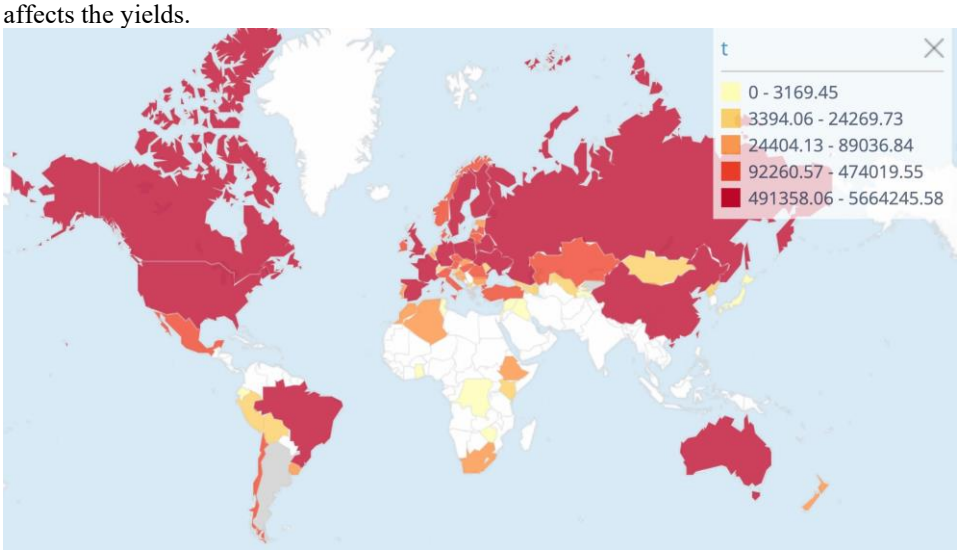

Figure 9. Oats: production quantities country with average 1993 – 2023. Data: FAO.

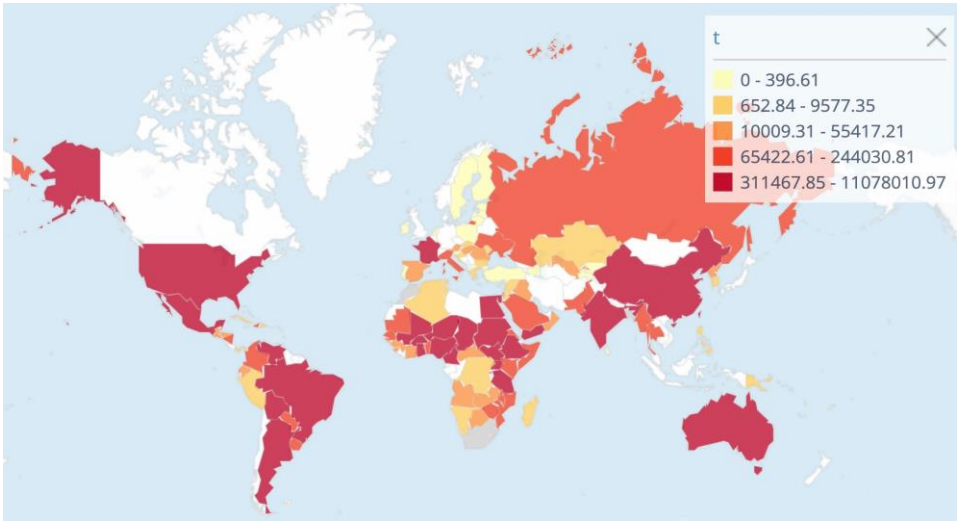

Figure 10. Sorghum: production quantities by country with average 1993 – 2023. Data: FAO.

The cumulative effects of these factors are the causes of the decline in minor cereals (rye, barley, oats and sorghum). Finally, the production volatility of minor cereals is also influenced by the geopolitical variables, including changes in land use practices, and the concentration of the production of these crops in selected areas due to globalization of the world food market.

Figure 11 shows the percentage of production share of major cereals by five global regions which illustrates the main producers of the crops globally.

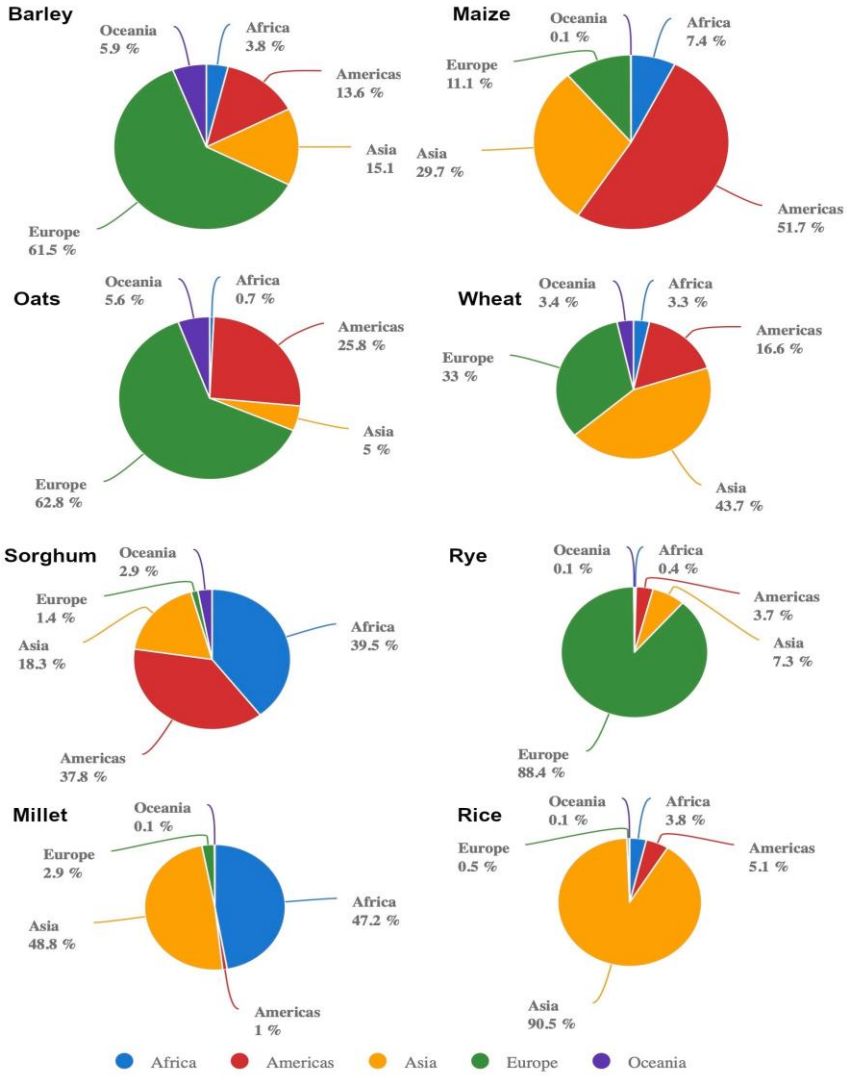

Figure 11. Percentage of production share of major cereals by five global regions for the period of 1993 – 2023. Data source: FAO. Compilation: author.

Development of the agricultural practices and novel technologies aimed at sustainable agriculture will drive an increase in global production of cereals and grain.
Overall, the FAO reports cereal consumption to be increased by 1.1% annually by 2034, mostly as a result of growing populations in Asia and Africa [27].

Accordingly, the rise of cereal production in Asia and the Americas will drive the increase in their use and consumption. The biggest challenge continues to be how to apply the potential of sustainable agriculture to contribute to the environmental protection and ecological monitoring [28-31]. The balance between safe fertilizers and economic growth may be difficult to achieve in the sector of agriculture. Nevertheless, the agricultural techniques and crop harvesting efforts are actively emerging and adopt novel technologies from the interdisciplinary sectors, including drones and nanotechnologies in agriculture, smart techniques of observation, safe substances as fertilizers and more.

Environmental monitoring and evaluating climate dynamics in the fertile lands for assessment of the external effects on land productivity is another valuable approach to sustainable agriculture [32-33]. Therefore, improving public knowledge, attitudes, and sustainable agricultural practices is essential for environmental management in order both to support successful harvest and maintained balanced nature conservation initiatives. To this end, current study highlighted current trends in cereal production globally using robust dataset from the FAO. The paper is target for interventions to enhance public awareness in sustainable agriculture and highlights recent dynamics in crop production during last 3 decades. In order to support sustainable agriculture practices and maintain production of minor crops (rye, barley, sorghum, oats), operative monitoring of agricultural data should be performed using multidisciplinary analysis. The latter includes spatial analysis (maps and cartographic referenced data), land management for nature conservation and biodiversity protection, and statistical analysis (visualization of graphs and plots). Hence, the measures on agricultural development and awareness of farmers and land managers should be supported through integrated data analysis and regular observations with detected trends in cereal production.

CONCLUSION

This study addressed the critical challenge of revealing trends in cereal production globally. The suggestion solutions are optimizing agriculture practices for maintaining and supporting minor cereals (rye, barley, sorghum and oats), water resource allocation in plant growing regions, land management measures in the areas characterized by fragmented terrain and complex relief patterns and use of sustainable fertilizers for protection of soil. By integrating statistical data analysis obtained from FAO with a literature review on current trends in agriculture practices, the presented study advances understanding of farming tendencies globally with example of 8 types of cereals: maize (corn), wheat, rice, barley, sorghum, oats, millet, rye. Optimization of agriculture practices by considering climate and environmental heterogeneity and the public need for food security ensures sustainable dynamics in agriculture and stable crop production.

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DINAMIKA GLOBALNE ŽETVE I PROIZVODNJE ŽITARICA: ISTRAŽIVANJE TRENDOVA ZA PERIOD OD 30 GODINA

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Apstrakt: Žitarice su najviše zastupljene kulture u Svetu, i ključni izvor osnovne hrane za milione ljudi širom Sveta. U ovoj studiji analiziraju se trendovi u proizvodnji i porastu najvažnijih i najrasprostranjenijih vrsta žitarica koje se gaje kao zrno širom Sveta:
1) kukuruz, 2) pšenica, 3) pirinač; 4) ječam; 5) sirak; 6) ovas; 7) proso; 8) raž.
Skup podataka za prikazani period o proizvedenim žitaricama, prikupljen je od Organizacije za hranu i poljoprivredu UN (FAO).
Metode obuhvataju analizu geoprostornih i ekonomskih podataka o poljoprivrednoj proizvodnji žitarica za period 1993-2023 sa pregledom relevantne literature.

Rezultati istraživanja su otkrili glavne trendove u poljoprivrednoj proizvodnji i žetvi žitarica na globalnom nivou: povećanje proizvodnje i prinosa je zabeleženo kod 4 vrste useva: kukuruz, pirinač, pšenica, proso. Nasuprot navedenom, ječam, sirak, ovas i raž pokazali su smanjenje obima žetve u poslednjih 30 godina.
Studija doprinosi analizi bezbednosti hrane i dostupnosti useva za održivi poljoprivredni razvoj.

Ključne reči: *Bezbednost hrane, poljoprivreda, statistička analiza, usev, održivost.*

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INFLUENCE OF FLOODING ON SOCIOECONOMIC ACTIVITIES AND MITIGATION MEASURES IN DESIGNATED COASTAL COMMUNITIES IN AKWA IBOM STATE

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Abstract: Influence of flooding on socioeconomic activities and mitigation measures in Obianga, Emereoke, Inua Eyet Ikot and Iwuo Okpom Opulom Communities of Eastern Obolo and Ibeno Local Government Areas, Akwa Ibom State was evaluated. The study employed cross-sectional survey with sample population consisted of inhabitants in the coastal communities and was found using purposive and random sampling techniques via by Godden formula. Data were collated from both primary and secondary sources. The participants were requested to indicate their sex and perceived influence of flooding on socioeconomic activities such as types of housing lived in, assets lost, sources of drinking water, health and educational facilities and crops, and sanitary facilities they have, and mitigating measures to lessen flooding effect. Ethical issues were duly addressed and the instrument (questionnaire) was tested for both face and content validity, and consistency before administered and retrieved for analysis using Microsoft Excel 2016. The results recorded a total of 287 participants. Majority (61.7%) were males. Their main source of drinking water was unprotected well/spring water (70.1%) and most of the health facilities were not available which gave rise to some significant diseases such as malaria (42.2%), cholera/typhoid (27.2%) and cough/ARI (24.7%). Greater number of respondents confirmed the availability of educational facilities (90.9%) but sometimes damaged (70.7%), and school disrupted due to flooding (73.0%). This had led to finance crisis (53.7%), hunger (44.3%) and road submersion (2.1%) in the areas.

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Their staple crops (cassava, maize and fluted pumpkin) (88.1%) are always damaged by flooding. Open defecation (70.7%) was the most common type of sanitary facilities found whereas the least was VIP toilet (2.9%). Majority of the inhabitants received financial aids from their social network and some credit facilities/ insurance to lessen the effect of flooding.
It appeared that Iwuo Owo Opulom and Emereoke Communities were more liable to flooding in terms of assets / property destroyed. It was recommended that drainage systems should be constructed and accurate flood warning system should be amounted mostly in the flood prone regions through various agencies and NGOs.

Keywords: *Flooding, socioeconomic activities, coastal Communities, mitigation measures*

INTRODUCTION

One third of West Africa's coastal regions 'population has the capacity to produce 56% of its GDP. These regions are wetlands and are characterized by oil and gas reserves, fisheries, and tourism potential [1]. But these regions are affected by climate variation and catastrophe risks. Consequently, the coastal areas are subjected to natural threats, especially flood. This is due to rising sea level which floods the wetlands and dry lands, and erodes the seashores. This could lead to loss of property and human life [2, 3]. For instance, after the 2004 floods in Bangladesh, unfortunate homes devastated by the flood lost more than twice as much of their total income as non-poor homes [4]. Besides, other consequences of flood include devastation of crops [5], destruction of educational infrastructures [6] and illnesses [7]. Crops such as rice paddy, fruit trees and vegetables were lost due to flood and the farmers were in no doubt lost also huge income that would have been generated after sales [8]. Sometimes, communication and power infrastructures, bridges and roads are damaged [6]. Some economic activities may be brought to a halt, forcing people to abandon their homes [1]. Meaningfully, flood catastrophes may result from human creation which is a consequence of our interrelationship with the environment. For instance, in the design and location of our amenities, exploitation of natural resources, urbanization, etc. [9, 10]. The coastline is in a continuous fluctuation, thus causing ostensible muddle which makes poor people more vulnerable to disasters which may affect their socioeconomic activities such as living conditions, education, resources, opportunities, etc. [3]. The most vulnerable are the aged, women and children [11]. The unceasing and increasing incidence of flooding often poses applicable danger to the attainment of both workable development and poverty-reduction programmes [12]. Several works were carried out in other regions of the world [5, 13, 14]. So, the present work focused on the influence of flooding on socioeconomic activities and mitigation measures in designated coastal communities (Obianga, Emereoke, Inua Eyet Ikot and Iwuo Okpom Opulom Communities of Eastern Obolo and Ibeno Local Government Areas) in Akwa Ibom State. The study would show the most vulnerable regions and give significant inputs regarding mitigation measures to minimize the influences of coastal flooding in Akwa Ibom State.

METHODOLOGY

Study Area

The study regions were few coastal communities (Obianga, Emereoke, Inua Eyet Ikot and Iwuo Okpom Opulom) in Eastern Obolo and Ibeno Local Government Area (LGA) of Akwa Ibom State (AKS), Nigeria as shown in Figure 1. Nevertheless, Eastern Obolo LGA lies between latitudes 4°28' and 4°53' and longitudes 7°50' and 7° 55' East while Ibeno LGA lies between 4°33′N and 8°4′E. The chief occupation of the populaces is fishing. Therefore, majority of them are fishermen. However, crop farming and petty trading are also found [15].

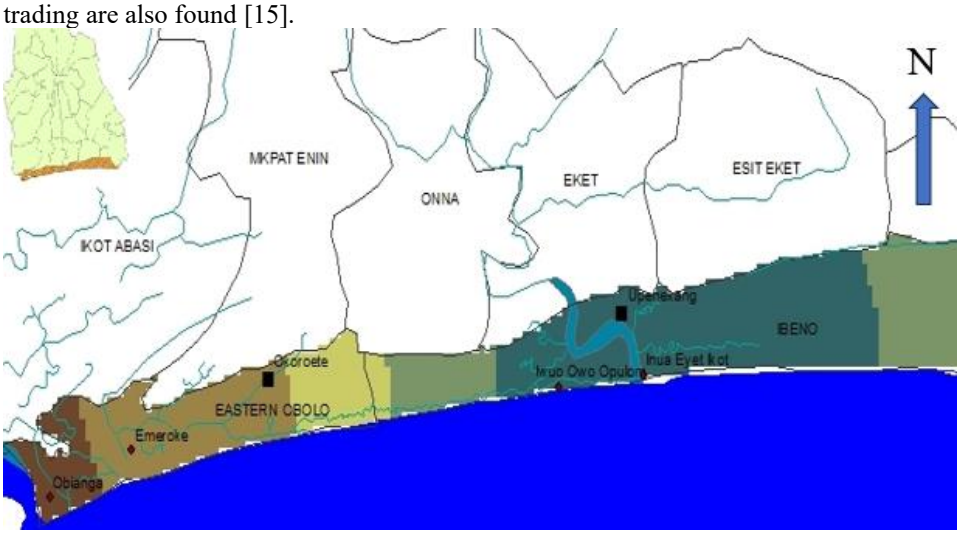

Fig. 1. The location of the study, [15].

Research Design, Sampling Method, Population and Sample Size

Research design implemented was cross-sectional survey. The sampling procedures used were being purposive and random sampling procedures. The population were the inhabitants in the coastal regions in Akwa Ibom State. The sample size (n) was computed using Z (1.96 for 95% confidence level), % population (P= 75%) [16] and C (0.05 for confidence interval) in Godden formula given in Equation (1):

$$n = \frac{Z^2.P.\ (1-P)}{C^2} \tag{1}$$

Sources of Data and Data Collation Methods

The study data were got from both primary and secondary sources. A researcher-made questionnaire was employed. It had either closed-ended or open-ended items or both. The secondary data were collected from archives [16] and United States Geological Surveys [USGS] [17].

Nevertheless, the participants were requested to indicate their sex. In terms of impact of flood on socioeconomic activities in their communities, they were asked to specify:

1. the types of housing they lived in and assets they normally lost to flood;
2. common sources of drinking water;
3. their degree of access to health facilities, damages to health facilities and health status resulting from flooding;
4. their extent of access and damages to educational facilities, and school disruption due to flood;
5. their perceived degree of damage to crops and main staple crops; and
6. the nature of sanitary facilities common in the study areas. Based on items on the questionnaire, they were also requested to specify coping approaches to mitigate the effect of flooding in their communities.

Ethical Issues, Instrument Validation, Consistency and Administration

Relating ethical issues, the participants were told of the intention of the study before copies of questionnaire were administered by qualified research assistants. However, the instrument was tested for both face and content validity using Equations 2 and consistency using Pearson's Product Moment Correlation Coefficient (r) embedded in Microsoft Excel 2019. However, content validity index (CVI) and correlation coefficient (r) greater than 0.7 is recommended [18].

$$\text{CVI} = \frac{\text{Total number of valid items (TNVI)}}{\text{Total number of items on the instrument (TNI)}} \quad (2)$$

Method of Data Analysis

The data got from the questionnaire were analyzed using Microsoft Excel 2019. The results were presented in table, percentage and chart for quick understanding.

RESULT AND DISCUSSION

Results

(a) Sample Population, Content Validity, Consistency, Response and Return Rate

The calculated least sample population, content validity, instrument consistency, response and return rate are presented in Table 1.

Table 1. Sample population, content validity, consistency, response and return rate

Item	Quantity
Minimum population computed using Godden formula	288 respondents
Content validity index (CVI)	0.996
Copies of questionnaire printed	300
Copies of questionnaire used for consistency test	4
Instrument consistency (r)	0.970
Copies of questionnaire administered in the field	295
Copies of questionnaire responded	287
% Return rate	97.29

From Table 1, the computed least population and content validity index were 288 respondents and 0.9960 respectively.

Once more, a sum of three hundred (300) copies of the questionnaire were reproduced, four (4) were employed for instrument consistency test (0.940) and two hundred and ninety-five (295) copies of questionnaire were administered in the field. Only two hundred and eighty-seven (287) copies were responded. Therefore, 97.78% of the copies of questionnaire were retrieved which is viewed as response and return rate.

(b) Sex of the Respondents

The sex of respondents is presented in Figure 2. There were fewer female respondents than males. Approximately 61.7% were males, while 38.3% were females.

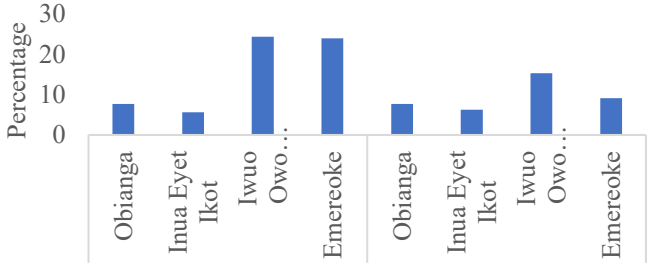

Fig. 2. Sex composition of household heads in each location

Influence of Flooding on Socioeconomic Activities in the Coastal Communities

(a) Types of Housing and Asset Loss

Tables 2 and 3 show types of housing and assets loss found in the study area.

Table 2. Types of housing

Type of Housing	Location	%	Total %
Mud and wattle	Obianga	11.1	74.5
	Inua Eyet Ikot	7	
	Iwuo Owo Opulom	40	
	Emereoke	16.4	
Blockwork	Obianga	4.2	25.5
	Inua Eyet Ikot	4.9	
	Iwuo Owo Opulom	0	
	Emereoke	16.4	

Table 3. Percent of loss of household property or assets

	Location				
Assets	Obianga	Inua Eyet Ikot	Iwuo Owo Opulom	Emereoke	Total %
Boat/ canoe	8.3	3.1	10.5	13.5	35.4
Fishing net	2.4	2.1	11.1	6.7	22.3
Chairs	2.4	2.1	11.1	5.6	21.2
Television	0.0	2.1	4.2	2.1	8.4
Radio	0.0	0.3	1.4	1.7	3.4
Hoe	0.0	1.0	0.0	0.0	1.0
Others	0.0	1.0	5.6	1.7	8.3
Total	13.1	11.7	43.9	29.9	100.00

From Table 2, 74.5% of the respondents lived in mud and wattle house. This was mostly seen in Iwuo Owo Opulom (40%), which is made up of sticks from the bamboo and thatch from the oil palm tree or raffia palm whereas 25.5% of the respondents that built block house were predominately seen in Emereoke (16.4%). However, to buttress flood menace as captured in Table 3, pictures of household property or assets lost are shown in Figures 3.

Fig. 3. Catalogues of household property or assets lost by flood

Table 3 revealed that a substantial number of productive and non-productive assets were damaged or lost by the floods. Of the productive assets which were lost, 35.4% were boat/ canoe mostly in Emeroke (13.5%), while 22.3% were fishing nets majorly in Iwuo Owo Opulom (11.1%) which contributed to 57.7% of properties destroyed by coastal flooding which are required to meet up with their daily livelihood. Again, 21.2, 8.4,3.4, 1.0 and 8.3% of chairs, television, radio, hoe and others as non-productive assets, respectively were lost to flooding. In a nut shell, Iwuo Owo Opulom Community (43.9%) had the highest % household property or assets loss.

(b) Sources of Drinking Water

Common sources of drinking water are presented in Table 4.

Table 4. Common sources of drinking water

Sources	Location	%	Total (%)
Borehole	Obianga	1.0	9.3
	Inua Eyet Ikot	5.2	
	Iwuo Owo Opulom	3.1	
	Emereoke	0.0	
Protected Well	Obianga	2.6	14.3
	Inua Eyet Ikot	3.6	
	Iwuo Owo Opulom	4.6	
	Emereoke	3.5	
Unprotected Well / Spring	Obianga	13.6	70.1
	Inua Eyet Ikot	7.4	
	Iwuo Owo Opulom	25.8	
	Emereoke	23.3	
Rainwater	Obianga	0.0	6.3
	Inua Eyet Ikot	0.0	
	Iwuo Owo Opulom	0.0	
	Emereoke	6.3	

From Table 4, the survey further established that 70.1% of household whose main source of drinking water was unprotected well/spring water. The percentage of household that used protected well, rainwater and borehole as their main water sources were 14.3%, 6.3% and 9.3% respectively.

(c) Health Status

The summary of the responses by the participants relating access to health facilities, damages to health facilities and health status resulting from flooding are presented in Tables 5 and 6.

Table 5. Health status of the respondents

	Statement	Yes (%)	No (%)	Undecided (%)
(a)	Access to health facilities	35.1	64.9	0.0
(b)	Damages to health facilities due to flood	34.8	40.1	25.1
(c)	House member sick due to flood	92.7	7.3	0.0

Table 6. Major disease outbreak due to flooding

Malaria (%)	Cholera / Typhoid (%)	Cough / ARI (%)	Measles (%)
42.2	27.2	24.7	5.9

Table 5 revealed that the sampled household (64.9%) indicated that health facilities were not available in their communities. Furthermore, 34.8% of the household had indicated that health facilities had been damaged by flooding in their communities, while 40.1% disagreed. The study further revealed that out of the 287 sampled household, 92.7% indicated having at least one member of their household getting sick due to floods.

Again, from Table 6, the most significant diseases experienced among the household members were malaria (42.2%), cholera/typhoid (27.2%), cough/ARI (24.7%) while measles had 5.9% due to the floods.

(d) Education

The extent of access and damages to educational facilities, and school disruption due to flood as perceived by the respondents is presented in Table 7.

Table 7. Access and damages to educational facilities, and school disruption due to flood

	Statement	Yes (%)	No (%)	Undecided (%)
(a)	Access to educational facilities	90.9	8.7	0.3
(b)	Damages to educational facilities	70.7	11.8	17.4
(c)	School disruption due to flood	73.0	11.5	15

Table 7 revealed that majority of the household (90.9%) indicated that there are educational facilities in their communities compare to 8.7% and 0.3% who disagreed and undecided, respectively. Furthermore 70.7% of the household had indicated damaged to educational facilities compared to 11.8% and 17.4% disagree and undecided respectively. The study further revealed that 73% of the respondents (household heads) indicated school disruption due to flood while 11.5% disagreed and 15% were undecided. However, impact of school disruption due to flood as perceived by the respondents is presented in Figure 3.

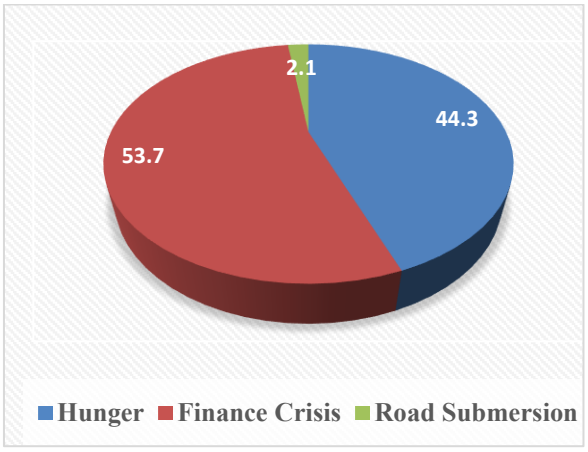

Fig. 4. Impact of school disruption due to flood

From the Figure 4, majority of the household (53.7%) indicated finance crisis as impact of school disruption due to flood, whereas 44.3% and 2.1% indicated hunger and road submersion respectively.

(e) Crops Damage

The degree of damage to crops experienced by household and the main staple crops damage during flood as perceived by the respondents are summarized in Table 8.

Table 8. Summary of damage to staple crops experienced by household

	Statement	Yes (%)	No (%)	Undecided (%)
(a)	Household experience to crops damage due to flood	88.1	11.0	0.9
		Cassava	Maize	Fluted Pumpkin
(b)	Main staple crops damage during flood	62.0%	25.0%	13.0%

About 88.1% of most of the sampled households indicated that their crops were damaged by flood, 11.0% did not affirmed whereas 0.9% were undecided. Most staple crop damaged by flood was cassava (62.0%), followed by 25.0% and lastly fluted pumpkin (13.0%).

(f) Sanitary Facilities

The nature of sanitary facilities used in the study areas are shown in Table 9.

Table 9. Nature of latrine

Type of Sanitary Facilities	Location	%	Total (%)
Open defecation	Obianga	9.7	70.7
	Inua Eyet Ikot	7.0	
	Iwuo Owo Opulom	33.4	
	Emereoke	20.6	
Traditional latrine	Obianga	3.5	20.8
	Inua Eyet Ikot	1.7	
	Iwuo Owo Opulom	3.1	
	Emereoke	12.5	
Pier latrine	Obianga	3.5	5.6
	Inua Eyet Ikot	0.0	
	Iwuo Owo Opulom	2.1	
	Emereoke	0.0	
VIP toilet	Obianga	0.0	2.9
	Inua Eyet Ikot	2.9	
	Iwuo Owo Opulom	0.0	
	Emereoke	0.0	

In terms of sanitary facilities as shown in Table 9, 70.7% of the sampled household had no sanitary facilities, but resort to using sand/ ocean bank as alternatives to defecate openly, with Iwuo Owo Opulom (33.4%) being the highest whereas Inua Eyet Ikot recorded the least (7%). About 20.8% and 5.6% used traditional and pier latrines. However, traditional latrine was found mostly in Emereoke (12.5%) while pier latrine was mostly seen in Obianga (3.5%). Furthermore, VIP toilet (2.9%) was recorded in Inua Eyet Ikot.

(g) Coping Measures to Lessen Influence of Flooding on Socioeconomic Activities

Figure 5 shows coping measures adopted by the inhabitants in each community and their strength to lessen the effect of flood on their socioeconomic activities.

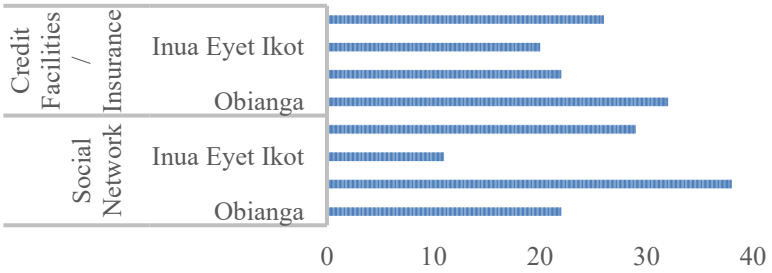

Fig. 5. Coping measures to lessen effect of flooding

From Figure 5, Obianga community had the highest (32%) coping measures, in terms of credit facilities/insurance, where they normally receive financial aids to lessen the negative impact of flood. This was followed by Iwuo Owo Opulom (26%) whereas the least was found in Inua Eyet Ikot (20%). However, in terms of social network, Emereoke community recorded the highest (38%), followed by Iwuo Owo Opulom (29%), and lastly Inua Eyet Ikot (11%).

Discussion

(a) Sample Population, Content Validity, Consistency, Response and Return Rate

As observed in Table 1, the total number of the participant involved were 287 which is just one less than the least population (288) required. This suggests a well-meaning sample population to begin the study. Also, CVI of 0.9960 infers that statements or items on the questionnaire were 99.60% exceptionally structured to deal with the research objective. Instrument consistency test of 0.970 submits that the instrument (questionnaire) structured helped the participant(s) to answer the research items with 95% uniformity and only 5% contradiction. So, the instrument was dependable. Moreover, out of 295 copies of questionnaire taken into the field, 287 were answered, and this denotes the questionnaire response and return rate of 97.29%. A questionnaire response and return rate of 50% is adequate to commence a study successfully [19]. In this work, the response and return rate was outstanding because it exceeded the required least return rate by 47.29%. This suggests a good response and return rate and that the respondent(s) were willing to participate.

(b) Sex of the Respondents

From Figure 2, more households were ruled by men, and this may be due to nature of the livelihood prevalent in the study areas. For example, fishing is always dominated by males. It was well-known from a significant informant that majority of the occupants of the areas were immigrants from the adjourning local government area who came to search for cheap labour.

Influence of Flood on Socioeconomic Activities in the Coastal Communities

Most houses built with mud and wattle (74.5%), seen in Iwuo Owo Opulom (40%) and Emereoke (16.4%) Communities must have been attributed to the reoccurring effect of coastal flooding which destroys houses and make the people retreat inland. This implies that Iwuo Owo Opulom and Emereoke Communities must have been the epicenters of flood disaster. Key informant also revealed that some years ago their houses were located in the area now taken by coastal flooding which also discourages them from building a permanent shelter. This has become a setback, affecting their economic realities (income). Most houses built with block-work are farther away from the seashore which may not easily threaten by the coastal flood. Some household assets or property, representing 8.3%, such as cooking pots, beds and clothes must have been lost too. Most of the losses were attributed to households' proximity to coastline or water bodies. This is in line with the comment of one of key informants who revealed that he indirectly lost some household assets, including income sources, due to flood incidence and subsequent collapse of his house. Generally, Iwuo Owo Opulom Community (43.9%) appears to be the most predominant flood threatening location in the study. In a similar study, Rakiba *et al*. [6] observed the devastation of infrastructural prospect, in their study area, as a consequence of flood hazards. This agrees with the findings of Hossain *et al.* [20] where health facilities and houses were damaged by flood and the major socio-economic activities were negatively impacted with severe implications.

(a) Water Source, Health Status and Education

Finding from the field data showed a lot of diversity on the type of drinking water sources they had. It was evident that unprotected well/spring, protected well and borehole were the most common water sources that communities used for drinking. The community with the highest unprotected well/spring was Iwuo Owo Opulom (25.8%) followed by Emereoke (23.3%). This means that households in these communities would continue to be vulnerable to increased disease outbreak as long as the unprotected well / spring continues to be their main source of drinking water, which is as a result of increased contamination that occurs during flooding. In a similar work, Okaka and Odhiambo [14] showed that household characteristics water and sanitation had greater impact on household vulnerability to contamination due to flood. Besides, a larger number of the inhabitants (64.9%) not having access to health facilities must have lived farther away or their relief (topography), being close to flood prune areas, must have not permitted the establishment of these facilities. Those that did not decide must have not experienced flood menace. Sickness in the household is an indication that the flood water was contaminated with pathogens or disease-causing organisms. The most common disease that attacked the inhabitants was malaria (42.2%). Female anopheles' mosquitoes do breed in an area where there is stagnant flood water. There is an urgent call to institute preventive measures such as sleeping under mosquito treated nets or regular check up to ascertain its level and adhere to doctors' prescription after test results. Result of the present study is in line with the study of Toufique and Yanus [7] who opined poor access to health facilities which could result in illnesses may be attributed to inhabitants' higher vulnerability to natural catastrophe and climate change, for example, flood. This implies that greater number of the inhabitants must have been interested in education and would like their wards to take another trade apart from fishing or trading.

Damaged to educational facilities may likely subject the learners to lousy or unconducive environment which eventually bring about drop in school attendance. Disruption of school due to flood may trigger delay in school calendar. This means that some trading activity must have been disrupted too, and those who worked in the surrounding schools may not have been paid for months, especially those in private sector. Again, transportation of food materials to market and other businesses would have been hindered due to road submersion in flood water; hence, putting many households in financial stress. In line with the present work, Rakib *et al*. [6] reported of the destruction of educational infrastructure as a consequence of flood.

(b) Crops Damage and Sanitary Facilities

The higher affirmation (88.1%) of crops damage due to flood in the study area is an indication of the severity of the flood incidence in the area. This situation might have led to hunger. The main staple crops (cassava, maize and fluted pumpkin) are mostly carbohydrate and minute vitamin / mineral giving foods. Seafoods (mainly protein) obtained from fishing could supplement the inhabitants' diets, improving their health if other factors are healthily regulated. The present study in consonant with Tuwilika [5] work, which revealed that flood had a great impact negative on animals and plants. Besides, Week and Wizor [21] showed that lack of basic food and crops due to flood caused food insecurity in core Niger delta. It is worthy to note that sand/ocean banks in the context of sanitary facilities are usually regarded as no sanitary facilities even though they are used as an alternative for excreta disposal. This implies that the scenario could aid spread diseases rapidly. The presence report is in agreement with the work of Toufique and Yanus [7] who maintained that lack of sanitary toilets in the coastal regions is as result of inhabitants' higher vulnerability to natural disaster and climate change, for instance, flood. Again, Okaka and Odhiambo [14] held that sanitation could also have influence on household vulnerability to diseases due to flood.

(c) Coping Measures to Lessen Effect of Flooding on Socioeconomic Activities

Social networks found in the study area were associations, village savings and loans associations (VSLAs), unions, cooperatives, etc. They also received some credit facilities / insurance to cushion the effect of flood menace. In Emereoke community, households had very useful strength in their social networks. For instance, they often times respond to disease outbreaks like cholera, typhoid, malaria, and so on by utilizing funds from cooperatives and VSLAs to cater for health emergencies.

CONCLUSION AND RECOMMENDATIONS

In this study, influence of flooding on socioeconomic activities and mitigation measures in Obianga, Emereoke, Inua Eyet Ikot and Iwuo Okpom Opulom Communities of Eastern Obolo and Ibeno Local Government Areas, Akwa Ibom State was evaluated. The results showed that the main source of drinking water was unprotected well/spring water (70.1%). Flooding had led to destruction of houses, loss of property and assets, damaged to health facilities, household members felling sick, damaged to educational facilities, disruption to school attendance, damaged to crops especially cassava and maize, lack of clean water and poor sanitation condition. It seemed that Iwuo Owo Opulom and Emereoke Communities were more liable to flooding in terms of destruction of assets.

It was proposed that drainage structures should be built and accurate flood warning mechanism should be amounted particularly in the flood prone areas through via various agencies and NGOs.

CONFLICT OF INTEREST

None is declared.

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UTICAJ POPLAVA NA SOCIO-EKONOMSKE AKTIVNOSTI I MERE UBLAŽAVANJA U ODREĐENIM PRIOBALNIM ZAJEDNICAMA U DRŽAVI AKVA IBOM

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Apstrakt: Evaluiran je uticaj poplava na socio-ekonomske aktivnosti i mere njihovog ublažavanja u zajednicama Obianga, Emereoke, Inua Eyet Ikot i Iwuo Okpom Opulom u lokalnim samoupravnim područjima Istočnog Obolo i Ibeno, lokalna zajednica oblast države Akwa Ibom, Nigerija.
Studija je koristila unakrsno istraživanje sa uzorkom populacije koji se sastojao od stanovnika priobalnih zajednica koji je utvrđen korišćenjem tehnika namernog i slučajnog uzorkovanja pomoću Godden formule.
Podaci su prikupljeni iz primarnih i sekundarnih izvora. Od učesnika je zatraženo da navedu svoj pol i prihvatljiv uticaj poplava na socioekonomske aktivnosti, kao što su: tip stanovanja gde su živeli, izgubljena imovina, izvori vode za piće, zdravstveni i obrazovni objekti i usevi, kao i sanitarni objekti koje poseduju, i mere ublažavanja za smanjenje posledica poplava.
Etička pitanja su blagovremeno rešena, a instrument (upitnik) je testiran na validnost i konzistentnost, kako u pogledu lica tako i sadržaja, pre nego što je primenjen i preuzet za analizu pomoću programa Microsoft Excel 2016.

Rezultati su zabeležili ukupno 287 učesnika. Većina (61,7%) bili su muškarci. Njihov glavni izvor vode za piće bila je nezaštićena bunarska/izvorska voda (70,1%) i većina zdravstvenih ustanova nije bila dostupna, što je dovelo do nekih značajnih bolesti kao što su malarija (42,2%), kolera/tifus (27,2%) i kašalj/ARI (24,7%).
Veći broj ispitanika je potvrdio dostupnost obrazovnih objekata (90,9%), ali ponekad oštećenih (70,7%), kada je rad škola prekinut zbog poplava (73,0%). Ovo je dovelo do finansijske krize (53,7%), pojave gladi (44,3%) i poplava lokalnih puteva (2,1%) u posmatranim područjima. Njihove osnovne kulture (kasava, kukuruz i bundeva) uvek su bile oštećene (88,1%), pojavom poplava.
Otvoreni tip sanitarno-higijenskih čvorova je bio najčešći tip i on preovađuje (70,7%), dok je najmanje bilo VIP toaleta (2,9%).
Većina stanovnika je dobila finansijsku pomoć od svoje društvene mreže i neke kreditne linije/osiguranja, kako bi se smanjio efekat poplava.
Činilo se da su zajednice Ivuo Ovo Opulom i Emereoke bile podložnije uticaju poplava u smislu uništene imovine.
Preporučena je izgradnja sistema za odvodnjavanje, sa uspostavljenjem precizanog sistema upozoravanja na poplave, uglavnom u regionima koji su skloni čestim poplavama, putem različitih Sistema/agencija i nevladinih organizacija.

Ključne reči:*Poplave, socio-ekonomske aktivnosti, priobalne zajednice, mere ublažavanja*

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ASSESSMENT OF ARABLE CROP PROCESSORS' SATISFACTION WITH UTILIZATION OF NIGERIAN STORED PRODUCTS RESEARCH INSTITUTE (NSPRI) POSTHARVEST TECHNOLOGIES IN ALAPA COMMUNITY, KWARA STATE, NIGERIA

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Abstract: The study assessed arable crop processors' satisfaction with utilization of NSPRI postharvest Technologies in Alapa Community of Kwara State, Nigeria. The population of the study includes all the arable crop processors in the study area. A multistage sampling procedure was employed to select 48 respondents for the study. The primary data obtained with the aid of a well-structured questionnaire were analyzed using descriptive and inferential statistics (Linear Regression model).

The mean age of the respondents stood at 38.31±10.743 years, majority of the respondents were male (60.4%) with a mean house holds size of 5.48±1.203. Most (WMS = 3.44) of the respondents were satisfied with the quality of products (color, taste and odour) derived from the usage of NSPRI postharvest technologies in the study area. Majority (54.2%) of the respondents were satisfied with NSPRI parabolic solar dryer on high level. Lack of training (WMS = 2.10) had been identified as the major challenge faced in the utilization of NSPRI postharvest technologies in Alapa community.

The result of linear regression model revealed that age (t = 4.136***) and household size (t = 2.752***) were significantly related with the level of satisfaction of NSPRI postharvest technologies.

Conclusively, most of the respondents were satisfied with NSPRI postharvest technologies on high level. It was therefore recommended that NSPRI, government and organized private sectors should provide training programs for beneficiaries of their technologies to improve their technical know-how so as to improve the output thereby boosting their income level.

Key words: *Parabolic solar dryer, arable crop, processors, satisfaction*

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INTRODUCTION

Technology transfer plays a vital role in driving innovation by accelerating the commercialization process, bridging the gap between academia and industry, facilitating cross-sector collaboration, and providing resources and support for startups. By understanding the importance of technology transfer and implementing effective strategies, organizations can unlock the full potential of their innovative ideas and contribute to societal progress. Moreover, satisfaction about a technology is an important impetus engendering the penetration and sustainable use of the technology. End users (customers) derive satisfaction from an innovation (technology), product, or a service based on whether their need is met effortlessly, in a convenient way that makes them loyal to the firm. Hence, customer satisfaction is an important step to gaining customer loyalty [1]. Organizations should be aware of the importance of the customer experience especially through feedback mechanism. With appropriate technology in service, customer satisfaction and loyalty rates should increase, and long-term relationships should flourish [2].

Satisfaction had been defined as a feeling of pleasure or disappointment of a person, resulting from comparing a product or service noticed performance (or result) towards his or her expectations [3]. Customer satisfaction is important for companies to gain the trust of consumers, and make them continue to use their services [4]. This can be formed by offering good and competitive services that are well received in the community [5,6].

Developing an effective technology transfer strategy requires the compilation of good data about end users (customers), competitors, and markets, and the innovative conversion of that data into meaningful and leverageable information [7]. Given today's competitive environment, a quality services firm must determine which channels are most appropriate and cost-effective for its various customer segments. It must accurately predict which customers will embrace technology as a substitute for personal service and still be highly satisfied and which customers will demand service with a predominantly personal touch [8]. It is especially important to understand this in the context of a firm's "highly valued" segments of its population.

Though several researches had been done on the customers' satisfaction and loyalty but there is insufficient information on the arable crop processors' satisfaction with utilization of NSPRI postharvest Technologies in Alapa community in Kwara State that could help in prioritizing mediations to improve their utilization.

This lack of understanding hinders efforts to optimize benefits inherent in the usage of NSPRI postharvest technologies which will invariably enhance the livelihoods of many households in this community.

To effectively improve end users satisfaction of technologies which will engender assurance of raising expectations to the highest level, while the tangibility meets the highest perception, it is imperative to assess the socio-economic characteristics of arable crops processors, identify NSPRI postharvest Technologies in the study area, and to assess arable crop processors' satisfaction with utilization of NSPRI postharvest Technologies in the study area.

MATERIAL AND METHODS

Study Area: The study was carried out in Alapa community, Asa Local Government area of Kwara State, Nigeria. It is located at an elevation of 316 meters above sea level and its population amounts to 174,152 in National Population Census [9]. Its coordinates are 8º37'0'N and 4º22'60'E in DMS (Degrees Minutes Seconds) or 8.61667 and 4.38333 (in decimal degrees). Alapa stands as "a thriving agricultural hub" in Kwara State with a rich farmlands and bustling trade. It serves as a vital marketplace where farmers and traders converge on market days. The major crops in Alapa are yam, cassava and maize. The study area is dominated mainly by Yoruba people.

Population of the study: the population of the study includes all the arable crop processors in the study area.

Sampling procedure and sample size: A multistage sampling procedure was employed to select 48 respondents for the study. The first stage involved purposive selection of Alapa community since it is one of adopted villages in Asa Local Government Area of Kwara State while the second stage involved the random selection of four (4) cells out of the eight (8) cells in Alapa community. The third stage involved the random selection of twelve (12) arable crop processors from each of the selected cells in the community to give a total number of forty eighty (48) respondents as the sample frame for the study.

Source and type of data: Primary data were used for this study. The primary data were obtained with the aid of a well-structured questionnaire.

Data analysis: The data collected were analyzed using descriptive statistics and inferential statistics (Linear Regression model).

Measurement of variables: The level of satisfaction with the utilization of NSPRI technologies was obtained using a 5-point Likert scale namely; outstanding = 5, exceed expectation = 4, meet expectation = 3, below expectation = 2, and needs improvement = 1. The benchmark was obtained by adding 5+4+ 3+2+1 = 15 which is divided by 5 to give 3.0. Any mean score of 3.0 and above is high level of satisfaction, otherwise low level of satisfaction (Author defined). The challenges faced in the utilization of NSPRI technologies was obtained using a 4-point scale namely; very severe = 3, severe = 2, mildly severe = 1, and not a challenge = 0. The benchmark was obtained by adding 3+2+1+0 = 6 which is divided by 4 to give 3.0. Any mean score of 1.5 and above is high level of challenge, otherwise low level of challenge (Author defined).

RESULTS AND DISCUSSION

Socio-Economic Characteristics of the espondents

Table 1 presents the socio-economic characteristics of the arable crop processors in Alapa community.

The results in the Table 1 showed that 31.3 percent of the respondents were between 41-50 years of age, 27.1 percent of the respondents were between 31-40 years of age, 22.9 percent of the respondents were within 30 years of age while 18.7 percent of the respondents were above 50 years of age. The mean age of the respondents stood at 38.31±10.743 years.

This implies that the respondents are still in their economically active age and can engage adequately in arable crops processing activities. This finding is in agreement with the earlier study of [10] who stated that individuals who are in active age group are highly productive in their undertakings. Similarly, the mean age in this research work is within the mean ages of 43 and 42 years recorded in Kwara State and Kogi State respectively as reported by [11].

Also, the results in Table 1 showed that majority (60.4%) of the respondents were male while 39.6 percent of the respondents were female. This finding indicated that most of the processors in Alapa community were male. However, this is inconsistent with the studies of [12] who reported that cassava processing industry is dominated by married women.

Table 1. Distribution of Respondents by Socio-Economic Characteristics (N = 48)

Socio-Economic Characteristics	Frequency	Percentage
Age range (Years)		
≤30	11	22.9
31-40	13	27.1
41-50	15	31.3
Above 50	9	18.7
Mean	Mean = 38.31 S.D= 10.743	
Sex		
Male	29	60.4
Female	19	39.6
Household size		
1-5	24	50.0
6-10	21	43.7
Above 10	3	6.3
Mean	Mean = 5.48 S.D = 1.203	
Educational level		
No formal education	6	12.5
Primary school	22	45.8
Secondary school	12	25.0
Tertiary school	1	2.1
Non-formal education	7	14.6

Source: Data Analysis Outputs, 2025., S.D = Standard Deviation

Moreover, it was also indicated in the Table 1 that 50.0 percent of the respondents had between 1-5 members in their house holds, 43.7 percent of the respondents had between 6-10 members in their households while only 6.3 percent of the respondents had above 10 members in their households. Moreover, the average member of the households was found to be 5.48±1.203 indicating a large household size. It was indicated that 12.5 percent of the respondents had no formal education.

However, 45.8 percent of the respondents had primary school education, 25.0 percent of the respondents had secondary education, 2.1 percent of the respondents had tertiary school education while 14.6 percent of the respondents had non-formal education.

The finding vividly connotes the fact that most of the respondents were educated which could go a long way in influencing the level of adoption of technology as related to cassava and yam handlings.

Available NSPRI postharvest Technologies at Alapa community

Table 2 presented the distribution of respondents based on the availability of NSPRI postharvest technologies in the study area. The result in the Table 3 indicated that all (100.0%) of the respondents indicated the availability of parabolic solar dryer provided by NSPRI in their area while 75 percent of the respondents identified with the NSPRI yam barn in the study area. The finding therefore revealed that both parabolic solar dryer and yam barn provided by NSPRI are readily available for the use of processors in the study area.

Table 2. Distribution of respondents by available NSPRI postharvest Technologies in the study area

NSPRI Technologies	Frequency	Percentage
Parabolic solar dryer	48	100.0
Yam barn	36	75.0

Source: Data Analysis Outputs, 2025

Satisfaction with NSPRI postharvest Technologies in Alapa community

Table 3 presented the distribution of respondents by the level of satisfaction with NSPRI postharvest Technologies in Alapa community. The result in the Table 3 indicated that most of the respondents were more satisfied with the quality of products (colour, taste and odour) with a weighted mean score (WMS) of 3.44. Other attributes in the rank order of satisfaction include accessibility of the technologies (WMS = 2.85), safety of products (WMS = 2.75), ease of use (operational design) (WMS = 2.71), location of the technologies (WMS = 2.44), timeliness of action/result/output (WMS = 2.33), capacity (WMS = 1.96), organizational supports (WMS = 1.44) and technology status/condition (WMS = 1.29). This finding implies that quality of products is a good determinant of the level of satisfaction with NSPRI postharvest technologies in the study area. The research results showed that quality of products has a positive and significant effect on satisfaction. This means that the better the quality of products obtained, the higher the customer satisfaction. These results support [13,14,4] which showed that service quality and price has a significant effect.

Table 3. Distribution of respondents by level of satisfaction with NSPRI postharvest Technologies in Alapa community

NSPRI Technologies	O	EE	ME	BE	NI	WMS	Rank
Quality of products (color taste odor)	5(10.4)	17(35.4)	22(45.8)	2(4.2)	2(4.2)	3.44	1st
Accessibility	2(4.2)	13(27.1)	13(27.1)	16(33.3)	4(8.3)	2.85	2nd
Timeliness of action/result/ output	0(0.0)	10(20.8)	9(18.8)	16(33.3)	13(27.1)	2.33	6th
Capacity	0(0.0)	5(10.4)	12(25.0)	7(14.6)	24(50.0)	1.96	7th
Location	2(4.2)	10(20.8)	13(27.1)	5(10.4)	18(37.5)	2.44	5th
Technology status/cond.	0(0.0)	2(4.2)	2(4.2)	4(8.3)	40(83.3)	1.29	9th
Safety of products	0(0.0)	13(27.1)	15(31.2)	15(31.2)	5(10.4)	2.75	3rd
Ease of use (operational design)	0(0.0)	12(25.)	16(33.3)	14(29.2)	6(12.5)	2.71	4th
Organizationa supports	0(0.0)	0(0.0)	4(8.3)	13(27.1)	31(64.6)	1.44	8th

O = Outstanding (5); EE = Exceed Expectation (4); ME = Meet Expectation (3);
BE = Below Expectation (2); NI = Need Improvement (1); WMS = Weighted Mean Score
Source: Data Analysis Outputs, 2025

Categorization of level of satisfaction with NSPRI Technologies in Alapa community

Table 4 presented the distribution of respondents by categorization of level of satisfaction with NSPRI postharvest Technologies in Alapa community. The result in the Table 4 indicated that 54.2 percent of the respondents were satisfied with NSPRI parabolic solar dryer on high level. About 18.8 percent of the respondents were satisfied with NSPRI parabolic solar dryer on moderate level while 14.3 percent of the respondents were satisfied with NSPRI parabolic solar dryer on a low level. It can be deduced from this present finding that a highly satisfied customers produce several benefits for the organization. In tandem with tis finding, [3] conceptualized satisfaction as a feeling of pleasure or disappointment of a person, resulting from comparing a product or service noticed performance (or result) towards his or her expectations. This feeling of pleasure or disappointment has decisive influence on the usage of any technology or services. In line with this idea, [4] opined that customer satisfaction is important for companies to gain the trust of consumers, and make them continue to use their services.

Table 4. Distribution of respondents by categorization of level of satisfaction with NSPRI postharvest Technologies (PHTs) in Alapa community

NSPRI Technologies	Categorization of satisfaction with NSPRI PHTs		
	High	Medium	Low
Processors	26(54.2)	9(18.8)	13(27.0)

Mean = 21.21; Standard Deviation = 5.124., Source: Data Analysis Outputs, 2025.

Hypothesis

Influence of selected Socio-economic characteristics and level of satisfaction with NSPRI postharvest Technologies

Table 5 presented the result of linear regression model showing the relationship between selected socio-economic characteristics and level of satisfaction with NSPRI postharvest technologies in Alapa community. It was revealed that age (t = 4.136***) and household size (t = 2.752***) were significantly related with the level of satisfaction of NSPRI postharvest technologies. The relationship was significant at 1% level indicating the fact that age of the respondents and household size are strong determinants of the level of satisfaction with the usage of NSPRI postharvest technologies. The positive relationship is an indication that a unit increase in any of the significant variables will result in an equivalent increase in the level of satisfaction with NSPRI postharvest technologies. This direction of relation connotes the fact that most of the respondents are highly innovative thereby developing positive attitude toward technology. People with high innovativeness traits have been described as those who possess powerful inherent inspiration when it comes to the use of new technology as they cherish the excitement of trying the innovation [15].

Table 5. Relationship between selected Socio-economic characteristics and level of satisfaction with NSPRI postharvest Technologies

Variables	B-Value	Standard Error	t-value	p-value
Constant	25.759	2.608	9.878	0.000
Age	7.326	1.179	4.136***	0.000
Household size	1.121	0.407	2.752***	0.009
Educational Level	0.865	0.606	1.428	0.160

R = 0.963; R2 = 0.886; Adj.R2 = 0.824; Std. Error of the Estimate = 4.467;
F-statistics = 5.944
***Significant at 1% level
Source: Data Analysis Outputs, 2025.

CONCLUSIONS

The study assessed arable crop processors' satisfaction with utilization of NSPRI postharvest Technologies in Alapa Community, Kwara State, Nigeria. The mean age of the respondents stood at 38.31±10.743 years, majority of the respondents were male (60.4%), educated (87.5%) with a mean households size of 5.48±1.203. All (100.0%) of the respondents indicated the availability of parabolic solar dryer provided by NSPRI in their area while 75 percent of the respondents identified with the NSPRI yam barn in the study area. Most (WMS = 3.44) of the respondents were more satisfied with the quality of products (colour, taste and odour) derived from the usage of NSPRI postharvest technologies in the study area.

Majority (54.2%) of the respondents were satisfied with NSPRI parabolic solar dryer on high level. The result of linear regression model revealed that age (t = 4.136***) and household size (t = 2.752***) were significantly related with the level of satisfaction with NSPRI postharvest technologies.

Based on the findings of this study, the following are recommended:

1. NSPRI, government and organized private sectors should provide training programs for beneficiaries of their technologies to improve their technical know-how so as to improve the output thereby boosting their income level.

2. Since NSPRI postharvest technologies are usually delivered to adopted village with no cost, it is may not be able to address the issue of limited capacity. There is therefore for donors to collaborate by providing funds in order to upscale those technologies in order to satisfy the needs of more beneficiaries.

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PROCENA ZADOVOLJSTVA PRERAĐIVAČA RATARSKIH USEVA KORIŠĆENJEM POSTŽETVENIH TEHNOLOGIJA NIGERIJSKOG INSTITUTA ZA ISTRAŽIVANJE SKLADIŠTENIH PROIZVODA (NISP), U ZAJEDNICI ALAPA, DRŽAVA KWARA, NIGERIJA

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Apstrakt: Studija je procenila satisfakciju prerađivača ratarskih useva korišćenjem NISP tehnologija Nigerijskog instituta za posležetvene obrade u zajednici Alapa u državi Kwara, Nigerija. Studija obuhvata populacije svih prerađivača ratarskih useva u području istraživanja.
Korišćen je višestepeni postupak uzorkovanja za izbor 48 ispitanika za ovu studiju. Primarni podaci su dobijeni uz pomoć dobro strukturiranog upitnika i analizirani su korišćenjem deskriptivne i interferencijalne statistike (model linearne regresije).
Prosečna starost ispitanika u ovoj studiji, iznosila je 38,31 ± 10,743 godina. Većina ispitanika bili su muškarci (60,4%), sa prosečnom veličinom domaćinstva od 5,48 ± 1,203. Većina ispitanika (WMS = 3,44) bila je zadovoljna kvalitetom proizvoda (boja, ukus i miris) dobijenih upotrebom NISP tehnologija nakon žetve u ispitivanom području. Većina (54,2%) ispitanika bila je zadovoljna NISP tehnologijom parabolične solarne sušare visokog nivoa korišćenja.
Nedostatak obuke (WMS = 2,10) je identifikovan kao glavni izazov u korišćenju NISP tehnologija Nigerijskog Instituta, nakon žetve u zajednici Alapa.
Rezultat linearnog regresionog modela pokazao je da su starost (t = 4,136***) i veličina domaćinstva (t = 2,752***) značajno povezani sa stepenom zadovoljstva NISP tehnologijama nakon žetve. Zaključno, većina ispitanika je bila zadovoljna na visokom nivou sa NISP tehnologijama nakon žetve.
Zato je preporučeno da NISP, Vlada i organizovani privatni sektor obezbede programe obuke za korisnike ovih tehnologija kako bi unapredili svoje tehničko znanje i poboljšali proizvodnju, a time i povećali svoj nivo prihoda.

Ključne reči: *Parabolična solarna sušara, ratarski usevi, prerađivači, zadovoljstvo*

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APPLICATION OF IT SYSTEMS IN AUDIT JOBS RELATED WITH EXPLOITATION OF AGRICULTURAL MECHANIZATION'S IN REPUBLIC OF SERBIA

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Abstract: In this study, the authors have shown that there is a strong influence between applications of IT systems within the framework of performing regular tasks of auditing agricultural machinery. We have found that there is a significant difference in the evaluation of the system that respects and applies the IT system and that provides support in the work of the company in the field of auditing agricultural machinery. This is of great importance in terms of making major management decisions in the regular business of the company. In addition, we found that on the basis of the most frequently used tractor IMT- 533, it is possible to predict the other analyzed factors within the acceptance of the use of IT support in the regular business of legal entities, because there is a pronounced significance ($F=69.779$, $p<0.0005$).

Key words*: IT system, audit, agricultural mechanization.*

INTRODUCTION

Real functioning of companies, especially in agriculture, leads to the fact that it is possible to show that there is a strong influence between the functioning of several management factors in the work of the same, for example, the possible application of IT systems within the framework of performing regular audits of agricultural machinery [1-5].

Making valid management decisions in the business of agricultural enterprises means essentially innovating the application of technical and technological factors that will contribute to successful business in the future [6-11].

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The formation of control and audit in the work of top management reporting is possible if technical support is established because the risks of reporting are reduced [11-16].

Realistic audit reporting with technical support for such work, primarily by auditors and controlling, leads to business forecasting in the future activities of an agricultural enterprise, which is the permanent target state of all management bodies [17-20].

MATERIALS AND METHODS

To conduct this study, the authors surveyed 205 top managers, 142 of whom worked in entities that had implemented an IT system to support the acquisition of quality audit certificates, and 63 top managers in companies that did not include an IT system that reviews the audit opinion.

The subject of observation was medium-sized agricultural enterprises in the Republic of Serbia. The research was conducted in the period from 01.03. to 31.03. 2025.

The analysis included three types of tractors that are regularly used in business, then the type of combine harvester and the use of small agricultural machinery in the audit reports of medium-sized agricultural enterprises.

They then performed statistical processing using IBM SPSS (Statistical Package of Social Science) version 25 software, to include a higher level of confidence using the t-test, and finally, the impact of IT in the audits was re-evaluated based on the constant represented by the IMT-533 tractor in relation to the other observed factors of agricultural mechanization. A significance level of 0.05 was used as the threshold value.

Table 1. Presentation of the form of IT influence on the audit of agricultural machinery

	Implemented exemplary IT systems (N=142)	Audit without using IT system (N=63)	t	p
	Ave rage value			
Tractor type IMT 539	6.70 ± 0.38	3.71 ± 0.39	61.650	<0.0005*
Tractor type IMT 577	7.61 ± 0.42	6.72 ± 0.29	13.620	<0.0005*
Tractor type Zetor 6341	6.22 ± 0.41	9.43 ± 0.44	44.568	<0.0005*
Combine harvester	7.06 ± 0.87	8.42 ± 0.43	15.790	<0.0005*
Small agricultural machinery	5.59 ± 0.43	8.43 ± 0.53	34.843	<0.0005*
Total	6.73 ± 0.28	7.33 ± 0.27	13.480	<0.0005*

Business forecasting in the following period for the surveyed companies was done in the form of systematized results in Table 2, where the assessment based on one factor (Tractor type IMT-533) is presented for all other factors in the following business period.

Table 2. Forecasting on the basis of an IT system based on the use of the basic tractor IMT- 539 in audit work related to management

	Beta	t	p
Constant	-	17.109	<0.0005*
Tractor type IMT-577	-0.603	-12.283	<0.0005*
Tractor type Zetor 6341	0.403	8.883	<0.0005*
Combine harvester	0.133	2.803	0.005*
Small agricultural machinery	-0.23	-0.519	0.604

The presentation of the results obtained in this study clearly shows that there is a difference in relation to the application of the IT support system in the work of audit work in agriculture, and that for all analyzed factors (Table 1).

However, we can point out that for the first two analyzed factors, i.e. tractors with less power, there are higher values in the case of applying the IT system, while for all other factors, as well as the overall evaluation, those values are lower than in the case of not using IT in the audit of the business of running and managing agricultural machinery (Table 2).

Prediction of the action of the application of the IT system in future periods based on the constant of the small tractor IMT-533 in relation to the other analyzed factors is possible and the obtained results are significant ($F=69.779$, $p<0.0005$),

CONCLUSION

The authors of this paper clearly indicated the existence of the following conclusions.

First, to see the existence of differences in the case of the application of IT systems in the audit operations of agricultural mechanization in relation to those entities that do not operate in accordance with those principles.

Another thing is that with smaller tractors in use, the existence of higher values can be seen in the case of applied IT factors influencing the revision of agricultural mechanization, while for all others, a drop in such values would be felt in favor of those entities that do not apply the benefits of the IT system in business.

Predicting the application of IT in the revision of agricultural machinery based on the small and basic tractor IMT-533 is possible and significant because we obtained values ($F=69.779$, $p<0.0005$),

Thus, this research fulfilled the expectations of the author, and in the future it is possible to extend the same to other forms of property use in agriculture, as well as to other countries, especially countries surrounding Serbia.

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PRIMENA IT SISTEMA U REVIZIJSKIM POSLOVIMA POVEZANIM SA EKSPLOATACIJOM POLJOPRIVREDNE MEHANIZACIJE U REPUBICI SRBIJI

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Abstract: U ovoj studiji Autori su pokazali da postoji snažan uticaj između primene IT sistema u okviru obavljanja redovnih poslova revizije poljoprivredne mehanizacije.

Autori su ustanovili da postoji značajna razlika u vrednovanju sistema koji uvažava i primenjuje IT sistem i koji daje podršku u radu preduzeća u oblasti revizije poljoprivredne mehanizacije. To je od velike važnosti u smislu donošenja krupnih upravljačkih odluka u redovnom poslovanju preduzeća.

Pored toga, Autori su ustanovili da se na osnovu često korišćenog traktora IMT-533, može se izvršiti predviđanje ostalih analiziranih faktora u okviru korišćenja podrške IT u redovnom poslovanju pravnih lica, jer postoji izražena važnosti ($F=69.779$, $p<0.0005$),

Key words: *IT sistem, revizija, poljoprivredna mehanizacija.*

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EFFICIENCY OPTIMIZATION OF SOLAR PHOTOVOLTAIC SYSTEMS FOR NKATA PRIMARY HEALTHCARE CENTER, IBEKU, ABIA STATE, NIGERIA

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Abstract: This research presents the analysis and efficiency optimization of a solar photovoltaic (SPV) system tailored for Nkata Primary Healthcare Center, in Umuahia, Abia state, Nigeria. Using solar radiation data, the study evaluates the solar resource potential of the region and simulates the system's performance ratio from January to December 2023. The design analysis was conducted on the component part of the SPV system such as the solar panel, charge controller, battery and inverter. The major findings of the solar photovoltaic system design are the energy requirement per day was found to be 21 kWh, and the total wattage becomes 2.6 kW. The number of solar modules or panels obtained was 25. The SunPower solar panel of 435 W was selected for the design of the SPV system. The current amperage of the solar charge controller realized was 107A for the SPV design, and the power rating for the charge controller was 11 kW.
The number of batteries calculated for the solar system was 12, and 250 Ah for a single battery was chosen for the SPV system design.
The input power of the inverter was determined to be 3.3 kW for the SPV system design. The maximum direct current DC and voltage for the proposed SPV system were 197 A and 24 V, respectively. At the same time, the maximum alternating current AC and voltage for the SPV system were 11.2 A and 230 V, respectively. It was observed that the highest number of solar panels occurred in August, during the period of minimum solar radiation.

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The proposed SPV system will meet the energy needs of the Nkata Primary Health Center, since the minimum (57.8 kWh) and maximum theoretical energy output (272.2 kWh) per day in a month were higher than the actual estimated energy requirement of the appliances (21 kWh) per day. The average solar performance ratio of the solar system was determined to be 66 %.

Key words *Design; solar photovoltaic system; panel, charge controller, battery; inverter; actual output energy; theoretical output energy; solar radiation; performance ratio*

INTRODUCTION

In recent years, the utilization of renewable energy sources has become increasingly crucial, especially in regions where conventional electricity supply is unreliable or insufficient [1]. This is particularly relevant in the context of healthcare facilities in rural areas, such as those in Abia State, Nigeria [11]. Rural health center's play a pivotal role in providing essential healthcare services to communities. These services range from basic medical care and emergency response to more complex procedures that require reliable power for medical equipment. The importance of consistent and sustainable energy sources in these settings cannot be overstated [10]. The World Health Organization (WHO) emphasizes the critical role of energy in healthcare delivery, noting that access to reliable power is fundamental to preserving life, reducing morbidity, and enhancing the quality of healthcare services [33]. In the context of Abia State, the challenges are accentuated by the region's geographical and infrastructural constraints, which hinder the consistent supply of electricity.

This issue of unsteady power supply is particularly problematic given the critical nature of healthcare services and the need for consistent power to operate is essential to medical equipment [2,3]. The central research problem of this work revolves around the design of solar photovoltaic (PV) systems as a solution to this challenge. The focus is on enhancing the efficiency of these systems to ensure a reliable and sustainable energy source [14]. This involves addressing the unique energy requirements of medical equipment and overcoming the rural infrastructural constraints in Abia State [21]

The theories and models related to solar photovoltaic systems encompass a wide range of topics, including photovoltaic reciprocity theory, electroluminescence, quantum efficiency, artificial neural network models, solar tracking systems, and maximum power point tracking [20]. The photovoltaic reciprocity theory establishes a relationship between the electroluminescence spectrum of a solar cell and the external photovoltaic quantum efficiency of the device [1].

Additionally, the detailed balance theory of fluorescent collectors has been shown to be compatible with conventional solar cells [29].

Furthermore, artificial neural network models have been developed to estimate the energy efficiency of photovoltaic systems using meteorological parameters such as temperature, humidity, wind, and solar radiation [20]. Solar tracking systems have been designed to automatically orient photovoltaic plants to the sun, thereby improving their efficiency [2]. Moreover, maximum power point tracking techniques have been explored to optimize the power output of solar photovoltaic systems [8].

In addition to these, the literature also covers the use of mathematical and simulation models for solar photovoltaic plants, the development of adaptive devices to enhance energy harvesting in solar photovoltaic tracking systems, and the application of model reference adaptive control to assure optimum operating conditions for solar photovoltaic systems [9,13]. Furthermore, the study of distributed knowledge dynamic integration and fusion for solar concentration photovoltaic systems has been proposed to facilitate in-depth research in this area [34]. The impact of neighboring photovoltaic systems on power forecasting has been assessed using artificial neural networks [32]. Additionally, the role of optical elements in holographic solar energy systems has been investigated [15]. Moreover, the use of dual-axis solar trackers to improve the performance of photovoltaic panels has been simulated [4]. The efficiency of different types of solar photovoltaic (PV) systems has been a subject of extensive research. Various studies have investigated the performance and optimization of solar PV systems, including maximum power point tracking (MPPT) techniques, concentrated solar power (CSP), photovoltaic-thermal hybrid systems, and PV levelized cost of electricity (LCOE) generation.

Author [14] compared the effectiveness and accuracy of Perturb & Observe (P&O) and Constant Current (CC) MPPT methods for solar PV systems, highlighting the importance of MPPT techniques in enhancing system efficiency.

Additionally, considered the performance of solar PV systems in rural areas, emphasizing the significance of solar PV and CSP in harnessing renewable energy resources [26]. Furthermore, [24] developed a model for a concentrated solar spectrum splitting PV cell-gas turbine hybrid system to evaluate and predict maximum efficiency, demonstrating the potential for optimizing system performance [24]. Moreover, [17] conducted experimental research on photovoltaic-thermal hybrid solar systems, achieving thermal efficiencies ranging from 51% to 67%, indicating the potential for high efficiency in heating water using PV/T solar systems. Additionally, discussed the economic feasibility of PV projects using LCOE generation, providing insights into the economic aspects of solar PV systems [12]. Furthermore, highlighted the potential of PV panels in contributing to the UK's energy policy goals, emphasizing the regional distribution and determinants of PV deployment [10]. Efficiency analysis of storage-type solar PV/thermal hybrid systems, the impact of temperature on PV panel efficiency, and the efficiency of PV systems in water pumping applications have also been studied [5,7]. Additionally, studies have explored the total efficiency of PV/T systems, the performance of PV systems in different geographical locations, and the influence of solar incentives on the efficiency of residential PV systems [18,23,35].

The use of solar photovoltaic (PV) systems in the healthcare sector has been a subject of interest due to its potential economic and environmental benefits. [3] conducted a case study in Riyadh, the capital of Saudi Arabia, to assess the cost-benefit perspective of solar-assisted power generation systems in hot desert climates.

The study focused on the ambitious goals of the country in the field of solar energy, providing insights into the economic viability of implementing solar PV systems in such regions. This case study is particularly relevant for healthcare facilities located in similar climatic conditions, as it offers valuable information on the economic impact and potential benefits of solar PV systems in hot desert climates. Furthermore, [22] undertook a case study in Sanoder village, Bhavnagar district, Gujarat, India, to optimize solar PV systems and analyze the tilt angle for enhanced performance.

This case study provides valuable insights into the practical implementation of solar PV systems in a specific geographical location, offering lessons that can be applied to healthcare facilities in similar regions. Understanding the optimization of solar PV systems and the impact of tilt angle on their performance is crucial for healthcare facilities seeking to maximize energy generation and efficiency. Moreover, [6] investigated the economic impact of 300 kWp PV rooftop penetration on soy sauce companies, emphasizing the cost-saving potential of solar PV systems in industrial settings. While the study focused on industrial applications, the findings are relevant to healthcare facilities seeking to assess the economic implications of integrating solar PV systems into their energy infrastructure. Understanding the economic impact of solar PV rooftop penetration can provide valuable insights for healthcare facilities aiming to reduce operational costs and enhance sustainability. These case studies collectively contribute to the understanding of solar PV energy use in healthcare by providing insights into the economic viability, performance optimization, and cost-saving potential of solar PV systems in diverse geographical and industrial settings. By synthesizing these case studies, it is evident that the economic viability, performance optimization, and cost-saving potential of solar PV systems are crucial considerations for healthcare facilities aiming to integrate sustainable energy solutions into their infrastructure [12]. The implementation of solar photovoltaic (PV) systems in healthcare settings in Africa faces several challenges but also presents opportunities for improvement.

Challenges include the lack of guaranteed funding, weak infrastructure, and limited resources, as evidenced by experiences in resource-limited countries such as the Democratic Republic of Congo (DRC) [28]. Additionally, the transition to clean energy security in Africa, including the implementation of solar PV systems, requires coordinated efforts of people, industry, and governments [11]. Furthermore, unequal societies, such as South Africa, face resistance and protest when relying solely on technical solutions to address access and inequality in electricity legitimacy dynamics [30]. In the context of healthcare, the challenges of implementing solar PV systems are compounded by the specific features of medicine safety and pharmacovigilance in Africa, which require resources, infrastructure, and expertise [21]. Moreover, the integration of mental healthcare into primary healthcare in South Africa has faced challenges despite efforts to align health-related policy development with international trends [19]. Access to biomedical healthcare services for Black South Africans living in low socio-economic settings remains limited and poor, indicating broader challenges in healthcare access and infrastructure [25]. However, amidst these challenges, there are opportunities for improvement. Lessons learned from the experiences of resource-limited countries, such as the DRC, demonstrate that it is possible to implement PV systems to promote patients' safety in sub-Saharan African countries with limited funding [28].

Additionally, South Africa has opportunities to adapt successful strategies from other areas of public health to improve healthcare, which could be extended to the implementation of solar PV systems in healthcare settings [16]. Furthermore, the potential for solar energy utilization in Africa is underscored by the long-term historical changes in solar irradiance in West Africa and the implications for photovoltaic systems [27]. In conclusion, the challenges in implementing solar PV in healthcare settings in Africa are multifaceted, encompassing funding, infrastructure, and societal dynamics.

However, there are opportunities for improvement, including lessons learned from other healthcare initiatives, the potential for solar energy utilization, and the need for coordinated efforts to achieve clean energy security. Addressing these challenges and leveraging the opportunities for improvement can contribute to the successful implementation of solar PV systems in healthcare settings in Africa. While there is extensive literature on solar energy applications in healthcare, there is a noticeable gap in studies focused on the specific energy needs and infrastructural constraints of rural health center's in regions like Abia State, Nigeria.

MATERIAL AND METHODS

The Nkata Primary Healthcare Centre is in Ibeku, a rural area within Abia State, Nigeria. This healthcare facility is situated at the geographical coordinates of 5.5376014 latitude and 7.5096301 longitude. Figure 1 provides a detailed map of the centre's location, highlighting its proximity to key roads, neighbouring buildings, and the surrounding natural landscape.

Figure 1. Map showing Nkata Primary Healthcare Centre

This center plays a vital role in the local healthcare system, primarily serving the rural population in and around Ibeku. The geographical setting of Ibeku presents unique opportunities and challenges for solar energy utilization.

The region benefits from significant solar exposure, making it an ideal candidate for solar photovoltaic (PV) systems. However, these benefits are countered by challenges such as variable weather conditions, limited infrastructure, and resource constraints typical of rural settings. The solar PV system currently in use at the healthcare center is a critical component of its infrastructure, designed to provide a reliable source of electricity. This system's specifications, such as its capacity, panel type, and configuration, are crucial for understanding its current efficiency levels and potential for optimization. The study of this

system, set against the backdrop of Ibeku's unique geographical and infrastructural context, is expected to yield valuable insights into the optimization of solar PV systems in similar rural healthcare settings. The focus on the Nkata Primary Healthcare Centre not only addresses the immediate need for reliable and efficient energy solutions in this specific location but also contributes to a broader understanding of renewable energy applications in rural healthcare environments across Nigeria and similar regions.

Data Collection Methods

Data collection for this study involves a combination of primary and secondary methods to gather comprehensive information on the solar PV system's performance and the healthcare centre's energy needs.

Primary Data Collection: Energy Usage and Solar Irradiance Data: Direct measurements of energy consumption at the healthcare center and solar irradiance levels will be recorded. Energy consumption data will be collected using energy meters attached to key equipment and overall facility metering. Solar irradiance will be measured using a pyranometer installed at the site.

Secondary Data Collection: Local Climate Data: Historical climate data for Ibeku will be obtained from local meteorological stations to analyze the impact of weather conditions on solar PV performance.

The Methodology.

In this section we will give a technical overview of the system components. Also, design methods and mathematical calculations for sizing these components are also presented [4,31].

The solar photovoltaic system's primary parts are:

(1) Solar PV panels array (2) Batteries (3) Solar charge controllers (SCC), and (4) Inverter

PV System Design

The system design calculations are conducted by the following steps:

(1) Estimating total load of all appliances in the three rooms bungalow.

(2) Sizing the solar PV system. This includes selecting the type of PV panels, number of panels, arrangement of PV array, and the orientation of panels (i.e. tilt angle).

(3) Sizing the battery bank, (4) Sizing the Inverters (5) Sizing the solar charge controller.

Estimating Total Daily Load

The total load includes all electrical appliances such as lighting and equipment that are used daily in the bungalow. The average daily solar insolation is mostly taken as 5 kW/m^2/day.

PV array Sizing:

Standard Testing Conditions (STC) involve 1 kW/m^2 of irradiation and a PV cell temperature of 25°C.

The Exact Design -Method 1.

The PV panel is characterized by its average efficiency, η_p which is a function of average panel temperature as given by [4,2] is presented in eqn. (1).

$$\eta_p = \eta_r\left(1 - \beta_p\left(T_p - T_r\right)\right) \quad \text{.....(1)}$$

where η_r is the panel efficiency at T_r. T_r is the reference temperature (25 ^{0}C). β_p is the temperature coefficient for module efficiency. The value of $\eta_r$and β_p are taken from Appendix A as 20.1% and -0.38%/K, respectively.

T_P is a function of the ambient temperature as stated by [2,7] is given in eqn. (2).

$$T_p = T_a + \left(219 + 832\bar{k}\right)\left(\frac{NOCT-20}{800}\right) \quad \text{.....(2)}$$

Where $\bar{k}$ is the clearness index. It ranges from 0.3, for cloudy areas to 0.8 for sunny areas. T_a is the ambient temperature of the solar panel (30 ^{o}C). NOCT is the Nominal operating cell temperature (45 ^{o}C).

The total area S_A of the PV panel array can be presented in eqn. (3) as stated by [20].

$$S_A = \frac{E_p}{\eta_{p\,G}} = \frac{E_p^!}{\eta_c \eta_b \eta_p\, G} \quad \text{.....(3)}$$

Where E_p is the energy provided by the PV array. $E_p^!$is the energy provided by the PV array after battery bank ($E_p^!$equals the daily load demand 21225 Wh). G is the daily irradiance (5kWh/m^2/day),$\eta_{c,}$ $\eta_b$and η_i are the efficiencies of controller, batteries, and inverter, respectively $(\eta_c = 95\%;\ \eta_b = 90\%;\ \eta_i = 96\%)$. The area of a SunPower 435W single solar panel S_p is equal to 2.067m ×1.046m =2.16 m^2 as in Appendix A.

The number of SPV panel as stated by [1,20] is given in eqn. (4)

$$N_{p1} = S_A/S_p \quad \text{.....(4)}$$

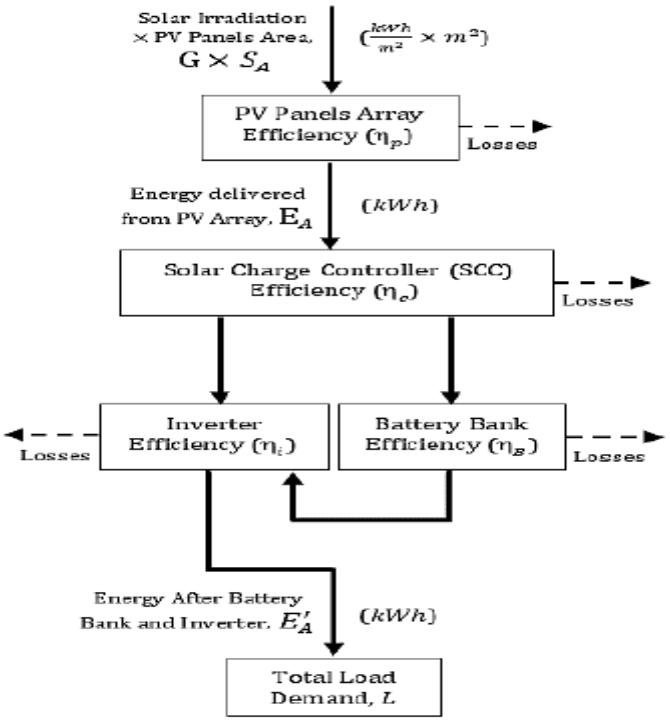

Fig. 2: Solar PV system design flow-chart.

The size of the solar panel and module estimation for method 2.

The total electricity demand of bungalow in Umuahia from the gathered data in Table.1., is used to determine the size of the PV system (in Wp).

The SPV Module Peak Wattage Estimation (Wp) according to [23] is presented in eqn. (5).

The total watt hour (Energy) using battery efficiency (η_b) of 90%.

Module Peak wattage (Wp) $= \frac{\Sigma(\text{Daily Energy Demand Wh})}{PSH \times \eta_b}$ .....(5)

Where PSH is peak sunshine hours and η_b is the battery efficiency.

Number of Modules or panels = $N_{P2} = \frac{\text{SPV Module Wattage Estimation}}{\text{Value of Each Panel}}$ .....(6)

The SunPower panel of 435 W was selected for the solar design.

The size of the solar panel for method 3.

The total appliances used per day = energy consumed per day (ECPD) = **21,225** Wh/day

Total PV panels energy needed (TPEN)

$TPEN = ECPD \times ELS$ (7)

Total Peak Wattage (Wp) of PV panel capacity needed (PWSP)= PGF x WSP

The total number of solar panels (N_{P3}) according to [21], is given in eqn. (8).

$N_{P3} = \frac{\text{Energy watt hour per day x Energy loss in the system}}{Panel\ generation\ factor\ (PGF) \times Wattage\ of\ single\ panel(WSP)} = \frac{TPEN}{PWSP}$ .....(8)

The energy loss in the solar system (ELS)= 1.3

Panel generation factor (PGF) = 3.596 for Nigeria.

The minimum clearance (distance) required between each row of panels is represented by distance (d) as seen in Plate 1 and the angles are calculated by Omni calculator in Fig. 3.

This distance can be calculated using eqn. (9) as stated by [4].

$d = h[(\sin(180^o - \beta - \gamma_s))/(sin\gamma_s)]$ (9)

Determining this clearance requires the angle γ_s of the sun at mid-day (12 Noon) in the shortest day of the year 2023 (i.e., 21st December). The angle (γ_s) is 60.27° (see Fig. 3). The collector height used is ≈ 1.8 m. The tilt angle used is β = 15°. Hence, the distance d ≈ 2m.

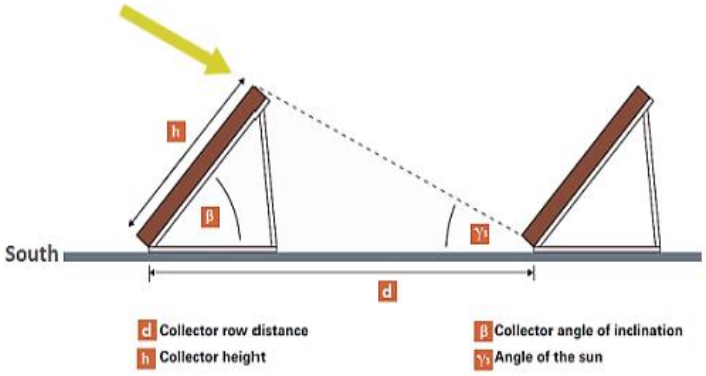

Plate 1. Clearance Between Collectors or PV Panels Rows.

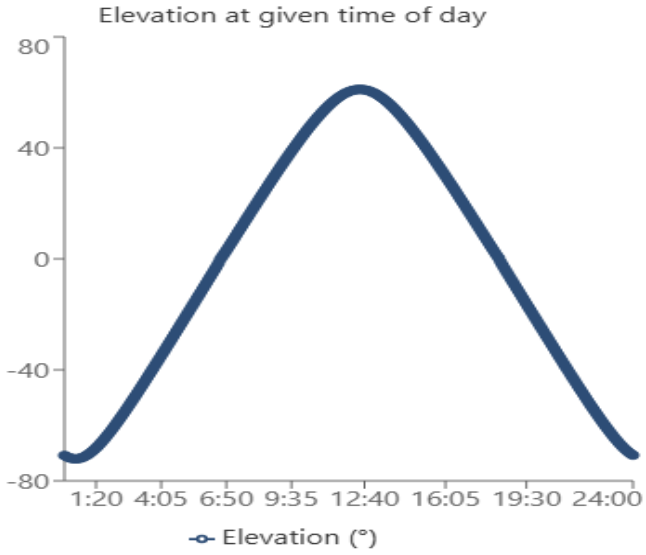

Fig.3. The angle γ_s of the sun at mid-day in the shortest day of the year 2023 (21st December) for Umuahia area (by Solar elevation angle Omni calculator).

The Batteries Sizing of the solar panel (Method 1), according to [11] is presented in eqn. (10).

The actual battery capacity = $B_{C1} = \frac{\text{Total Energy (Wh)}}{\text{Depth of Discharge} \times \text{System Volt}}$ ……(10)

The system volt used for this system is 12 volts and 0.5 depth of discharge.

Number of batteries = $N_{B1} = \frac{\text{Actual Battery Capacity}}{\text{Value of Each Piece}}$

The Batteries Sizing of the solar panel (Method 2) as given by [21] is presented in eqn. (11).

The actual battery capacity = $\frac{\text{Total Energy (Wh) x Days of autonomy}}{\text{Battery loss x Depth of Discharge} \times \text{System Volt}}$ ……(11)

The nominal battery voltage is 12 volts; Battary loss-0.85; depth of discharge is 0.6 and Battery days of autonomy is 2.

Number of batteries = $N_{B2} = \frac{\text{Actual Battery Capacity}}{\text{Value of Each Piece}}$ …..(12)

Since 250Ah batteries can be easily found in the market, and has more storing capacity, it is selected for the final calculation to know the actual number of batteries for the solar panel design.

The Charge Controller Selection for Method 1.

To obtain the needed charge controller as given by [31] is represented in equation (13)

Solar Charge controller (SCC_{1cu}) is given bellow

$SCC_{1cu} = \frac{\text{Total Wattage}}{\text{Voltage}}$ …..(13)

The system volt used is 24 V.

The Solar charge controller sizing: Method 2, according to [20] is given in eqn. (14).

According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc =6.43 A from Appendix A) of the PV array and multiply it by Energy panel lose (ELS-1.3).

Solar charge controller rating (SCC_{2cu})

SCC_{2cu} = panels in Series array x total short circuit current of PV array x 1.3 ….(14)

In 72 panels calculated, there are 8 strings to be arranged in parallel while 9 panels will be arranged in series connection as a single string.

The solar charge controller sizing SCC_3cu for Method 3.

The charge controller's rated power is greater than the maximum power the PV array could produce since a safety factor of 1.3 is used.

The following are the steps to determine the SCC_{3cu} by [20] presented in eqn. (15).

(1). Wattage of the PV array = (number of PV panels) × (PV panel rated power) ….(15)
(2). Rated voltage of SCC_{3v} = (number of panels in series) × (Voc of panel) …..(16)
(3) Rated current of SCC_{3cu} = (number of strings of panels) × (Isc of PV panel) × (safety factor)

The Inverter Capacity Selection for the solar panel as stated by [18] is in eqn. (17) for Method 1.

Therefore: Input Power = $\frac{\text{Output Power}}{\text{Efficiency of inverter } (\eta_i)}$ …(17)

The inverter sizing for Method 2 as presented by [20] is stated in eqn. (18).

For safety, the inverter should be considered 25-30% bigger of total wattage of all appliances.

$$Inverter\ Input\ power = 30\% \times total\ wattage + total\ wattage \quad (18)$$

3.3.1. The Output Power from the SPV system according to [5] is given in eqn. (19).

$$P_{out} = G \times S_{tp} \times \eta_{sys} \quad \text{…...(19)}$$

Where (S_{tp}) is the area of the SPV panel array, (η_{sys}) is the panel system efficiency; G is the solar radiation.

The maximum direct/alternating current and voltage of wire of the solar photovoltaic system as given by [6,7] are represented in eqns. (20) and (21).

$$\text{The maximum direct current (DC)} = \frac{Max\ DC\ wattage\ (W)/module\ \ wattage}{DC\ system\ voltage\ (V)} \quad \text{…..(20)}$$

The maximum DC voltage and current are 24V and 711.6A.

$$\text{The maximum alternating current (AC)} = \frac{Max\ AC\ wattage\ (W)/Total\ \ wattage}{AC\ system\ voltage\ (V)} \text{….(21)}$$

The maximum AC voltage and current are 230V and 44.7 A.

Solar Performance Ratio (SPR%) according to [23;17;18] is stated in equation (23)

$$SPR(\%) = \frac{Actual\ Energy\ Output}{Theoretical\ Maximum\ Energy\ Output} \times 100 \quad \text{……..(22)}$$

$$SPR(\%) = \frac{Daily\ Energy\ Demand\ (Wh)}{total\ solar\ area\ (m^2) \times panel\ efficiency(\eta_r) \times Insolation\ \ G\ (\frac{kwh}{m^2})} \times 100 \quad \text{…...(23)}$$

G= Solar insolation on tilted panel (kwh/m^2/day): η_r = Total solar panel efficiency (%).

S_A =Total solar area (m^2).

Table 1. AC Load for Nkata Health Center

S/N	Appliances	Watts (W)	Quantity	Total Watt (W)	Hour	Energy (Wh)
1	Led light bulb	18	10	180	12	2,160
2	Fan	70	8	560	12	6,720
3	Inverter Refrigerator	250	1	250	12	3,000
4	Inverter Refrigerator	125	2	250	24	6000
5	Inverter Air-condition	500	1	500	3	1500
6	Inverter Sumo pump	760	1	760	2	1,520
7	Computer	65	1	65	5	325
				2,565		21,225

Table 2. Weather parameters from Metrological Unit at (NRCRI)

Monthly average solar radiation and ambient temperature from Jan. to Dec. 2023.					
S/N	Daily Solar Radiation (G_r) ($W/m^2/d$)	Ambient temperature (Ta) (°C)	Monthly Theoretical Output Energy (kWh)	Monthly Actual Output Energy (kWh)	SPR (%)
1	5192	27.61	4206	658	39.01
2	6508	29.76	5271	594.3	30.55
3	4588	28.94	3716	658	47.76
4	4384	28.38	3551	636.8	64.64
5	3536	28.74	2861	658	70.64
6	2512	27.41	2035	636.8	91.77
7	2432	27.11	1970	658	89.03
8	1780	27.24	1442	658	100
9	2300	27	1863	636.8	93.86
10	2528	27.76	2048	658	84.98
11	4120	27.32	3337	636.8	48.88
12	4980	29.11	4034	658	39.08

Table 3. The Characteristics of The SPV System

Solar Photovoltaic Panel Capacity	435 W
Type	E 20/435 Solar Panel
Manufacturer	SunPower
Model	SPR-435NE-WHT-D
Number of Module	25
Efficiency	20.1 %
Nominal operating cell temperature	45 %
Temperature coefficient	-0.38 %/K
Solar collector area	2.16 m^2

RESULTS AND DISCUSSION

The design results from the SPV system.

Table 1 shows the collected data from a Nkata health center in Umuahia, while Table 4 reveals the actual results from the design analysis of the proposed solar photovoltaic system. The environmental weather parameters used in the SPV design, such as solar radiation and ambient temperature, were collected from the meteorology unit inside the National Root Crops Research Institute (NRCRI) for 12 months in 2023

Table 4. The results from the proposed SPV design of a three-room bungalow in Umuahia

	Total energy hour (kWh)	Watt (kW)	Number of solar components	Capac. of the single product	Input power (kW)	Ampere (A)	Volt (V)	Effic. (η %)
		2.6	20, 19.7 & 19	435 (W)				20.1
Charge controller		11				107, 42 & 42	428	95
Battery (Ah)			12 & 28	250				90
Inverter					2.5 & 3.2			96
Max. DC.						197	24	
Max. AC.						11.2	230	
SPV system	21 & 121							
SPR								68

Discussion of results in Table 3.

Table 1 displays the Nkata Health Center energy estimate, while Table 4 shows a summary of the determined design outcomes. The analysis found a wide range of energy-consuming appliances with different power ratings and operating times. It was determined that the facility (solar panel) would use 21225 Wh (21 kWh) of actual energy each day while the theoretical energy per day is 121 kWh. For the solar photovoltaic panel, the estimated module peak power was 2.6 kW.

For the SPV design, a SunPower single solar panel with a wattage of 435 W was chosen. The results of methods 1, 2, and 3 showed that there were 20, 19.7, and 19 solar panels, respectively. Method 1 was chosen for the design of the solar photovoltaic system since it has the most panels number of 20, but it is approximated to 25 panels due to factor of safety to accommodate future improvement. The efficiency of the solar panels was found to be 20.1%. Methods 1, 2, and 3 all yielded solar charge controller amperages of 107 A, 42 A, and 42 A, respectively. For the SPV system design, the best result is 107 A from method 1 was chosen. 11 kW was determined to be the solar charge controller's wattage. There were 12 batteries from method 1 and 28 batteries from method 2. Even though method 2 produced the maximum number of batteries, the number of batteries from method 1 (12) was chosen for the SPV system design. While method 2's outcome is required in situations when high energy storage is crucial, method 1's result is economically feasible. The 250 Ah single solar lithium-ion battery was used for the design because it was readily available and had a good product storage capacity. The inverter's input power was 2.7 kW for method 1 and 3.3 kW for method 2. Method 2 is used for the design of the SPV system because it has the largest inverter input power (3.3 kW). The suggested SPV system has a maximum direct current (DC) of 197 A and a maximum voltage of 24V. The SPV system's maximum voltage and alternating current (AC) were 230V and 11.2 A, respectively. The solar system's average solar performance ratio was found to be 68 %, indicating that it effectively transforms sunlight or solar irradiance into electrical power.

Table 1 shows that appliances with large energy demands, including refrigerators and fans dominate the consumption profile. Their respective energy demands are 9,000 and 6,000 Wh. Other appliances, including, computer, and LED lightbulbs, use less energy on their own, but because of their longer use hours, they add to the total demand. However, it can usually be optional. The availability of solar energy is in good alignment with the peak energy demand, which usually happens during the day when operating activities are at their highest [4;10;11;12].

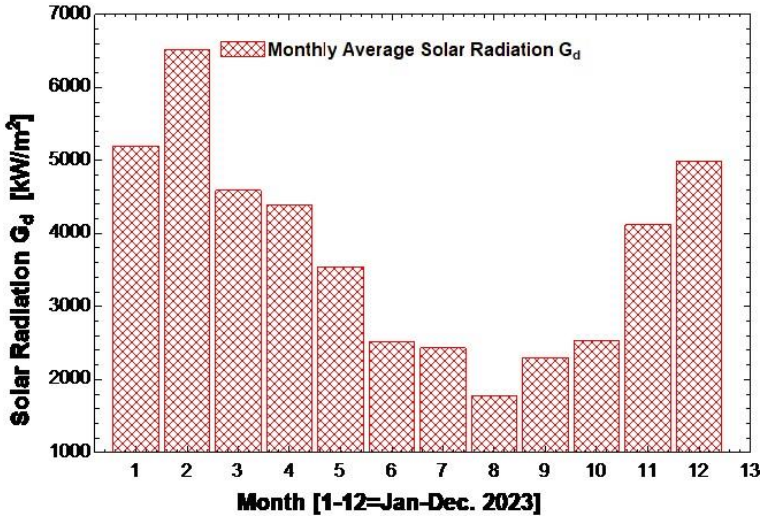

Fig.4. The solar radiation for the photovoltaic system

The solar radiation bar chart for the photovoltaic system from January to December 2023 is shown in Fig. 4. Solar radiation was at its lowest in August and then rose from September to February. In August, the sun radiation summary, average, minimum, and maximum were 44300, 1780, 800, and 3800, respectively. In February, the solar radiation summary, average, minimum, and maximum were 162700, 6508, 3200, and 8400, respectively. Accordingly, February 2023 revealed the maximum amount of solar radiation (8400 W/m2/day) in Umuahia, Abia State, while [8,9,10] found a similar outcome. This is because February had the highest solar radiation, resulting in a maximum theoretical output energy of 121 kWh per day compared to Table 1's Actual consumption energy of 21 kWh per day.

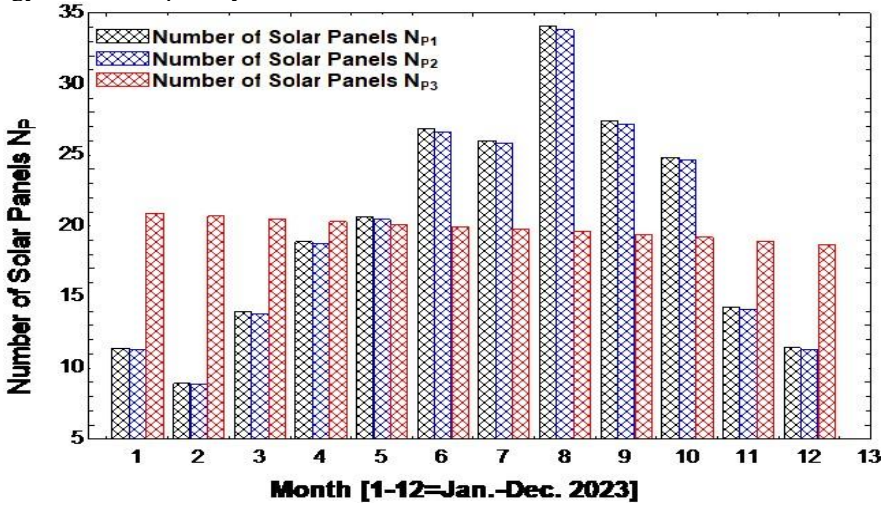

Fig. 5: The Number of panels of the solar photovoltaic system.

Fig. 5 shows the number of solar panels calculated from three methods, and they were simulated by the Engineering Equation Solver (EES) software. The total summation, average, minimum, and maximum number of panels (N_{P1}) from method 1 are 239, 19.9, 8.9, and 34.1, respectively. The number of solar panels obtained from method 2 was also simulated, and the total summation, average, minimum, and maximum number of panels (N_{P2}) are 236, 19.7, 8.85, and 33.8, respectively. The total summation, average, minimum, and maximum number of solar panels (N_{P3}) from method 3 are 238, 18.79, 18.7, and 20.9, respectively. It can be observed that method 1 has the highest average number of solar panels of 19.39, and it is approximated to be 25 for the SPV design, which is in line with the findings of [4,5]. Another observation can be seen from the bar chart that the results from method 3 are higher from January to April and become lowest from May to October. The results from methods (1 and 2) are higher during the rainy season, while method 3 is higher in the dry season. It can also be seen in the bar chart that during the rainy season, there is always poor solar radiation or sunshine; therefore, a greater number of solar panels will be needed, as observed in August, which recorded maximum number of solar panels of 34.1.

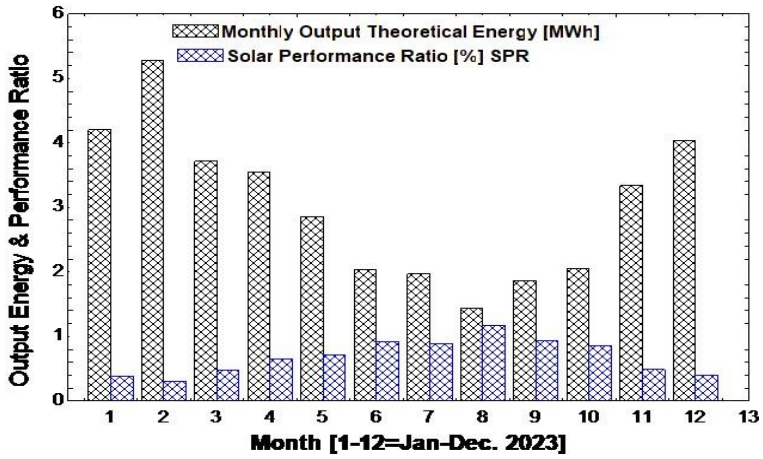

Fig.6. The output Energy and Performance ratio of the solar photovoltaic system

Fig. 6 is the output theoretical energy of the solar photovoltaic system. Fig. 6 illustrates show the output energy fluctuates based on the influence of daily solar radiation, with a minimum output energy of 26.16 kWh in August and a maximum output energy of 210.9 kWh in February. With an average monthly energy production of 3028 kWh, the system generates 36,330 kWh of energy for the site annually. The Nkata Health Center in Umuahia will have its daily energy needs met by the solar photovoltaic system because the projected energy requirement per day is 21225 kWh (21 kWh) from Table 1, which is less than the minimum theoretical energy output (57.7 kWh) and maximum energy output (272.2 kWh) per day in a month in February. The findings regarding the highest energy output in February and the lowest in August are consistent with [11,20,28]'s observations. The solar performance ratio (SPR) spread across the bar chart from January to December with average of 68 %. This results of SPR shows that sunlight energy was totally converted throughout the year.

CONCLUSION

The proposed design of solar photovoltaic system for Nkata Health Center in Umuahia, Abia State, Nigeria, has been completed. The major findings of the solar photovoltaic system are: The energy requirement per day was found to be 21 kWh, and the total wattage becomes 2.6 kW. The number of solar modules or panels obtained was 25. The SunPower solar panel of 435 W was selected for the design of the SPV system. The current amperage of the solar charge controller realized was 107 A for the SPV design, and the power rating for the charge controller was 11 kW. The number of batteries calculated for the solar system was 12, and 250 Ah for a single battery was chosen for the SPV system design. The input power of the inverter was determined to be 3.3 kW for the SPV system design. The maximum direct current DC and voltage for the proposed SPV system were 197 A and 24 V, respectively.

At the same time, the maximum alternating current AC and voltage for the SPV system were 11.2 A and 230 V, respectively. It was observed that the highest number of solar panels occurred in August, during the period of minimum solar radiation.

The proposed SPV system will meet the energy needs of the Nkata health center , since the minimum (57.8 kWh) and maximum theoretical energy output (272.2 kWh) per day in a month were higher than the actual estimated energy requirement of the appliances (21 kWh) per day. The average solar performance ratio of the solar system was determined to be 66 %.

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Appendix A.

SUNPOWER® E20/435 SOLAR PANEL

MODEL: SPR-435NE-WHT-D

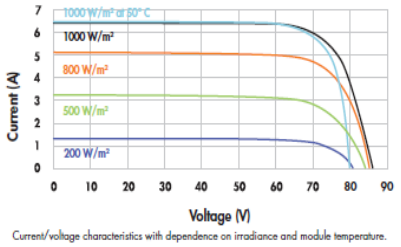
ELECTRICAL DATA
Measured at Standard Test Conditions (STC): Irradiance 1000W/m², AM 1.5, and cell temperature 25° C

Nominal Power (+/-5%)	P_{nom}	435 W
Cell Efficiency	η	22.4%
Panel Efficiency	η	20.1 %
Rated Voltage	V_{mpp}	72.9 V
Rated Current	I_{mpp}	5.97 A
Open-Circuit Voltage	V_{oc}	85.6 V
Short-Circuit Voltage	I_{sc}	6.43 A
Maximum System Voltage	IEC	1000 V
Temperature Coefficients	Power (P)	– 0.38%/K
	Voltage (V_{oc})	-235.5mV/K
	Current (I_{sc})	3.5mA /K
NOCT		45°C +/– 2°C
Series Fuse Rating		20 A
Limiting Reverse Current (3 strings)	I_r	16.1 A
Grounding		Positive grounding not required

ELECTRICAL DATA
Measured at Nominal Operating Cell Temperature (NOCT): Irradiance 800W/m², 20° C, wind 1 m/s

Nominal Power	P_{nom}	323 W
Rated Voltage	V_{mpp}	67.2 V
Rated Current	I_{mpp}	4.81 A
Open-Circuit Voltage	V_{oc}	80.1 V
Short-Circuit Voltage	I_{sc}	5.20 A

I-V CURVE



Current/voltage characteristics with dependence on irradiance and module temperature.

TESTED OPERATING CONDITIONS

Temperature	– 40° C to +85° C
Max load	550 kg/m² (5400 Pa), front (e.g. snow) w/specified mounting configurations
	245 kg/m² (2400 Pa) front and back (e.g. wind)
Impact Resistance	Hail: 25 mm at 23 m/s

WARRANTIES AND CERTIFICATIONS

Warranties	25-year limited power warranty
	10-year limited product warranty
Certifications	IEC 61215 Ed. 2, IEC 61730 (SCII)

OPTIMIZACIJA EFIKASNOSTI SOLARNIH FOTONAPONSKIH SISTEMA ZA PRIMARNI CENTAR ZDRAVSTVENE ZAŠTITE NKATA, IBEKU, DRŽAVA ABIJA, NIGERIJA

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Abstract: Istraživanje predstavlja analizu i optimizaciju efikasnosti solarnog fotonaponskog (SFS, eng. SPV) sistema prilagođenog za centar primarne zdravstvene zaštite Nkata, grada Umuahija, država Abija, Nigerija.

Koristeći podatke o solarnom zračenju, studija procenjuje potencijal solarnih resursa regiona i simulira odnos performansi sistema od januara do decembra 2023. godine. Analiza dizajna je sprovedena na komponentama SPV sistema kao što su solarni panel, regulator punjenja, baterija i invertor. Glavni rezultati ispitivanja ovog dizajna solarnog fotonaponskog sistema su: utvrđeno da je potrebna energija dnevno 21 kWh, a ukupna snaga 2,6 kW. Broj dobijenih solarnih modula ili panela je 25. Za dizajn SPV sistema izabran je solarni panel SunPower od 435 W.

Ostvarena električna energija solarnog regulatora punjenja bila je 107 A za dizajn SPV-a, a nominalna snaga regulatora punjenja bila je 11 kW. Broj baterija izračunat za solarni sistem bio je 12, a za dizajn SPV sistema izabrano je 250 Ah za jednu bateriju. Ulazna snaga invertera je određena od 3,3 kW za dizajn SPV sistema. Maksimalna jednosmerna električna energija (jačina struje) (DC) i napon za predloženi SPV sistem bili su 197 A i 24 V, respektivno. Istovremeno, maksimalna (jačina struje) naizmenična električna energija (AC) i napon za SPV sistem bili su 11,2 A i 230 V, respektivno.

Najveći broj solarnih panela bio korišćen u avgustu, tokom perioda minimalnog sunčevog zračenja. Predloženi SPV sistem će zadovoljiti energetske potrebe Doma primarne zdravstvene zaštite grada Nkata, jer je minimalna (57,8 kWh) i maksimalna teoretska izlazna energija (272,2 kWh) dnevno u mesecu bila veća od stvarne procenjene dnevne potrebe za energijom uređaja (21 kWh).

Prosečan odnos solarnih performansi solarnog sistema je određen na 66%.

Ključne reči: *Dizajn; solarni fotonaponski sistem; panel, kontroler punjenja, baterija; inverter; stvarna izlazna energija; teoretska izlazna energija; sunčevo zračenje; odnos performansi.*

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ANALYSIS OF CIRCULAR ECONOMY PRACTICES IN YOUTH EMPOWERMENT IN THE OIL PALM INDUSTRY OF OSUN STATE, NIGERIA

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Abstract: Despite the vast potential of the oil palm industry in Osun State to drive sustainable economic growth through circular economy (CE) practices, youth participation remains critically low and underdeveloped. This study sought to investigate the impacts of CE on youth empowerment in the oil industry of Osun State, Nigeria. Primary data were sourced with the aid of well-structured questionnaire using two-stage sampling procedure to randomly select 150 youths from the study area. Descriptive and inferential statistics such as Pearson correlation were used for data analysis. The results showed that 48 youths (32%) realize they engage in CE efforts concurrently, while 102 youths (68%) do not engage. Some of the biggest challenges preventing circular economy efforts include limited access to funds and credits (78%), limited technical know-how (72%) and limited awareness of the circular economy benefits (68%). Correlation analysis showed that the calculated Z-value was found to be 4.55 as compared to the critical Z-value at 5% significance level (two-tailed) of ±1.96.
This proves that barriers and opportunities identified in the study have a significant effect on youth engagement hence emphasizing the need for policies that would reduce the constraints as well as strengthen enabling factors towards circular economy participation.

Keywords*: Youth, empowerment, circular economy, practices, palm oil*

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INTRODUCTION

The oil palm industry, a principle subsector of Nigeria's agriculture with potential for fostering CE models, has tremendous capacity for innovation, waste reduction as well as the sustainability of palm oil production. In the context of Osun State, Nigeria, the interplay of the demography makes it a necessity for the youth to be engaged in sustainable development. Particularly as the youth population constitute over 60% of the workforce, involving the youth in circular economy practice is crucial in relation to both the unemployment rates and the environmental destruction. [1]. Through CE practices, for instance, youths are afforded microenterprise opportunities that create a positive impact on the environment, linking the project to SDG 8 [2].

While the oil palm sector offers clear opportunities for innovation, waste valorization, and microenterprise development that align with Sustainable Development Goal 8 [3], systemic barriers such as limited access to finance, inadequate policy support, weak cooperative structures, and insufficient training continue to exclude young people—especially those in rural and disadvantaged communities—from fully engaging in and benefiting from CE initiatives [4]. Without targeted interventions to dismantle these structural constraints and promote inclusive youth-led innovation, Osun State risks missing a critical opportunity to transform its oil palm industry into a sustainable, circular model capable of generating economic empowerment, environmental resilience, and social equity for its rapidly growing youth population [1], [4].

Empowered youth and circular economy literature suggest benefits across the board. For instance, CE solutions create opportunities for economic growth and the emergence of leadership, innovation, and social integration [5]. In addition, CE operates with technologies made by young people such as digital access, agricultural technology, and environmentally friendly entrepreneurial frameworks [6].The other side of the narrative is many institutions are now providing trainings and mentorship sessions to instill the right caliber in the young entrepreneurs to succeed in this place. Leveraging on the Projects while the projects are successful, the wider systemic push for these initiatives are currently disaggregated especially in countries like Nigeria.

In order to enhance the effects of CE in youth empowerment, the approach must be comprehensive. This requires overcoming significant barriers including lack of access to education and financial resources and to knowledge-sharing networks [5]. Strengthening collaboration between academia, industry and policymakers can spark youth involvement and ensure the infusion of CE principles in all sectors [7]. By placing youth at the head of the table in driving the circular economy shift, the oil palm trade in Osun State cannot only meet environmental sustainability but also achieve shared economic growth and social fairness [8], [9]. This will include a firm plan to build up young people, give them incentives to take part, and provide a good setting for their success [10], [11]. The circular economy in the Oil Palm sector of Osun State, Nigeria brings a unique channel for youth empowerment and sustenance of development.

MATERIAL AND METHODS

Study Area

Osun is an agrarian State in south west of Nigeria. Its capital is located at Osogbo. It is bounded in the north by Kwara State, in the east partly by Ekiti and Ondo States, in the south by Ogun State and in the west by Oyo State. It has substantial farm settlements and some oil palm production activities. The state has several farm settlements where oil palm production and processing activities are concentrated.

The average annual rainfall is 52.35 inches (1,330 mm), though there are great deviations from this mean value from year to year. Usually, the rainy season lasts from April to October. The topography of the Local Government Area is hilly, so crops grown there are tree crops, Cocoa, Kolanut, Coconut, Oil palm and arable crops such as yam, cassava and pepper.

Sampling Technique and Sample Size

The study was carried out using a two-stage sampling procedure. The first stage involves the purposive selection of three (3) farm settlements in the Osun West Senatorial District due to the preponderance of the palm oil production activities in the State. The selected farm settlements include Ago-Owu farm settlement, Orile-Owu farm settlement, and Mokore Farm Settlement. The second stage is the random selection of fifty (50) youth that are engaged in oil palm processing in each of the three (3) farm settlements to make a total of 150 youths.

Method of Data Analysis

The tools that were used in analyzing collected data include; descriptive statistics and inferential statistics. Simple descriptive statistics such as means, percentages and frequency distribution were used to describe youth participation in oil palm production in the concept of CE. Also, Pearson correlation was used to test the research hypotheses and examined the relationships among variables.

RESULTS AND DISCUSSION

Level of awareness and understanding of circular economy among youth in the oil palm enterprise

Table 1 presents Level of awareness and understanding of circular economy among youth in the oil palm enterprise. The results in Table 1 show that the the majority of respondents (68.67%) have heard about circular economy but do not understand it, suggests that they are only familiar with the concept at a surface level. Approximately 29.33% understand how circular economy works at a low level with only 0.67% declaring that they understand it at a medium/high level. Furthermore, another 0.67% has never heard about it. Therefore, this indicates that while there are some levels of awareness among youths about the concept, awareness is not enough, for the levels of knowledge are critically low which goes to show that more education and sensitization needs to be done for these youths to understand more about the concept and how it may be effective for them in the future.

Table 1. Level of awareness and understanding of circular economy among youth in the oil palm enterprise

Characteristics	Frequency	Percentage (%)
Heard but don't understand	103	68.67
Basic	44	29.33
Never Heard	1	0.67
Moderate	1	0.67
Advanced	1	0.67

Source: Field Survey Data, 2024.

Youth currently involved in circular economy practices in the oil palm enterprise

Table 2 presents engagement of the youth circular economy practices in the oil palm enterprise in the study area. Youth engagement in circular economy (CE) efforts in the oil palm industry, however, indicated that none of the youths are currently engaged. From the 150 respondents, 48 youths (32%) realize they engage in CE efforts concurrently, while 102 youths (68%) do not engage. Therefore, a low practical engagement gain for CE exists amongst youths, despite varying degrees of awareness. In addition, engagement occurs based on certain areas of the oil palm value chain.

Processors are the most engaged with 33 processors engaging in CE versus 16 not. On the other hand, the marketer group is not very involved either, as only 3 of 46 respondents engage in CE. The same goes for the farmer group—when combining the two entries of "Farmer" and "farmer"—boasts 54 persons not applying CE but only 12 involved. Therefore, the results show that processors are currently the only segment applying for CE, while farmers and marketers have significantly lower participation. This implies that something needed it along the value chain for support and awareness to increase youth participation in circular economy activities.

Table 2. Distribution of involvement of youth in circular economy practices in the oil palm enterprise

Involvement in CE	Frequency	%
Yes	48	32
No	102	64

Source: Field Survey Data, 2024.

Hypotheses Testing

First Hypothesis

H_0: There is no significant difference among youth in the oil palm industry in terms of their awareness and knowledge of circular economy.

H_1: There is a significant difference among youth in the oil palm industry in terms of their awareness and knowledge of circular economy.

The test of hypothesis examined whether the knowledge level of the circular economy among young people varies significantly with a hypothetical mean of 50%. The value of Z for 150 respondents was computed to be 2.60, 1.96± at a 5% level of significance. Z is 9 and it is higher than the critical Z; therefore, the null hypothesis should be rejected. This result indicates that the level of awareness and understanding among youth in the oil palm

enterprise is significantly higher than the average baseline, reflecting a generally good awareness of circular economy practices.

Second Hypothesis

H_0: Youth do not actively participate in circular economy projects within the palm oil enterprise to a significant degree.

H_1: Youth actively participate in circular economy projects within the palm oil enterprise to a significant degree.

The null hypothesis was that the children spend 10 hours per week on activities of a circular economy that make a difference. The calculated Z was 6.13 (based on 150 respondents), which is higher than the critical Z value of ±1.96 for a 5% level of significance. The null hypothesis is thus rejected. This means that the level of involvement of the youth is much greater than the neutral value and that positive has been shown strong engagement in circular economy practices in the communities.

Third Hypothesis

H_0: Barriers and opportunities do not significantly affect youth participation in circular economy efforts.

H_1: Barriers and opportunities significantly affect youth participation in circular economy efforts.

The test established whether barriers and opportunities have a significant influence on youth participation in circular economy initiatives. From a correlation result, the calculated Z-value was found to be 4.55 as compared to the critical Z-value at 5% significance level (two-tailed) of ±1.96. Since this calculated Z-value is greater than the critical Z, the null hypothesis is not accepted. This proves that barriers and opportunities identified in the study have a significant effect on youth engagement hence emphasizing the need for policies that would reduce the constraints as well as strengthen enabling factors towards circular economy participation.

The key barriers and opportunities influencing youth participation in circular economy initiatives in the oil palm value chain in the study area

Table 3 presents the major constraints and opportunities influencing youth participation in circular economy initiatives in the oil palm value chain in the study area. Table 3 reveals that some of the biggest challenges preventing circular economy efforts include limited access to funds and credits (78%), limited technical know-how (72%) and limited awareness of the circular economy benefits (68%). In addition, 64% of survey participants responded that there is insufficient government support and policy, 60% claim there is insufficient market access for resale of recycled goods, and 55% say there is cultural stigma against reuse of waste. Among the other challenges are high costs of new recycling machinery (50%), low institutional support (48%) and poor infrastructure such as bad roads and storage (45%), low collaborative efforts between stakeholders (40%).

On the contrary, many opportunities were revealed with much potential for increased youth involvement. The greatest opportunity was the availability of excess raw materials like oil palm waste (85%) and a growing market for green products (80%). 75% claim that the government's attention to sustainable development is a facilitative factor. Other opportunities include the willingness of youth to embrace new innovations (72%), availability of training and capacity building (70%) and the presence of partnerships with NGOs and developmental agencies (65%).

Finally, among the other opportunities are the potential for job and income generation (60%), community sensitizations (58%), access to social media platforms for product sale (55%) and improved R&D and technological innovation (50%). These results are presented in percentages so that an analytical approach for a weighted sense of what challenges and opportunities mean most relative to youth engagement in circular economy efforts. The overwhelming data presents stakeholders with the necessary information to minimize the greatest challenges and advocate for the greatest opportunities. Ultimately it establishes an efficient environment in which youth can take action and be empowered agents of sustainable development within the oil palm value chain in Osun State.

CONCLUSIONS

This study fills the gap in information regarding the major challenges and opportunities available to youths engaging with circular economy initiatives along the oil palm value chain in Osun State. While youths generally are aware of the potentials of circular economy initiatives and want to participate, there are many challenges that stop them from taking action. The most significant challenges preventing youths from participating include no access to funds and credits, no technical know-how and poor awareness. Yet with excess raw materials available and increased market demand for eco-friendly products, there are positive opportunities that could increase levels of participation for more sustainable efforts. These can help enhance youth participation in the circular economy while aligning with various SDGs. Policymakers and stakeholders seeking to improve sustainability should first prioritize available funding and credit options that cater directly to young people involved in the oil palm industry. They should also conduct practical training, attitudinal change campaigns regarding recycling/reuse and skills acquisition to determine the socio-cultural aversions and technical gaps that create negative challenges. Government agencies, NGOs and the private sector should operate continuously with one another to provide regulations and supports relative to digital avenues where young people can sell creations from recycled materials while continuously seeking options for value addition

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ANALIZA PRAKSE PRIMENE CIRKULARNE EKONOMIJE U OSNAŽIVANJU MLADIH U INDUSTRIJI PALMINOG ULJA U DRŽAVI OSUN, NIGERIJA

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Abstract: Uprkos velikom potencijalu industrije palminog ulja u državi Osun, Nigerija, za podsticanje održivog ekonomskog rasta kroz prakse cirkularne ekonomije (CE), učešće mladih i dalje je izuzetno nisko i nedovoljno razvijeno.
Ova studija imala je za cilj da ispita uticaj cirkularne ekonomije na osnaživanje mladih u industriji palminog ulja u državi Osun, Nigerija.
Primarni podaci su prikupljeni pomoću jasno strukturisanog upitnika, primenom dvostepenog uzorkovanja radi nasumičnog odabira 150 mladih iz oblasti istraživanja. Za analizu podataka korišćene su deskriptivne i interferencijalne statističke metode, uključujući Pearson korelaciju.
Rezultati su pokazali da 48 mladih (32%) shvata da istovremeno učestvuje u aktivnostima cirkularne ekonomije, dok 102 mlade osobe (68%) ne učestvuju.
Neke od najvećih prepreka sprovođenju cirkularne ekonomije uključuju ograničen pristup finansijskim sredstvima i kreditima (78%), nedostatak tehničkog znanja (72%) i nedovoljnu svest o prednostima cirkularne ekonomije (68%).
Korelaciona analiza je pokazala da je izračunata Z-vrednost iznosila 4,55, u poređenju sa kritičnom Z-vrednošću od ±1,96 na nivou značajnosti od 5% (dvostruki test).

Ovo potvrđuje da identifikovane prepreke i mogućnosti imaju značajan uticaj na angažovanje mladih u industriji prerade palminog ulja, čime se naglašava potreba za politikama koje bi smanjile ograničenja, kao i ojačale faktore koji podstiču učešće u cirkularnoj ekonomiji.

Ključne reči: *Mladi, osnaživanje, cirkularna ekonomija, prakse, palmino ulje*

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EVALUATION AND MODELLING THE EFFECT OF TILT ANGLE, PENETRATION CHARACTERISTICS AND MOISTURE CONTENT ON DRAWBAR POWER REQUIREMENT OF RIDGER ON LOAMY SANDY SOIL

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Abstract: The evaluation and modeling of the effect of tilt angle, penetration characteristics and moisture content on drawbar power requirement of ridger on loamy sandy soil was carried out for apposite choice of ridgers for tillage operations. Results showed that, the ridger operation requires drawbar power range from 10.43 – 11.38 kW to operate under tilt angle between 15 – 25º while operating at depth varying from 14 – 28 cm.

The highest drawbar power of 11.38 kW was attained when the ridger was operated at a tilt angle of 20º, cutting depth of 14 cm and at average moisture content of 20.5% while the least drawbar power of 10.43 kW was obtained at tilt angle of 25º, cutting depth of 28 cm and average moisture content of 15.5%. Results of statistical analysis indicated that, the interaction of the tilt angle and depth of cut, and the moisture content of the soil were statistically significant ($p< 0.05$). The coefficient of determination, R^2 and adjusted R^2 values were resolutely reliable.

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Thus, the experimental values were appropriate with the coefficient of determination of $R^2 = 0.9983$, suggesting exceptional correlations among the independent variables.
The optimum drawbar power of 10.90kW was attained with the desirability of 1.000 at optimal tilt angle of 16.24°, cutting depth of 19.31cm and average moisture content of 14.44%.

Key words: *Depth, drawbar-power, farmers, loamy-sandy, moisture, tilt-angle, ridger.*

INTRODUCTION

The environment for crop production needs a number of field operations, such as preparation of seed bed, seeding, fertilizer application, spraying of pesticides or herbicides, dusting, irrigation, harvesting and threshing [1]. The first operation in production of crop after land clearing is tillage. Tillage is a mechanical manipulation of soil to provide favourable conditions for crop production. Soil tillage consists of breaking the compact surface of earth to a certain depth and to loosen the soil mass, so as to enable the roots of the crops to penetrate and spread into the soil. Soil tillage is a cultural practice that effects the soil's physico-chemical characteristics, and, henceforth, produces variations in the crop growth and/or development, the aerial cover, the growth of roots, and the overall yield performance of the crop [2]. Tillage may be called the practice of adjusting the condition of soil to offer favorable environments for plant growth and development. It is the most labor intense and difficult operation compared to all subsequent operations in the field. The main objectives of tillage are the production of a suitable tilt, the destruction of weeds, the destruction of pests and burying the rubbish and the incorporation of fertilizers into the soil.

The main source of power in agriculture is the tractor, which is now available in different sizes. Tractor power utilization is achieved through the driving wheels as traction to provide the drawbar power required for draft implements and to provide mobile support for attached machine. Draft, energy and fuel requirements for agricultural implements have been recognized as essential factors when attempting to correctly match an agricultural implement with tractor power. Soil condition and speed of operation to carry out tillage operation in soil were found to be important and should be given proper attention. The use of machines for agricultural production has been one of the outstanding developments in the global agriculture during the last century. The benefits of the application of the farm machinery can be seen in many aspects of human life.

The dynamic variations of soils in response to tillage devices are main concern in evaluating their enactment [3]. The alliance amid tillage tools and soil is of a major consideration to scheming and applying the tools intended for soil pulverization [4].
Tillage task encompasses the utmost energy and power expended on farms. Hence, drawbar power requirements are imperious for apt choice of size of tractor for a specific implement. Naderloo et al. [5] propounded that soil type/conditions also influence the draft needed for a specified device. A good measure used to consider the fitness of an implement for tillage operation is the power required in drawing the machine to pulverize through the soil [6]. Drawbar power is the power transmitted through the drive wheels or tracks to move the tractor and implement during the field operation [7].

Ridgers requires drawbar power for its operation. The dynamic differences of ecological soils in response to tillage devices are key concern in evaluating the enactment of the ridging implements for apposite selection and engagement to task.

According to Abu [8], it is important to select the suitable machine or machines to carry out a specific operation with minimum cost of energy and in the required time under suitable field condition. Disk plows, which are primarily suitable for the tillage of virgin, stony and wet soils, cut through crop residues and roll over the roots. Blades on disk plows are concave, usually representing sections of hollow spheres. The action of a concave disk blade is such that the soil is lifted, pulverized, partially inverted, and displaced to one side. The disk blades are set at an angle, known as disk angle from the forward line of travel and also at a tilt angle from the vertical; the disk angles vary from 42° to 45°, whereas tilt angles vary from 15° to 25°. Al-Hashimy [9] concluded that the increase of tilt angle decreased discs penetration in the soil which led to an increase in the effective field capacity due to the increase of the actual cutting width. Osman, *et al*. [10] found that as disc and tilt angles increased, the field capacity and fuel consumption rate increased. The increase of tilt angle increases rear wheel slippage. Abu-Hamdeh and Reeder [11] stated that the reason of increasing slippage when tilt angle increased may be attributed to the increase of the tensile force.

Effectual equipment application and/ or utilization desires correct performance data on the proficiencies of the specific machineries to accomplish a specified work plan and to acquire a stable mechanization scheme by matching the performance of diverse farm equipment. The differences in agro-ecological soil state also necessitates the information of the field proficiencies or capabilities of the coupled implements. Nevertheless, manufacturers of those tools do not make the data available for the users in Nigeria, which would have been a better guide in the selection of the implements based on the soil variances applicable in various agricultural areas in Nigeria [12].

According to Oduma et al. [13], farmers are practical and greatly concerned about the quality and extent of the recitals of their machineries during operation to be able to recuperate the costs of either hiring/purchase or maintenance of such apparatus. Sale et al. [14] upheld that agricultural operation is exceedingly sensitive to time and weather situations, and much expenses are involved in the venture, therefore, it remained prudent to assess the capacitive recital of farm machineries for apposite selection, optimization of production and appropriate farm planning.

Evaluation and modelling the effect of operation angle, penetration characteristics and moisture content on drawbar power requirement of ridger on loamy sandy soil is a simple means of assisting the farmers/users of the implements in evaluating and envisaging the possible performance capabilities of the equipment in order to make proper selection based on soil type/conditions before purchasing and/or engagement to task.

This will go a long way to reduce failures, unnecessary break down, mismatching of implement to prime movers, minimize fuel consumption (energy loss), reduce cost and largely maximize production and profit [15].

The objective of this research is to evaluate and model the effect of operation angle, penetration characteristics and moisture content on drawbar power requirement of ridger on loamy sandy soil that will help farmers to predict the field recitals of tractor hitched ridger for improved field operation.

MATERIAL AND METHODS

3.1 The experimental area

The study was conducted at the experimental farm of Michael Okpara University of Agriculture, Umudike (05◦ 25′N/ 7◦ 34′E), Abia State, Nigeria located at Olokoro. The climatic nature of the farm is characterized by an average temperature of 27 ◦C, rainfall between 2250 to 2500 mm annually and average relative humidity of 75%, distinctive of humid rain forest zones [16]. Loamy-sand is suitable for arable agrobusiness/farming. The research farm has mean soil bulk density of 1.68 g/cm^3, porosity of 37.40%, moisture content ranging from 12.35% to 18.90% and structurally granular [17].

3.2 Machine and implement used for the experiment

A Massey Ferguson tractor of model MF430E, with capacity of 55.2 kW which has average field efficiency of 74.05% and mean fuel consumption rate of 31.25l/ha; and a disc ridger with different tilt angles and coupled by means of 3-point hitch system was used for the research. This tractor and the coupled implement were obtained from Works Department, Michael Okpara University of Agriculture was used for the research.

3.3 Field experiment procedure and Evaluation of drawbar power requirement of the ridger

The ridging process which proceeded after ploughing and harrowing the farm site was carried out at selected tillage angles of 15, 20 and 25 degrees; cutting depths of 14, 21 and 28cm and selected moisture contents of 10.5, 15.5 and 20.5%. The area ridged and time taken to make the ridges were recorded according to [17]. Then, the drawbar power which is the power transmitted through the drive wheels or tracks to move the tractor and implement during the field operation was determined from Equation (1) according to Rangapara et al [7]

$$\text{DBP} = \frac{DT \times S}{3.6} \quad (1)$$

Where,
DBP = drawbar power, kW; DT = total draft force, kN; S = operational speed, hr
Note: The total draft force of the ridger was assessed from Equation (2) suggested by Hunt [27] as

$$\text{Total Draft} = \text{implement working width, m X draft per unit width, kN/m} \quad (2)$$

The draft per unit width of the ridger was gotten from the standard draft per unit width of tractor drawn tillage implements according to Williams [18].

3.4 Design of Experiment

The investigational design applied in the study was a three level – three factor full factorial design. The test comprises of three factors varied at three levels of tilt angles (15, 20 and 25 degrees), three levels of cutting depths (14, 21 and 28cm) and three levels of moisture contents (10.5, 15.5 and 20.5%). The Central Composite Response Design which gave 16 test runs were made using Eq. (3), [19].

$$N = 2^K + 2\text{k} + nc \quad (3)$$

Where,
N = number of test runs,
k = experimental factors and
nc = Centre point

To attain the anticipated data, the range of each one of the 3 factors (k) was assessed (Table 1). Tilt angles, cutting depths and moisture contents were adopted as independent factors for the drawbar power requirement (response) of the ridger. Four (4) replications of the centre points were espoused so as to envisage a well and succinct calculation of errors; and the experiments were carried out in randomized form.

Table 1. Actual values, codes and levels of the test variables for design of experiment

Factors	Symbols	Codes and Levels		
		-1	0	1
Tilt angles, degrees	T_a	15	20	25
cutting depths, cm	Dc	14	21	28
moisture contents, %	Mc	10.5	15.5	20.5

3.4.1 Statistical Analysis Using Response surface methodology (RSM)

The Design Expert of version 11.0 was used to design the experiment, analyze data obtained, optimize the investigational factors and obtain model expression for the prediction of the drawbar power of the ridger. The quadratic, cubic, linear and two factorial interaction (2F1) models were designated to analyze the drawbar power of the device; and the models were fixed to the generated experimental data. Data attained were analyzed using the Response Surface Methodology (RSM) to fit the quadratic polynomial equation obtained from the Design Expert Software as stated in Equation (4) conferring to Chih et al. [20] as adopted by Oduma et al. [17].

$$Y = \beta_0 + \sum_{i=1}^{2} \beta i Xi + \sum_{i=1}^{2} \beta ii Xi^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{2} \beta ij XiXj \quad (4)$$

Where,
Y = Response;
β_0 = constant term;
$\sum_{i=1}^{2} \beta i$ = Summation of coefficient of linear terms;
$\sum_{i=1}^{2} \beta ii$ = Summation of quadratic terms;
$\sum_{i=1}^{2} \sum_{j=i+1}^{2} \beta ij$ = summation of coefficient of interaction terms;
$XiXj$ = independent variables.

RESULTS AND DISCUSSION

Ridger operation

The ridging process was achieved at designated tilt angles (15, 20 and 25 degrees) with selected cutting depths (14, 21 and 28 cm) and at soil moisture content ranging from 10.5 to 20.5%; and the results of the drawbar power necessities of the ridger was presented in Table 2. Results obtained showed that, the ridger operation requires drawbar power range from 10.43 – 11.38 kW to operate under tilt angle between 15 – 25^o while operating at depth varying from 14 – 28 cm.

The highest drawbar power of 11.38 kW was attained when the ridger was run at tilt angle of 20°, cutting depth of 14 cm and at average moisture content of 20.5% while the least drawbar power of 10.43 kW was obtained at tilt angle of 25°, cutting depth of 28 cm and average moisture content of 15.5%. It may therefore be inferred that the ridger exert the highest drawbar power when operated at a lower tilt angle, cutting depth and at a higher soil moisture content. The drawbar power obtained in this research work is slightly lower than the drawbar power estimated by Williams [18] and was accredited to variations in soil conditions (such as bulk density, moisture content and/or structural disposition of the soil) due to differences in geographical areas as detected by Arvidsson et al. [21] and Naderloo et al. [5]. The results is broadly in line with the observation of Oduma et a l[15] in their study of the effect of soil type and operational speed on performance of some selected agricultural field machinery in south east Nigeria.

Table 2. Observed/Actual values and predicted values of drawbar power of ridger in loamy sand soil

Trial Runs	Coded factors			Actual Tilt Angle (Ta), degrees	Actual Depth of cut (Dc), (cm)	Actual Moisture content (Mc), (%)	Draw bar power (kW)	
	Ta	Dc	Mc				Actual/ observed values	Predicted values
1	0	-1	1	20	14	20.5	11.375	11.350
2	0	0	0	20	21	15.5	11.313	11.280
3	0	0	0	20	21	15.5	11.249	11.280
4	0	1	-1	20	28	10.5	11.186	11.190
5	0	0	0	20	21	15.5	11.122	11.280
6	0	0	0	20	21	15.5	11.060	11.280
7	0	0	0	20	21	15.5	10.996	11.280
8	0	0	0	20	21	15.5	10.934	11.280
9	-1	0	0	15	21	15.5	10.896	10.902
10	0	0	0	20	21	20.5	10.807	11.393
11	0	0	1	20	21	15.5	10.733	11.280
12	9	0	0	20	21	15.5	10.681	11.280
13	0	0	0	20	21	15.5	10.617	11.280
14	-1	-1	-1	15	14	10.5	10.554	10.550
15	1	0	-1	25	21	10.5	10.490	10.490
16	1	1	0	25	28	15.5	10.428	10.406

Figure 1presents the response surface plot of tilt angles, cutting depths and moisture contents against the drawbar power requirement of the ridger demonstrating the correlation amid the factors and the response.

Results of figure 1 specified that the topmost drawbar power of 11.38 kW was accomplished when the ridger was betrothed at tilt angle of 20°, at cutting depth of 14 cm average moisture content of and 20.5%. The highest drawbar power attained at lower tilt angle and is in agreement with the observations of Olatunji [23] and was accredited to the high traction and draft strength related to low operational angle enabling the implement to cut practically deep, thus breaking down the resisting force and /or strength of the firmed soil thereby creating an apposite ecological environment for root penetration, growth and proper development as acknowledged by Sale *et al*. [14] and Oduma et al. [22]

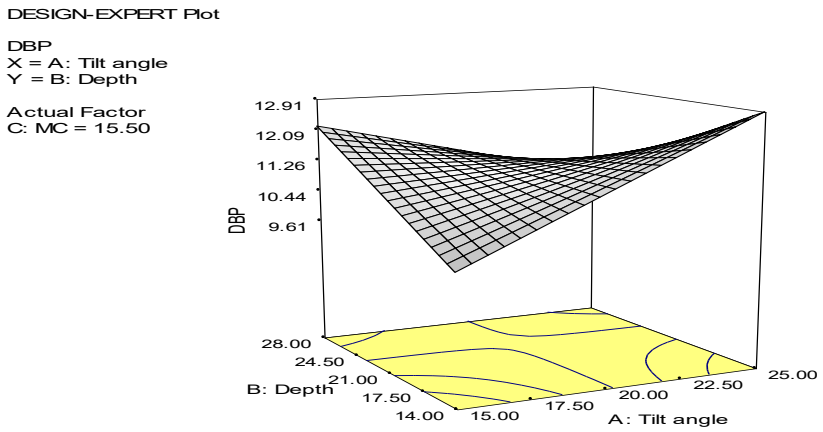

Figure 1. Response surface plot of tilt angle, cutting depth and moisture content against power requirement of the ridger in loamy-sand soil.

Model equation of drawbar power requirements of ridger in loamy-sand soil

The drawbar power necessities of the ridger in loamy-sand soil is dependent on the results illuminating the significant variation for combination of experimental factors (the tilt angle, cutting depth and moisture content). The model coefficient, effect, contribution, test of lack of-fit and the significance of the factors and their interactions on the drawbar power were evaluated according to Fakayode *et al*. [24] and Umani *et al*. [19]. Both mean and 2F1 models were statistically significant for the response ($P < 0.05$) and therefore were suggested (Table 3). This implies that the significant model term was identified at 95% significance level. The 2F1 model with the highest order polynomial, $R^2 = 0.9983$ (Table 4) and with significant additional terms as revealed in Table 3 is designated. The 2F1 model equation produced to estimate the drawbar power requirement relating to the independent variables (working width, operational speed and tillage depth) is as presented in Eq. (5).

Table 3. Sequential Model Sum of Squares

Source	SS	DF	MS	F Value	Prob F	
Mean	959.22	1	959.22			Suggested
Linear	0.43	3	0.14	0.95	0.4956	
2FI	0.60	3	0.20	111.62	0.0694	Suggested
Cubic	0.000	0				Aliased
Quadratic	0.000	0				Aliased
Residual	1.800E-003	1	1.800E-003			
Total	960.26	8	120.03			

Table 4. Model Summary Statistics

Source	Std. Dev.	R-square	Adjusted R-Square	Predicted R-Square	Press	
linear	0.39	0.4168	-0.0206	-1.9766	3.09	
2F1	0.042	0.9983			±	Suggested
Quadratic					+	Aliased
Cubic					+	Aliased

$$DBP=7.16269+0.18335T_a+0.73119D_c-0.82008Mc-0.036321T_aD_c+0.042283T_aM_c-1.42857e^{-4}D_cM_c \quad (5)$$

Where,
DBP = drawbar power, (kW);
T_a = tilt angle, degree, (cm);
D_c = depth of cut;
M_c = moisture content, (%)

The moisture content and the interaction of tilt angle and depth of cut with p-values of 0.0428 and 0.0509 respectively have significant effects on the drawbar power of the ridger. Thus, these p-values which are less than the selected α- level of 0.05 stipulate that the model expressions are statistically significant (Table 5). This is in line with the discoveries of Oduma *et al*. [15] and Ajav and Adewoyin [25].

Table 5. Analysis of variance for drawbar power requirement of ridger

source	ss	df	ms	F-value	F-value
T_a	0.096	1	0.096	54.48	0.06365
D_c	7.426E-004	1	7.426E-004	0.41	0.1542
M_c	0.029	1	0.029	16.37	0.0428
T_aD_c	0.40	1	0.40	220.37	0.0509
T_aM_c	0.28	1	0.28	155.87	0.9253
D_cM_c	2.500E-005	1	2.500E-005	0.014	
Pure Error	1.800E-003	1	1.800E-003		
Cor Total	1.11	7			

Validation of the model for drawbar power requirement of ridger in loamy-sand soil

Figure 2 show the validation of the suitability of the order 2F1 model using the normal % probability plot of the draft force requirement residuals as well as the plot of the predicted versus experimental draft force demand. The plotted points tailored adequately on the line of best fit which postulates that the predicted drawbar power and experimental drawbar power are within acceptable array. The model equations generally did not over or under-predict the experimental results, thus, the estimates are within appropriate range, a signal of good relations and adequate correlation amid the independent variables and a sign showing that the response model of the drawbar power might define the general variableness in the response.

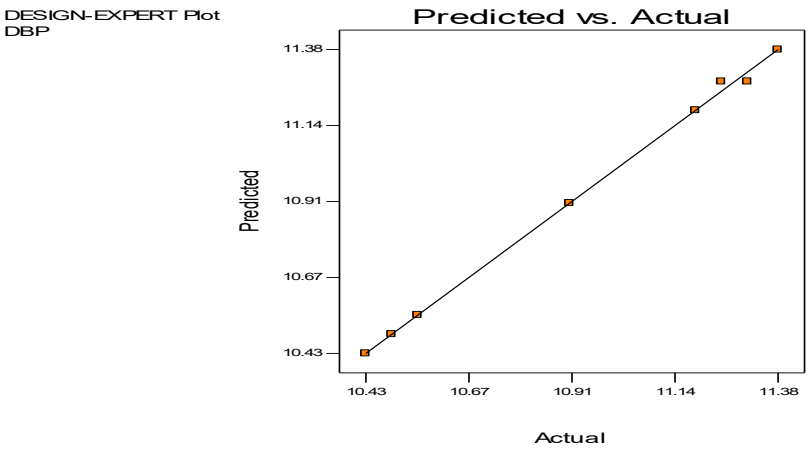

Figure 2. Normal % probability plot of the draft force requirement residuals as well as the plot of the predicted versus experimental draft force demand of the ridger

Similarly, the validation of the generated model for the drawbar power of the ridger is also shown in Table 6. According to this result, the model has coefficient of determination, R^2 of 0.9984 which demonstrates a notable relationship within the independent variables and it postulates that, the response model could clarify 99.84% of the whole changeability in the response. The model equation simulation indicated that the ridger's drawbar power requirements fall within the experimental range according to Kothari [26]. The adjusted R^2 attained is also compatible with the R^2 of 0.9615 obtained by Almaliki *et al.* [4]. The adequacy precision of 23.938 ratio attained is greater than 4 is apposite to establish a tolerable signal, indicating that the model might be adopted to navigate the design space.

Table 6. ANOVA of validation of model term for drawbar power of the ridger

Std. Dev.	0.042	R-Squared	0.9984
Mean	10.94	Adj R-Squared	0.9886
C.V.	0.39	Pred R-Squared	N/A
PRESS	N/A	Adeq Precision	23.938

Optimization of the drawbar power requirement of disc plough

Optimization of the drawbar power requirement of the ridger was carried out using a design expert in response surface methodology. Figure 2 presents the response plot of the optimization process with the optimum practical factors of tilt angle of 16.24°, cutting depth of 19.31cm and average moisture content of 14.44%. Congruently, the optimum drawbar power requirement of 10.90kW and the desirability of 1.000 was obtained. The optimum value of drawbar power in this study falls within the range obtained by Kareem and Sven [3] but slightly higher than the observations of Oduma et al. [22]. However, the trivial variance may be attributed to the disparity in ecological soil conditions.

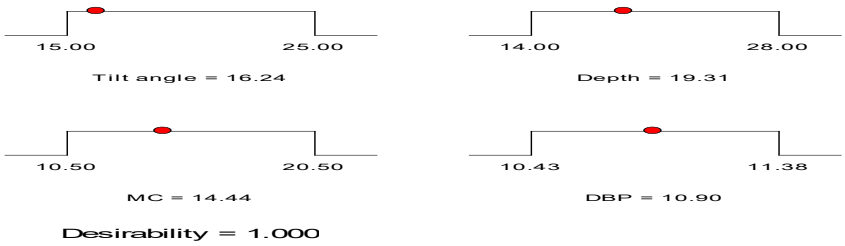

Figure 2. Optimization plot of tilt angle, cutting depth, moisture content and drawbar power requirement of ridger

CONCLUSIONS

The evaluation and modeling of the effect of operation angle, penetration characteristics and moisture content on drawbar power requirement of ridger on loamy sandy soil was efficaciously carried out. During the ridging process, it was observed that, the ridger operation requires drawbar power range from 10.43 – 11.38 kW to operate under tilt angle between 15 – 25° while operating at depth varying from 14 – 28 cm.

The highest drawbar power of 11.38 kW was attained when the ridger was run at tilt angle of 20°, cutting depth of 14 cm and at average moisture content of 20.5% while the least drawbar power of 10.43 kW was obtained at tilt angle of 25°, cutting depth of 28 cm and average moisture content of 15.5%.

The interaction of the tilt angle and depth cut, and the moisture content of the soil were statistically significant ($p< 0.05$). The coefficient of determination, R^2 and adjusted R^2 values were resolutely reliable.

Thus, the experimental values were appropriate with the coefficient of determination ($R^2 = 0.9983$), suggesting exceptional correlations among the independent variables.

The model equation simulation indicated that the ridger's drawbar power requirements fall within the experimental range.

The model obtained will help farmers/agronomist in assessing the enactment of the ridger for suitable choice and engagement to task. The optimum drawbar power of 10.90kW was attained with the desirability of 1.000 at optimal tilt angle of 16.24^{o}, cutting depth of 19.31cm and average moisture content of 14.44%.

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PROCENA I MODELIRANJE UTICAJA UGLA NAGIBA, KARAKTERISTIKA PRODIRANJA I SADRŽAJA VLAGE NA POTREBNU SNAGU VUČE KOD RAONIKA ZA ILOVASTO-PESKOVITO ZEMLJIŠTE

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Apstrakt: Istraživanje i modeliranje uticaja ugla nagiba, karakteristika prodiranja i sadržaja vlage na potrebnu snagu vuče za ronik koji formira bankove na peskovito-glinovitom zemljištu, sprovedeno je u cilju pravilnog izbora odgovarajućeg oblika raonika za operacije obrade zemljišta.

Rezultati su pokazali da rad raonika zahteva snagu vuče u rasponu od 10,43 do 11,38 kW za rad pri uglu nagiba između 15° i 25°, uz dubinu rada koja varira od 14 do 28 cm.
Najveća potrebna snaga vuče od 11,38 kW dobijena je pri uglu nagiba od 20°, dubini rezanja od 14 cm i prosečnom sadržaju vlage od 20,5%.
Najmanja vrednost od 10,43 kW zabeležena pri uglu nagiba od 25°, dubini rada od 28 cm i prosečnom sadržaju vlage od 15,5%.

Rezultati statističke analize pokazali su da je interakcija između ugla nagiba i dubine rezanja, kao i sadržaja vlage u zemljištu, statistički značajna ($p< 0,05$). Koeficijenti determinacije R^2 i prilagođeni R^2 bili su veoma visoki, što ukazuje na pouzdanost modela. Naime, eksperimentalne vrednosti su bile odgovarajuće uz koeficijent determinacije R^2=0,9983, što ukazuje na izuzetnu korelaciju između nezavisnih promenljivih.

Optimalna snaga vuče od 10,90 kW postignuta je sa poželjnošću (stepen pogodnosti) od 1,000 na optimalnom uglu nagiba od 16,24°, dubini rezanja od 19,31 cm i prosečnom sadržaju vlage od 14,44%.

Ključne reči: *Dubina, snaga vuče, poljoprivrednici, peskovito-glinovito zemljište, vlaga, ugao nagiba, raonik za bankove.*

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ASSESSMENT OF ECONOMIC AND FOOD SECURITY OF SMALL RUMINANT FARMERS IN OSOGBO AGRICULTURAL ZONE OF OSUN STATE, NIGERIA

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Abstract: The study assessed the economic and food security status of small ruminant farmers in Osogbo Agricultural Zone, Osun State, Nigeria. A multistage sampling procedure was used to sample 120 farmers, with data collected through interviews. The results showed that the average age, years of formal education, and household size of respondents were 53.31 years, 9.74 years, and 5 persons, respectively. The average ruminant production experience, flock size, and monthly primary income were 12.34 years, 15 animals, and ₦73711.07. Over half (52.50%) of the sampled respondents were food secure, while 19.17% were economically secure. The study found positive relationships between household size and years of formal education and economic security, while age was negatively related to economic security. However, age and years of formal education were positively related to household food security, while household size was negatively associated with food security. The study concluded that small ruminant production only provided food for respondents and recommended adult literacy classes for small ruminant farmers to increase their production scale and maintain a large household size for improved economic security and food security.

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***Key words**: Economic security, food security, small ruminant farmers, extension services, Osun State*

INTRODUCTION

Small ruminant production, particularly goat and sheep rearing, has long been a vital livelihood activity among rural households in Africa, including Nigeria. These animals are adaptable to diverse environmental conditions, require relatively low investment, and serve multiple purposes providing meat, milk, skins, manure, and income. In rural Nigeria, smallholder farmers rely heavily on these livestock as a buffer against economic shocks and food insecurity [1].

Goats and sheep, often referred to as "village banks," are especially important among marginalized populations such as women and landless households. Their small size, quick reproductive cycle, and resilience to harsh conditions make them ideal for subsistence farmers. Yet, despite their significance, small ruminant farming in Nigeria remains largely subsistence-based and under-commercialized. As a result, its full potential in enhancing livelihoods and improving food and economic security remains largely untapped [2].

Studies ([3]; [4]) reveal that over 90% of the small ruminant population in Africa comprises indigenous breeds that are well-adapted to local environments. However, challenges such as inadequate access to veterinary services, poor housing systems, limited feed resources, and lack of market information hinder productivity and profitability. Additionally, there is limited data and documentation on the current practices, constraints, and economic viability of small ruminant production in many parts of Nigeria, including Osun State [5].

In Osun State, particularly in the Osogbo Agricultural Zone, smallholder farmers increasingly engage in goat and sheep production either as a main livelihood or a complementary source of income. However, there is a pressing need to evaluate the role of this enterprise in enhancing household food availability and economic resilience, especially in the face of fluctuating agricultural yields and increasing poverty in rural areas [6].

Nigeria, like many developing countries, faces a significant food and nutrition challenge. The Food and Agriculture Organization (FAO) recommends a daily per capita protein intake of 70 grams, with 35 grams expected from animal sources. However, the average animal protein consumption in Nigeria is estimated at just 10 grams per person per day [7], revealing a severe shortfall that contributes to malnutrition and food insecurity, particularly in rural areas. While substantial efforts have been made to improve crop-based agriculture, the livestock sub-sector particularly small ruminant farming has not received commensurate attention. In Osun State, smallholder goat and sheep farmers face challenges such as poor access to veterinary services, lack of improved breeding stock, limited extension support, and weak market linkages. Moreover, production remains largely informal and poorly integrated into commercial value chains [8].

Despite its potential to enhance food security and rural incomes, the small ruminant sector remains under-researched, especially in terms of its economic viability and impact on household welfare.

Existing studies often overlook gender-specific constraints and opportunities in small ruminant production, even though women are heavily involved in livestock rearing and management [6].

Poverty remains pervasive in rural Nigeria, and many households struggle to maintain a consistent food supply throughout the year. In this context, small ruminants can play a pivotal role in improving household resilience by serving as a source of emergency income and nutrition. However, a lack of empirical data on the contribution of small ruminant farming to food and economic security impedes the formulation of targeted policies and interventions [9] and [10].

This study, therefore, seeks to fill this gap by assessing the socio-economic characteristics, food security status, and economic contributions of small ruminant production among men and women farmers in Osogbo Agricultural Zone. It will also explore the coping strategies employed during periods of food insecurity and analyze the relationships between farmers' characteristics and their levels of food and economic security.

The following hypothesis were tested in the study;

Ho: There is no significant relationship between selected socio-economic characteristics and economic security status of respondents.

Ha: There is no significant relationship between selected socio-economic characteristics and food security status of respondents.

MATERIAL AND METHODS

Study Area

This research was carried out in the region of Osogbo (7°48″ N, 4°35″ E), Osun state, Nigeria. Osogbo, the capital of Osun state, is located in the southwestern region of Nigeria. Osogbo city has boundaries with Ede, Olorunda, Obokun, Egbedore, Orolu, Ifelodun, Boripe, Atakumosa and Ilesa. Osogbo is the administrative and commercial center of Osun state. Osogbo has been witnessing tremendous increase in population since the creation of Osun state but this city has witnessed increase in road expansion and construction since the advent of the present government (2011 till date), which had led to increase urbanization and population inflow into Osogbo and its suburbs. The area is one of the three (3) agricultural development project (ADP) zones namely, Osogbo, Iwo and Ife/Ijesha in the state.

Population of the study

The population of the study are the small ruminant farmers in Osogbo ADP Zone of Osun State, Nigeria.

Sampling Techniques and Sample Size

The sampling technique and sample size for a study on the effect of goat and sheep production on food and economic security in Osun State was carried out using three stage sampling procedure. The first stage involved random selection of two (2) LGAs (Osogbo & Ifelodun) representing approximately 30% of the seven (7) LGAs (Ede south, Ede north, Irepodun, Ila, Egbedore, Ifelodun, Boripe.) housed by Osogbo Agricultural Zone.

The second stage involved random selection of three (3) villages each from the selected LGA to make a total of six (6) villages.
The third and last stage involved snowball technique to select an estimated 120 goat and sheep farmers proportionate to size, to constitute the study sample.

Source of Data and Method of Data Collection

Data used in this study were obtained from primary sources. Data were collected with the aid of a well-structured interview schedule. The interview schedule captures the socio-economic characteristics, economic and food security indicators and coping strategies used by small ruminant farmers at times of food shortage in the study area.

Method of Data Analysis

Descriptive and inferential statistical tools were used to analyze the data collected. These include frequency counts, percentages, mean, standard deviation. Likert scale was used to assess the coping strategies employed by the small ruminant farmers at times of food shortage and PPMC was used to test the stated hypotheses.

Measurement of variables

Independent variables

1. Age: This was measured in actual years
2. Sex: This is measured as dummy variable, 1= Male and 2= Female
3. Marital status: Respondents were asked to choose their marital status from available listed options. This includes single, married, separated, widowed
4. Household size: This was measured in actual number of people eating from the same pot in the household
5. Number of years spent in school: This was measured in actual years of time used in school
6. Farming experience: This was measured as the years the respondents have been involved in small ruminant farming

Dependent Variables

1. Food security status was measured using adapted FANTA food insecurity measurement scale developed by USAID.

Economic security was measured as a function of the proportion of respondents' monthly savings in relation to their income and expenditure.

Table 1. Food Security Status Assessment Using FANTA Scale

Recall Period: 30 Days/ 4 Weeks		Never (0)	Rarely (1)	Sometimes (2)	Often (3)
		No Occurrence	1-3 Days	4-6 Days	7 Days & Above
1.	Were there times you worry that food would run out before the household gets money to buy more				
2.	Food bought didn't last and there was no money to get more				
3.	You couldn't afford to eat balanced meals				
4.	Adult(s) cut size of meals or skipped meals				
5.	Contin. Table 1. You ate less than what you felt you should eat				
6.	You were hungry but didn't eat				
7.	You lost weight				
8.	Adult(s) did not eat for a whole day				
9.	Relied on few kinds of low-cost food to feed child(ren)				
10.	Couldn't feed child(ren) balanced meals				
1.	Cut size of child(ren) meals				
2.	Child(ren) were hungry				
3.	Child(ren) skipped meals				
4.	Child(ren) did not eat for a whole day				

Maximum Obtainable marks = 42 Minimum Obtainable marks = 00

RESULTS AND DISCUSSION

Socioeconomic characteristics of the small ruminant farmers

The selected respondents' socio-economic characteristics of the study are presented in Tables 2a and 2b.

Age distribution

Table 2 shows the distribution of the respondents according to their age. The table reveals that majority (36.67%) of the respondents fall within the age range of 46-55 years. The mean age is 53.31 year, this result implies that majority of the respondents are gradually getting aged which may have adverse effects on their ability to achieve food security.

Gender distribution

Majority (84.17%) of the respondents were married. 10.00% were widowed, 3.33% were divorced, 2.50% were separated, 0% were single. This result implies that there is likelihood of having more food secured household as a result of expected mutual cooperation and understanding between couples.

Marital status distribution

Many (37.50%) of the respondents had secondary education, 24.17% had primary education, few 26.67% had tertiary education and very few 11.67% had no formal education. This result implies that most of the respondent are knowledgeable enough to respond to the question for eliciting information in this study.

Education level distribution

Majority (71.67%) had 1-6 years, Majority (13.33%) of the respondents had 0 years of formal education, and 15.00% had 7-13 years, while 0.00% had 14-20 years of formal education.

Household size distribution

More than half (60.00%) of the respondents had 1-5 person in their household, 37.50% had 6-10 persons while 2.50% had 11-15 persons. The mean household size was 5 persons. The implication of this result is that there is a high tendency of many households to be food insecure due to high household food expenditure relative to the household income.

Primary occupation distribution

Most (39.17%) of the respondents were primarily engaged in trading, 30.83% were artisan,10.83% were civic servant well as crop production, while 8.33% were small ruminant.

Table 2a. Socioeconomic characteristics of the smallholder farmers (n=120).

Socio-economic variable	Frequency	Percentage	Mean
Age			
26-35	7	5.83	
36-45	21	17.50	
46-55	44	36.67	53.31 years
56-65	33	27.50	
66-75	14	11.67	
76-85	1	0.83	
Marital status			
Single	0	0.00	
Married	101	84.17	
Separated	3	2.50	
Divorced	4	3.33	
Widowed	12	10.00	
Educational level			
No formal education	14	11.67	
Primary education	29	24.17	
Secondary education	45	37.50	
Tertiary education	32	26.67	
Years of formal education			
0	16	13.33	
1-6	86	71.67	9.74 years
7-13	18	15.00	
14-20	0	0.00	
Household size			
1-5	72	60.00	5 persons
6-10	45	37.50	
11-15	3	2.50	
Primary occupation			
Small ruminant	10	8.33	
Crop production	13	10.83	
Civil servant	13	10.83	
Trading	47	39.17	
Artisan	37	30.83	

Source: Field survey, 2024.

Primary income distribution

Majority (69.17%) of the respondents earned between ₦51,000 - ₦100,000, 25.00% earned ₦6,000 - ₦50,000, 6.67% earned ₦101,000- ₦150,000, 2.50% earned ₦151,000 - ₦200,000, 0.83% earned ₦201,000 - ₦250,000, 0.83% earned ₦251,000-₦300,000 mean primary income of the respondent was found as ₦73711.07

Secondary occupation distribution

Few (5.83%) of the respondents were civil servant, 4.17% were small ruminant, 0% were artisan,0% were crop production, while 0% were trading.

Secondary income distribution

Majority (88.33%) of the respondents earned between ₦1,000 - ₦50,000, 6.67% earned ₦51,000 - ₦100,000, 2.50% earned ₦101,000 - ₦150,000, 2.50% earned ₦151,000 - ₦200,000, mean secondary income of the respondent was found as ₦31317.92**.**

Types of ruminants kept

Most (53.33%) of the respondents were into sheep and goat, 44.17% of the respondents were into goat, 2.50% of the respondents were into sheep.

Ruminant keeping experience distribution

More than half (65.83%) of the respondents had 3-12 ruminant keeping experience, 24.17% had 13-22 ruminant keeping experience, 6.67% had 23-32 ruminant keeping experience while 1.67% had 33-42 & 43-52 ruminant keeping experience. The mean was 12.34yrs.

Flock size distribution

Most (43.33%) of the respondents had 1-10 flock size, 32.50% had 11-20 flock size, 15.00% had 21-30 flock size, 5.83% had 31-40 flock size, 2.50% had 51-60 flock size while 0.83% had 41-50 flock size. The mean was 15 animals.

Table 2b. Socioeconomic characteristics of smallholder farmers (n=120)

Variables	Frequency	Percentage	Mean
Primary income (₦)			
6000-50000	30	25.00	
51000-100000	77	64.17	
101000-150000	8	6.67	
151000-200000	3	2.50	
201000-250000	1	0.83	₦73711.07
251000-300000	1	0.83	
Secondary occupation	108	90.00	
Small ruminant	5	4.17	
Crop production	0	0.00	
Civil servant	7	5.83	
Trading	0	0	
Artisan	0	0	
Secondary income (₦)			₦31317.92
1000-50000	106	88.33	
51000-100000	8	6.67	
101000-150000	3	2.50	
151000-200000	3	2.50	
Types of ruminants kept			
Sheep	3	2.50	
Goat	53	44.17	
Sheep and goat	64	53.33	
Total	120	100	
Ruminant keeping experience			

Contin. Table 2b.			
3-12	79	65.83	
13-22	29	24.17	
23-32	8	6.67	12.34 yrs
33-42	2	1.67	
43-52	2	1.67	
Flock size			
1-10	52	43.33	
11-20	39	32.50	
21-30	18	15.00	15 animals
31-40	7	5.83	
41-50	1	0.83	
51-60	3	2.50	

Source: Field survey, 2024

Economic security of small ruminant farmers

Table 3 shows the economic security status of the household. Data in the Table shows that the majority (80.83%) of the rural households are economically insecure, while 19.17% of the households are economically secure. The result shows that the majority of them, their income could not keep up with their household expenditure, hence they hardly have savings, which is why they are economically insecure.

Table 3. Distribution of respondents based on their economic security status

Variables	Frequency	Percentage
Economically insecure	97	80.83
Economically secure	23	19.17
Total	120	100.0

Source: Field survey, 2024.

Note: Economic security was measured as a function of the proportion of respondents' monthly savings in relation to their income and expenditure.

Respondents; Food Security Status

Table 4 presents the food security status of the household, categorized using a meal FANTA score of 18.50 to classify the household as either food secure or insecure. The data in the table shows that 52.50% of rural households are food secure, while 47.50% of the households are food insecure.

Table 4. Distribution of respondents according to their food insecurity status

Status	Frequency	Percentage
Food secure	63	52.50
Food insecure	57	47.50
Total	120	100

Source: Field survey, 2024.

Coping strategies

Table 5 presents the coping strategies employed by the rural households to food insecurity in the study area. The table reveals that the most employed coping strategies against food insecurity in the study area is the substituting commonly bought food items with cheaper ones, and the second most employed coping strategy against food shortage in the study area is the reduce in the number of meals per day.

Furthermore, other coping strategies employed by the rural household against food shortage are eating of less food (father and mother) and the modification of meals cooking method. This result implies that to cope against food shortage, the respondent buys cheaper food items, reduce the number of meals per day, Parents eat less amount of food related to other member of the family and make modifications.

Table 5. Distribution of the respondents according to their coping strategies.

S/N	Coping strategies in use	WMS	Rank
7	Substituted commonly bought food items with cheaper ones	0.86	1st
2	Reduced the number of meals	0.84	2nd
3	Mother ate less	0.82	3rd
6	Modified cooking method	0.80	4th
4	Father ate less	0.79	5th
1	Borrowed money to buy food/got food on credit	0.71	5th
9	Borrowed food items from neighbors	0.43	7th
5	Children ate less	0.42	8th
10	Went for work for food programmers	0.41	9th
8	Mortgaged/sold assets	0.37	10th
11	Children involved in business activities	0.33	11th
12	Children suspended school to generate income	0.33	11th

Source: Field survey, 2024.

Results of the Tested Hypotheses

Relationship between selected socioeconomic characteristics and Household Food Security Status of the Respondents

Result presented in Table 6 shows the relationship between selected socioeconomic characteristics and household food security status of the respondents in the study area. The result shows that three (age, household size, and years of formal education) have significant relationship with the household food security of the respondents. Age (r= 0.47, p= 0.045 was positive and significantly at 5% to the household food security of the respondents. Household size (r=-0.56, p=0.054) negatively affected the household food security of the respondents at 5% and lastly, Year of formal education (r=0.64, p=0.000) positively affected the household food security status of the respondents by 1%.

Table 6. Test of relationship between selected socioeconomic characteristics and economic security

Hypothesis	r value	P-value	Decision
Age	0.47	0.045**	Significant
Household size	-0.56	0.054**	Significant
Years of formal education	0.64	0.000*	Significant

*mean significant at 1% level; **mean significant at 5% level

Source: Data Analysis, 2024.

Relationship between selected socioeconomic characteristics and economic security status of the respondents

Table 7 shows the result of the tested hypothesis reveals a positive and significant relationship was found between the selected socioeconomic characteristics and the economic security status of the respondents.

The results show that Age (r=-0.57, p=0.045**) was negative and significant at 5% to the economic security status of the respondents, and household size (r=0.56, p=0.006*) was positively affected the economic security status by 5%. Year of formal education (r=0.68, p=0.000*) was positively affected the economic security status by 1%.

Table 7. Test of relationship between selected socioeconomic characteristics and economic security

Hypothesis	r value	P-value	Decision
Age	-0.57	0.045**	Significant
Household size	0.56	0.006*	Significant
Years of formal education	0.68	0.000*	Significant

*mean significant at 1% level; **mean significant at 5% level
Source: Data Analysis, 2024.

CONCLUSIONS

The result showed that more than half of the sampled respondents were food secure, while just about twenty percent were economically secure. This showed that small ruminant farming provides the small ruminant farmers' households enough to feed their families, but it hardly guarantees them economic security. Based on the findings, the study recommends that small ruminant farmers should be encouraged and supported to increase their scale of production to enhance their economic gains and improve their savings culture, thus enhancing their economic security status. They should also be encouraged to keep a moderate household size to enhance their food and, hence, economic security status.

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PROCENA EKONOMSKE I SIGURNOSTI ISHRANE MALIH FARMERA KOD PROIZVODNJE PREŽIVARA U POLJOPRIVREDNOJ ZONI OSOGBO, DRŽAVA OSUN, NIGERIJA

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Apstrakt: Istraživanje je procenilo ekonomski status i nivo prehrambene sigurnosti malih farmera kod proizvodnje preživara u poljoprivrednoj zoni Osogbo, država Osun, Nigerija. Primenjena je višestepena metoda uzorkovanja kojom je odabrano 120 malih farmera, a podaci su prikupljeni putem intervjua.

Rezultati su pokazali da je prosečna starost ispitanika iznosila 53,31 godina, trajanje formalnog obrazovanja 9,74 godina, a prosečna veličina domaćinstva je 5 članova. Prosečno iskustvo u proizvodnji preživara bilo je 12,34 godina, veličina stada 15 grla, dok je prosečan mesečni osnovni prihod iznosio ₦73.711,07. Više od polovine (52,50%) anketiranih farmera bilo je prehrambeno sigurno, dok je 19,17% bilo ekonomski sigurno.

Studija je pokazala pozitivnu povezanost između veličine domaćinstva i godina formalnog obrazovanja sa ekonomskom sigurnošću, dok je starost ispitanika bila negativno povezana sa ekonomskom sigurnošću.

Međutim, starost i godine formalnog obrazovanja bile su pozitivno povezane sa prehrambenom sigurnošću domaćinstva, dok je veličina domaćinstva pokazala negativnu povezanost sa nivoom prehrambene sigurnosti.

Zaključeno je da proizvodnja preživara ispitanicima uglavnom obezbeđuje hranu, ali ne i dovoljnu ekonomsku sigurnost.

Preporučeno je uvođenje programa opismenjavanja i dodatnih edukacija za male farmere uzgajivače preživara, sa ciljem povećanja obima proizvodnje i očuvanja većeg broja članova domaćinstva radi poboljšanja ekonomske i prehrambene sigurnosti.

Ključne reči: *Ekonomska sigurnost, prehrambena sigurnost, mali farmeri-proizvođači preživara, poljoprivredne savetodavne službe, država Osun*

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PERFORMANCES OF OXYGENATION DEVICES ON TROUT FARMS IN REPUBLIC OF SERBIA, REPUBLIC OF NORTH MACEDONIA, AND BOSNIA AND HERZEGOVINA

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Abstract: Dissolved oxygen is universally recognized as the most decisive limiting factor in intensive trout aquaculture, exerting profound effects not only on production efficiency but also on fish welfare, physiological stability, immune competence, and the capacity to resist disease. When oxygen levels fall below optimal thresholds, trout are exposed to chronic stress, impaired metabolic processes, reduced feed intake, and a heightened susceptibility to pathogens, all of which compromise both productivity and sustainability. To counter these risks, water oxygenation—defined as the technological process of enriching aquaculture water with pure oxygen—has become an indispensable intervention for modern trout farming. In Republic of Serbia and Republic of North Macedonia, oxygenation systems have been continuously applied for more than two decades, while in Bosnia and Herzegovina their use has been established for over ten years, collectively enabling production intensification, seasonal stability, and improved economic outcomes.

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This study explores the diversity of oxygenation technologies currently employed, ranging from diffuser systems and low-head oxygenators to pressurized tanks and devices with rotating mechanical components.

Particular emphasis is placed on their operational principles, efficiency parameters, and exploitation characteristics, with attention to how these technologies are adapted to the specific environmental conditions and management practices of rainbow trout farms in the region.

Keywords: *trout farms, water oxygenation, operational characteristics*

INTRODUCTION

The first oxygenation devices in trout farms in the Republic of Serbia were introduced in 2004. In the Republic of North Macedonia, the adoption of these devices started several years later, driven mainly by individual farm owners' investments and partly supported by state subsidies. Over time, oxygenation has become a critical technology for maintaining production stability, particularly during summer months and under conditions of elevated stocking densities. Initial steps toward the implementation of water oxygenation systems in trout farms in Bosnia and Herzegovina were recorded in 2008, planned as a pilot system for recirculating aquaculture (RAS) at a salmonid hatchery in the Krušnica River valley, Bosanska Krupa [1]. More intensive work on water oxygenation in Bosnian trout farms has been evident over the past six years, during which modern equipment for improving and maintaining optimal oxygen regimes in rearing ponds has been successfully implemented. A leading role in this development is held by Tropic Ribarstvo ("Ribnjak Janj"), located in the Republika Srpska, Bosnia and Herzegovina. The company operates extensive production areas with several large trout farms at different locations, including a hatchery, production of consumable rainbow trout, and trout for processing. The necessity for implementing oxygenation systems is also driven by climate change, which affects the availability of water required to maintain production intensity based on high stocking densities. Simultaneously, Tropic Ribarstvo has become the largest producer of rainbow trout in Bosnia and Herzegovina. Thanks to the implementation of modern technical and technological solutions, the company has experienced continuous growth in rainbow trout production. Dissolved oxygen in water represents the primary limiting factor in trout production. For this reason, oxygen enrichment of water constitutes the most direct means of increasing the carrying capacity of production ponds at a given time, which consequently leads to an increase in production over a specific period. It is important to note that proper planning and organization of production play a crucial role both under traditional production conditions and in intensified systems utilizing oxygenation.

Figure 1. Mortality of rainbow trout fry caused by hypoxia (Photo: S. Čanak, 2007).

Insufficient dissolved oxygen in water represents a production risk [2], the probability of which can be estimated from natural conditions, the production plan, and the evaluated competence of farm personnel.

For water oxygenation to be feasible, it is essential to design and construct a system in accordance with legal, technical, and safety requirements. Such a system comprises a source of "pure" oxygen (technical or medical), which may be an O_2 generator or an oxygen tank, evaporators, pressure regulators, oxygen distribution lines from the source to the manifold, manifolds with rotameters for dosing O_2, and devices for oxygen enrichment of water [2]. In Serbia, North Macedonia, and Bosnia and Herzegovina, liquid oxygen tanks serve as the oxygen source, while the distribution lines are aboveground and made of stainless steel. Oxygen is stored in the tank in liquid form and, after passing through the evaporators and pressure regulators, is delivered to the distribution network in gaseous form.

Devices and equipment for water oxygenation can be operated in different modes:

- Regular oxygenation
- Intermittent oxygenation
- Emergency oxygenation

Regular oxygenation involves continuous use of the equipment, either constantly or over an extended period, such as during the summer months. Intermittent oxygenation is applied in specific situations, for example during medicinal baths without water flow or during fish grading. Emergency oxygenation is aimed at rescuing fish in the event of a sudden drop in dissolved oxygen levels. Devices and equipment for water oxygenation can be classified according to their operating principles: passive oxygenators without overpressure (low-head oxygenators), passive oxygenators with low overpressure (jet platforms), downflow bubble contactors, devices with active components (e.g., FAS Turboxygen, Loxy, Force 7), and perforated hoses or ceramic diffusers.

MATHERIALS AND METHODS

This study is based on data obtained from multiple trout farms located in the Republic of Serbia, Republic of North Macedonia, and Bosnia and Herzegovina. In Serbia, data were collected from six trout farms over an extended observation period. Data acquisition employed two complementary approaches: (i) oral and telephone interviews and (ii) experimental measurements on farms conducted under varying water temperatures, stocking densities, and flow conditions. In a limited number of cases, where direct measurement of dissolved oxygen concentrations was not feasible, estimates of oxygenation effectiveness were derived from published sources. The analysis was primarily directed toward assessing the operational performance of oxygenation devices under field conditions.

The dataset encompassed information on: the modes and locations of oxygenation device and equipment operation, dissolved oxygen concentrations across different water temperatures, the efficiency of diverse technical oxygenation systems, and the cost of oxygen. The study offers an analysis of the working principles, applications, and operational characteristics of oxygenation devices across the three countries examined.

RESULTS AND DISCUSSION

In Serbia, the following oxygenation devices are in use: boxes for passive oxygen enrichment (low-head oxygenators and oxy-jet), devices with pressurized chambers (oxy-trans), devices with active working elements (FAS Turboxygen), perforated hoses, and ceramic diffusers. In North Macedonia, on larger trout farms, FAS Turboxygen and FORCE7 aerators/oxygenators are commonly used, in combination with pure oxygen. In Bosnia and Herzegovina, the following devices are employed: oxygen boxes with nozzles (Oxygen-box with lifting pump), devices with active working elements (FAS Turboxygen, Loxy), perforated hoses, and ceramic diffusers.

Operational principles and performance of oxygenation devices on the investigated trout farms

To evaluate the performance of water oxygenation devices under operational conditions, it is necessary to have various pieces of information. Among all of the needed information for the exploitation of oxygenation devices the most important are amount of oxygen supplied to the water ($kg \times day^{-1}$) and oxygenation efficiency rate (%). Other information can help calculate the cost of the injected oxygen (€×kg$O2^{-1}$; €×kg^{-1} fish), etc.

Low-head oxygenators may have either a single chamber or multiple parallel chambers. Single-chamber devices are simple systems for water oxygen enrichment. Water can be supplied to these devices by gravity or pumps, and they may have circular or rectangular cross-sections, often constructed in-house based on literature designs.

Typically, these devices consist of three horizontally divided working spaces, separated by perforated plates: (i) the water distribution chamber, (ii) the oxygen–water mixing chamber, and (iii) the chamber of oxygen-enriched water from which water exits into the pond. Water enters the distribution chamber via overflow or piping, while oxygen is supplied directly into the mixing chamber through a hose. In the distribution chamber, water passes through a perforated plate (hole diameter 8–15 mm) before entering the mixing chamber. The oxygen–water mixing chamber can be filled with various plastic media (e.g., BioBlock®, EXPO-NET Danmark A/S) to further disperse water in the pure oxygen atmosphere.

In Serbia, low-head oxygenators are used on several trout farms, primarily in hatcheries, and are generally supplied with water by gravity. An exception is a system with partial water recirculation for the production of fry from 1 g to 20 g, where water is supplied using a pump. These devices may be equipped with various plastic media or operate without any media. In some hatcheries, they are constructed from plastic PVC pipes and filled with plastic media. Multi-stage low-head oxygenators represent an advanced version of the previously described devices. They feature a larger number of parallel chambers (7–10), with the same internal arrangement as single-chamber devices. These systems are based on a patented design [3]. In Serbia, they are used at a single trout farm in the first series of ponds for the production of fry up to 50 g. The efficiency of oxygen utilization in these devices depends on several factors, including the water level difference, device dimensions, oxygen-to-water ratio, and perforation size, typically ranging between 65 % and 91 % [5], [6], [7].

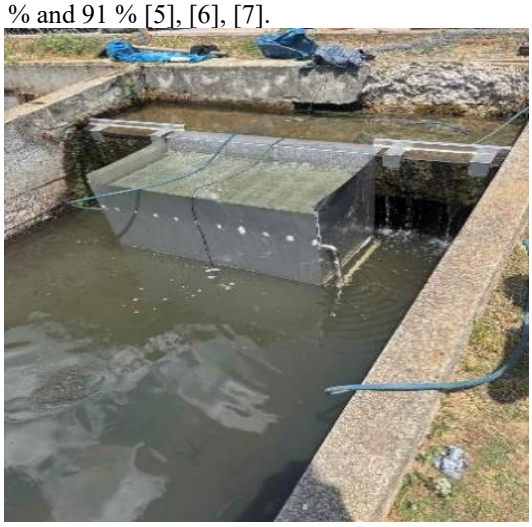

Figure 2. Low-head oxygenator on trout farm in Serbia (foto: S. Canak, 2025)

Based on testing of this device at a trout farm in Serbia under operational conditions during the summer of 2025, the following results were recorded: water temperature ranged from 15 °C to 18 °C, water flow rate from 8 $l \times s^{-1}$ to 12 $l \times s^{-1}$, and the difference in dissolved oxygen concentration in the water ranged between 5 $mg \times l^{-1}$ and 6 $mg \times l^{-1}$. The amount of oxygen dissolved in the water ranged from 4,1 $kgO2 \times day^{-1}$ to 6,2 $kgO2 \times day^{-1}$.

Devices with low overpressure and nozzles (Jet box) are similar in construction to the previously described devices, with the following differences: the water distribution chamber is significantly deeper with a higher water level, while the oxygenation chamber is of lower height. This design creates a small overpressure in the oxygenation chamber, enabling higher dissolved oxygen levels in the water. Instead of a large number of perforated openings, water passes through a few specially designed nozzles into an atmosphere of pure O_2, penetrating the water layer and forming numerous bubbles.

Figure 3. Oxygen-box with lifting pump at the trout farm of Tropic Fishery in Bosnia and Herzegovina (foto N. Savić, 2020)

The oxygen box with a lifting pump is used for water oxygenation integrated into existing channels or ponds. The lifting pump is incorporated into the oxygen box. This system is characterized by high oxygen dissolution efficiency, requiring only 0.7 m of water lift for optimal oxygen transfer. Nozzles with a diameter of 51 mm result in low energy costs for oxygenation and minimal maintenance, approximately 1 kW per 1.5 kg of dissolved oxygen. The devices are manufactured according to customer specifications (water flow, target DO values, etc.; source: https://frea-solutions.dk/en/produkt/oxygen-box-with-lifting-pump/).

Such devices have been widely used worldwide in intensive trout production systems, particularly over the past decade. One device operating on this principle was acquired in 2007 at a trout farm in Serbia. The device was intensively tested at the outlet of a pond used for rearing larger fingerlings (100–200 g), with a water column height above the nozzles of 60 cm, water flow rates between 10 $l \times s^{-1}$ and 25 $l \times s^{-1}$, and water temperatures ranging from 14 °C to 17.5 °C. Under these conditions, the device was able to increase dissolved oxygen levels from 5–6 $mg \times l^{-1}$ to 8–10 $mg \times l^{-1}$ before significant oxygen losses occurred in the form of O_2 bubbles exiting the device with the water.

These results were comparable to those obtained when testing low-head oxygenators of similar dimensions under the same conditions. Observations indicated that the device was likely still in a developmental stage.

Down-flow bubble contactors: devices of this type, also known as Speece cones [8] or oxygenation cones, are most commonly conical, although cylindrical versions also exist. Both types have similar working principle with a difference in oxygen bubbles size and distribution within the device. Water is supplied by a pump, creating elevated pressure in the oxygen–water mixing chamber, which results in high dissolved oxygen concentrations ranging from 25 $mg \times l^{-1}$ to 50 $mg \times l^{-1}$. The most common configuration of these devices is conical, although cylindrical versions were produced in Europe for a certain period. Several cylindrical Oxy-trans devices were imported into Serbia during 2004–2005, including one larger unit and several smaller ones. The larger Oxy-trans device was configured to operate at an overpressure of 0.5–0.6 bar and supplied with 100 $l \times s^{-1}$ of water via a pump. The smaller units operated at 0.7–0.8 bar with a water flow of 8 $l \times s^{-1}$. A key characteristic of these devices is their ability to deliver smaller volumes of water with high dissolved oxygen content.

Figure 4. Downflow bubble contactor at a trout farm in Serbia (Photo: S. Čanak, 2007).

Devices with active working elements: devices with different working principle fall in this group of oxygenating equipment and some of them are used in analized countries: FAS® turboxygen, (F.A.S. srl. Italia), Loxy® (LINN Gerätebau GmbH, Germany), Force7® (Acqua&Co S.R.L, Italy).

Figure 5: FAS KR94/L devices in operation at a trout farm in Republic of Serbia (Photo: S. Čanak, 2007)

FAS Turboxygen KR94/L devices consist of a pontoon or float that allows the unit to float on the water surface, a hood submerged from below, and a drum with blades. Oxygen is supplied to the hood via a hose. Beneath the hood, a pocket of pure oxygen is trapped between the hood above and the water below. The drum with blades disperses water into the oxygen atmosphere under the hood. Due to the shape of the hood, the oxygen-enriched water is directed forward and downward. These devices process large volumes of water, but the dissolved oxygen content at the outlet typically reaches only 110 % - 120 % of saturation. The amount of oxygen dissolved in the water can be adjusted to fish needs and ranges usually from 12 $kgO2 \times day^{-1}$ to 20 $kgO2 \times day^{-1}$ under farming conditions. Higher scores are also possible but lower oxygen transfer efficiency will be the consequence.

In Serbia and Bosnia and Herzegovina, devices of this type are used on several trout farms. They are also employed in the Republic of North Macedonia, applied on two larger trout farms, particularly during the summer months and under conditions of increased biomass.Perforated hoses and ceramic diffusers are positioned at a distance of between ¼ and ½ of the pond length from the water inlet, based on measurements of dissolved oxygen in the water under conditions of high fish biomass. The aim of this positioning is to further enrich the water with oxygen after partial consumption by the fish, thereby ensuring survival and optimal growth in the downstream section of the pond. Experimental measurements of dissolved oxygen have shown that stable oxygen levels are highest at approximately 2 m from the device, near the pond bottom at a depth of about 1 m. Maximum measured oxygen concentrations in the water reached approximately 120 % saturation. For this type of device, it is not straightforward to accurately measure either the dissolved oxygen content immediately after passage through the device or the device's operational efficiency.

Figure 6. FAS KR94/L devices at a trout farm in North Macedonia (Photo: A. Trajchovski, 2020)

Figure 7. FAS KR94/L device, Tropic Ribarstvo, Bosnia and Herzegovina, Republic of Srpska (Photo: Lj. Todorović, 2025.)

The LOXY® oxygenation system features an innovative rotating mixing mechanism within a plastic housing. It is driven by an electric motor located above the water surface. Due to rotation, the mixer pushes water outward within the closed system. The resulting high-velocity water flow creates a vacuum, drawing pure oxygen through a pipe into the mixer, where it is dispersed in the water as very fine bubbles. LOXY® achieves a very high level of oxygen enrichment with low energy consumption. Its main advantage is that, thanks to the rotating mixer, only a very small portion of the water needs to be accelerated, and no water pressure is required. A fluidized layer forms on the surface of the innovative rotating mixer, reducing energy consumption and enabling excellent oxygenation.

Figure 8. LOXY25220, Tropic Ribarstvo, Bosnia and Herzegovina, Republic of Srpska (Photo: N. Savić, 2024)

Additionally, on two large trout farms in North Macedonia, the Force7 system is used. It belongs to the group of aspiration aerators, with the option of adding pure O_2. This device independently injects large volumes of air or pure oxygen, creating microbubbles that dissolve in the water, ensuring optimal oxygen transfer. Thanks to its high-speed propeller, a strong water current is generated, enabling circulation and homogenization of the entire water body, preventing thermal stratification, and improving ecosystem stability. A key advantage of this device is its ability to directly inject pure oxygen or ozone, achieving high dissolution efficiency even under intensive farming conditions. The Force7 system can be installed in multiple configurations—floating, static, or dock-mounted—making it suitable for ponds with high stocking densities, lakes, or tanks of varying depths. On the trout farms analyzed in North Macedonia, Force7 devices are employed as oxygenators. Practical advantages include adjustable operating depth and angle, the option to select different propellers depending on the purpose (circulation, pure oxygen injection, or conventional aeration), corrosion protection via anodes, and ease of maintenance. These features also make the device suitable for use in systems with floating cages.

Figure 9. Force7 device at a trout farm in North Macedonia (Photo: A. Trajčovski, 2020)

Perforated hoses and ceramic diffusers: perforated hoses and ceramic diffusers are primarily used to maintain dissolved oxygen levels in the water during fish transport. Additionally, they can be employed during therapeutic baths, ceramic diffusers in small tanks for fry and perforated hoses for market-size fish. Perforated hoses play a particularly important role in emergency oxygenation, when a fish crisis has already occurred due to depleted dissolved oxygen levels and mortality has begun. In such cases, it is essential to rapidly increase dissolved oxygen concentrations to provide conditions for fish survival.

Ceramic micro-bubble diffusers for pure oxygen release operate on the principle of generating fine oxygen bubbles that rise slowly through the water column, ensuring maximum O_2 solubility. This makes oxygenation both efficient and cost-effective. Certain characteristics of perforated hoses are particularly important for their operation and maintenance. Perforated hoses must be weighted to ensure proper placement on the pond bottom. Maintenance of perforated hoses includes removing algae from their surface at least once per year.

The oxygen utilization efficiency of perforated hoses typically ranges from 3 % – 7 % per meter of water depth, while for ceramic diffusers usually ranges from 10–20 % and in some applications even more. Oxygen transfer efficiency for ceramic diffusers had increase over the years, from below 15 % [9] to above mentioned.

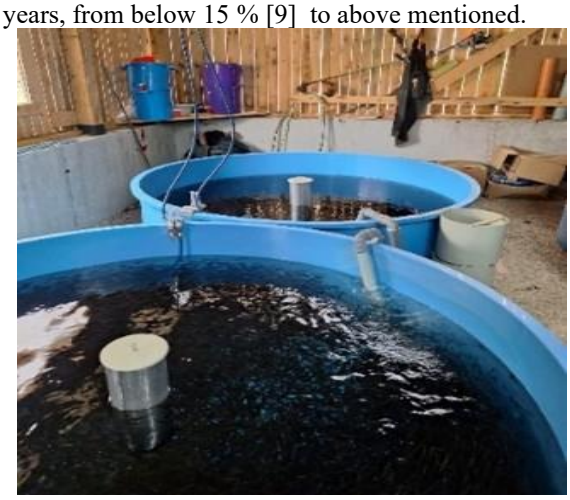

Figure 10. Use of pure oxygen for rearing trout fry, injected into the water via ceramic micro-bubble diffusers – Tropic Ribarstvo, Bosnia and Herzegovina, Republika Srpska (Photo: N. Savić, 2024)

In Republic of Serbia, on several trout farms that rely heavily on oxygen supplementation, perforated hoses are installed in every rearing pond for potential emergency oxygenation. Sometimes, two hoses are placed in a single pond: one along the length of the pond, covering 2/3 to the entire pond length, and another in the first 3–5 m from the pond inlet. The purpose of the hose near the inlet is to save fish that instinctively gather at the inflow of fresh water. Experience has shown that a significant portion of the fish (several tons) instinctively congregates near the fresh water inlet during sharp drops in dissolved oxygen levels.

CONCLUSIONS

The use of water oxygenation devices in trout farms has a long history in all three analyzed countries. The method of use and placement depends on the type of oxygenator. Ceramic diffusers are suitable for smaller tanks for rearing fry. Perforated hoses are primarily used in tanks for transporting live fish and play an important role as an emergency oxygenation system.

Downflow bubble contactor devices are currently used on only one trout farm in Serbia. Globally, devices operating on this principle are widely employed in intensive and super-intensive (RAS) systems for producing rainbow trout, and their use can be expected to increase in the observed countries in the near future.

Overall, devices with active working elements, specifically the FAS KR94/L model, are the most commonly used oxygenators in all three countries.

This is primarily because they allow significant production intensification without the need for additional equipment or technology.

Box-type oxygenation devices (Oxy-box) with nozzles are used in Bosnia and Herzegovina, Republika Srpska, and their further adoption can be expected in all three countries. Similarly, low-head oxygenators are among the devices whose usage is expected to increase in the near future.

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PERFORMANSE UREĐAJA ZA OKSIGENACIJU NA PASTRMSKIM RIBNJACIMA U REPUBLICI SRBIJI, REPUBLICI SEVERNOJ MAKEDONIJI I BOSNI I HERCEGOVINI

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Sažetak: Rastvoreni kiseonik se univerzalno prepoznaje kao najznačajniji ograničavajući faktor u intenzivnoj akvakulturi pastrmke, jer ima dubok uticaj ne samo na proizvodnu efikasnost, već i na dobrobit riba, fiziološku stabilnost, imunološku kompetentnost i sposobnost odolevanja bolestima. Kada nivo kiseonika padne ispod optimalnih vrednosti, pastrmke su izložene hroničnom stresu, poremećajima metaboličkih procesa, smanjenom unosu hrane i povećanoj osetljivosti na patogene, što sve zajedno negativno utiče na produktivnost i održivost proizvodnje. U cilju ublažavanja ovih rizika, oksigenacija vode, definisana kao tehnološki proces obogaćivanja vode čistim kiseonikom, postala je nezamenjiva mera u savremenoj pastrmskoj akvakulturi. U Srbiji i Severnoj Makedoniji sistemi za oksigenaciju se kontinuirano primenjuju više od dve decenije, dok su u Bosni i Hercegovini u upotrebi duže od deset godina, čime su omogućeni intenziviranje proizvodnje, sezonska stabilnost i poboljšani ekonomski rezultati. Ova studija razmatra raznovrsnost tehnologija za oksigenaciju koje se trenutno koriste, uključujući difuzorske sisteme, niskonaponske oksigenatore, rezervoare pod pritiskom i uređaje sa rotirajućim mehaničkim komponentama. Poseban akcenat stavljen je na njihove principe rada, parametre efikasnosti i eksploatacione karakteristike, uz razmatranje načina na koji su ove tehnologije prilagođene specifičnim ekološkim uslovima i upravljačkim praksama na ribnjacima sa kalifornijskom pastrmkom u regionu.

Ključne reči: *Pastrmski ribnjaci, oksigenacija vode, eksploatacione karakteristike*

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