eISSN 2544-0659
ISSN 2081-6960 (zawieszony)

Zeszyty Naukowe
Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie

Scientific Journal
Warsaw University of Life Sciences – SGGW

PROBLEMY ROLNICTWA ŚWIATOWEGO

PROBLEMS OF WORLD AGRICULTURE

Vol. 23 (XXXVIII) 2023
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Warsaw University of Life Sciences Press
Warsaw 2023

Lista recenzentów jest publikowana w ostatnim zeszycie w roku oraz na stronie internetowej czasopisma. / The list of reviewers is published in the last issue of the year and on the journal's website.
Wersja elektroniczna jest wersją pierwotną. / The primary version of the journal is the on-line version.

Indeksacja w bazach danych / Indexed within:
ERIH PLUS, Index Copernicus, Baza Agro, BazEkon, System Informacji o Gospodarce Żywnościowej, Arianta Naukowe i Branżowe Polskie Czasopisma Elektroniczne, AgEcon search, CEJSH, PBN, Biblioteka Narodowa, Repozytorium Cyfrowe Polona, Google Scholar, DOAJ, Crossref, EBSCO.

prs.wne.sggw.pl
e-ISSN 2544-0659, ISSN 2081-6960 (zawieszony)

Wydawnictwo SGGW / Warsaw University of Life Sciences Press
www.wydawnictwosggw.pl

Spis treści

List of Reviewers 2023 / Recenzenci artykułów w 2023 r.:

Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 23(XXXVIII), number 4, 2023: 5-16
DOI: 10.22630/PRS.2023.23.4.13

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Socio-Economic Consequences and Mitigation Strategies of the COVID-19 Pandemic (Phases One and Two) on Rural Farmers in Ebonyi State, Nigeria

Abstract. This study assessed the socio-economic consequences and mitigation strategies of the COVID-19 pandemic (phases one and two) on rural farmers in Ebonyi State, Nigeria. Specifically, the study described the socio-economic characteristics of rural farmers, assessed the perceived socio-economic consequences of the COVID-19 pandemic, and identified strategies used by farmers to cope with the effects of the COVID-19 pandemic. A multistage random sampling technique was employed to select 120 respondents from whom data were collected using a semi-structured questionnaire. Data collected were analysed using descriptive statistics and a mean score. The results showed that disruption in children's education ($\bar{X}$=3.02), reduced purchasing power and increased rate of inflation across the country ($\bar{X}$=2.83), a reduction in diversity and amount of food consumed ($\bar{X}$=2.77), a reduction in the standard of living ($\bar{X}$=2.68), a reduction of farm income ($\bar{X}$=2.63), reduced off-farm employment and income ($\bar{X}$=2.61), loss of lives ($\bar{X}$=2.61), an increase in prices of food items ($\bar{X}$=2.59), reduced religious activities and gatherings ($\bar{X}$=2.57), reduction of remittance ($\bar{X}$=2.54) and high foreign exchange rates ($\bar{X}$=2.53) were some of the perceived socio-economic consequences of the pandemic. Meanwhile, 80.00% and 70.83% of the rural farmers reduced the quantity of meals eaten and prayed to God, respectively. It was recommended that government assistance programmes must be modified and augmented in order to better reach rural populations, many of whom do not have access to formal contributory social insurance systems.

Keywords: COVID-19 pandemic, socio-economic consequences, mitigation and rural farmers

JEL Classification: Z0, Q0, Q1

Introduction

Agriculture has always played an essential role in the economy of all countries. This is not only because the sector provides food for the population of a country but also because of the interconnectivity and interaction that the sector has with all the other sectors of the economy (Brivery and Yunike, 2021). In many developing countries, including Nigeria, agriculture is a key sector of the economy and provides the basis for any development strategy (Aminou et al., 2021). It provides employment for about two-thirds of Africa's working population and, according to the World Bank (2020a), can help reduce poverty, raise income, and improve food security for 80% of the world's poor, who live mostly in rural areas and work mainly in farming. However, recent evidence suggests that these potentials could have been hampered by the COVID-19 pandemic (Brivery and Yunike, 2021).

Like climate change, a pandemic is a global risk. The COVID-19 pandemic that broke out in the city of Wuhan, China, in December 2019 and later spread to different countries,

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including Nigeria, has inflicted negative macro socio-economic impacts on developed and developing countries globally (Onwuka, 2021). The COVID-19 pandemic affected and continues to affect the world in a way that has not been seen since World War II (International Monetary Fund (IMF), 2020). The pandemic has led to loss of lives, and death tolls around the world are, in many cases, unacceptably high (World Health Organization (WHO), 2020).

Nigeria recorded the first confirmed COVID-19 case in Sub-Saharan Africa in late February 2020, after which it began to spread in Lagos State, Ogun State, the Federal Capital Territory (FCT) Area of Abuja and all other states of the country. To control the spread of the pandemic, given the rapid increase in the number of infected people, Nigeria governments at various levels (federal and state) initiated some policy actions, including health and education campaigns, lockdowns, self-isolation, social distancing, fiscal and monetary measures and compensating measures in the form of social protection for poor and vulnerable people (Onyekwena and Amaramma, 2020; Ibukun and Adebayo, 2020). These unanticipated restrictions in physical, social, and economic activities interrupted the ability of various individuals and groups to earn a living and affected various sectors of the economy, ranging from the agriculture sector to manufacturing and services (Nicola et al., 2020; Niles et al., 2020).

Acharya and Porwal (2020) noted that because of high globalisation, economic integration, and interconnectedness among the different sectors of the economy, a change in any part of the economy or country could affect other sectors of the economy or other countries in other parts of the world. Therefore, while the health impact of COVID-19 in most parts of the world, including Nigeria, was primarily felt in urban areas due to dense population, its adverse economic impacts spread or trickled down to rural areas (Oscar, 2021).

Globally, the COVID-19 crisis is primarily viewed as an unprecedented public health challenge. While it is not as deadly as the H1N1 flu epidemic or the Ebola epidemic, it is unprecedented in the rapid transmission of viral agents from one human to another worldwide (Yazdanpanah et al., 2021). It profoundly and widely affects socio-economic activity, work life, food systems, and many other sectors. Thus, the pandemic's effects go far beyond just public health (Udmale et al., 2020; Swinnen and McDermott, 2020) as it has wiped out or disrupted various jobs and, as of December 2020, put almost half of the world's 3.3 billion workforce at risk of losing their livelihoods or worsening their poverty status.

Border closures, quarantines, social distancing, curfews, and trade restrictions prevented farmers from accessing farms and/or markets—including the purchase of inputs and the sale of their products. Controls also prevented workers from harvesting agricultural products, triggering significant socio-economic consequences for people's livelihoods (WHO, 2020). While these restrictions are crucial for limiting the spread of the disease, they often disrupt chain markets and trade in agricultural and non-agricultural products, thus affecting the nutrition and food security of all (WHO, 2020).

Rural residents and farmers in developing countries are more vulnerable to the impact of the COVID-19 pandemic because, in their local communities, most of them have inadequate or lack access to resources such as clean water, schools, electricity, health centres, a good transportation network, financial services, communication facilities, and social support, all of which are more readily available in urban areas. The lack of these resources, services, and support puts these populations at a higher risk and vulnerability (WHO, 2020).

Carlo et al. (2020) asserted that the economies of most African countries, including Nigeria, were hit hard by the COVID-19 pandemic. They posited that in Nigeria, for instance, the pre-COVID-19 employment level was at 85%, but after the lockdown measures, self-reported employment levels fell to 43%. Also, according to Carlo et al. (2020), a significant share of the population—between 46 and 80%—had to get by with less income in Nigeria during the period under review. These could have long-term negative effects on the livelihood and poverty status of most Nigerians, including rural farmers, even though the federal government has since put in place measures to boost economic activities.

According to Bordi et al. (2021), rural economies are interwoven into national and global markets through complex networks of production, trade, migration, and remittance flows. These links, combined with disproportionately higher levels of pre-COVID-19 pandemic poverty and food insecurity, make rural areas and rural livelihoods acutely vulnerable to the adverse economic impacts of the pandemic. Moreover, informality is a key feature of rural life in many countries. As a result, rural people, including farmers, are less likely to have access to contributory social insurance (e.g. health insurance, unemployment benefits) and to other services, such as credit and insurance, which help to reduce the livelihood risks of the pandemic. This informs the need for a study of this nature to determine any impacts of the COVID-19 pandemic on rural farmers' livelihoods and poverty levels, and provide recommendations that will help ameliorate the situation.

In order to inform long-term COVID-19 recovery and mitigation policy responses, it is critical to understand the extent of the economic impacts of the pandemic on rural farmers. To this end, this study intends to consolidate the emerging evidence of the impact of COVID-19 in rural areas by empirically assessing micro-level data on the socio-economic consequences of the COVID-19 pandemic as it relates to livelihood and poverty levels of rural farmers in Ebonyi State, Nigeria.

Currently, the main focus of researchers globally, irrespective of discipline, is on the COVID-19 pandemic. This study contributes to the current debate on the pandemic, especially as it affects the livelihood and poverty levels of rural farmers. It is hoped that the findings of this study, if implemented, would help in fulfilling some of the aspirations of the National Economic Empowerment Development Strategy (NEEDS) and the United Nations Sustainable Goals, and serve as a base for further research on similar issues.

In view of the foregoing, this study specifically:

i. describes the socio-economic characteristics of rural farmers;
ii. assesses farmers' perceived socio-economic consequences of the COVID-19 pandemic in the study area;
iii. identifies strategies used by farmers to cope with the effects of the COVID-19 pandemic in the study area.

Research methodology

Area of study

This study was carried out in Ebonyi State, Nigeria. Ebonyi State has a land area of 5,533 km^2, with a total population of 2,173,501 people, made up of 1,132,517 males and 1,040,984 females (NPC, 2006). Large proportions of the inhabitants of the state are farmers and live in rural areas with a population density of about 580 people per km^2. Ebonyi State is located between latitudes $5^0 10'$ N and $6^0 35'$ north of the equator and longitudes $7^0 30'$ E and $8^0 30'$ east of the Greenwich Meridian. It shares boundaries with Cross River State to the east, Enugu State to the west, Benue State to the north, and Abia State to the south. The state is landlocked and situated about 200 kilometres from the Gulf of Guinea to the south and 70 kilometres from the Republic of Cameroon to the east. Annual rainfall in the state ranges from 1613.8 mm to 2136.27 mm, which is distributed from April to October (Ogbuene, 2010). The state has an annual temperature range of 23^0C and 40^0C. The relative humidity is highest at 09.00 hours (Nigeria time) and usually between 70% and 80% in most months of the year.

Sampling technique

A multistage random sampling technique was employed in selecting respondents for the study. In stage one, one local government area with predominantly rural characteristics was randomly selected from each of the three agricultural zones of the state. In stage two, two agrarian communities were randomly selected from each of the three LGAs to give six communities. In stage three, two villages were randomly selected from each of the six communities to give twelve villages. A list of rural farmers in each village was formulated with the help of the village secretaries. This list served as the sampling frame from which ten farmers from each village were selected at random. This gave a sample size of one hundred and twenty rural farmers.

Method of data collection

The study made use of primary data. Data for this study were collected from primary sources (the rural farmers). The data were collected using a pre-tested semi-structured questionnaire, which addressed issues on the socio-economic characteristics of the rural farmers such as their age, gender, education level, extension services contact, farm income, membership of association and access to remittance. In addition, data were also collected on the rural farmers' level of awareness of the COVID-19 pandemic, their perceived socio-economic consequences of the pandemic, coping strategies, and livelihood and household welfare indicators before and after phases 1 and 2 of the pandemic.

Method of data analysis

In order to realise the purpose of the study, a number of statistical tools were employed in analysing data. Objectives (i) and (iii) were analysed using descriptive statistics of mean, frequencies, and percentages. Objective (ii) was realised with the aid of mean scores that were obtained using a 4-point Likert scale.

Model specification

Assessment of farmers' perceived socio-economic consequences of the COVID-19 pandemic (Objective iii) was realised using a mean score which was obtained following the use of a 4-point Likert scale (where perception of the socio-economic consequences of the COVID-19 pandemic will be captured with a 4-point Likert scale graded thus: Strongly agree = 4, agree = 3, disagree = 2, strongly disagree = 1).

The values of the responses were added and further divided by 4 to obtain a mean score of 2.5, which was regarded as the mean level for the perception of the socio-economic consequences of COVID-19. Responses with a mean score of 2.5 and above were regarded as being perceived by the farmers, while responses with a mean score of less than 2.5 were regarded as not being perceived.

Thus, mean perception score = $\bar{X}$

$$\bar{X} = \sum fx/N, \text{ (the mean score)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (1)}$$

The mean ($\bar{X}$) of each item will be computed by multiplying the frequency of positive responses to each question with its appropriate Likert nominal value, and the sum will be divided by the sum of the number of respondents to the items. This is summarised with the equation below:

$\bar{X} = \sum fn/N$.

Where:

$\bar{X}$= mean score;

$\sum$ = summation sign;

F = frequency or number of respondents who responded positively;

n = Likert nominal value;

N = number of respondents.

Results and discussion

Age of the rural farmers

The distribution of the respondents according to age is presented in Table 1. As shown in the table, 39.17% and 25.50% of the rural farmers were aged between 40 and 49 years and 50 to 59 years, respectively. The mean age of the farmers was 48.18 years. This indicates that the farmers were active and energetic enough to withstand the tedium associated with farming. According to Nwaru (2004), the risk-bearing abilities and innovations of a farmer, as well as his/her mental capacity to cope with the daily challenges and demands of farm production activities, decrease with advancing age. The low percentage (19.16%) of youth (20-39 years) among the farmers indicates low involvement of youths in farming in rural areas of the state. This finding agrees with Ajani et al. (2015) and Dankyang (2014), who assert that most youths in rural parts of Nigeria have left agriculture and migrated to urban centres in favour of employment in the non-agricultural sector. Although this could have negative implications on the supply of farm labour in the area, the remittances sent home by rural migrant youths could help the farmers cope with the impacts of the COVID-19 pandemic. The result compares favourably with Osondu et al. (2013), who found a mean age of 47 years among rural farmers in Abia State, Nigeria.

Household size of the rural farmers

The distribution of the respondents according to household size is presented in Table 1. The table shows that 52.50% of the rural farmers had household sizes within the range of 5-8 people, while 31.67% of them had a household size of between 1 and 4 people. The mean household size of the farmers was 7 people. This result compares favourably with Emerole et al. (2014) and Chukwuone et al. (2018) with findings of 7 people as the mean household size of farmers in Southeast Nigeria and suggests that more of the farm labour utilised in farm production in the study area is supplied by household members, since the majority of farmers in rural areas use more household labour compared to hired labour (Ojogho, 2010). In the absence of well-functioning labour markets, large households face fewer labour bottlenecks at critical points in the farming cycle, such as land preparation and harvest (Ezeh et al., 2012). Thus, it is expected that large farm households may likely not experience a shortage of farm labour supply as a result of phases one and two of the COVID-19 pandemic.

Table 1. Description of the respondents' socio-economic characteristics (n=120)

Variables	Frequency	Percentage
	Age (Years)	
20 – 29	7	5.83
30 – 39	16	13.33
40 – 49	47	39.17
50 – 59	27	22.50
60 – 69	14	11.67
≥ 70	9	7.50
Mean (years)	48.18	-
	Education Level	
No formal education	18	15.00
Primary education	33	27.50
Secondary education	64	53.33
Tertiary education	5	4.17
	Household Size	
1 – 4	38	31.67
5 – 8	63	52.50
9 – 12	16	13.33
13 – 16	3	2.50
Mean	6.74	
	Farming Experience (Years)	
1 – 10	37	30.83
11 – 20	51	42.50
21 – 30	19	15.83
31 – 40	11	9.17
41 – 50	2	1.67
Mean (years)	14.34	
Total	120	100.00

Source: Field survey, 2021.

Education level of the rural farmers

The distribution of the respondents according to the level of formal education attained is presented in Table 1. The table shows that 53.33% of the rural farmers had attained secondary school education, while 27.50% and 4.17% of them had attained primary education and tertiary education, respectively. Cumulatively, 85.00% of the farmers had attained diverse levels of formal education. Education raises human capital and significantly increases the ability to make correct and meaningful farm management decisions. The ability to read and write enables the farmers to effectively and efficiently utilise whatever resources are at their disposal and be better able to cope with the impacts of the COVID-19 pandemic. Also, as noted by Ebewore and Okedo-Okojie (2016), widespread illiteracy among farmers hinders their understanding of information as well as their perception of changes occurring around them. Educated farmers are expected to have a higher level of perception of the pandemic.

Farming experience of the rural farmers

The distribution of the respondents according to farming experience is presented in Table 1. The table shows that 42.50% and 30.83% of the rural farmers had farming experiences within the range of 1 to 10 years and 11 to 20 years, respectively. The mean farming experience of the rural farmers was 15.54 years. The result shows that many of the farmers were well-versed in farming as they had been in the business for many years. This is expected to have positive implications on their perception of the COVID-19 pandemic. Osondu and Nwaobiala (2013) asserted that from experience gained in farming over the years, farmers are likely to perceive changes that occur on their farms, especially with respect to farm output and income. The result supports Umeh and Ekwengene's (2017) finding of mean farming experience of 14 years among farmers in Enugu State, Nigeria.

Perceived socio-economic consequences of phases one and two of the COVID-19 pandemic by the rural farmers

The distribution of the respondents according to the level of perceived socio-economic consequences of phases one and two of the COVID-19 pandemic is presented in Table 2. The table shows that some social and economic changes were perceived by the rural farmers as being aftermaths of phases one and two of the COVID-19 pandemic, which occurred in Nigeria. As shown in the table, disruption in children's education ($\bar{X}$=3.02), loss of lives ($\bar{X}$=2.61), reduced religious activities and gatherings ($\bar{X}$=2.57), and reduced access to healthcare facilities due to increased strain on health workers ($\bar{X}$=2.57) were perceived by the rural farmers as social consequences of the pandemic, while an increase in social tension ($\bar{X}$=2.53) was the only psychological consequence of the pandemic.

Furthermore, with respect to the economic consequences of phases one and two of the COVID-19 pandemic, Table 2 shows that the aftermath of the pandemic was perceived by the rural farmers to include reduced purchasing power and increased rate of inflation across the country ($\bar{X}$=2.83). This result lends credence to the assertion of the Global Alliance for Improved Nutrition (GAIN) (2021) that from the onset of the COVID-19 pandemic in Nigeria in February 2020, an inflationary trend has been on the rise and has continued into 2021. According to them, if left unchecked, this could have devastating negative economic impacts on rural farmers. Other economic consequences of the pandemic perceived by the farmers were: a reduction in diversity and amount of food consumed ($\bar{X}$=2.77), reduction in the standard of living ($\bar{X}$=2.68), reduction of farm income ($\bar{X}$=2.63), reduced off-farm employment and income ($\bar{X}$=2.61), increase in prices of food items ($\bar{X}$=2.59), reduced savings capacity ($\bar{X}$=2.56), reduction of remittance ($\bar{X}$=2.54), reduction in investment levels ($\bar{X}$=2.54), high foreign exchange rates ($\bar{X}$=2.53), reduced demand/sales of farm outputs ($\bar{X}$=2.53), low access to agricultural inputs due to movement restrictions ($\bar{X}$=2.52), and food scarcity/reduced access to food ($\bar{X}$=2.51).

Table 2. Distribution of the rural farmers according to the level of perception of socio-economic consequences of the COVID-19 pandemic

Socio-economic consequences of the COVID-19 pandemic	**Strongly agree (4)**	**Agree (3)**	**Disagree (2)**	**Strongly disagree (1)**	**Total**	**Mean score**
Social Consequences						
Reduced access to healthcare facilities due to increased strain on health workers	29(116)	30(90)	41(82)	20(20)	308	2.57
Loss of lives	26(104)	43(129)	29(58)	22(22)	313	2.61
Disruption in children's education	44(176)	51(153)	18(36)	7(7)	372	3.10
Disruption in traditional ceremonies	24(96)	25(75)	43(86)	28(28)	285	2.38
Reduced religious activities and gatherings	30(120)	27(81)	44(88)	19(19)	308	2.57
Mistrust in government actions	19(76)	30(90)	34(68)	37(37)	271	2.26
Psychological Consequences						
Increase in social tension	26(104)	35(105)	36(72)	23(23)	304	2.53
I had a lot of anxiety and worry about getting COVID-19	30(120)	25(75)	28(56)	37(37)	288	2.40
Increase in depression and high blood pressure	22(88)	23(69)	31(62)	44(44)	263	2.19
COVID-19 caused farmers to be reluctant to make farm management plans	19(76)	24(72)	39(78)	38(38)	264	2.20
Economic Consequences						
Reduction of farm income	24(96)	42(126)	40(80)	14(14)	316	2.63
Reduction of remittance	21(84)	40(120)	42(84)	17(17)	305	2.54
Reduced savings capacity	26(104)	38(114)	33(66)	23(23)	307	2.56
High foreign exchange rates	28(112)	31(93)	38(76)	23(23)	304	2.53
Reduced access to banks	24(96)	27(81)	23(46)	46(46)	269	2.24
Reduction in the standard of living	33(132)	38(114)	27(54)	22(22)	322	2.68
Reduced purchasing power and increased rate of inflation across the country	37(148)	43(129)	23(46)	17(17)	340	2.83
Reduced off-farm employment and income	26(104)	40(120)	35(70)	19(19)	313	2.61
Low access to agricultural inputs due to movement restrictions	28(112)	34(102)	30(60)	28(28)	302	2.52
Food scarcity / reduced access to food	25(100)	34(102)	38(76)	23(23)	301	2.51
Reduction in diversity and amount of food consumed	38(152)	39(117)	20(40)	23(23)	332	2.77
Reduction in the quality of food consumed	27(108)	30(90)	31(62)	32(32)	292	2.43
Reduced demand/sales of farm outputs	27(108)	36(108)	30(60)	27(27)	303	2.53
Reduction in investment levels	31(124)	29(87)	34(68)	26(26)	305	2.54
Increase in prices of food items	36(144)	30(90)	23(46)	31(31)	311	2.59
Shortage of farm labour	21(84)	30(90)	21(42)	48(48)	264	2.20
Grand Mean						2.52

Decision Rule: Mean score values of ≥ 2.5 = Perceived; < 2.5 = not perceived

Figures in parentheses are Likert scores; figures not in parentheses are response frequencies.

Source: Field Survey, 2021.

The International Fund for Agriculture Development (IFAD) (2020) noted that rural farming communities tend to have little or no savings, and many depend on daily-generated income for food access. Interruptions in daily wages and unexpected disruptions in income may force rural farmers into severe food insecurity. Confirming that reduced access to food is driven primarily by high prices and reduced income, Carreras et al. (2020) reported that more respondents from Ghana, Ethiopia, Kenya, Malawi, Nigeria, Tanzania and Zimbabwe were constrained from accessing food as a result of reduced income and a rise in food prices.

Strategies used by rural farmers to cope with the effects of phases one and two of the COVID-19 pandemic

The distribution of the respondents according to strategies used to cope with the effects of phases one and two of the COVID-19 pandemic is presented in Table 3. The table shows that 80.00% of the farmers reduced the quantity of meals eaten. This result supports the FAO (2021a) finding that 94% of sampled rural farm households in Liberia reduced food consumption as a strategy to cope with COVID-19-induced income losses. In a similar vein, Egger et al. (2021) found that changes in income due to COVID-19 are significantly associated with an increased probability of rural farmers consuming less food. Meanwhile, 76.67% and 75.00% of the farmers skipped meals and reduced purchases of non-food items, respectively. This finding lends credence to results obtained by Carreras et al. (2020) in Nigeria, in which 79% of sampled respondents reported skipping meals as a coping strategy. Evidence emanating from the FAO (2021b) study showed that in Yemen, 67% of sampled rural households reported a reduction in non-food expenditures, while 54% of the respondents reported selling productive inputs as COVID-19 coping mechanisms.

Table 3. Distribution of the rural farmers according to strategies used to cope with the effects of the COVID-19 pandemic

Coping Strategies	*Frequency	Percentage
Skipped meals	92	76.67
Borrowed money	60	50.00
Reduced quantity of meals eaten	96	80.00
Buying food on credit	55	45.83
Obtained remittance money from migrant household members	44	36.67
Accessed palliative care from social groups and the government	29	24.17
Sold personal belongings	38	31.67
Sold productive assets	60	50.00
Consumed plant materials stocked for the next planting season	66	55.00
Reduced the level of farm investments		
Reduced purchases of non-food items	90	75.00
Ate less expensive food	61	50.83
Spent savings	88	73.33
Prayed to God	85	70.83

*Multiple responses recorded

Source: Field survey, 2021.

Furthermore, 70.83%, 67.50%, and 52.50% of the farmers prayed to God, spent savings, and sold productive assets, respectively, as coping strategies for the pandemic. The result highlights the religious belief of the farmers in a superior being. Also, the result with respect to reduced savings lends credence to Rahman and Matin's (2020) report that in Bangladesh, savings were the most prevalent strategy used by rural farm households to cope with the effects of the COVID-19 pandemic. These results support the Josephson et al. (2020) report that in Ethiopia, Nigeria, Malawi, and Uganda, rural households are more likely to liquidate assets as a COVID-19 coping strategy than urban ones. Also, the FAO (2021c) reported that 49% of sampled respondents in Afghanistan sold productive assets as a means of coping with the pandemic. Lastly, 55.00% and 50.00% of the farmers reported consuming plant materials stocked for the next planting season and borrowing money, respectively. Similar results were obtained in Liberia and Yemen by previous studies (FAO, 2021a; FAO, 2021b). In Liberia, 51% of the surveyed households reported borrowing money, while a very high 86% of households in Yemen reported incurring debt or purchasing food on credit.

Conclusions and recommendations

Conclusions

The study showed that COVID-19 has negatively impacted the social, psychological, and economic status of rural farmers. The study has been able to make an important contribution to the discourse pertaining to the impacts of the COVID-19 pandemic, especially from the angle of rural farmers.

Recommendations

Based on the findings of this study, the following recommendations are made:

i. Government assistance programmes must be modified and augmented in order to better reach rural populations, many of whom do not have access to formal, contributory social insurance systems. This will require both financial resources and investments in systems for identifying and targeting those in need. In the context of rural farmers, a combination of flexible cash transfers plus interventions to support and strengthen food and input markets can help reduce reliance on adverse short-term coping strategies, while also enabling productive investments in farm and non-farm activities that have been hindered by the pandemic.

ii. There is a need for all levels of government and other development agencies to provide more support or grants to rural farmers (especially those with low economic status) so as to help minimise livelihood shock and aid recovery of rural households' economic capacity both during and after the COVID-19 pandemic.

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For citation:

Nmerengwa J.K. (2023). Socio-Economic Consequences and Mitigation Strategies of the COVID-19 Pandemic (Phases One and Two) on Rural Farmers in Ebonyi State, Nigeria. *Problems of World Agriculture*, 23(4), 5-16; DOI: 10.22630/PRS.2023.23.4.13

Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 23(XXXVIII), number 4, 2023: 17-30
DOI: 10.22630/PRS.2023.23.4.14

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The Present Status of the Agriculture Sector Towards Sustainable Development in Sri Lanka: A Review of Existing Policies and Suggestions for Improvements

Abstract. Agriculture plays a significant role in the national economy, helping to ensure food security and achieve sustainable development in Sri Lanka. This paper presents a review of the present situation of the agriculture sector and suggestions for the improvements needed to achieve sustainable development in Sri Lanka. As per the findings of the study, Sri Lanka had conventional agriculture practices a few decades ago, and agricultural policymakers were introduced to organic agriculture for commercial farming systems a few years ago. In particular, the application of organic agriculture practices has gradually reduced in commercial farming systems recently. This is because certain issues are still prominent in the agriculture sector: yield losses, lower ability to share the latest information and experiences of organic agriculture, lower responsiveness of hybrid seeds in organic farming, unavailability of properly directed organic agricultural regulations and national standards, post-harvest losses during long distance transportation, limited research and development, higher prices of organic products, higher input costs, higher susceptibility to pests and diseases, and a shortage of organic inputs, etc. As a result, the majority of agricultural authorities have introduced GAP farming practices for farmers. GAP is important to address the issues of food safety, trade, and sustainability. In addition to that, it also helps to reduce the unregulated use of agrochemicals, and avoid adverse climate change impacts or any negative externality that threatens the overall agriculture production, people's health, and the environment, thereby challenging the sustainability of the sector. Thus, pick-up orders at stations, usage of proper storage facilities to avoid post-harvest losses during long-distance transportation, formulating and implementing regulations for the development of the export market of GAP products, organising extension programs and training to disseminate the latest information to enhance farmers' adoption to GAP farming, encouraging field experts to gain international training opportunities, introducing proper control mechanisms to protect the local market, conducting research and development activities, and enhancing links between GAP farmers and other supply chain components to maintain a strong certification system for their products may lead to achieving sustainable agriculture development in Sri Lanka.

Keywords: existing policies, GAP farming, organic agriculture, sustainable development, Sri Lanka

JEL Classification: Q01, Q18

Introduction

Sri Lanka is predominantly an agricultural-based country, and the growth of the agricultural sector has been stagnant since the evolution of civilization (International Trade Administration [ITA], 2021). However, the country has fertile topsoil within the tropical areas, which has the potential to cultivate a variety of crops. When conventional farming practices are more popular within the farming community, the volume of the fertile topsoil gradually decreases due to the loss of the microbial population in the soil

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(Perera and Dayananda, 2021). Additionally, resilience in food production is an essential requirement for the increasing population in Sri Lanka (Thibbotuwawa, 2020). Therefore, food security needs to be ensured to avoid issues associated with malnutrition and other health problems (World Bank, 2020). Sustainable agriculture performs an important national role with three basic aspects: the environment, the economy, and the social well-being of inhabitants (Smith, 2019). Additionally, sustainable agriculture is expected to fulfil different goals, perhaps even conflicting ones, and to do so for a long time, following the changing societal demands and environmental conditions (Jastrzębska et al., 2022). Sri Lanka has 6,561,000 hectares of land and around 2.8 – 2.9 million hectares of agricultural land (World Bank, 2019). Accordingly, Figure 1 shows the evolution of the total agricultural land in Sri Lanka.

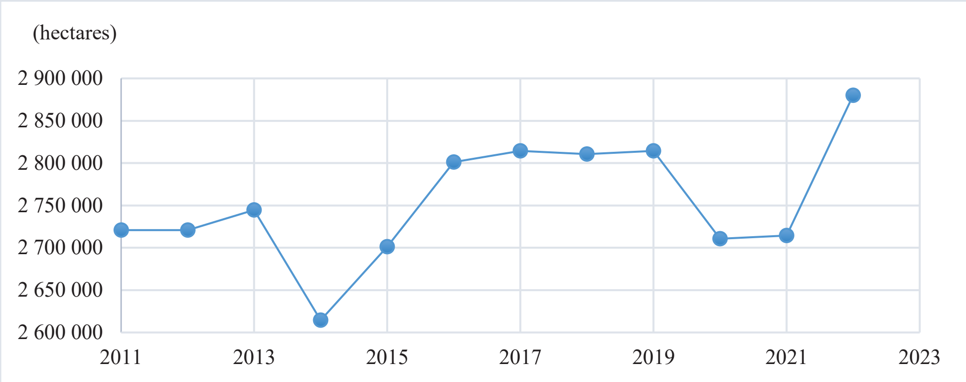

Fig. 1. Evolution of total agricultural land (hectares)

Source: FiBL, 2023.

As per Figure 1, total agricultural land is considered to be the combination of organic farms and conventional farms. In 2011, the total agricultural land was 2.7 million ha. However, it has gradually fluctuated until 2022 (World Bank, 2022).

Nowadays, the agriculture sector contributes about 8.75 percent to the national GDP of Sri Lanka (Neill., 2021; Central Bank Report, 2022). It is the most important source of employment for the majority of the Sri Lankan workforce, especially for people in rural areas. The agriculture sector plays a significant role in the implementation of strategies which are aimed towards the sustainable development of the country (Sri Lanka National Agriculture Policy, 2019).

Considering most developing countries, Sri Lanka is rich in biodiversity and has suitable climatic conditions for organic farming (Sri Lanka Export Development Board [SLEDB], 2020). Recently, the term “organic” has become more popular among most nations of the globe. Therefore, agricultural policymakers pay greater attention to achieving sustainable development by implementing the policies associated with organic agriculture (Luczka et al., 2021).

The evolution of organic farming practices is proved by historical evidence from more than 2,500 years ago. Farmers performed their agricultural practices with indigenous knowledge (Das et al., 2020). Hence, organic farming is not a novel concept, and it is very important for the development of sustainable agriculture in the country. Sri Lankan agricultural policymakers and researchers aim to promote organic agriculture for the protection of land for future generations, producing high-quality food and using traditional agricultural methods (SLEDB, 2017).

Table 1. Farmland under organic production in Sri Lanka (hectares)

2006	2008	2010	2014	2015	2016	2017	2018	2019	2020	2021
15,379	19,190	31,585	62,560	96,318	96,318	165,553	165,553	165,553	73,393	66,623

Source: FiBL, 2023.

According to the statistics in Table 1, organic farming areas have been increasing until 2017. After 2017, it remains stagnant until 2019. However, it gradually increased to 165,553 ha in 2019 (FiBL, 2023). Thus, this figure illustrates that the amount of organic farmland is considerably lower than the share of total agricultural land in Sri Lanka.

In 2020, agricultural policymakers realised this situation, and they supported extension activities related to organic farming in Sri Lanka (Dandeniya., 2020; Sri Lanka National Agriculture Policy, 2019). In addition to that, organic fertiliser-producing activities, introducing subsidies to the organic fertiliser producers, and research and development activities related to organic farming are the key actions taken to minimise the use of conventional farming practices in Sri Lanka (Dandeniya, 2020; Edirisinghe et al., 2019). As a result, around two million farmers have adopted organic farming due to the sudden policy changes of the policymakers, e.g. the removal of chemical fertiliser subsidies and import limitations of chemical fertilisers. However, most of the organic fertiliser producers are unable to fulfil the domestic fertiliser production requirements for farming (Guzman, 2022). Additionally, domestically produced organic fertiliser has been suspected to lack the NPK (nitrogen, phosphorous and potassium) fertiliser recommendations that are required for cultivated crops. Thus, the total production of export-oriented crops and rice decreased, and this created a critical situation for Sri Lanka's national economy as well as the food security of other nations (Wijesinghe, 2021). In a commercial basis of farming, organic fertiliser is not enough to fulfil the nutritional requirements of cultivated crops due to more time consumption in the decomposing process. Thus, farmers recently returned to using chemical fertiliser applications for their crops (Dandeniya and Caucci, 2020). Then, policymakers decided to disseminate knowledge related to GAP (Good Agricultural Practices) to minimise the hazards associated with the application of chemical fertiliser (Bamunuarachchi et al., 2019).

Therefore, this paper aims to present a way of achieving sustainable development through the appropriate agricultural practices by discussing the global status and the scenario in Sri Lanka regarding GAP, the challenges encountered with sustainable development through agriculture, and the identification of existing gaps in the sector and suggestions for overcoming them.

Methodology

The concept of sustainable development in the agriculture sector is not novel for Sri Lanka, although its practicable utilisation in the country is limited. Moreover, most developed countries, as well as developing countries, are utilising this concept to achieve sustainability within the agricultural sector. Recently, most countries, including Sri Lanka, have identified the present status of the agriculture sector as an essential strategy for achieving sustainable development. The study aimed to identify the present status of the agriculture sector in Sri Lanka and the challenges encountered in sustainably managing the agriculture sector in order to draft out strategies for overcoming them and identify the existing gaps and issues for sustainably managing the sector. Sri Lanka is administratively distributed into nine provinces with twenty-five districts. Among them, five districts were purposively selected for the study according to the higher number of farmers, namely, Anuradhapura, Badulla, Monaragala, Ratnapura and Colombo. 1000 farmers were randomly selected as the sample of this study. Data collection was done by using a literature review, a pre-tested self-administrated questionnaire survey, and a focus group discussion from July to October 2022. SWOT analysis was conducted based on the findings of the focus group discussion and questionnaire survey. A literature review was conducted by referring to several research reports, relevant books, journal articles, and news articles to understand the present status of the country's agriculture sector. Moreover, a field survey and focus group discussion were used to further elaborate on the present status of the agriculture sector and issues occurring in this sector in Sri Lanka, and to identify the challenges encountered with the sustainable management of the agriculture sector and the important strategies for overcoming them. Moreover, these findings support the development of a framework for sustainably managing the agriculture sector in Sri Lanka.

Results and discussion

Socio-demographic profile of respondents

The socio-demographic factors of the farmers are presented in Table 2.

Table 2. Socio-demographic profile of respondents (n = 1000)

Factor	Category	Frequency	Percentage (%)
Age (Years)	< 30 years	350	35.0
	40-59	600	60.0
	> 60 years	50	5.0
Gender	Male	754	75.4
	Female	246	24.6
Marital status	Single	11	1.1
	Married	989	98.9
	Other	0	0.0
Educational level	No primary education	6	0.6
	Primary education	28	2.8
	Junior secondary education (O/L)	824	82.4
	Senior secondary education (A/L)	142	14.2
Monthly income (LKR)	Less than 20,000	274	27.4
	20,001 – 40,000	629	62.9
	40,001 – 60,000	97	9.7
Number of family members	less than 4	273	27.3
	4 - 5	698	69.8
	more than 5	29	2.9
Cultivated land size (Acres)	0.0-0.5	296	29.6
	0.5-1.0	627	62.7
	1.0-1.5	74	7.4
	1.5-2.0	3	0.3
Farming experience (Years)	0-5	176	17.6
	5-10	458	45.8
	10-15	282	28.2
	15-20	84	8.4

Source: Field survey, July - October 2022.

As per the results of Table 2, the mean age range of the respondents was 40-49 years, indicating that they were in the middle age category. A share of 35.0% of the respondents was reported as below 30 years and 60.0% of respondents were in the middle age range (30-59 years). In addition, 5.0% of respondents were more than 60 years old. While 75.4% were male farmers and 24.6% were female farmers. According to the results of the study, 1.1% of respondents were single in their marital status, while the majority of the respondents (98.9%) were married.

The majority of the farmers have only 3 or 4 children. Regarding the respondents' level of education, 96.6% of farmers had gained secondary education, and 0.6% of the respondents had no formal education.

Considering the family size of the respondents, 27.3% had only 4 family members, 69.8% had 5 members, and 2.9% had 6 members in their family. Furthermore, 91% of the respondents were earning between 20001-40000 LKR as the monthly average income, while 22.4% of them were receiving between 0-20000 LKR.

Table 3. SWOT analysis of the agriculture in Sri Lanka

Strengths	**Weaknesses**
Availability of an adequate level of technological know-how within the supply chain members of the food market.	The public sector has poor knowledge and experience regarding organic products and also GAP-based production: (Export Development Board - EDB and the National Organic Control Unit - NOCU).
Considerable private sector involvement in the farming sector.	Unavailability of properly directed policies for GAP farming.
Well-managed food supply chains to penetrate into the export market.	Some standards and legislation are irrelevant to the local conditions.
Most of the producers are certified with quality standards: Sri cert, HACCP, and ISO 22000 for organic products, as well as GAP-certified products.	Some national standards are not directed at developing local markets.
Optimal climatic conditions for farming.	Sri Lanka still does not exchange the latest information relevant to GAP farming with other countries.
The importance of farming was emphasised by policymakers.	Transportation issues occur within the food supply chains and value chains
Considerable share of GAP-certified farmland.	Lack of bottom-level support for the development of GAP farming.
Lower level of competition for the international certification requirements	Limited research and development in GAP farming
Most of the rural inhabitants, around 2 million of the Sri Lankan population, are performing farming activities (Guzman, 2022).	Rapid transformation to GAP farming
	Hybrid seeds with lower responsiveness used in organic farming.
Opportunities	**Threats**
Increasing demand for GAP products.	The national standards are not directed to develop both the local and export markets.
Public policymakers implement timely updated policies for the development of GAP farming.	Agricultural extension programs are still directed towards conventional agriculture.
Protect biodiversity and improve the health of soil.	Lower adoption of farmers of GAP farming.
Availability of field experts	Higher prices of organic products as well as GAP products

Source: Field survey, July - October 2022.

SWOT analysis of agriculture in Sri Lanka

A SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) was conducted to recognise the key problems of agriculture in Sri Lanka. The findings are presented in Table 3.

Recently, farmers have gradually adapted to GAP-based agriculture in Sri Lanka because of the sudden policy implications to minimise imports of agrochemicals and chemical fertilisers and the removal of chemical fertiliser subsidies for farmers. Also, policymakers have emphasised the importance of institutional intervention to promote organic agriculture through policies and periodic plans. Moreover, Sri Lanka is still not adequately directed to such endeavours. Hence, most commercial farmers have transitioned to GAP in order to reduce the negative externalities of chemical farming. Thus, up-to-date GAP policies, rules and regulations regarding the farming practices, production and trading of GAP products need to be formulated. National standards of GAP production need to be formulated by directing both local and export markets to overcome the current issues arising in agricultural markets, such as processing, reducing threats to new entrants into the agricultural producing industry, and the promotion of certified GAP products.

The public and private institutional collaboration is important to uplift the GAP sector while underling the various factors such as rules and regulations, legislations, well-directed action plans and risk management in formulating GAP policies. When implementing government policy roles and interventions, fund allocation acts as the key determinant in Sri Lanka as it does in other developing countries.

Quality standards for GAP-based agriculture and packaging, as well as market regulation mechanisms for the monitoring of fake products, are favourable factors for the optimum regulation of GAP value chain systems in Sri Lanka. Mostly, these aspects should be regulated through government intervention. Thus, they support and promote the development of GAP through various regulations, policies, and programmes such as subsidies for large-scale organic fertiliser producers, market strategies for GAP products and research and development activities of pest repellents & NPK recommendations of organic fertilisers.

The shortages and surpluses in the supply and demand of GAP products can be overcome through the proper links between the supply chain and the value chain components of GAP markets. Legislations, regulations, and GAP policies need to address this situation by implementing a GAP development policy, and national GAP standards and certification programs to minimise price discrimination of organic and inorganic products, as well as adequate institutional interventions to promote GAP farming.

Research and development activities need to be promoted with public and private institutional collaboration to gain the optimum benefits for the development of GAP. Brainstorming how to overcome these circumstances through innovative methods will enhance the information dissemination of GAP farming to each and every component of the sector.

However, higher prices of GAP products act as a constraint to the majority of consumers willing to purchase agricultural products. Hence, GAP products should be available in the market at affordable prices, or inorganic products need to be available to cater to consumer demand. Organic cultivations require higher amounts of organic fertiliser when compared to conventional cultivations, especially at the initial stage of transformation into organic farming after many years of conducting conventional practices. In addition to that, necessary inputs are needed to produce organic fertiliser with recommended NPK levels. Thus, the NPK levels of the organic fertilisers and the recommended application amounts generate concerns for crop yield in commercially based cultivations. Thus, GAP farming is considered an important remedy for it.

The agriculture sector and sustainable development in Sri Lanka

The Sustainable Development Goals (SDGs) aim to formulate and implement strategies to improve education, gender equality, and economic growth, minimise climate change, and achieve the optimum utilisation of natural resources for the future (UN, 2020). Substantial evidence has proved that the management practices of conventional agriculture are not sustainable for the future (Oberc and Schnell, 2020; Shennan et al., 2017). Hence, most of the developing countries have hindered their attempt to reach the SDGs (Oberc and Schnell., 2020). In Sri Lanka, agricultural practices are performed both conventionally and organically. However, sustainable agriculture is a distinct set of practices. It is a system of food production that uses the productivity of natural resources. It encompasses the efforts that develop more efficient production systems while providing a direction that makes remarkable savings for farmers (Nedumaran, and Manida., 2019). Thus, organic agriculture plays a significant role in achieving the sustainable development of the country, and it helps achieve better results under timely and important policy mechanisms (Malkanthi, 2019; Kariyawasam, 2010).

Organic agriculture is broadly combined regarding sustainability aspects - both environmentally and socially - compared to conventional agriculture (Luczka et al., 2021; Meemken and Qaim., 2018). Organic fertiliser enhances the soil quality and minimises pollution from chemical fertilisers or excess agrochemical run-offs (Chen et al., 2018). Farmers perform organic farming practices to fertilise the soil and maintain optimum crop growth (Yuvaraj et al., 2020). Based on previous studies and the latest findings, most researchers still pay greater attention to the crop productivity of organic farming and conventional farming, which varies on the crop type and their management practices. The yield variations concern annual crops rather than other crops. Hence, organic fertiliser slowly releases its nutrients to the environment, and the crops have higher exposure to pests and diseases as well. However, there is considerable crop productivity for biannual and perennial plants in organic farming compared to conventional farming (Timsina, 2018; Shennan et al., 2017). Even though theoretical findings demonstrate the lower yield variations between organic and conventional farming, there were considerable yield losses when the crop cultivations were performed in a commercial manner in Sri Lanka. For example, paddy farming showed around a 30 percent yield loss in the 2021/22 *maha* season in Sri Lanka. In addition to that, tea cultivations reported about an 18 percent yield loss due to the higher fertiliser sensitivity of tea plants than the other crops (Guzman, 2022). Moreover, organic cultivations are usually susceptible to pests and diseases due to the absence of suitable pest repellents for commercial cultivation in Sri Lanka (Wijesinghe, 2021). Thus, this situation creates concerns for performing organic farming practices in a commercial manner.

Crop productivity is generally influenced by the profitability of organic farming. Organic agriculture is associated with a lower level of farming inputs than conventional systems (Smith et al., 2019). Therefore, organic products have higher market prices due to a shortage of labour, intensive crop management practices for controlling pests and diseases, and the environmental recovery costs from converting to organic practises from conventional ones, harvesting, processing, packaging, storage, and transportation. The environmental recovery costs are associated with the clean-up process of polluted water bodies and remediation for agrochemical contamination (Singh, 2021). However, organic farming practices are performed within the home garden, and commercial-scale farming requires more labour for intensive crop care (Dandeniya and Caucci, 2020).

When compared to conventional farming, organic farming offers additional benefits to society and the environment, such as:

- agrochemical residuals are removed from soil,
- reduce run-off of excess agrochemicals to the water bodies,
- organic foods have adequate concentrations of vital elements,
- enhanced bio-diversity,
- reduce usage of non-renewable energy resources,
- organic foods increase resilience in foods regarding floods, droughts, and pest attacks/diseases (Smith et al., 2019).

An environmentally sustainable agricultural system consists of a stable resource base, minimal overexploitation of renewable resources, and regulatory usage of non-renewable resources. Thus, the protection of biodiversity, atmospheric stability, and other ecosystem resources that are not classified as economic resources create an environmentally sustainable agricultural system (FAO, 2017). Both health and environmental benefits should encourage the government to support the organic sector. Despite issues related to commercial organic farming, Sri Lanka should move to GAP farming.

GAP is one of the most important contributors to the preventative practices proposed earlier, and it ensures that on-farm practices result in products reaching the farm gate using the GAP system proposed by the Food and Agriculture Organisation (Malkanthi et al., 2021). Consumer interest in safe food while protecting the environment and ensuring worker well-being has been growing in recent times. The four 'pillars' of GAP are economic viability, environmental sustainability, social acceptability, and food safety and quality (Bamunuarachchi et al., 2019). Hence, GAP is important to address the issues of food safety, trade, and sustainability. In addition to that, it also helps to reduce the unregulated use of agrochemicals, avoid adverse climate change impacts or any negative externality that threatens overall agriculture production, and improve people's health and the environment, which improves the sustainability of the sector (Kharel et al., 2022). In Sri Lanka, SLSI, 2016 was initiated to make standardised quality products for fresh fruits and vegetables. Moreover, the Department of Agriculture implemented a GAP certification scheme for rice, spices and other crops to penetrate the GLOBAL GAP market (Malkanthi et al., 2021).

GLOBAL GAP is a private voluntary service body of certification standards and procedures for good agricultural practices. It focuses on elevating the consumers' confidence in food safety by developing GAP to be adopted by agri-food producers. Although GLOBAL GAP is aimed at food safety and traceability, it also comprises of health, safety and welfare of workers and environmental conservation. GLOBAL GAP certification covers the sowing of the seeds to the planting areas and until the product leaves the farm after its maturation (Malkanthi et al., 2021).

ASEAN GAP certification is also one of the most important GAP certification systems for trading fresh fruits and vegetables in the ASEAN region. ASEAN GAP was established by the ASEAN secretariat in 2016, and it led to the creation and harmonisation of national GAP programs in the ASEAN region. However, ASEAN GAP is a voluntary standard that regulates the procedures of planting crops or seeds, crop caring practices, harvesting, and post-harvesting operations. However, it does not regulate fresh products and also sprouts (Saulan, 2023).

According to Singh (2022), there are key elements included in GAP:

- Risk assessment
- Preventing problems before they occur
- Food safety commitment at all levels
- Mandatory educational training for operational employees
- Chain-wide communication
- Integrated pest management
- Field and equipment sanitation
- Third-party audits for verification
- Oversight and enforcement

Therefore, the Sri Lankan government has been promoting various training and extension programs for GAP to improve farmers' awareness of the existing GAP market and to enhance farmer adoption towards GAP (Malkanthi et al., 2021).

Existing gaps in the agriculture sector of Sri Lanka

Farmers' adoption of GAP is still not satisfactory. Even though the public sector encourages extension programs for the farmers, it is not enough for farmers to practice GAP. This is because conventional farming practices are deeply retained in their minds. Recently, organic farming moved away from commercial farming systems due to certain issues: yield losses, lower ability to share the latest information and experiences of organic agriculture, lower responsiveness of hybrid seeds in organic farming, unavailability of properly directed organic agricultural regulations and national standards, post-harvest losses during long distance transportation and limited research and development, higher prices of organic products, etc.

Thus, farmers moved away from organic agriculture, and they returned to conventional farming. However, the social and environmental hazards of conventional farming persuade them to adopt GAP. As a matter of fact, recent research and innovations related to GAP consist of less public sector involvement and a lower level of dissemination of the latest information for the farmers and producers of the agricultural sector due to certain issues at a basic level. There is lower funding for the training programs at the regional level, extension officers, as well as farmers, and the unavailability of adequate transportation facilities for field observations. It is also difficult to distribute agricultural products to the market at the correct time. Moreover, the sudden transfer of farming methods into GAP limits the time duration for research and innovations.

Hybrid seeds have lower responsiveness to organic agricultural practices. Hence, the implementation of indigenous seed production mechanisms is suitable to fulfil the local seed requirement of the agriculture sector in Sri Lanka. Thus, GAP has the ability to overcome the issues in organic farming.

In addition to that, GAP farming systems cannot acquire the proper mechanisms to control pests and diseases of the cultivations on a commercial basis. Even though field experts conduct several experiments, pest repellents and disease control mechanisms still occur at the experimental level for commercial cultivations in Sri Lanka.

Institutional intervention required for the maintenance of GAP product quality within the local market is the same as in the export market. Thus, consumer protection is ensured by maintaining a threat to the entrance of fake products to the local market. The pick-up orders at stations can be promoted to minimise the issues arising from labour shortages in GAP farms and to reduce post-harvest losses during long-distance transportation. The “Export GAP Products Regulations” need to be formulated to protect product quality and market status.

Generally, organic products have a higher price due to higher labour requirements, intensive care, and management practices. Also, the quantity of organic fertiliser is higher than chemical fertiliser to facilitate adequate NPK levels for the crops, etc. Thus, lower-income consumers find it difficult to purchase organically produced products in the market. However, GAP products have the ability to remedy certain issues of organic farming.

The institutional authorities have no adequate background related to GAP farming, and they have poor knowledge and experience in the field. A well-functioning platform for GAP stakeholders does not exist in Sri Lanka. Proper links between the supply chain and the value chain need to be ensured to control the GAP certification process in Sri Lanka. The national standard of GAP agriculture should be directed to promote the local market to reduce issues associated with the certification of organic products. Sri Lanka should be a member of the ALOGA in order to ensure the exchange of knowledge and experience in the development of the organic agriculture sector.

Suggestions for the issues of farming in Sri Lanka

- Labour shortage issues and transportation issues are minimised by pick-up orders at stations.
- Usage of proper storage facilities to avoid post-harvest losses during long-distance transportation
- Formulate and implement important regulations for the development of the export market of organic products and GAP products.
- Organise extension programs and training to disseminate the latest information for enhancing farmers' adoption of GAP farming in Sri Lanka.
- Encourage international training opportunities for GAP experts.
- Introduce proper control mechanisms to protect the local market.
- Conduct research and development activities regarding the burning issues of the agriculture sector in Sri Lanka.
- Well-balanced regulations need to be introduced to develop both local and export markets.
- Enhance links between farmers and other supply chain components to maintain a strong certification system for GAP products.

- Policies and strategies need to be updated for the development of the agriculture sector.
- Formulate indigenous seed production mechanisms for the cultivations instead of hybrid seeds.
- Conduct a feasibility study for the agriculture sector before promoting GAP farming into the agriculture sector in Sri Lanka to minimise the issues arising for the food security of nations.

Conclusion

Sri Lanka has a very good potential for agriculture due to favourable climatic conditions for a wide variety of crop cultivations. However, there is only gradual improvement for organic farms as organic agriculture has a lower level of crop productivity and profitability than conventional farming systems. However, organic farming offers additional benefits to society and the environment. Organic farming is an environmentally sustainable agricultural system consisting of a stable resource base, minimal overexploitation of renewable resources, and regulatory usage of non-renewable resources.

Organic agriculture plays a significant role in achieving the sustainable development of the country, and it helps achieve better results under important policy mechanisms. In addition to that, extension and training programs related to organic farming led to increasing farmers' adoption of organic farming. In Sri Lanka, certain issues are still prominent in organic farming, such as a low ability to share the latest information and experiences of agriculture, the unavailability of properly directed organic agricultural regulations and national standards, post-harvest losses during long distance transportation, limited research and development, difficulty of transporting agricultural products, and a lack of storage facilities of agri-products, etc. Thus, policymakers have been promoting policy updates regarding GAP farming.

GAP is not a novel concept, and it became more widespread in 2016. It has the capability to address problems associated with organic farming, such as the issues of food safety, trade, and sustainability. In addition to that, it also helps to reduce the unregulated use of agrochemicals, avoiding adverse climate change impacts and any negative externality that threatens overall agriculture production, people's health, and the environment, thereby challenging the sustainability of the sector.

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For citation:

Rathnachandra S.D.D. (2023). The Present Status of the Agriculture Sector Towards Sustainable Development in Sri Lanka: A Review of Existing Policies and Suggestions for Improvements. *Problems of World Agriculture*, 23(4), 17-30; DOI: 10.22630/PRS.2023.23.4.14

Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 23(XXXVIII), number 4, 2023: 31-43
DOI: 10.22630/PRS.2023.23.4.15

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Determinants of Demand and Participation by Poultry Farmers in Formal and Informal Credit Markets in Cross River State, Nigeria

Abstract. A typical challenge for over 65 percent of the Nigerian population living in rural areas and surviving through agricultural activities is access to credit facilities needed to procure technological inputs that trigger productivity. This has consequently limited the capacity of small and micro agro-enterprises - especially poultry enterprises - to develop. Therefore, this study was undertaken to analyse factors affecting the demand and participation of agro-entrepreneurs, particularly poultry farmers, in formal and informal credit markets in Cross River State, Nigeria. Purposive and random sampling techniques were used to select 295 poultry farmers. Data were collected for the 2022 production cycle using structured questionnaires and interviews, and the results were analysed using a multinomial logit model. The results revealed that socioeconomic and enterprise characteristics such as educational level, gender, farm capacity, poultry training, and household assets were significant factors that influenced the participant's choice of credit institution in the study area. Also, favourable terms, outstanding loans and easier access to loans were the institutional factors that affected credit demand. Training and workshop programmes should be organised by government and corporate financial institutions to encourage participation in credit markets so that the abundant available funds can be efficiently utilised in the production process.

Keywords: demand, participation, farmers, poultry, credit

JEL Classification: Q1, Q12, Q13, R15

Introduction

Access to credit is crucial for agricultural development, particularly for small-scale farmers who often face financial constraints. The demand and participation of poultry farmers in credit markets are influenced by a range of factors, including socioeconomic characteristics, farm-specific variables, and institutional factors. Previous studies have identified factors such as farm size, education level, farming experience, interest rates, collateral requirements, and access to information as significant determinants of credit demand and participation in the agricultural sector (Ajayi et al., 2019; Ogunleye et al., 2021). However, it is important to note that the poultry sector has unique characteristics that may differentiate it from other agricultural sub-sectors. Factors such as disease outbreaks, high input costs, and seasonality may affect poultry farmers' credit demand and participation differently (Duru, 2021).

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While there have been studies (Ajayi et al., 2019; Oluwatayo, 2020; Duru, 2021; Ogunleye et al., 2021; Ogunniyi, A. I., & Agbola Ogunniyi et al., 2022) conducted on the factors affecting demand and participation of credit among farmers in Nigeria, there exists a research gap specifically concerning poultry farmers and the differentiation between informal and formal credit sources. The existing literature (Balana et al., 2022; Chandio et al., 2021; Mwongo and Naho, 2021; Asenath and Yiorgos, 2020; Murendo et al., 2020) has primarily focused on credit access and utilisation in the broader agricultural sector, without specifically examining the unique circumstances and challenges faced by poultry farmers.

The knowledge gap lies in the need for a more comprehensive understanding of the factors that influence the demand and participation in informal and formal credit among poultry farmers in Nigeria. Poultry farming is a significant subsector of agriculture in the country, and access to credit plays a crucial role in facilitating investment, expansion, and the adoption of modern production techniques (Osuntade & Babalola, 2021). However, the determinants and barriers to credit access and utilisation among poultry farmers, particularly in relation to informal and formal credit sources, remain understudied.

Additionally, there is limited research that explores the specific characteristics and dynamics of informal credit sources utilised by poultry farmers. Informal credit, such as loans from friends, family, or local moneylenders, often serves as an important source of financing for farmers, especially those with limited access to formal financial institutions. Understanding the drivers and constraints associated with informal credit among poultry farmers can provide insights into the informal financial networks that exist within the sector and inform policies and interventions that support their inclusion and sustainability (Egbo et al., 2021).

Furthermore, the existing literature may lack a comprehensive analysis of the factors that differentiate the demand and participation in informal and formal credit among poultry farmers. Factors such as farmers' socioeconomic characteristics, farm characteristics, the ease of getting a loan, favourable terms, outstanding loans, being deprived of a loan, poultry training, easier formalities, and flexible payback may influence their preference for informal or formal credit sources. Investigating these factors can provide a deeper understanding of the decision-making processes of poultry farmers and help tailor credit policies and programmes to better meet their specific needs and preferences.

In Nigeria, the poultry sector plays a significant role in the agricultural economy. The Nigerian poultry industry contributes approximately 25% to agricultural GDP (Masak et al., 2022) and understanding the factors that affect the demand and participation of poultry farmers in formal and informal credit markets is essential for promoting sustainable growth in the industry. This study seeks to build upon this existing body of research by conducting a comprehensive analysis of the factors affecting the demand and participation of poultry farmers in both formal and informal credit markets in Cross River State, Nigeria. Cross River State is an ideal location for this investigation due to its diverse agricultural landscape and the increasing importance of poultry farming in the region. Understanding the factors that influence poultry farmers' demand and participation in formal and informal credit is crucial for several reasons. Firstly, the poultry sector plays a significant role in the Nigerian economy, contributing to food security, employment generation, and income generation for farmers (Mohammed, 2015). Enhancing credit access for poultry farmers can contribute to the growth and development of the sector.

Secondly, the unique characteristics and challenges poultry farmers face require tailored interventions. Factors such as high input costs, market volatility, and disease outbreaks pose specific challenges to poultry farmers (Anosike et al., 2018), which may influence credit demand and participation differently compared to farmers in other agricultural sectors. Therefore, studying the factors specific to poultry farming can provide insights into designing targeted credit programmes and policies.

Thirdly, the informal credit market plays a significant role in Nigeria's agricultural finance system (Asom et al.,2023). Understanding the factors that influence poultry farmers' participation in informal credit markets can help identify opportunities to enhance the effectiveness and inclusiveness of these informal credit channels. Additionally, studying the factors that influence poultry farmers' participation in formal credit markets can inform policies aimed at improving access to formal financial institutions.

Despite the importance of credit in poultry farming, there exists a research gap in understanding the specific factors that influence poultry farmers' decisions to seek credit and their choice between informal and formal credit sources in Nigeria. While some studies have explored credit access in agriculture more broadly (Oluwatayo, 2020; Ogunniyi et al., 2022), there is a need for more focused research that considers the unique characteristics and challenges faced by poultry farmers. Furthermore, Nigeria's credit sector's evolving financial landscape, policy changes, and technological advancements necessitate an updated and context-specific analysis of credit utilisation among poultry farmers.

Over the past few years, several studies have highlighted the challenges and opportunities facing poultry farmers in Nigeria. According to a report by the Central Bank of Nigeria (2017), the agricultural sector, including poultry farming, has shown substantial growth potential, but access to finance remains a critical bottleneck. This finding is echoed by research conducted by Adeoye et al. (2019), which emphasises the need for improved credit access for small-scale poultry farmers in Nigeria to enhance their productivity and income.

However, the factors influencing poultry farmers' decisions to seek credit and their choice between formal and informal credit sources have evolved over time, as Ogunniyi et al. (2022) underscore the role of technological advancements and changing market dynamics in shaping credit preferences among poultry farmers in Nigeria. It is to this effect that this study aims to determine the factors affecting the demand and participation of poultry farmers in formal and informal credit markets in Cross River State, Nigeria.

In the subsequent sections of this study, we delve into the overview of the determinants of agricultural credit demand and participation, the analytical framework, materials and methods, results and discussion, and a conclusion.

Determinants of agricultural credit demand and participation - literature review

Several studies have examined the determinants of credit demand and participation among farmers in various contexts. For instance, Osei et al. (2019) found that factors such as farm size, education level, and access to extension services significantly influenced farmers' credit demand in Ghana. Similarly, Murendo et al. (2020) identified factors such as land tenure security, risk perception, and distance to financial institutions as important determinants of credit participation among smallholder farmers in Zimbabwe. Kumar et al. (2017) found that land ownership positively correlates with credit participation among farmers in India, emphasising the role of collateral in formal credit markets. Mishra et al. (2019) revealed that factors such as age, experience, and risk aversion were important determinants of credit demand among smallholder farmers in India. Murendo et al. (2018) found that farmers located closer to markets were more likely to participate in formal credit markets, while those in remote areas preferred informal credit. Additionally, the perception of risk, especially regarding weather-related uncertainties, affects the credit decisions of farmers in Zimbabwe. Asfaw et al. (2021) highlighted the role of mobile phone usage and access to market information in enhancing farmers' participation in both formal and informal credit markets in Ethiopia. Similarly, Rahman et al. (2023) found that access to digital financial services positively influenced farmers' credit demand and participation in Bangladesh. Ali & Sarker (2018) found that the availability of government-sponsored agricultural credit programmes significantly influenced farmers' credit demand and participation in Bangladesh.

In the context of formal credit markets, several studies have focused on the role of institutional factors in influencing credit demand and participation. For example, Birungi et al. (2018) found that the level of financial literacy and the quality of financial institutions were key determinants of farmers' participation in formal credit markets in Uganda. Karimov et al. (2020) highlighted the importance of collateral requirements and loan processing time in shaping farmers' decisions to participate in formal credit markets in Tajikistan.

In contrast, studies examining the factors influencing credit demand and participation in informal credit markets have also provided valuable insights. For instance, Doss et al. (2018) in Ethiopia found that social networks and trust played a critical role in farmers' decisions to access informal credit. Similarly, Agbola et al. (2022) revealed that factors such as social capital, informal savings groups, and cultural norms significantly influenced farmers' participation in informal credit markets in Nigeria. Similarly, Alemayehu et al. (2020) in Ethiopia and Murendo et al. (2021) in Zimbabwe highlighted the importance of social networks and trust in facilitating farmers' participation in informal credit markets.

Research data and methods

The study area

The study was carried out in Cross River State, in south-south Nigeria. The state was created in 1967 from part of the former Eastern Region, and was known as the South-Eastern State until 1976, when it adopted its present name. The state originally included what is now called Akwa Ibom State. It has a land mass area of 20,156km2 and borders Cameroon to the east. It is named for the cross river which passes through the state. Its capital is Calabar, and consists of 18 local government areas with three major languages of Efik, Ejagham, and Bekwara, found across the three senatorial districts of south, central, and north, respectively. The state lies between latitude 5.8702oN, and longitude 8.5988oE. The people of the state are highly engaged in farming, trading, fishing, and hunting. The major crops grown include: yam, cassava, cocoyam, rice, maize, vegetables, bush mango, oil palm, and cocoa (Bassey and Nzeakor, 2019).

Fig. 1. Map of Cross River State, Nigeria, showing local government areas

Source: own work.

Population, sampling procedure and data collection

A two-stage sampling technique was adopted. The first stage was a purposive sampling of two local government areas from each of the agricultural zones. This was done with due regard to the relative concentration of poultry farms in these areas. The second stage follows a random sampling process of sampling five (5) percent of the registered poultry farms (Registered farms had a minimum of two hundred (200) birds on the farm) from these local government areas. Data was collected from 147 poultry farmers for the 2022 production cycle.

Table 1. Sampling frame

Agricultural zone	Local Government Area	Registered Farm Population	Estimated Sample
Calabar	Akamkpa	1920	96
	Calabar Municipal	260	13
Ikom	Ikom	320	16
	Obubra	260	13
Ogoja	Ogoja	140	7
	Yala	40	2

Source: Cross River State Ministry of Agriculture, Department of Livestock Development and Services.

Analytical framework

The multinomial logit (MNL) model is used to analyse choices among multiple discrete alternatives (McFadden, 1974). It is widely applied in various fields, including economics, marketing, transportation, and social sciences. The MNL model is based on random utility theory, which assumes that individuals make choices based on the utility they derive from each alternative (Train, 2009).

The MNL model assumes that individuals face a set of mutually exclusive and exhaustive alternatives and must choose one option from the available alternatives. It models the probability that an individual chooses a specific alternative as a function of the alternative-specific utility and a scaling parameter. The MNL model assumes that the utility of each alternative can be decomposed into a systematic component and a random error term.

Mathematically, the MNL model can be represented as shown in Greene (2012):

$$P(i) = \exp(Vi) / \sum[\exp(Vj)] \quad \ldots\ldots(1)$$

where P(i) is the probability of choosing alternative i, Vi is the systematic utility associated with alternative i, and the sum in the denominator is taken over by all available alternatives.

The systematic utility Vi is typically modelled as a linear function of explanatory variables and associated coefficients:

$$Vi = \beta'Xi \quad \ldots\ldots(2)$$

where β is a vector of coefficients and Xi is a vector of explanatory variables for alternative i. The coefficients represent the marginal impact of each explanatory variable on the utility of the corresponding alternative.

The MNL model assumes the independence of irrelevant alternatives (IIA) property, which implies that the ratio of choice probabilities between any two alternatives is constant and unaffected by the presence or absence of other alternatives (Greene, 2012). This assumption allows for tractable estimation and prediction but may be violated in certain contexts, leading to the development of alternative models such as nested logit or mixed logit.

Variable specification / model specification

The multinomial logit model is based on the random utility model (Oluoch-Kosura et al., 2001). The utility to a participant (farmer) is a linear function of factors characterised by socioeconomic characteristics, enterprise characteristics, credit status, and institutional

factors. The essence is to ascertain the relative choice between formal and informal sources or both by participants.
Thus,

$$\left.\begin{matrix}(U\ (\text{alternative } 0) = \beta jXo + ei) \\ (U\ (\text{alternative } 0) = \beta jXo + ei) \\ (U\ (\text{alternative } 0) = \beta jXo + ei)\end{matrix}\right] \ldots\ldots\ldots\ldots(3)$$

The probability of a participant choosing an alternative is equal to the probability that the utility of that particular alternative is greater than the choice set. That is, given (0Dependent variable) = choice 1, if U (alternative1) > U (alternative2),
Where $1 \neq 2$, then

$$B_1X_1 + e_j > B_2X_2 + e_2 \ldots\ldots\ldots\ldots(4)$$

The dependent variable was a discrete variable taking values 0, 1, 2, 3 for cases where a farmer did not obtain credit at all, obtained credit from formal institutions, informal sources, or both formal and informal sources, respectively.
The analysis of the problem proceeds in the following way

$$P_{0i} = a_0 + \beta_0 X_i \ldots\ldots\ldots\ldots(5)$$
$$P_{1i} = a_1 + \beta_1 X_i \ldots\ldots\ldots\ldots(6)$$
$$P_{2i} = a_2 + \beta_2 X_i \ldots\ldots\ldots\ldots(7)$$
$$P_{3i} = a_3 + \beta_3 X_i \ldots\ldots\ldots\ldots(8)$$

Where P_0, P_1, P_2 and P_3 = probability of no credit, formal credit, informal credit or both formal and informal credit.
Thus,
P_{0i} = Probability that individual i will seek no credit;
P_{1i} = Probability that individual i will seek credit from formal sources;
P_{2i} = Probability that individual i will seek credit from informal sources;
P_{3i} = Probability that individual i will seek credit from both formal and informal sources;
Xi = Value of X for the ith individual (independent variables);
a = Intercept;
B = Coefficient.
In addition, the objective of using the multinomial model was to test the relationship between the determining factor and to use the estimated coefficient to generate the probabilities of the respondents falling into one of the credit markets.

Research results

The result of the socioeconomic characteristic of poultry farmers presented in Table 2 shows that poultry farmers in the study area were mostly male. This is attributed to the fact that the males most often represent the head of the household while their wives assist. Most female household heads were widows or divorcees. Over 96.6% had formal education at different levels. The majority (68 percent) of the farmers had tertiary education, while 28.6 % had lower levels of education. This shows that poultry farmers in the study are usually educated, which probably reflects their awareness of and access to credit information. The farmers were mostly part-time farmers, given that they had other sources of income. The majority (74.1 percent) of the respondents were married, while 15.6 percent were single, 9.5 percent were divorced, and 0.70 percent were widowed. Farmers with the highest frequency (43.5 percent) had a farm capacity range of between 1 and 600. This indicates that the bulk of the farmers are small-scale farmers. The second highest frequency is 27.2 percent, with a farm capacity of between 601 and 1200.

Table 2. Socioeconomic characteristics of poultry farmers

Socioeconomic Characteristics		Frequency	Percentage
Gender	Female	16	10.9
	Male	131	89.1
	Total	147	100.0
Education	No formal education	5	3.4
	Primary education	22	15.0
	Secondary education	20	13.6
	Tertiary education	100	68.0
	Total	147	100.0
Marital status	Single	23	15.6
	Married	109	74.1
	Divorced	14	9.5
	Widowed	1	0.7
	Total	147	100.0
Farm capacity (number of birds)	1-600	64	43.5
	601-1200	40	27.2
	1201-1800	15	10.2
	1801-2400	19	13.0
	2400-3000	9	6.1
	Total	147	100.0

Source: Field survey, 2022.

The Chi2 at 51 degrees of freedom was given as 71.36, and probability > Chi2 being 0.0314 reveals that it is significant at 5%. The result of the multinomial logit model is presented in Table 3. Three categories of credit markets were defined earlier. These include formal institutions, informal sources and both formal and informal sources. The coefficient of the probabilities of the formal, informal and both formal and informal sources was estimated with respect to no credit demand (i.e. the probability that the farmer did not seek credit at all). A positive coefficient shows that the probability of a respondent falling in the numerator category is greater than the probability of falling in the denominator category, while a negative coefficient gives the opposite.

Table 3. Multinomial logit model result of the factors affecting the demand and participation of poultry farmers in Cross River State credit markets

Independent Variables	Dependent Variables		
	$\frac{P_1}{P_0}$	$\frac{P_2}{P_0}$	$\frac{P_3}{P_0}$
Gender	1.7438 (0.9826)*	0.1432 (1.2929)	-0.5141 (1.1517)
Education	-1.5885 (1.1014)	-2.8314 (1.4765)*	-2.1812 (1.3824)
Household size	1.0747 (0.7585)	-0.6615 (0.9691)	0.4772 (0.9288)
Years of experience	-0.7742 (0.8601)	-0.0168 (1.1682)	-1.6910 (1.1305)
Household assets	-0.8651 (0.4491)*	-0.3279 (0.6415)	0.4363 (0.5422)
Membership of association	-21.4701 (13.4332)	-21.6003 (13.3243)	-22.018 (13.4637)
Farm capacity	1.2928 (0.7294)*	0.3351 (1.1997)	1.0403 (0.9622)
Distance from a lending institution	0.1099 (0.4430)	0.9441 (0.6233)	0.1393 (0.5839)
Output	-0.8167 (0.6979)	0.3259 (1.1317)	-0.2424 (0.8700)
Outstanding loan	1.3363 (0.9606)	3.3297 (1.2489)***	2.7951 (1.1666)**
Deprived of loan	-0.0983 (1.0326)	1.5869 (1.2224)	0.8060 (1.2341)
Poultry training	2.0876 (1.2432)*	3.0200 (1.7184)*	2.1045 (1.4609)
Easier formalities	0.5201 (0.7447)	0.8693 (0.9688)	0.5144 (0.9054)
Flexible payback	-1.1143 (0.709)	-0.9661 (0.9700)	-1.3659 (0.9426)
Interest rate charged	-1.4983 (1.0599)	-1.8349 (1.2753)	-1.1767 (1.2371)
More favourable terms	0.6487 (0.8528)	1.8014 (1.0754)*	-1.0363 (1.3607)
Easier to get a loan	-3.4624 (1.1931)***	-4.5209 (1.6004)***	-3.9167 (1.6069)**
Constant	34.7779 (11.0596)***	18.4263	26.4615 (12.3700)**
Log-likelihood:	106.577		
LR Chi^2	71.36		
df	51		

*, **, *** refer to significant at 10%, 5%, and 1%, respectively; Figure in () is standard error

Source: Author's analysis.

Formal institutions

In the model, for demand from formal institutions, five variables were significant at different levels. They are gender, household assets, farm capacity, training and how easy it is to get a loan. The coefficient of gender was statistically significant at 1%. This implies that gender affects credit demand from formal institutions. The positive sign of the coefficient reveals that the probability of males seeking loans from formal sources is higher than for females. The male respondents showed a higher probability of seeking credit from formal sources than not seeking it at all. This can be attributed to the fact that land and property ownership are traditionally biased towards men, and formal financial institutions often require collateral to provide credit. If men have greater ownership rights over land and other assets, they may find it easier to meet these requirements. This finding is contrary to the findings of Mwonge & Naho (2021), who found decreased credit demand by smallholder farmers in Morogoro, Tanzania.

Household assets were significant at 5% in determining participation in formal institutions. A respondent with low-value household assets has a higher probability of seeking formal credit. The higher the household assets, the lower the probability of seeking credit from formal sources than not seeking credit because when households have higher levels of assets, they may have greater financial resources available to fund their agricultural activities without relying on external credit. Credit demand from households with lower household assets has a high probability of improving welfare. The result is contrary to the Assogba et al. (2017) study on the determinants of credit access by smallholder farmers in North-East Benin. They found that access to credit among smallholder farmers is determined by the number of years of schooling, literacy, membership, guarantor, collateral and interest rate.

The sign of the coefficient for farm capacity was found to be positive and statistically significant at 1% for formal institutions. This implies that a farmer with a large farm capacity has a higher probability of seeking credit from formal sources than not seeking credit since farmers with large farm capacities may have greater investment opportunities to expand their operations, purchase machinery, or implement new technologies. These activities often require substantial financing, which formal sources of credit are better equipped to provide. As a result, farmers with large farm capacities are more likely to seek credit from formal sources to seize these investment opportunities. The result also showed that farm capacity significantly affected participants' choice of formal institutions. This result is in line with Chandio et al. (2021), who found that landholding size significantly influences credit demand.

Poultry training was found to be a determining factor that affects farmers seeking formal credit. The positive sign implies that farmers who had one form of training, e.g. production, farm risk management, waste management or marketing) will most likely seek formal credit. It was also found to be statistically significant at 10%.

Institutional factors like being able to get a loan more easily significantly affected farmers seeking formal credit. The negative sign reveals that the probability that a farmer seeks credit from formal sources decreases with the difficulty experienced in getting a loan. It was found to be statistically significant at 5%. This finding is in line with Balana et al. (2022), who found that difficulty in getting loan factors such as interest rate, location and inadequate collateral security reduced credit demand in Tanzania and Ethiopia.

Informal sources

In the model, five variables were found to have significantly affected informal credit demand. These include education, outstanding loans, poultry training, more favourable terms, and easier access to a loan.

The educational level of the respondent was found to be statistically significant at 1%. This shows that educational level was a determining factor for the choice of informal credit sources. The negative sign of the coefficient implies that the lower the level of education of respondents, the more likely they are not to seek credit than to seek credit from informal sources. Farmers with lower levels of education may have limited knowledge and awareness about the availability of credit from informal sources. They might not be familiar with the services and benefits offered by such institutions or may not know how to access them. As a result, they may choose not to seek credit from these sources. This finding is in line with the findings of Asenath & Yiorgos (2020), who found that education increases credit demand among rural livestock farmers in Nigeria.

In contrast, the coefficient of easier access to a loan was significant and negative, implying that the easier it is to get a loan, the more likely it is for the farmers not to seek a loan from informal credit sources. This finding is in line with Balana et al. (2022). The coefficient of outstanding loans was found to be positively related to informal credit demand. The positive sign indicates that a farmer with an outstanding loan has a higher probability of seeking credit from informal sources than not seeking it at all. A farmer who already has an outstanding loan from a formal institution might face difficulties in obtaining additional credit from the same source, and in such cases, farmers may turn to informal sources as an alternative option for accessing additional credit.

It was found to be statistically significant at 5%. This is contrary to the findings of Balana et al. (2022), who found that farmers with outstanding loans had no reason to seek credit in Ethiopia and Tanzania. Furthermore, poultry training was found to be a determining factor that affects farmers seeking informal credit. The positive sign implies that farmers who had one form of training (e.g. production, farm risk management, waste management, or marketing) would show a higher probability of seeking a loan from informal credit sources than not seeking credit. It was also found to be statistically significant at 10%.

More favourable terms were found to have significantly affected credit demand from informal sources. The positive coefficient indicates that respondents show a higher probability of seeking credit from informal sources as the terms and conditions favour them more than not seeking credit. It was statistically significant at 5%, indicating that it significantly affected informal credit demand. This finding is in line with Taremwa et al. (2022), who found that favourable terms ease credit demand in Rwanda.

Both formal and informal credit

For the formal and informal sources, two variables significantly affected credit demand. These were outstanding loans and easier access to a loan. An outstanding loan was found to be statistically significant at 1%. The positive sign of the coefficient reveals that there is a higher probability for respondents to seek both formal and informal sources than not to seek credit. The institutional factor of making it easier to get a loan also significantly affected credit demand from both formal and informal sources. The probability of seeking loans from both formal and informal sources increases with terms and conditions that favour the farmers. When the terms and conditions of loans are favourable, such as lower interest rates, longer repayment periods, or flexible repayment terms, farmers are more likely to perceive borrowing as a cost-effective option. Lower borrowing costs make loans more attractive, which can increase the credit demand from both formal and informal sources.

Conclusion

This study was carried out to analyse factors affecting the demand and participation of poultry farmers in formal and informal credit markets in Cross River State, Nigeria. The results revealed that the majority of the poultry farmers were male, married and had one form of formal education. Socioeconomic and enterprise characteristics such as educational level,

gender, farm capacity, poultry training, and household assets are significant factors that influenced the participant's choice of credit institution in the study area. Also, favourable terms, outstanding loans and easier access to loans were the significant factors that affected credit demand. Against this background and from the results of the research, the following policy recommendations are made:
i) Training and workshop programmes, especially in areas of production, farm risk management, marketing, and waste management, should be organised by government and corporate financial institutions to encourage participation in credit markets so that the abundant available funds can be efficiently utilised in the production process.
ii) Credit institutions should give due consideration to policy conditions as more favourable terms and interest rates during policy formulation make it easier to get a loan while maintaining mutual benefit between farmers and the institutions.

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For citation:

Ukpe U.H., Ewung B.F. (2023). Determinants of Demand and Participation by Poultry Farmers in Formal and Informal Credit Markets in Cross River State, Nigeria. *Problems of World Agriculture*, 23(4), 31-43; DOI: 10.22630/PRS.2023.23.4.15

Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 23(XXXVIII), number 4, 2023: 44-60
DOI: 10.22630/PRS.2023.23.4.16

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The Energy Potential of Agricultural Biomass in the European Union

Abstract: The objective of this study is to conduct a quantitative assessment of the theoretical potential of agricultural biomass in EU countries for energy production. It explores various biomass sources, such as agricultural residues, animal husbandry by-products, and energy crops. Using data, the study examines the potential biomass across different EU countries, emphasising the disparities due to diverse agricultural practices. The analysis underscores the need for customised biomass strategies tailored to each Member State's specific agricultural conditions. The study identifies biomass as a vital energy source for the EU's energy independence and reducing fossil fuel reliance. It also highlights the necessity for future research on improving biomass conversion technologies and policy development for integrating agricultural biomass into the energy framework, considering the unique aspects of each country's agricultural sector.

Keywords: bioenergy market, energy biomass, agricultural biomass, energy security

JEL Classification: P28, Q16, Q42

Introduction

Biomass, as a term, has evolved and diversified in its meaning across various scientific and industrial contexts. Initially defined simply as the total quantity or weight of organisms in a given area or ecosystem at a given time (Ward, 1983), the term has expanded to encompass a wide range of materials of biological origin, particularly in the context of renewable energy and environmental sustainability. In the realm of renewable energy, biomass is predominantly considered as plant-derived materials. This includes agricultural residues, by-products of industrial processes, and dedicated energy crops (Hames, 2009). This definition aligns with the growing emphasis on sustainable and renewable energy sources, highlighting the role of biomass as a key player in this sector. From a broader biological perspective, biomass includes all living entities across the three domains of life – Archaea, Eukarya, and Bacteria – along with their wastes (Polizeli, et al., 2011). This definition underscores the comprehensive nature of biomass, encompassing both the living and the by-products of the living, thereby playing a crucial role in the carbon cycle and ecological balance. The concept of biomass also extends into specific applications such as biochar and biofuels. Biochar, for instance, is derived from biomass that is heated in the absence of or at low concentrations of oxygen, primarily for soil application (Madari, et al., 2012). This application not only highlights the versatility of biomass but also its significance in soil enhancement and carbon sequestration. In the context of the United Kingdom's

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renewable energy strategy, biomass is defined more specifically as a substance derived from plant or animal matter, with a focus on energy crops grown for burning (Wood, 2004). This definition reflects the policy and economic dimensions of biomass, particularly in the context of national energy strategies and sustainability goals. Agricultural biomass plays a significant role in enhancing energy security within the European Union (EU). The EU's transition to a low-carbon economy heavily relies on biomass as an alternative to fossil resources. In this context, agriculture is a primary source of biomass, contributing 68% of the total supply (Beluhova-Uzunova, et al., 2021). This significant contribution underscores the importance of agricultural biomass in the EU's bioeconomy strategy, which aims for a resource-efficient, competitive, and sustainable economy. The demand for biomass in the EU is projected to increase from 7 EJ to 10 EJ by 2023, indicating a growing reliance on this renewable energy source (Wieruszewski & Mydlarz, 2022). This increase is partly due to the EU's commitment to reducing greenhouse gas emissions and increasing the use of renewable energy sources. Agricultural biomass, including forest biomass, agricultural residues, and energy crops, is expected to play a crucial role in this transition. The potential land availability for energy crops in the EU is also significant. It is estimated that up to 26.2 million hectares could be available for non-food crops by 2030 (Krasuska, et al., 2010). This availability of land for biomass production is vital for the EU's energy security, as it reduces dependence on imported fuels and contributes to the sustainability of the energy sector. Furthermore, the use of agricultural biomass for energy purposes aligns with the EU's broader environmental and economic goals. For instance, the production of bioenergy from agricultural biomass can lead to cost-effective climate change mitigation and employment creation (Berndes & Hansson, 2007). In countries like Poland, agriculture plays a significant role in ensuring energy security, with the potential for dynamic growth in energy crop farming (Bielski, et al., 2021).

The ongoing challenges of climate change and the imperative to diversify energy sources have become pivotal global issues. Recognising this, the European Commission unveiled the 2020 Energy Strategy, urging EU member states to escalate the integration of renewable resources in their energy frameworks. Concurrently, the European Council has articulated a long-term vision with specific operational guidelines. This strategic direction aligns with the broader commitment of the EU and other industrial nations to ambitiously curtail greenhouse gas emissions by 80-95% by the year 2050, marking a decisive step towards environmental sustainability and energy resilience (European Commission, 2014).

The EU bioenergy market's prominence, driven by policy and economic factors, underscores the strategic importance of bioenergy, particularly biomass, in the EU's renewable energy portfolio. Government policies, notably the Renewable Energy Directive (RED) and its subsequent amendments, shape the bioenergy landscape, influencing the development and adoption of bioenergy across member states. The EU's policies, including the "Fit for 55" package and the REPowerEU plan, reflect its commitment to increasing renewable energy targets, advocating for renewable fuels like biomass in various sectors.

The European Union bioenergy market reflects its prominence as a leading renewable energy source, with bioenergy maintaining a dominant position in the EU's renewable energy portfolio (Mandley et al., 2020). Biomass is the most extensively used renewable energy source across member countries (Anca-Couce et al., 2021), exemplified by the increasing application of biofuels in the transportation sector. This aligns with the EU's broader strategic goals of reducing dependence on imported hydrocarbons and mitigating climate change (Bórawski & Bełdycka-Bórawska, 2019). The EU's focus on advancing biofuels aims to address concerns about using food crops for energy and enhance sustainable development in the bioenergy sector (Anca-Couce et al., 2021). The trajectory is shaped by the EU's renewable energy goals and policies, indicating the strategic significance of bioenergy in achieving medium and long-term climate objectives (Mandley et al., 2020.; Anca-Couce et al., 2021). However, challenges remain, such as sustainable supplies of liquid biofuels and pressure on high bioenergy-consuming countries, which must be carefully managed to balance energy needs with environmental stewardship (Mandley et al., 2020).

Biomass plays a significant role in the energy strategies of the European Union and is a key component in achieving objectives related to renewable energy. Some studies indicate that its share in the renewable energy resources of the EU ranges from 50% to almost 60% (European Commission, 2023). The heating and cooling sector is the largest end-user, using about 75% of all bioenergy. However, the exact percentage contribution of biomass to renewable energy resources may vary depending on the source and methodology of the research (European Commission, 2023).

The profound impact of policy on the EU bioenergy market is undeniable. Government policies and regulations fundamentally shape the bioenergy landscape, dictating the pace and direction of its development (Faaij, 2006). This is further affirmed by the Renewable Energy Directive (RED) of 2009, a key policy measure adopted by the EU to strengthen the bioenergy sector (Albrecht et al., 2017). RED and similar strategies underscore the Union's commitment to promoting bioenergy, as these policies establish clear goals and provide the necessary legal frameworks to encourage investment and development (Faaij, 2006). The effectiveness of these policies is evident in how member states have incorporated them into national legislation, ensuring a harmonised approach across the Union in developing bioenergy (Albrecht et al., 2017). Thus, EU policy decisions not only set the stage but also actively drive the evolution of the bioenergy market, illustrating the inseparable link between policy and market dynamics (Faaij, 2006). In July 2021, as part of the "Fit for 55" package, the Commission proposed an amendment (RED II) to the Renewable Energy Directive to align its renewable energy targets with the new climate goals. The Commission suggested increasing the EU's binding target for renewable energy in its energy mix to 40% by 2030, advocating for the use of renewable fuels such as hydrogen in industry and transport while setting additional targets. In May 2022, under the RE Power EU plan following Russia's aggression in Ukraine, the Commission proposed the first amendment (RED III) to accelerate the transition to clean energy in line with the gradual reduction of dependency on Russian fossil fuels. The Commission proposed the installation of heat pumps, increased capacity of photovoltaic systems, and the import of renewable hydrogen and biomethane to raise the renewable energy target to 45% by 2030. On November 9, 2022, the Commission proposed the second amendment (RED IV) to the Council Regulation to accelerate the deployment of renewable energy. According to the proposal, power plants using renewable energy sources would be considered to be in the public interest, enabling expedited permitting for renewable energy projects and specific exemptions from EU environmental legislation. In March 2023, the Parliament and the Council informally agreed to increase the renewable energy target for 2030 to 42.5%, with member states aiming to achieve a target of 45%. For the first time, industry was included by establishing binding targets (42% of renewable hydrogen in total hydrogen consumption by 2030) and indicative targets (a 1.6% annual increase in renewable energy consumption) (European Commission, 2023).

In the EU, the shift towards bioenergy is largely driven by a complex interplay of economic, environmental, and political factors. Rising costs of conventional energy sources, exacerbated by their finite nature, underscore the urgent need for alternative solutions to meet growing energy demand. Energy security remains a primary concern for the EU, with bioenergy offering a renewable option that can reduce reliance on imported fuels, thereby addressing energy security issues. Moreover, the risks and costs associated with nuclear energy have reduced its attractiveness as a sustainable energy source, propelling bioenergy as a more viable alternative (McCormick & Kåberger, 2007). The EU's commitment to mitigating climate change has necessitated a shift away from high-emission fuels like coal and oil, making bioenergy a key player in transitioning to a low-emission economy. However, the bioenergy sector faces significant barriers, including economic conditions affecting affordability and profitability, lack of institutional capacity, and supply chain coordination challenges. Despite these obstacles, supportive EU policies, such as financial incentives and regulatory frameworks, play a crucial role in promoting the adoption and development of bioenergy, signalling collective efforts to overcome barriers and leverage favourable factors for a sustainable and secure energy future (Philippidis et al., 2018.; McCormick & Kåberger, 2007).

The diversification of biomass resources has become a cornerstone of the renewable energy landscape in the EU, with agricultural residues, forest residues, and surplus forest wood serving as primary components (Van Dam et al., 2007). However, the cultivation of energy crops plays a significant role, especially considering the strategic use of land that does not compete with food and feed production. This is particularly true in Central and Eastern European countries, where energy crops represent a dominant biomass potential, reflecting regional agronomic practices and land-use dynamics. Long-term prospects suggest that energy crops, due to their high yield potential and compatibility with existing agricultural systems, may contribute the most to bioenergy production in the EU (Van Dam et al., 2007). EU strategic planning, as evidenced by research, consistently focuses on potential biomass supplies from agricultural lands, emphasising understanding the relative contribution of forest lands to this supply. Furthermore, the use of wheat yields as an indicator of energy crop yields highlights the nascent stage of energy crop cultivation, underscoring the need for further development and reliable data to optimise production (Ericsson & Nilsson, 2006). Overall, this suggests that energy crops not only play a key role in the current biomass resource portfolio but are also expected to become the forefront of biomass for energy purposes in the EU in the 21st century (Bentsen & Felby, 2012).

As the EU increasingly relies on bioenergy, sustainability criteria have become essential to ensure that renewable energy goals do not inadvertently lead to environmental degradation. The EU has implemented detailed sustainability criteria for biomass energy, including stringent regulations on greenhouse gas emissions and land use to mitigate any potential negative impacts. These criteria are crucial, given that sustainable biomass resource development depends on factors such as biomass origin and the efficiency of its conversion to energy. However, the implementation and effectiveness of these criteria are subjects of ongoing debate and concern, reflecting the complexity of balancing energy needs with ecological management (Proskurina et al., 2016). As the EU Renewable Energy Directive sets ambitious targets, a significant emphasis has been placed on woody biomass, which is expected to play a substantial role in achieving the goal of a 20% share in renewable energy consumption by 2020. However, this focus raises difficult questions about carbon neutrality, considering that woody biomass is not inherently carbon-neutral, and concerns about the potential for deforestation, which could undermine the environmental objectives of using biomass for energy purposes. Therefore, while the EU strives to achieve its energy policy goals and reduce greenhouse gas emissions through biomass resources (Bentsen et al., 2012), it must proceed cautiously to ensure that the use of these resources does not threaten the same sustainability goals it seeks to maintain.

The strategic significance of biomass resources in the European Union cannot be overstated, especially considering the medium and long-term climate goals to which the region is committed. Estimates indicating that the technical potential of domestic biomass for energy purposes by 2050 could vary significantly from 9 to 25 exajoules per year (eJyr-1) make it clear that there is a substantial domestic resource base that could theoretically meet future demands entirely (Moiseyev et al., 2011). However, this potential is not without challenges. Part of the biomass resource base may be economically inaccessible due to various factors, such as extraction or transportation costs. This economic accessibility is further complicated by uncertainties, including raw material yields, contributing to a wide range of potential biomass resource estimates. Moreover, the development and integration of biomass resources in the EU are influenced by the complex interplay of factors such as forestry economics, land availability, and policy frameworks, which in turn are shaped by the political landscape, as noted earlier, under the influence of EU policies and strategies on the bioenergy market. Additionally, forest biomass is particularly promising, as it can significantly contribute to the EU's renewable energy (RES) targets (Moiseyev et al., 2011). Thus, the development of biomass resources in the EU presents a multifaceted challenge, encompassing technical, economic, and political dimensions, each requiring careful consideration to harness the full potential of biomass in transitioning to a more sustainable energy system.

From a global perspective on energy production, it is of paramount importance to enhance the utilisation of renewable resources, particularly biomass. This emphasis stems from the growing recognition of biomass as a sustainable and eco-friendly alternative to conventional fossil fuels. Biomass, as a renewable energy source, offers a plethora of benefits, including the reduction of greenhouse gas emissions and the promotion of energy diversification. Moreover, the strategic deployment of biomass aligns with global efforts to mitigate climate change and fosters a transition towards a more sustainable energy paradigm. Therefore, the increased adoption and integration of biomass into the global energy mix not only addresses environmental concerns but also contributes to the resilience and sustainability of energy systems worldwide (Turkenburg, 2020; Böttcher et al. 2010; De Wit et al. 2008; Ericsson and Nilsson, 2006; Andersen et al. 2021; Fischer et al. 2007). The European Union has distinguished itself by establishing renewable energy goals that are notably more ambitious compared to other global regions. This is exemplified by the revised Renewable Energy Directive, which was adopted in 2023. This directive escalates the EU's mandatory renewable energy target for 2030 to a minimum of 42.5% (European Commission, 2023). Notably, the EU had already surpassed its 2020 target, achieving a 22.1% share of gross final energy consumption from renewable energy sources. In contrast, the United States, through its Energy Policy Act, promotes a diverse spectrum of renewable energy sources, including wind, solar, hydro, geothermal, and biomass, with a particular emphasis on the development of liquid biofuels. This Act is indicative of a wider international trend towards diversification of energy sources, highlighting the growing global consensus on the pivotal role of renewable energy in fostering sustainable development (European Commission, 2023). This trend reflects an increasing awareness of the need for a sustainable energy transition and the critical role renewable energy plays in this global shift. Numerous studies conducted over the past two decades on energy biomass resources in Europe and globally have demonstrated an increase in bioenergy potential. This growth is anticipated to provide a larger supply of biofuels derived from wood and agricultural biomass for both industrial and various other applications (Fischer & Schrattenholzer, 2001; Haberl et al., 2010; Hoogwijk et al., 2005).

The primary objective of this study is to quantitatively evaluate the theoretical potential of agricultural biomass as a renewable energy source within the European Union. This research aims to provide a comprehensive analysis of the capacity of agricultural biomass, considering the varied geographical and agricultural landscapes across EU countries. By assessing the potential of this resource, the study seeks to contribute to the strategic development of sustainable energy policies within the EU, aligning with its broader goals of energy diversification and environmental sustainability.

The research problem addressed by this study centres on the lack of a detailed, quantitative understanding of the potential of agricultural biomass for energy production across the EU. Despite biomass being a key component in the EU's renewable energy mix, a significant gap exists in the assessment of its full potential, particularly in the context of agricultural sources. This study aims to bridge this gap by systematically analysing the available agricultural land resources, the sustainability of biomass production, and the potential energy yield from these sources across different EU member states. The investigation focuses on unravelling the disparities and prospects of agricultural biomass utilisation for energy production, thereby providing a foundation for informed policy-making and strategic planning in the EU's renewable energy sector.

The paper is organised as follows: the next section describes the methodology, i.e., the study's aim, description of methods used, and data sources. The subsequent section presents the empirical findings, and the final section offers the conclusions.

Data and methods

The objective of this study is to conduct a quantitative assessment of the theoretical potential of agricultural biomass in EU countries for energy production. In the study, a series of statistical methods were employed to conduct an analysis of the collected data. The following statistical methods were used in the study:

- Mean: The mean was calculated for each biomass category across the entire data set. This method involves summing all values within a category and then dividing by the number of values to obtain a central point reflecting the typical magnitude of biomass potential in the European Union. The mean is a fundamental indicator of central tendency, providing a general idea about the data distribution;

- Median: The median, representing the middle value of an ordered data set, was calculated to provide a measure of central tendency less affected by outlier values. In cases of asymmetric data distribution, the median often better reflects the "typical" value than the mean, avoiding the influence of extreme observations;
- Standard Deviation and Variance: These two measures were used to quantify the degree of variability or dispersion of biomass potential values relative to their mean. Standard deviation is a measure of data spread, while variance, being the square of standard deviation, offers deeper insight into the variability of the data. Higher values of both indicators suggest greater differences between individual values and the mean;
- Skewness: Skewness was calculated to assess whether the data distribution is symmetrical around the mean or skewed. A positive skewness value indicates a distribution with a majority of data on the right side of the mean (right-skewed), suggesting a concentration of lower values and the presence of higher outlier values. This is crucial for understanding how the data distribution deviates from normality;
- Kurtosis: Kurtosis was determined to evaluate the "tailedness" of the distribution. Higher kurtosis values indicate a distribution with 'heavy tails', meaning a larger number of extreme values (outliers). Lower kurtosis values suggest a less extreme, more flattened data distribution. This is important in the context of identifying and analysing outlier values, which can have a significant impact on data interpretation and the conclusions drawn.

Data on the theoretical potential of agricultural biomass in EU countries in 2019 come from Eurostat, the European Commission, and Janiszewska & Ossowska (2022).

Research results

Agricultural production is based on agricultural land resources. In the case of Poland, in 2020, it occupied 14 681.6 thousand hectares. In the domestic structure of agricultural land, the largest area was occupied by cultivated land - 10 741.9 thousand hectares, and then permanent grassland - 350.2 thousand hectares, while permanent meadows were cultivated on an area of 2 775.1 thousand hectares, and permanent pastures on an area of 414.5 thousand hectares (Statista, 2023).

The pursuit of sustainable energy solutions has become a cornerstone of environmental policy within the European Union, catalysing extensive research and development in the field of renewable energy. This paradigm shift is driven by the urgent need to mitigate climate change impacts and reduce reliance on fossil fuels. Recent studies in the EU have focused on evaluating the efficacy, scalability, and socio-economic impacts of various renewable energy sources, including solar, wind, hydroelectric, and biomass. These investigations are critical in informing policy decisions and guiding the transition towards a more sustainable and resilient energy infrastructure. The integration of renewable energy sources into the existing grid, the optimisation of energy storage technologies, and the exploration of innovative financing models are among the key areas of focus. The findings from these studies are expected to provide valuable insights into the feasibility, challenges, and opportunities presented by renewable energy adoption in the EU context. Key types of renewable energy utilised within the EU include wind power, which harnesses the energy of wind currents; solar power, generated from sunlight; hydroelectric power, derived from the energy of moving water; biomass, which includes organic materials like wood and agricultural waste; and geothermal energy, sourced from the natural heat of the Earth.

The transition to renewable energy sources is a pivotal element of the European Union's strategy for achieving sustainability and energy independence. This study presents an analysis of the progression in renewable energy adoption by EU member states over a three-year period from 2020 to 2022. The data encapsulate the percentage share of energy derived from renewable resources as a part of each country's final gross energy consumption, reflecting the collective and individual efforts towards meeting the EU's ambitious climate targets. The European Union has been at the forefront of the global shift towards renewable energy, implementing policies and incentives to promote the use of wind, solar, hydroelectric, biomass, and geothermal energy. The integration of these renewable sources into national grids is crucial for reducing carbon emissions and mitigating the impact of climate change. Our data analysis focuses on quantifying the extent to which EU countries have increased their renewable energy usage, contributing to the overall EU objective of a sustainable energy future. The dataset under study provides a yearly breakdown of the total share of renewable energy consumption for the EU as a whole and for individual member states. The following key observations have been made: Overall, the EU saw a modest increase in renewable energy share from 22% in 2020 to 23% in 2022. Denmark demonstrated a significant rise, with renewable energy consumption jumping from 32% in 2020 to 42% in 2022. Estonia also showed notable growth, with an increase from 30% in 2020 to 38% in 2022. In contrast, Croatia observed a slight decrease, moving from 31% in 2020 to 29% in 2022. Sweden maintained the highest percentage share, climbing from 60% in 2020 to 66% in 2022. The data for countries like Bulgaria, Italy, and Romania exhibit stability in renewable energy consumption with minimal variation over the three years. These figures underscore the varying rates of adoption of renewable energy technologies across the Union, influenced by national policies, resource availability, and economic factors.

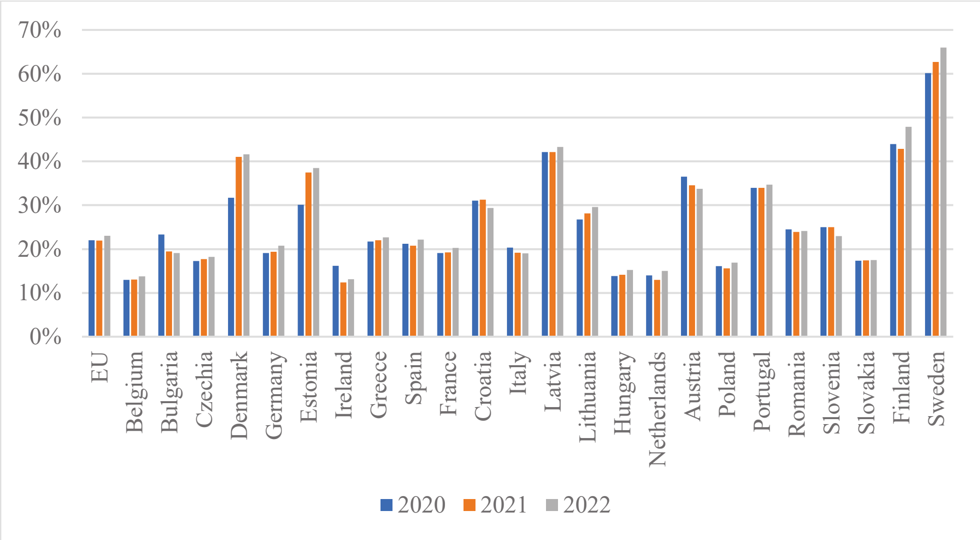

Fig. 1. The percentage share of renewable energy in individual EU member states between 2020 and 2022.

Source: Own elaboration based on Eurostat data.

The incremental, yet positive, trend in renewable energy uptake across the European Union signals a steady commitment to a greener energy portfolio; however, while some countries showcase accelerated progress, others maintain a steady course or display minor fluctuations. Continued investment and policy support are essential for sustaining growth in renewable energy use, ultimately contributing to the EU's long-term environmental and economic objectives.

The composition of the energy portfolio within the European Union (EU) is a complex amalgamation of domestically produced energy and imports from external nations. To comprehensively understand the EU's energy landscape, it is imperative to consider both these aspects in tandem. In the year 2021, approximately 44% of the EU's energy requirements were met through domestic production, while the remaining 56% was supplemented through imports. Predominantly, the EU's energy framework in 2021 was characterised by a diverse array of sources. The predominant contributor was crude oil and petroleum products, accounting for 34% of the energy mix. This was followed by natural gas at 23%, renewable energy sources at 17%, nuclear energy at 13%, and solid fossil fuels comprising 12% of the mix. However, this distribution of energy sources exhibited significant variability across different EU member states. For instance, in 2021, Cyprus (86%), Malta (85%), and Luxembourg (61%) predominantly relied on petroleum products. In contrast, natural gas was a major energy contributor in Italy (40%), the Netherlands (35%), and Hungary (34%). Renewable energy sources were most prevalent in Sweden (48%) and Denmark (41%), whereas nuclear energy formed a substantial part of the energy mix in France (41%) and Sweden (25%). The reliance on solid fossil fuels was notably high in Estonia (56%) and Poland (43%). This diverse energy landscape within the EU underscores the region's multifaceted approach to energy sourcing, reflecting a blend of traditional and renewable energy sources tailored to the unique geographical and economic contexts of each member state (Eurostat, 2023)

In the context of climate change and the increasing demand for bioenergy, the agricultural sector is confronted with a spectrum of opportunities and challenges. Table 1 illustrates how modern technologies and practices can support agriculture in adapting to these global trends, while simultaneously emphasising the necessity of natural resource management and environmental protection.

Table 1. Opportunities and challenges of developing agricultural biomass production in EU countries

Opportunities	Challenges
• Introduction of advanced agricultural machinery (implementing cutting-edge agricultural equipment and machinery to enhance farming efficiency and productivity). • Optimisation of crop management techniques (refining agricultural practices to maximise crop yield and resource utilisation through effective management strategies). • Adoption of precision agriculture (utilising data-driven approaches and technology in farming to achieve more accurate and controlled agricultural processes). • Development of region-specific crop varieties (breeding and cultivating new plant varieties that are specifically tailored to thrive in local agroecological environments). • Expansion of agricultural knowledge via digital tools (leveraging intelligent applications to broaden agricultural understanding, coupled with the engagement of a growing number of young, innovative farmers). • Sustainable soil management practices (implementing soil health improvement techniques, such as organic matter enrichment and erosion control to sustain long-term agricultural productivity). • Integration of renewable energy sources in farming (incorporating solar, wind, and energy solutions in agricultural operations to reduce the carbon footprint and enhance energy efficiency).	• Pressure for eco-friendly land utilisation (encouraging the transformation of agricultural lands to support environmental enhancements, including carbon sequestration and biodiversity conservation). • Addressing land degradation (implementing measures to prevent soil erosion, replenish nutrients, and counteract salinisation, thereby combating the deterioration of agricultural land). • Implementation of sustainable water management practices (adopting efficient irrigation techniques and water conservation strategies to mitigate the impact of agriculture on water resources). • Promotion of agroforestry practices (integrating tree planting with agricultural activities to enhance ecological balance, improve soil quality, and increase biodiversity on farmlands).

Source: own study.

Table 1 encapsulates the intricate interplay of opportunities and challenges in modern agriculture. While advancements in technology and practices offer pathways for enhanced efficiency and sustainability, the sector must also navigate complex environmental and resource management challenges. Addressing these challenges is essential for ensuring the sustainable development and resilience of agricultural practices, particularly in the face of global challenges such as climate change and the growing demand for bioenergy.

The strategic harnessing of agricultural biomass as a pivotal renewable energy resource underscores a commitment to the European Union's sustainability objectives and energy independence directives. This analysis delves into the theoretical potential of agricultural biomass across EU member states in 2019, drawing from an extensive dataset encapsulating diverse biomass sources.

An examination of the dataset reveals a total potential of 198.3 thousand Ktoe, with an intricate composition stemming from various agricultural residues and by-products. Notably, cereal straw constitutes a substantial 41.2% of the total potential, underscoring its pre-eminence as a bioenergy feedstock. In close parity, permanent grassland hay represents 40.0% of the potential, reflecting the extensive pastoral landscapes prevalent across the continent. Natural fertilisers from animal husbandry contribute a significant 10.5%, while energy plantations, such as willow, account for 7.9%. Waste wood from permanent crops, albeit the smallest contributor at 0.4%, highlights the comprehensive utilisation of agricultural resources.

Country-specific potentials exhibit a broad spectrum, ranging from a modest 6.4 Ktoe to a robust 34,528.5 Ktoe, with an average of 7,082.9 Ktoe. The heterogeneity in potential is pronounced, with smaller EU nations like Malta (6.4 Ktoe), Cyprus (76.1 Ktoe), and Luxembourg (160.5 Ktoe) manifesting the lower end of the spectrum. In contrast, France emerges as the frontrunner with an impressive potential of 34,528.5 Ktoe, followed by Spain and Germany, collectively amassing over 40% of the EU's total theoretical biomass potential.

The disparities observed can be attributed to a multitude of factors, including geographical size, agricultural land utilisation, and energy policy frameworks. For instance, France's extensive agricultural land and diversified cropping systems facilitate a higher biomass yield, whereas Malta's limited land area inherently constrains its potential.

The implications of this analysis are manifold, extending to energy policy formulation and agricultural management. The robust potential of biomass as an energy source could significantly contribute to the EU's energy self-sufficiency and reduce dependence on fossil fuels. Furthermore, the sustainable management of agricultural residues and by-products can foster circular economy principles within the agro-energy sector. In conclusion, this data-driven exploration highlights the substantial, yet varied, potential for agricultural biomass across EU countries. It underscores the need for tailored strategies that leverage the unique agricultural landscapes and conditions of each member state. Future research should focus on optimising biomass conversion technologies and developing policies that incentivise the integration of agricultural biomass into the energy matrix.

Table 2. The theoretical potential of agricultural biomass in EU countries in 2019

The theoretical potential of agricultural biomass						
Country	Straw from cereal crops	Permanent grassland hay	Natural fertilisers from animal husbandry	Growing energy crops on fallow land	Waste wood from permanent crops	Total
Ktoe						
Belgium	650.2	608.7	655.3	25.2	1.3	1940.7
Bulgaria	3023.1	1803.2	120.6	339.9	10.1	5296.8
Czechia	1988.2	1269.8	291.6	51.2	2.7	3603.5
Denmark	2317.9	264.6	799.0	93.4	1.6	3476.6
Germany	9822.5	6082.8	3019.8	858.4	13.2	19797
Estonia	406.8	370.2	55.4	45.9	0.3	878.6
Ireland	508.8	5223.9	1164	9.1	0.1	6905.9
Greece	773	2728.8	121.8	349.2	79.3	4052.1
Spain	4981.8	9289.5	2460.5	6570.8	329.8	23632
France	17.323.3	12303.5	3570.8	1261.3	69.6	34.528.5
Croatia	1137.7	776.0	115.2	50.2	4.9	2084.0
Italy	4042.9	4854.4	1442.7	1039.6	159.9	11540.0
Cyprus	12.9	2.0	28.2	31.1	1.8	76.1
Latvia	778.6	809.0	80.6	145.1	0.6	1813.8
Lithuania	1260.4	930.9	129.7	187.3	2.0	2510.3
Luxembourg	37.3	86.9	35.5	0.6	0.1	160.5
Hungary	4789.0	1011.9	272.8	387.2	11.3	6472.2
Malta	0.0	0.0	3.9	2.4	0.1	6.4
Netherlands	341.1	982.6	1136.3	20.3	2.5	2482.8
Austria	1545.1	1611.5	430.8	138.0	4.4	3729.9
Poland	7445.9	4004.3	1548.3	455.7	22.5	13477.0
Portugal	325.8	2402.9	383.0	692.7	51.6	3856.0
Romania	9326.3	5693.8	486.2	1069.1	20.8	16596.0
Slovenia	195.3	355.6	91.7	2.9	1.8	647.3
Slovakia	1204.6	663.7	99.4	122.1	1.2	2091.0
Finland	957.5	30.1	186.5	500.7	0.2	1675.1
Sweden	1433.6	590.5	296.6	474.6	0.2	2795.6
Total	59306.3	64751.1	19026.2	14924.0	793.9	141596.8

Source: own elaboration based on data from Eurostat, the European Commission, and Janiszewska & Ossowska (2022).

This study quantifies the theoretical potential of agricultural biomass in various European Union countries, as exemplified in the comprehensive data table. The data delineates potential biomass sources, including straw from cereal crops, hay from permanent grassland, natural fertilisers from animal husbandry, energy crops grown on fallow land, and waste wood from permanent crops, with their cumulative potential quantified in kilotonnes of oil equivalent (Ktoe). The analysis reveals significant heterogeneity in biomass potential across countries. For instance, France exhibits a remarkably high potential, primarily driven by straw from cereal crops and permanent grassland hay, amounting to a total of 34,528.5 Ktoe. In contrast, smaller countries like Malta and Luxembourg show minimal biomass potential, with totals of 6.4 Ktoe and 160.5 Ktoe, respectively. This variability underscores the diverse agricultural landscapes and practices prevalent across the EU. The data also highlights the predominant role of certain biomass sources in specific countries. For instance, Spain's significant contribution of 23,632 Ktoe is largely attributed to its high potential in both straw from cereal crops and permanent grassland hay. Conversely, countries like Denmark and Ireland demonstrate considerable potential in natural fertilisers from animal husbandry, reflecting their specific agricultural practices. Overall, the table presents a comprehensive view of the agricultural biomass potential in the EU, offering vital insights for policy-making and strategic planning in the renewable energy sector. The data underscores the vast, yet varied, potential for agricultural biomass across Europe, emphasising the importance of region-specific strategies for biomass utilisation and sustainable energy production.

Table 3. Statistical analysis of the theoretical potential of agricultural biomass in selected EU countries in 2019

Category	Mean	Median	Standard Deviation	Variance	Skewness	Kurtosis
Straw from cereal crops	4179.56	2153.05	5442.82	2.96243e+07	1.9344	3.5121
Permanent grassland hay	3994.50	2266.00	4153.82	1.72542e+07	1.0890	0.1709
Natural fertilisers from animal husbandry	1225.88	727.15	1309.63	1.71514e+06	0.9380	-0.7282
Growing energy crops on fallow land	960.44	216.65	2014.68	4.05893e+06	2.9265	8.8365
Waste wood from permanent crops	50.80	6.40	102.41	1.04869e+04	2.7180	7.7568
Total biomass potential	10411.18	4674.45	11452.64	1.31163e+08	1.3507	0.6967

Source: own calculations based on data from Table 2.

In this extended statistical analysis of the theoretical potential of agricultural biomass in selected EU countries for the year 2019, the data delineates the quantitative measures across various biomass categories. The mean values suggest an average biomass potential, with straw from cereal crops exhibiting the highest mean potential (4179.56 Ktoe), indicative of its substantial contribution to the agricultural biomass sector. The median values, which are less sensitive to extreme values in the data set, present a more conservative estimate of central tendency, with straw from cereal crops and permanent grassland hay being the most significant contributors at 2153.05 Ktoe and 2266.00 Ktoe, respectively. The standard deviation and variance metrics illustrate considerable variability within each biomass category, particularly in straw from cereal crops and permanent grassland hay, which have higher standard deviation values of 5442.82 and 4153.82, respectively. This variability is further evidenced by the variance, with straw from cereal crops presenting the most pronounced variance (2.96243e+07), signifying diverse biomass potential across countries. Skewness values across all categories confirm the data's deviation from a normal distribution, with a rightward (positive) skewness indicating a distribution with an extended tail on the right side. The skewness is particularly notable in the category of straw from cereal crops (1.9344) and growing energy crops on fallow land (2.9265), suggesting a concentration of countries with lower potential and fewer countries with exceptionally high biomass potential. Kurtosis values provide insight into the peakedness and the presence of outliers within the data distribution. High kurtosis in the categories of growing energy crops on fallow land (8.8365) and waste wood from permanent crops (7.7568) suggests a distribution with heavy tails and a significant presence of outliers, which could potentially be attributed to specific environmental, economic, or agricultural practices unique to certain countries. The tabular presentation encapsulates the complexity and disparity in the theoretical potential of agricultural biomass across EU countries. The right-skewed distributions and high kurtosis in certain biomass categories emphasise the need for tailored strategies to harness the full potential of biomass, taking into consideration the idiosyncratic attributes of each country's agricultural sector.

Conclusion

The examination of scholarly literature highlights that harnessing agricultural biomass for energy yields multifaceted advantages encompassing economic, social, and environmental dimensions. Calculations suggest a considerable capacity for agricultural biomass. Nonetheless, given the diverse applications of biomass within the agricultural sector, only a limited portion of this potential is viable for energy generation. The study reveals significant disparities in biomass potential among EU countries, ranging from a modest 6.4 Ktoe in Malta to a robust 34,528.5 Ktoe in France. This heterogeneity reflects the diverse agricultural landscapes and practices across the EU and underscores the importance of region-specific strategies for biomass utilisation. The data highlights that certain biomass sources play a predominant role in specific countries. For example, Spain's significant biomass potential is largely attributed to straw from cereal crops and permanent grassland hay. This emphasises the need for tailored strategies that leverage the unique agricultural landscapes and conditions of each member state. The extended statistical analysis reveals the average biomass potential across the EU, with cereal straw contributing significantly. The standard deviation and variance metrics indicate considerable variability within each biomass category, suggesting diverse biomass potential across countries. The findings have crucial implications for energy policy formulation and agricultural management in the EU. The robust potential of biomass as an energy source could significantly contribute to the EU's energy self-sufficiency and reduce dependence on fossil fuels. The sustainable management of agricultural residues and by-products can foster circular economy principles within the agro-energy sector. The analysis points to the need for future research focused on optimising biomass conversion technologies and developing policies that incentivise the integration of agricultural biomass into the energy matrix. Understanding the idiosyncratic attributes of each country's agricultural sector is vital for harnessing the full potential of biomass. In conclusion, this data-driven exploration underscores the substantial, yet varied, potential for agricultural biomass across EU countries. It highlights the strategic significance of biomass resources in the European Union, particularly in the context of medium and long-term climate goals. The study's findings contribute to the broader discourse on sustainable energy and environmental policy, providing a foundation for informed decision-making in the renewable energy sector.

The current geopolitical climate in Europe is fostering a growing interest in renewable energy, particularly agricultural biomass. This context is likely to boost energy production from such biomass soon. Agricultural biomass, being primarily derived from the by-products of essential food production, offers a stable source of material for energy. Its resilience to energy crises is further strengthened by its local availability.

The limitations of this study include potential inaccuracies in data collection and analysis, as agricultural biomass estimates are subject to varying methodologies and reporting standards across EU countries. Additionally, the study's focus on theoretical potential may not fully account for practical constraints such as economic feasibility, land use competition, and regional policy variations. The analysis also does not deeply explore the environmental impacts of scaling up biomass production, which is crucial for maintaining sustainable practices. These limitations suggest the need for further research to refine data accuracy and address practical implementation challenges.

The challenge for future research lies in addressing the complexities of sustainable biomass production. This includes enhancing the efficiency of biomass conversion technologies, developing more comprehensive policies for integrating agricultural biomass into energy frameworks, and better understanding the environmental impacts of large-scale biomass utilisation. Future studies should also explore innovative approaches to balance energy production with ecological and social sustainability, particularly in the context of evolving climate change dynamics and regional agricultural practices.

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For citation:

Weremczuk A. (2023). The Energy Potential of Agricultural Biomass in the European Union. *Problems of World Agriculture*, 23(4), 44-60; DOI: 10.22630/PRS.2023.23.4.16

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