Impacts of crop and income diversification on poverty and inequality among rural farm households in Ghana

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Abstract

This paper investigates the linkages between differences in agro-ecological environment, income inequality and poverty among rural farmers in Ghana. It interrogates the effects of crop and income diversities among other factors on income inequality and poverty using countrywide data and different analytical methods. The findings show that a rise in both income and crop diversities leads to a reduction in income inequality. The analyses suggest that policy targets to reduce income inequality must pay attention to income and crop diversities within and between the zones. The results indicate that the poorer zones are more dominant in diversifying crops production, but the wealthier areas seem to be more dominant in diversifying income sources. Also, as smallholders show a greater poverty level, the medium- and large-scale farmers experience lower poverty incident, and that intra-zonal disparities are the main sources of income inequality and poverty. It is recommended that policymakers in an attempt to reduce income inequality must pay attention to diversity in the agro-ecological locations, gender, as well as changes in crop diversity and differences in income sources among the rural farm households. Finally, crop diversification must be intensified in the poorer agro-ecological environments, whereas income diversification is increased in less poor environments for effective poverty alleviation.

Keywords Agro-ecological environments and economy · Crop and income diversities · Poverty · Inequality · Ghana

1 Introduction

Diversity in an agro-ecological environment is often directly linked to types of crops cultivated (Okonya et al., 2013; Tittonell & Giller, 2013; Cortinovis et al., 2020; Singh et al., 2020), and the dominance of income generating activities used by farm households as means of livelihoods within a specific area (Mugido & Shackleton, 2017; Mugido & Shackleton, 2019). Also, economic well-being of rural farm households could invariably depend on farm production and other complementary nonfarm income sources, which in

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turns, hinge on the types of agro-ecological environments being inhabited by the farmers (Tittonell & Giller, 2013, Lu & Horlu, 2017, Asfaw et al., 2021). An implication is that, by the virtue of ecological environments domiciled by rural farmers, equal opportunities might not be granted them to cultivate similar crops nor access the same income sources. This might lead to economic inequality, which could result in unbalanced effects of poverty reduction strategies in rural farm sector, particularly in developing countries.

In the case of Ghana, the country is generally divided into three main agro-ecological zones which comprise of the coastal, the forest and the savannah (Ghana Statistical Service, 2014; Owusu et al., 2021; Tsiboe et al., 2022). A key distinguishing characteristic of these zones includes variations in the levels of annual precipitations, with the lowest occurring in the savannah areas and the highest in the forest zones. Other factors include differences in types of soils and vegetation cover across the regions (Owusu et al., 2020; Asante et al., 2019). Hence, types of crops and patterns of farm production vary accordingly by the locations of agro-ecological environments. For instance, cultivation of staple crops e.g. cereals, legumes, roots and tubers are heavy rainfall dependent and, therefore, are produced annually following the annual or bi-annual erratic precipitations of a given agro-ecological zone (Aryee et al., 2018; Asare-Nuamah & Botchway, 2019). Another example is that the savannah zones experience annual unimodal rainfall which encourages one-season crop production and supports a limited number of perennial tree crops e.g. cashew (Aryee et al., 2018; Asante et al., 2019; Antwi-Agyei et al., 2021). The forest and most parts of coastal areas experience bimodal rainfall and thus allows a two-seasonal crop production per year and the locations favour several perennial cash crops e.g. cocoa, oil palm, plantain and bananas among others (Karki et al., 2020). This means that, most crops produced in Ghana are susceptible to ecological environments. For example, cocoa and plantains strive best in forest areas as sorghum and millet optimally perform in savannah zones. Similarly, crops like maize, cassava and vegetables are mostly produced in the coastal zones (Olesen et al., 2013; Bationo et al., 2018). This phenomenon reflects crop diversity in line with ecological differences. As well, it shows disparities in sources and levels of incomes among the households. Hence variations in poverty and inequality might be experienced among the farmers by virtue of their agro-ecological locations.

Moreover, it has been generally suggested that locations of farmers in terms of diverse agro-ecological environmental conditions denotes different experiences of climatic conditions, income sources, types of crops, markets and technologies among other factors. Also, farm sizes vary for several reasons including land availability, soil fertility, capacities and credits among other constraints across ecological zones (Lu & Horlu, 2017; Dasmani et al., 2020). Similar evidence has been reported in the literature on Ghana that farm sizes cultivated by farmers depend on agro-ecological locations, productive resources and the types of crops produced (Chapoto et al., 2013; Dasmani et al., 2020). Besides, seeking additional incomes from nonfarm sources has been unstable among rural farmers in Ghana (Dzanku, 2015; Ochieng et al., 2017), because skills and technological differences between the agro-ecological zones and, therefore, dissimilar barriers of entry into nonfarm employment by the zonal locations could lead to inequality (Senadza, 2011; Agyire-Tettey et al., 2018; Tabiri et al., 2022). Based on the differences in agro-ecological locations, the opportunities offered by the rural agrarian system in sub-Saharan Africa to farmers in harnessing their economic wellbeing has not been equal and it is not clear how diversities in income sources and crop production per the ecological zones influence income distribution and poverty levels among rural farmers. Hence, the current paper analyses income inequality and poverty as economic outcomes. It, therefore, considered income inequality to be a dispersion in the overall income distribution in rural farm sector and measures poverty in

terms of both the number of people that are poor and the extent to which they fall below the poverty line in terms of households' consumptions per adult equivalent.

Several countries in sub-Saharan Africa have achieved continuous economic growth over the last few decades. However, the patterns of growth hardly translate into improving the economic well-being of most households, particularly in the rural farm sector of the continent (Molini and Paci, 2015). For instance, there is evidence that poverty remains significant and endemic among rural farmers in Africa (Chambers, 2014; Davis et al., 2012; (Bjornlund et al., 2022). More specifically, even though a country like Ghana seems to be one of the African countries experiencing exceptional economic growth, reflected by a general reduction in national poverty in recent times, the majority of the poor continue to be farm households in rural areas of the country. Exasperatingly, the country is being faced with the challenges of rising inequality among the populace (Cooke et al., 2016), such that the observed economic growth hardly translates into improved economic well-being of rural households (Clementi et al., 2018). In particular, rural farm households still experience the worse form of poverty and this has brought about doubts as to whether or not the benefits of the economic growth are transferred down to the poorest individuals in the rural agricultural sector, where poverty alleviation remains a considerable challenge (Ghana Statistical Service, 2014).

The economy of Ghana is mainly agrarian and the majority of agricultural production takes place in rural areas, where poverty is endemic over the years. Meanwhile, issues on poverty reduction have been the core of national economic policy interventions. In particular, agricultural economic policies of the country are usually targeted at rural farmers, most of whom can be classified as the poorest of the poor. The main goals of these policies are to provide support for agricultural production, improve farm incomes and incomes from other economic activities to promote the welfare of farm households. However, rural farmers differ in terms of the types of crops produced, agro ecological regimes and incomes generated from nonfarm sources. Besides, most technology-based policy interventions usually exclude poor subsistent farmers, leading to income distributive failures (Hoffmann & Jones, 2021; Marandure et al., 2021). As a result, measures to bridge income gaps between the poorer and the wealthier farmers have become complicated (Liu et al., 2019; Hoque et al., 2018). Hence understanding of crop and income diversity is relevant for appropriate policy formulation that could alleviate poverty and income inequality in rural agrarian economy across the agro-ecological environments.

Studies on Ghana have suggested that inequality has been rising among various sects of the country's population (Agyire-Tettey et al., 2018) and that it exerts a significant effect on poverty in some rural areas of the country (Annim et al., 2012; Lu & Horlu, 2017). Other scholars have argued that regional wealth disparities, gender and educational differences, as well as development gaps between the urban and rural, southern and northern zones of the country, are the main causes of the inequality (Senadza, 2011; Agyire-Tettey et al., 2018), Anlimachie et al., 2020), and that income gaps have been rising in recent times between the poor and the rich, such that, the incidence of income inequality is increasing in the country (Cooke et al., 2016). Similarly, there have been some debates in the literature as to whether or not types of crops e.g. cash or food crops cultivated lead to income inequality (Herrero et al., 2014; Lu & Horlu, 2017; Herrera et al., 2021). Whilst it has been accepted that cultivation of cash crops causes income inequality among farmers, some other scholars have argued that production of cash crops minimises inequality because it improves income distribution through employment creation which benefits the poor households (Herrero et al., 2014). Nonetheless, scarce empirical studies exist on the implications of agro-ecological dependent

diversities for spread in income inequality and poverty in rural farm sector of Ghana and other parts of Africa (Lu & Horlu, 2017; Aniah et al., 2019; Asante et al., 2021). The current paper contributes to this debate by arguing that differences in crop diversity as a result of dissimilar agro-ecological locations might lead to variations in poverty and income inequality among rural farmers. Thus, this study bridges this gap in knowledge by providing some empirical understanding of the distributional effects of agro-ecological induced crops and income diversities, among other factors, on poverty and income inequality in the rural farm sector using data on Ghana. Understanding of the issues raised in this paper can be used as premises for formulating well-informed policies and creating mechanisms for reducing rural poverty and income inequality more effectively.

Additionally, the past literature suggests that ecological dynamics across regions influence changes in livelihood strategies (Machado, 2018). In this study, the focus is on rural farmers because their livelihoods depend on the types ecological environments available to them, implying differences in land cover, access to markets, resource endowments among others might have some differential impacts of poverty levels by their locations (Aniah et al., 2019; Owusu et al., 2021). This paper argues that differences in the agro-ecological conditions might influence the livelihood strategies adopted by the rural households, which in turn, depend on the dissimilarities in skills, assets and endowments, among other factors, at the location of the farmers. Besides, ecological locations of farmers could also determine whether or not a household would be engaged mainly in farming or wage work or own a nonfarm business or combinations of them to enhance income and level of consumption. As well, there has been an increased interest among scholars in examining ecological perspectives of economic activities and livelihood strategies with an emphasis on rural transformations, (Gibson-Graham & Miller, 2015; Gibson et al., 2015). The current paper contributes to this aspect of growing literature by emphasising differences in the agro-ecological zones dependent income diversities and examines how it influences inequality and poverty as economic outcomes across the zones.

On the whole, the issue of poverty among rural farmers has been extensively discussed in the literature and inequality has also been identified as an impediment to lifting people out of poverty, (Iniguez-Montiel, 2014); Rodríguez-Pose & Hardy, 2015). However, scarce empirical studies have been conducted to examine how agro-ecological environmental differences influence income inequality and poverty among rural farmers. Thus, this paper answers questions on how the ecological dependent diversities of crop production and sources of income among others could lead to disparities in incomes and poverty levels among rural farmers. Hence, the main aim of this paper is to investigate how agro-ecological dependent diversity influence income inequality and poverty among rural farmers in Ghana. It uses a comprehensive nationwide data to specifically test the following hypotheses; 1. Whether or not crops and income diversities significantly vary across the agro-ecological environments. 2. The crop and income diversities as a result of differences in agro-ecological environments significantly impact poverty and income inequality differently among the rural farmers. Thus, the analyses illustrate how incomes inequality and poverty differ among the rural farmers with respect to their ecological locations and have provided evidence for some main factors that influence income inequality and poverty at the upper extreme, the middle and the lower end. This is achieved by contrasting the effects at various points of the distributions of the poverty and inequality indicators using quantile regression and Lorenz curves respectively among other analytical methods, so as to informatively draw well-informed conclusions on the questions put forward in this study.

2 Analytical methods

2.1 Statistical tests for dominance of crop and income diversities

In rural economic literature, various approaches are used to measuring diversity. Some past studies described diversity as incomes from multiple sources (Leng et al., 2020). Income diversity in this paper refers to earning additional incomes apart from agriculture production (Sibhatu & Qaim, 2018; Ho et al., 2022) and thus generating incomes from multiple sources. Some researchers have used the Herfindahl-index as an indicator of diversity in income sources (Baird & Gray, 2014; Singh et al., 2020); Harkness et al., 2021). Unlike these past studies, this paper adopts Simpson's diversity index estimation approach to measure the income diversity across the agro-ecological zones. This method has edge over others because it considers both the income sources as well as the value of income earned from each of the sources at a specific period of time (Dzanku, 2015; Liu & Lan, 2015). The Simpson's diversity index at the time t and for the $i\,th$ household can be expressed as:

$$D = 1 - \left\{ \left(\sum_{i=1}^{N} I_i^2 \right) \left[\left(\sum_{i=1}^{N} I_i \right)^2 \right]^{-1} \right\} \tag{1}$$

where N denotes the number of income sources for each household per the employment options and I is the value of income generated from each source per the employment category at each given survey period. The diversity index, D ranges between zero (0), thus if the total income is generated from a single source, and one (1), if the income is obtained from a number of sources. This paper considers agricultural incomes, nonfarm work, wage employment, rentals, and remittances plus other sources of income within the respective agro-ecological zones in estimating the income diversity index. Based on the nature of the living standard data used for this study it is difficult to distinguish between land sizes allocated for each crop and the value of income earned from each of the crops. Hence, using the Simpson's diversity approach to estimate crop diversity index might be misleading in this case. Instead, the study has adopted the detailed cropping information from the survey data as applied by some previous studies e.g. (Michler & Josephson, 2017), to estimate the crop diversity indices per farm households in each of the agro-ecological zones. We, therefore, estimate the crop diversity index, CDV_{it} as;

$$CDV_{it} = \left(Ch_{it} / C_{it} \right)^2 \tag{2}$$

where Ch_{it} denotes the total number of different crops grown by a household within a given ecological zone over a year, and C_{it} is the total number of different kinds of crops cultivated within a given ecological zone within the same year. The paper has compared the distribution of the economic welfare indicator of consumption across the three ecological zones using the cumulative dominance curves to examine if there is a significant difference over the study periods. In this case, one distribution is said to dominate the other at the order n, if over the range of $[M^-, M^+]$ if and only if $P_1(u : \varphi) < P_2(u : \varphi) \forall u \in [M^-, M^+]$ for $\varphi = n - 1$. Thus, where P_1 and P_2 are the cumulative distribution function of distribution belonging to the ecological zone 1 and distribution of ecological zone 2 respectively, such that if there is a value of u at which if $P_1(u : \varphi) = P_2(u : \varphi)$ and the value of P_1 turn out to be greater than the value of P_2, then none of the distributions dominates the other on the interval of M^-, M^+. Besides, density curves have been used to show the distributions of the welfare indicators of the farm households by their ecological locations and then adopted

the multivariate analysis of variance for significant differences between the indicators. In cases of multiple response, where households cultivate more than one crops, Chi-square tests adjusted by Holm-Bonferroni probability were conducted to investigate whether the types of crop cultivated are significantly different across the various ecological zones. The reason is that, in Ghana, many rural farm households cultivate multiple crops and hence, several hypotheses are simultaneously tested.

2.2 Income inequality indicators

Various methods have been proposed in the literature on measuring inequality in economic wellbeing indicators and they include income, wealth, and consumption, but the most commonly used indicator among farm households is the income earned (Lu & Horlu, 2017; Mullan et al., 2018; Ibrahim, 2023). The reason is that, this study considers only rural agricultural households the per capita income adjusted by constant prices which is used in measuring inequality among the farmers. The paper preferably uses the Gini coefficient as an indicator of the inequality indicator because its composition into sources of the income inequalities also produces interactions between the sources. Moreover it is the most commonly used in the literature. It must be emphasised that the Gini indicator is associated with the Lorenz curve (Firpo et al., 2018; Lakshmanasamy & Maya, 2020). As a result, Lorenz curve has been used to comparatively demonstrate income inequality among the rural farm households across the three main agro-ecological environments in Ghana.

2.3 Poverty indicator

The available literature advocates that the consumption expenditures are more reliable indicators for measuring economic welfare and poverty at the household level (Wossen et al., 2017; Akinlo & Dada, 2021). In the case of this paper, and for the purpose of ensuring a clear comparison of poverty incidence among the households across the three different ecologies, the consumption expenditures are adjusted by price indices of the respective survey periods and the adult equivalents of the farm households are used instead of the household sizes in estimating the capita adult equivalent consumptions (Ghana Statistical Service, 2014). Thus, paper argues that the ratio of the consumption per capita adult equivalent to the poverty line, as an indicator of poverty.

2.4 Regression analyses

Apart from the inequality and poverty indices, the paper, in addition, has conducted regression analyses to investigate the impacts of some explanatory variables on the consumption-poverty line ratio (poverty) and the income inequality distribution curves respectively. Various forms of regression analyses have been proposed in the literature, among which the Ordinary Least Squares (OLS) estimate and assumptions are the most popular. The OLS models are based on the basic assumption for estimating the impacts of some independent variables on the population unconditional mean of the dependent variable. Thus, the conditional mean of the outcome variable with respect to the explanatory variable is equivalent to the average of the unconditional mean of the outcome variable as the result of law of iteration expectation. Hence, the estimated coefficients of an OLS regression represents the effects of the independent variables on the population mean of the dependent variable, assuming constant variance.

However, investigating some specific issues for economic policy decision, it is more relevant and important to consider other forms of distributions rather than the mean value (Firpo et al., 2018; Lakshmanasamy & Maya, 2020). For instance, the famous conditional quantile regression which provides marginal effects of the independent variables at various specific quantiles of the distribution of the outcome variable. Based on these premises, (Firpo et al., 2009) and (Firpo et al., 2018) have also proposed using the Re-centered Influence Functions (RIF) approach to estimate the impacts of a set of explanation variables on the variance and Gini inequality distributions of outcome variables rather than the mean (see for instance, (Firpo et al., 2007; Firpo et al., 2009); Firpo et al., 2018; Lakshmanasamy & Maya, 2020) for technical details), which the paper finds very relevant and appropriate for this study to find some effects of some determinant variables on the variance in the poverty indicator and the income inequality among the rural farm households.

This study has pointed that consumption per poverty-line ratio is observed in the presences of the covariates of the explanatory variables. Thus, both the dependent variable, the consumption per adult equivalent/poverty line ratio and the independent variables have a joint variance distribution. The paper, therefore, investigates the factors that influence the changes in the variance of the poverty distributions based on this notion. Most often than not, poverty models are applied, however, the consumption model approach is preferable because it gives a more reliable measurement of poverty since it is centred on the consumption expenditures. Also, lots of information might be lost using poverty models which apply censoring with respect to poverty lines (Tsiboe et al., 2022).

Additionally, unlike poverty models, consumption approach does not require rigorous distributional assumptions (Sakuhuni et al., 2011; Tredennick et al., 2021). We, therefore, apply the Recentered Influence Function (RIF) proposed by (Firpo et al., 2018) to investigate how some specific factors that influence the variance in the distribution of consumption/poverty line ratios by specific categories of households based on the three main ecological zones of Ghana. The estimated parameters of the RIF function, therefore, give consistent values of the marginal effect of the exogenous variables on the variance distribution, (Firpo et al., 2007; Firpo et al., 2009; Firpo et al., 2018) of the poverty indicator. Following the commonly used household consumption function in literature, the paper estimated the following model,

$$CR_{ij} = \gamma_j + \beta_{ij}X_{ij} + \varepsilon_j \tag{3}$$

where CR_{ij} denotes the ratio of consumption per adult equivalent to the absolute poverty line, of the ith household in the jth survey period; γ_j is the constant term of the jth survey, X_{ij} is the vector of the independent variables of the households' characteristics and endowments and ε_j is the error term. Also, β_{ij}, are the estimated coefficients of the explanatory variables. The results of obtained from the analyses give a complete overview of the effects of changes in the explanatory variables on the variance of the distribution of poverty. Likewise, the paper considers RIF regression model of income inequality per the survey periods which is represented as;

$$Y_{ij} = \alpha_j + \delta_{ij}X_{ij} + \varepsilon_j \tag{4}$$

where Y_{ij} denotes the natural logarithm of the per capita income of the ith household engaged in the jth survey; α_j is the constant term of the jth category, X_{ij} is the vector of household assets, endowments and other characteristics and ε_j is the error term. Also, δ_{ij}, are the estimated coefficients of the explanatory variables on the Gini income inequality distribution (Lakshmanasamy & Maya, 2020). The results analyses give a complete overview of

the changes in the independent variables on the income inequality distribution with respect to each ecological locations. In this study, the standard errors and coefficients are obtained by 500 bootstrap replications in each case.

Also, the paper has considered various factors influence poverty based on the consumption per adult equivalent to poverty-line ratio across some selected quantiles. Thus, this study has distinguished the effects on the variables on the poverty indicator at the upper extremes, from the middle and the lower ends. By contrasting the effects of these variables at several points of distributions of the consumption-poverty line ratio, this paper has informatively drawn conclusions on the hypotheses put forward in this study. In this wise, the study has used quantile regression estimation procedure to investigate the marginal effects of the explanatory variables on different points of distribution across some selected quantiles is based on Eq. (5), for q_i^{th} quantile which is given by the conditional quantile function as:

$$CR_{ij_{qi}}(\mu_i|X_i) = X_i\prime\gamma_{qi} + e_i \tag{5}$$

where γ_{qi} denotes the vector of unknown parameters of the distribution of total consumption-poverty line ratio CR_{ij}, at the q_i^{th} quantile of 35 th, 50 th and the 75 th. Hypothetically, the minimum consumption expenditure to meet adequate calorie requirement and nonfood needs of a given individual is generally used as basis for poverty incidence, therefore the poverty line represents the value of nutritional requirements and nonfood necessities of household members, and below which they are considered poor to afford the daily standard of living.

3 Data source and descriptive results

3.1 Data source

The data used in this study are taken from the Ghana Living Standards Survey (GLSS), rounds 5 and 6, which was collected by the Ghana Statistical Service (GSS) over the period of 2005/6 and 2012/13, respectively.[1] The living standard survey has been a Ghanaian country-wide household representative survey conducted by the Ghana Statistical Service at 6-year intervals, in collaboration with the World Bank and few other agencies in order to provide comparable, detailed and dependable estimates for a variety of living standard indicators in order to set out policies to improve the life of the people in the country.

The GLSS 5 comprised 8,687 households covering about 37,128 individual members gathered from 580 enumeration areas across the country. It is observed that out of the 8,687 households about 5,069 of them were located in rural areas, among which 4,515 have at least a member engaging into farming.

The GLSS 6 survey included 16,772 households consisting of 73,708 members drawn from 1,200 enumeration areas all over the country. Considering the 16,772 households, about 10,327 of them were rural dwellers, out of which 8,062 have at least one member in agricultural production. This study has considered only rural farm households in its analyses, and for the 2005/6 survey, 664 households were in the coastal areas, 1,906 in the forest

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[1] The GLSS 7 has also been collected by the Ghana Statistical Service (in 2018/2019) but has not been accessed by the author as at the time of writing this papers.

and 1,945 in the savannah zones. Also, for the 2012/13 survey covered 752 farm households located in the coastal zones, 3,258 in the forest and 4,052 in the savannah areas. The two surveys offer information on agriculture, health, employment, income, fertility, expenditure, communication and nutritional status of the households among others.

The Ghana Living Standard Survey has over the years been adopting a two-stage stratified sampling approach. The first stage consists of the selection of the enumeration areas (EAs) to be the primary sampling units (PSUs), embracing the 10 regional administrative areas of the country and using a probability proportional to population size (PPS). Subsequently, the EAs were divided into urban and rural localities, and then, the secondary sampling units (SSUs) were generated from the complete list of households in the selected PSUs to give rise to the stratified domains of the whole country, the 10 administrative regions of the country and the three agro-ecological zones across the country. This study finds the information provided by the survey data to contain the important variables for the required analyses of this study. As the agro- ecological zones are one of the analytical strata, it provides a reliable domain for analysing activities of farm households since patterns agricultural production and crop types cultivated vary across the zones. Also, the data provide information on the types of crops grown by the households and their compositions across the agro-ecological zones as well as differences in income sources, farm sizes among others. In addition, data provide the sampling weight, household sizes, and the adult equivalents of the households and reliable survey design framework which are the prerequisites for the simulation process used for most of the analysing methods used in this paper for generating the estimates that reflect income inequality and poverty levels for the entire population of rural farmers in the country.

The paper uses the absolute poverty line of 1314 Ghana Cedis (GHS) per adult equivalent per year, which is equivalent to or $1.10 per day in January 2013 prices (Ghana Statistical Service, 2014). The poverty line used during the 2005/6 survey period was 370.89 GHS per adult equivalent per annum is equivalent to $1.00 per day in January 2007 prices (Ghana Statistical Service, 2008). The two poverty lines imply that the consumption expenditures on the basic food basket and the basic nonfood items per adult equivalent have been used as estimated by the (Ghana Statistical Service, 2014). Besides, the paper used the corrected incomes (net incomes adjusted for constant prices/consumer price indices of the respective survey years) in estimating the per capita incomes for both survey periods using the new Ghana Cedis as the unit for currency. The paper has classified total farm sizes cultivated by the farmers as smallholders (0–5 hectares), medium-scale farmers (5–20 hectares), large-scale farmers with farm sizes greater than 20 hectares, (Houssou et al., 2016; Lu & Horlu, 2019), since a farm size might be an important determinant in the types crops cultivated and locations of the farms and might also be sources of income inequality and poverty distribution among the farmers. The three main ecological regions considered in this study include the coastal, the savannah, and the forest.

3.2 Crop diversity and agro-ecological zones

Using descriptive statistical methods, the paper first investigated whether or not the agro-ecological zones have significant distributional effects on the composition of the types of crops cultivated by the farm households. This information is presented in Table 1. The table shows the percentage distributions of the main crops cultivated by the households within the agro-ecological zones. The Chi-squared tests adjusted by the Holm-Bonferroni probability results have indicated that some significant differences

Table 1 Types crops cultivated by the categories of the agro-ecological zones

Types of crops	GLSS 5				GLSS 6			
	Coastal	Forest	Savannah	P-value[a]	Coastal	Forest	Savannah	P-value[2]
Avocado	0.84	2.24	0.40	0.00	0.18	1.89	0.13	0.00
Coffee	0.34	1.64	0.06	0.00	0.00	0.10	0.05	0.61
Kola nut	0.50	1.26	0.29	0.02	0.00	0.24	0.03	0.17
Cashew	0.34	0.38	5.30	0.00	0.00	0.51	3.72	0.00
Cocoa	13.76	46.61	2.17	0.00	12.07	51.87	1.30	0.00
Coconut	11.07	1.37	0.11	0.00	3.42	0.37	0.03	0.00
Oil palm	24.83	28.80	0.80	0.00	12.79	15.76	0.52	0.00
Mango	2.35	0.93	2.39	0.02	0.00	0.10	0.73	0.00
Citrus	8.22	5.68	0.11	0.00	4.68	3.44	0.10	0.00
Shea nut	0.00	0.00	22.81	0.00	0.00	0.00	4.01	0.00
Rubber	0.17	0.05	0.51	0.17	0.90	0.13	0.03	0.00
Woodlot	0.34	0.71	1.54	0.08	0.00	0.24	0.13	0.69
Maize	43.12	31.15	40.08	0.00	52.97	39.89	66.89	0.00
Millet	0.00	0.05	29.36	0.00	0.18	0.13	31.57	0.00
Sorghum	0.00	0.11	27.14	0.00	0.00	0.00	20.61	0.00
Rice	0.00	1.20	14.88	0.00	1.62	2.40	23.37	0.00
Groundnut	1.01	2.46	28.22	0.00	6.13	1.92	46.67	0.00
Cowpea	2.35	1.97	16.70	0.00	1.08	2.40	27.41	0.00
Roots and tubers								
Cocoyam	3.36	14.81	1.82	0.00	1.08	8.91	0.52	0.00
Cassava	66.61	54.59	24.12	0.00	69.73	62.64	18.35	0.00
Yam	3.36	8.58	29.08	0.00	1.26	11.68	34.33	0.00
Sweet potato	0.17	0.05	0.97	0.00	0.90	0.13	1.04	0.00
Okra	3.69	1.58	9.86	0.00	7.21	3.88	16.19	0.00
Onion	0.17	0.33	1.54	0.00	0.00	0.20	1.07	0.00
Papaya	1.17	1.48	0.29	0.01	0.36	0.47	0.16	0.35
Pepper	10.40	5.03	9.29	0.00	18.74	5.87	14.16	0.00
Pineapple	3.19	1.64	0.06	0.00	1.44	0.37	0.08	0.00
Tomato	5.70	2.40	3.93	0.01	6.31	3.00	7.52	0.00
Water melon	0.00	0.05	0.06	0.85	0.72	0.10	0.13	0.03
Banana	1.01	4.97	0.40	0.00	0.36	1.96	0.34	0.00
Garden eggs	2.68	1.80	0.63	0.00	1.98	2.46	0.49	0.00
Leafy vegetables	0.67	0.16	1.14	0.02	0.54	0.27	2.32	0.00
Ginger	0.34	0.05	0.06	0.74	0.18	0.17	0.05	0.91
Other crops								
Cotton	0.00	0.00	2.17	0.00	0.00	0.00	1.28	0.00
Plantain	23.32	48.36	2.45	0.00	6.85	37.26	1.43	0.00
Sugarcane	3.02	0.38	0.11	0.00	2.52	0.20	0.03	0.00
Tiger nut	0.00	0.11	0.06	1.00	0.00	0.00	0.16	0.32
Tobacco	0.17	0.05	0.23	1.00	0.00	0.00	0.36	0.02
Other fruits	0.17	0.05	6.10	0.00	0.00	0.13	0.03	0.76
Mean of crop diversity index (CDV)	0.0061	0.0067	0.0072	0.05[b]	0.0042	0.0062	0.0089	0.00[b]
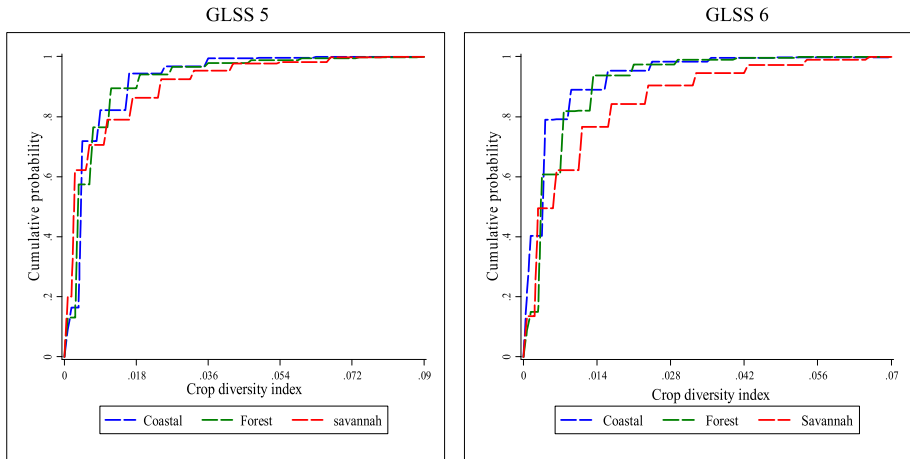
Fig. 1 Cumulative distribution of crop diversity by agro-ecological zones

exist between the proportions of crops cultivated within the agro-ecological zones for both survey periods, except in few cases, for instance, rubber, watermelon, ginger during the GLSS 5 period and coffee, kola nut, other fruits during the GLSS 6 period. The analyses in Table 1, therefore, revealed that nearly all the major crops cultivated significantly vary in proportions across the agro-ecological zones. Thus, in general, the findings do not reject the null hypotheses that the proportions of the main crops cultivated vary across the ecological zones. This points to an evidence of potential differences in crop and income diversities between the zones, and as a probable incident of income inequality and poverty among the farm households across the ecological locations. A probable explanation is that the types of crops (either cash or staple crops) can bring about differences in the income levels among the farmers and therefore can be a source of income inequality which might have some distributional effects on poverty across the zones. Thus, the proportions of cash crops e.g. cocoa and oil palm and the staple crops e.g. maize and cassava in terms of levels of production differ across the agro-ecological zonal locations and, therefore, might induce inequality in income distributions and poverty levels among the farm households.

The paper as well examines the crop diversity dominance across the ecological zones using cumulative distributive function, Fig. 1. Although, there has not been complete dominance in the cumulative probability distributions of the crop diversity indices for both survey periods, it can be observed that crop diversity is more dominant in the savannah zones than both the coastal and the forest regions (Fig. 1). Also, the figure and Table 1 have shown that the incidence of crop diversity reduced in value for the forest and the coastal areas. Thus, whilst the savannah zones experience hikes in the crop diversity index by about 19 percent, the coastal and the forest experience the reductions of 45 and 16 percent respectively. However, the spread in the crop diversity indices has increased in magnitude

Table 2 Income sources adopted by farm households across the agro-ecological environments

| Sources of income	GLSS 5 (%)				GLSS 6 (%)			
	Coastal	Forest	Savannah	*P*-value	Coastal	Forest	Savannah	*P*-value
Wage employment	19.16	16.74	6.53	0.00	76.03	79.95	48.81	0.00
Nonfarm self-work	37.10	38.41	41.85	0.03	44.21	36.10	30.77	0.00
Agricultural production	96.38	98.58	98.66	0.00	82.56	92.84	95.63	0.00
Rentals	62.90	57.14	79.23	0.00	94.54	93.23	98.94	0.00
Remittances and others	50.08	59.08	44.99	0.00	40.21	38.10	30.15	0.00
Mean of income diversity index (IDV)	0.313	0.292	0.279	0.00[a]	0.354	0.370	0.366	0.13[a]

[a]Pillai's trace result probability for multivariate analysis of variance reported

over the study period and the trends in dominance basically remain quite stable across the zones between the two survey periods.

In spite of the fact that the savannah zones are more dominant in crop diversification than the other agro-ecological zones, farmers in the zone are being challenged and hampered by their locations such that, they are not in a position to diversify into high valued tree crops e.g. cocoa, oil palm, citrus and pineapples, which are important for higher income generation for poverty reduction (Birthal et al., 2015). Instead, the higher level of crop diversity in the savannah zones are more associated with staples food crops for instance, sorghum, maize, and millet as well as low valued cash the like legumes and pulses etc., which are more or less grown for food security reasons since the farmers in this zone experience unimodal rainfall patterns, as indicated in the earlier part of the paper. This is in line with the assertion by some scholars that growing a wide variety of food crops might be in order to reduce the risk of weather and unreliable patterns of precipitations, as well as for increasing food productions meant for household consumption (Harris et al., 2020; Zhang et al., 2022), as it pertains in the savannah areas of Ghana and several areas in Africa. This occurrence can be a challenge to poverty reduction and a source of income inequality between the rural farmers in the savannah zones and other ecological locations. Contrarily, the forest and the coastal areas have been identified to grow more trees cash crops as well as some important staple crops to include cassava, maize and plantains by virtue of the climatic conditions of their locations. We, therefore, expect poverty to be lower in the forest and the coastal areas, even though they experience lower rates of crop diversity than in the savannah areas. Forest zones harbouring cultivation of most cash crops is expected to have lowest income inequality, but it might produce the largest share of the overall income inequality among the rural farmers across the ecological zones.

3.3 Income sources and diversity across the agro-ecological zones

Another point of interest in this paper is that it expected diversity in the income sources, assets and resource endowments between them ecological zones. Table 2 shows tests for differences in the proportions of income sources used by the rural farm households across the agro-ecological zones of Ghana. The table shows that significant differences exist in the proportions of the households using various income sources across the ecological locations. The results have also indicated that wage employment avenues are
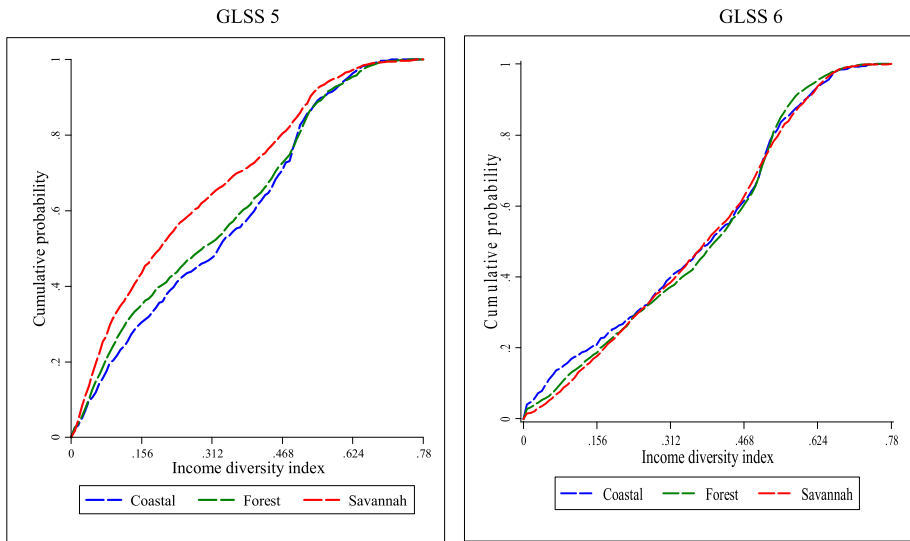
Fig. 2 Cumulative distribution of income diversity by agro-ecological zones

increasing in every zone. Likewise, rental incomes are rising, signifying productive asset accumulation is increasing among the farm households irrespective of the agro-ecological locations. However, agricultural production remains predominantly the main source of income in every zone. The significant differences in the income sources might also suggest a potential cause of income inequality and difference in poverty levels across the locations. The reason is that the values of income generated might depend on the income sources and the places of habitation of the farm households. This leads to a question of whether the incidence of income diversity varies significantly across the agro-ecologies or not in the next step.

The multivariate test analysis of variance reported in Table 2 has shown that significant differences exist between the income diversity indices during the 2005/6 survey period. However, even though the income diversity indices increase during the 2012/13 period, the test statistics have revealed that there is no significant differences between them. This observation is further emphasised by the cumulated probability curves in Fig. 2. The figures show that there is wider spread during the earlier survey period with greater dominance of both coastal and the forest over that of the savannah areas, but this observation breaks down during the latter survey period, though the income diversity incidents increased in magnitudes (Table 2). The observation that no complete dominance ordering occurs for each of the periods and over time between income diversity indices implies that some level of instability might exist in the income diversity statuses of the households over time and across the agro-ecological zones. Thus, there are about 11, 21 and 24 percentage changes in income diversity status in the coastal, forest and the savannah zones, respectively, over the period.

The observations in the magnitudes of the income diversities (Table 2) and incomes across the zones in Table 3 confirm the findings of some past studies that income diversity is normally bigger among high-income rural households (Atuoye et al., 2019; (Balié et al., 2021).

Table 3 Economic welfare indicators and household sizes by agro-ecological zones
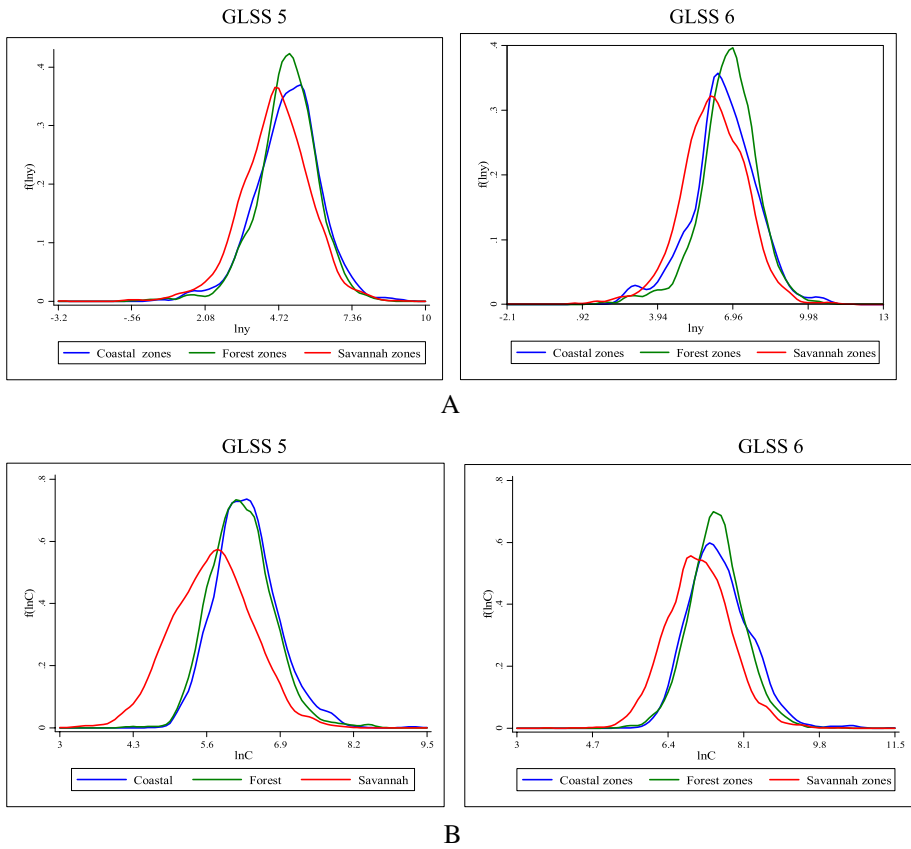
Agro-ecological zones	Observation	Per capita income		Consumption per adult equivalent	
		Mean	Std. Dev	Mean	Std. Dev
GLSS 5					
Coastal	664	341.45	677.69	777.66	654.58
Forest	1,906	294.99	436.26	693.64	504.14
Savannah	1,945	186.12	382.12	404.55	360.52
GLSS 6					
Coastal	752	1787.12	4926.16	3027.62	4503.28
Forest	3,258	2221.80	8762.83	2615.79	2510.59
Savannah	4,052	1025.42	2982.45	1679.30	1735.33

3.4 Comparison of economic well-being indicators of poverty and inequality

In this section, the paper first presents in Table 3 the descriptive statistics on per capita incomes, consumption per capita adult equivalent, the household size and the adult equivalent of the households. It is found that there have been general increases in the incomes and the consumption levels between the two survey periods and across the respective agro-ecological zones. The household sizes and the adult equivalent of the households have been fairly the same over the period but are inconsistent across the locations. The analyses in Table 3 also suggest that the standard deviations are generally high indicating gross variations in the distributions of the welfare indicators of income and consumption. Also, it has been observed that in 2005/6, coastal zones recorded the highest mean income while the savannah the lowest, but in 2012/13, the forest regions have the highest average income. As well, the coastal zones exhibit the largest levels of consumption for both survey periods, whereas the Savannah areas persistently remain the lowest in consumption of good and services.

Second, the study focused on the economic welfare indicators and examined whether the agro-ecological locations have impacted some significant differential distributional effects on the per capita incomes and the consumption per adult equivalents of the households. Using in the foremost, density curves, the paper has shown the per capita incomes distributions by the ecological zones in Fig. 3A. The logarithmic density curves are used so as to give clearer distributive patterns of the graphs and also to cater for the huge standard deviations in the distributions of the standard of living indicators. The figure has also demonstrated that there is an increase in the per capita incomes over the period. It has been observed that though the income of the households in the coastal areas is greater in 2005/6, the income growth in the forest regions is larger than those in both coastal and savannah areas for the period 2012/13, but the savannah zones lag behind in the levels of income earned for both periods. Regardless the differences in the income distributions, the density curves in Fig. 3A show that the distributions overlap, implying that it is not all households in each of the agro-ecological zones whose incomes are lower than that of the other households in a different location.

Similarly, the paper has examined the density curves of the consumption per capita adult equivalent distributions by the agro-ecological zones as presented in Fig. 3B. The figure follows similar patterns of distributions of the per capita incomes. It has shown that

Fig. 3 **A** Income capita density distribution by agro-ecological zones. **B** Consumption per capita adult equivalent density distribution by agro-ecological zones. Source: authors' estimations

there is an increase in the consumption per capita over the period and across the zones. The curves have illustrated that though the consumptions of the farm households in the coastal areas are greater in 2005/6, the rise in consumption in the forest areas is greater than those located both in the coastal and Savannah for the period 2012/13 (Fig. 3B), but the savannah zones lag behind in the values of goods and services consumed for both periods. Irrespective of the differences in the distribution of the per capita adult equivalent consumptions, the density curves in Fig. 3B have illustrated that the distributions intertwine as some points, implying that it is not all households in each of the agro-ecological zones whose levels of consumption are inferior to others in different ecological locations.

Also, the tests of whether significant differences exist between incomes across different locations of the farm households are carried out using the multivariate analysis of variance. Thus, the paper tests for whether there is equality in mean incomes across the ecological locations or not. The results in Table 4 show that the mean per capita incomes are significantly different at 1 percent between the zones. Hence, it has rejected the null hypothesis that the mean incomes are equally distributed among the farm households across the 3 ecological zones (Pillai's trace tests are reported in Table 4), in favour of the alternate hypotheses. These imply that agro-ecological zones

Table 4 Descriptive statistics of the household characteristics by the agro-ecological zones

Variable	Description of the variables	GLSS 5				GLSS 6			
		Coastal	Forest	Savannah	P-value[b]	Coastal	Forest	Savannah	P-value[a]
		Mean	Mean	Mean		Mean	Mean	Mean	
Numerical variables									
INC	Income per capita (Ghana Cedis-GHS)	341.45	294.99	186.12	0.00	1787.12	2221.80	1025.42	0.00
CON	Adult-equivalent consumption per capita (GHS)	777.66	693.64	404.55	0.00	3027.62	2615.79	1679.30	0.00
AGE	Age of the farm household head (year)	46.977	46.985	46.757	0.89	49.461	48.854	47.547	0.00
EDU	Years of education	5.244	6.016	2.136	0.00	5.290	6.398	2.527	0.00
YWK	Average years of working	14.840	14.254	14.113	0.36	14.403	14.419	14.379	0.99
WCR	welfare ratio (consumption/poverty line)	2.097	1.870	1.091	0.00	2.304	1.991	1.278	0.00
AQS	Adult equivalent of the household (heads)	2.993	3.271	4.331	0.00	3.283	3.324	4.287	0.00
Dummy variables		%	%	%	P-value[c]	%	%	%	P-value[6]
SEX	Sex, male=1, 0 otherwise	71.17	72.03	88.00	0.00	64.78	75.29	86.01	0.00
ELE	Access national electricity grid=1, 0 otherwise	25.64	26.55	11.44	0.00	56.82	45.87	23.09	0.00
MEF	Own a medium farm size=1, smallholder=0	4.86	11.20	12.93	0.00	4.05	11.95	16.32	0.00
LAF	Own a large farm size=1, smallholder=0	0.61	1.26	4.33	0.00	0.13	0.62	1.18	0.00
Observation		664	1,906	1,945		752	3,258	4,052	

[a] I also generated dummy variables for the agro-ecological locations, forest zones=1, 0 coastal zones (FOR) and Savannah=1, 0 coastal zones (SAV)

[b] Pillai's trace result probability for multivariate analysis of variance reported

[c] Chi-square test result of unadjusted probability reported

might exert some significant distributional effects on the income inequality among the farm household and therefore require further investigations in terms of what factors might be responsible, in the subsequent sections.

In the same way, in order to ascertain whether significant differences exist between consumption per adult equivalents among the households across the ecological regions, the paper has adopted the multivariate analysis of variance and the test results are presented in Table 4. Thus, the table shows tests for whether or not the average levels of consumptions are equal across the ecological locations. The results have revealed that the means per adult equivalent consumptions are significantly different at 1 percent. Thus, the study rejects the null hypothesis that the mean consumptions are equal among the households across the 3 ecological zones while assuming both homogeneity and permitting heterogeneity in favour of the alternate hypotheses. This means that agro-ecological zones might exert some significant distributional effects on the poverty among the farm households and, therefore, require further investigations in terms of what factors might be responsible for the differences in the standard of living indicator of poverty in the subsequent section.

Additionally, the paper has examined some characteristics of the rural farm households which perhaps could contribute to the dispersion in income inequality and poverty across the agro-ecological zones. This information is presented in Table 4. The test statistics have shown that the average ages of the household heads were not significantly different in the period of 2005/6 survey data, but substantial differences exist in that of the 2012/13 period. Likewise, there were no significant differences between the average years of working during the 2005/6 survey period and the distribution of the public sector jobs as the main occupation of the household heads in 2012/13 data across the ecological regions.

Moreover, it has been observed that the number of years of education is substantially different across the ecological zones with the highest found in the forest areas and the lowest in the savannah zones, implying that significant skills differences might exist between the agro-ecologies, which might as well contribute to income inequality and poverty inconsistencies among the locations. The consumption per adult equivalent to poverty line ratio is observed to be greater than 1 (and generally above the poverty line) across all farm households irrespective of their ecological locations. However, deducing from the ratios, the statistical results have shown that the poorest proportion of the households are found in the savannah areas, although they have indicated the highest number of adult equivalent of the household members, crop diversity and the least stable income diversity. Thus, though the households in the savannah zones have the highest number of adults that might be able to work they happened to be the poorest, whereas the coastal areas show the lowest of the adult equivalent per household, but they emerged as the least of the poor. Besides, the proportions of sex composition of the household heads are predominantly males but significantly inconsistent across the locations. Also, farm sizes owned by the households vary across the zones. Considering the main occupation of the household heads, it has been observed that apart from the public sector jobs which are uniformly distributed, the rest of the main jobs significantly vary across the ecological locations and therefore might cause dispersions in income inequality and poverty indicators, as reflected by the income diversity indices. Hence, the paper argues that the agro-ecological zones might have some distributional effects on the types of jobs of the household heads which in turn might impact the spread of poverty and income inequality among the farmers and these are discussed in the subsequent section.

GLSS 5

GLSS 6
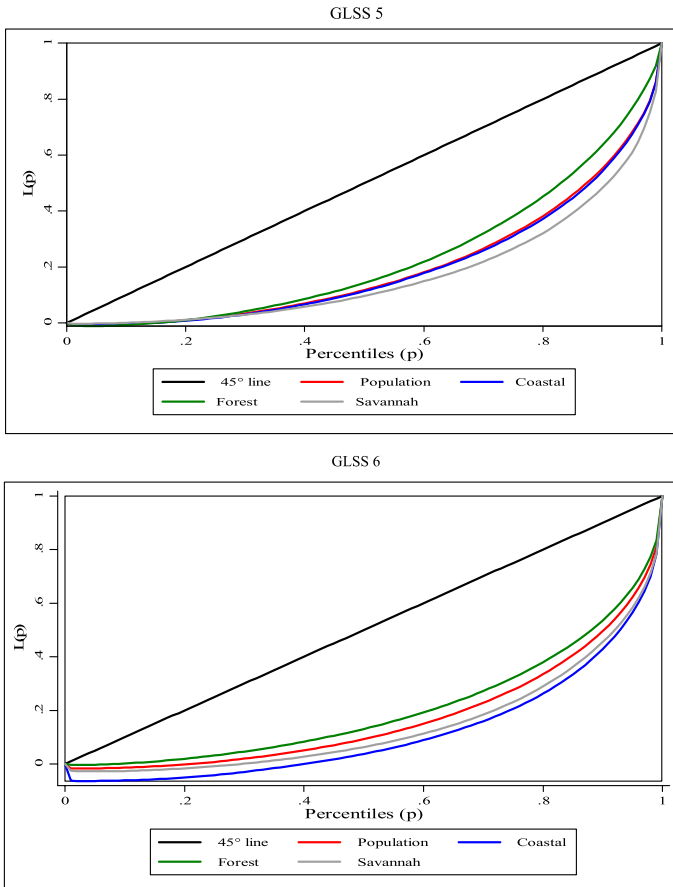
Fig. 4 Lorenz curve for income inequality of farm households across the agro-ecological locations

4 Analytical results

4.1 Variations in income inequality across the agro-ecological zones

In this section, the paper examines how income inequality is dispersed among the agro-ecological zones. The analytical results in Fig. 4 show that the savannah zones were more engulfed in income inequality than both forest and the coastal areas. However, income inequality in the coastal and the savannah areas are above the overall population inequality for both survey periods. This implies that the spread in the income gaps from the population mean income among the households in the savannah and coastal areas is greater than what was observed in the forest areas and the entire population of rural farmers. Thus, the forest zones experience the least incidence of income inequality among the rural farmers.

Also, the evidence that income inequality has increased over the period suggests that the gaps between individual household's incomes and the overall mean income of rural farm households have increased, and this indicates an increased dispersion in the income distributions among the households across the agro-ecological zones, which can be attributed to

the unstable nature of crop and income diversities, as well as differences in other household characteristics within and between the zones, (Lu & Horlu, 2017). These results, therefore, point out that rural agro-ecological differences promote and widen income inequality gaps among the rural the farm households (Lamega et al., 2021). The current situation could pose some policy concerns and challenges as to whether to develop a general or agro-ecological specific capacities and strategies for improving the standard of living evenly among the rural farm households and, therefore, mandates the understanding the drivers of the disparities in the incomes. Additionally, The Lorenz curves, Fig. 4, illustrates the distribution of income inequality from the middle, the lower and the upper extremes. The figure consistently shows that rural forest areas experience lower income inequality and a more favourable standards of living than the farm households located in both the coastal and the savannah.

The income inequality in the coastal areas was lower than in the savannah areas during the GLSS 5 period, but the farm households in the coastal regions experience the highest inequality and became worse of in GLSS 6 era, which might be attributed the higher instability in the crop and income diversities. The Lorenz curves have indicated that rural farm households inhabiting both the coastal and the savannah zones have been persistently below the population inequality. On contrary, those located in the forest areas remain above the population inequality curve and are observed to be better off, (Lu & Horlu, 2017; Nhem et al., 2018; Mendako et al., 2022). On the whole, comparing the Lorenz curves, and the crop diversity indices and the income diversity indices (in Tables 1 and 2) it can be deduced that a lower crop diversity index per the zones is associated with a greater income inequality, and also a lower income diversity implies a higher income inequality. Thus, rising crop and income diversities could point to lowering income inequality among rural farmers.

Further, the paper uses the Re-entered Influence Function (RIF) regression with Gini distribution approach to investigate factors that influence the dispersions in income inequality among the farm households and the results are presented in Table 5. The results show that the R-squared values appear to be low which is peculiar with RIF and inequality models in the literature, for instance (Halvarsson et al., 2018), p. 14), estimated some income inequality regressions and got R-squared values ranging between 0.027 and 0.128 in one year and in another year between 0.02 and 0.13. It is, therefore, not surprising that the constant term is highly significant across board, indicating that some exogenous factors might also be responsible for the changes in the income inequality among the rural farmers, which might be beyond the scope of the variables within the rural farm economy. In order to check potential collinearity or mutual relationships between the variables used in the model, the paper estimates the correlation matrix of the variables. The correlations between the variables are generally low to suspect any collinearity between them.

The paper focused on the total samples for the respective surveys. The analyses in Table 6 have clearly demonstrated that both rising income and crop diversities lead to a reduction in income inequality among rural farmers, but crop diversity seems to have a greater impact. Also, the results show that although the sex of the household head produced a negative significant influence on income inequality during the 2005/6, it exerts a positive effect for the 2012/13 period and this has indicated the dominance of males as household heads increasingly leading to higher inequality among the rural farm households than where the female counterparts are the heads. This could be attributed to lowering bargaining power of females than males within families and some societies as well as controlling critical productive resources e.g. lands, by the males than females (Phiri et al., 2022; Alare et al., 2022). This also reflects the issue of gender inequality in Ghana as mentioned

Table 5 RIF Gini model of factors influencing income inequality among the farm households

RIFGINI	GLSS 5		GLSS 6	
	Coefficient	Std. Err	Coefficients	Std. Err
EDU	0.0011	0.0007	0.0003	0.0003
IDV	− 0.0617***	0.0148	− 0.0525***	0.0064
CDV	− 1.3107***	0.3038	− 0.9579***	0.1289
AGE	0.0004	0.0002	− 0.0001	0.0001
YWK	− 0.0009***	0.0003	0.0004***	0.0001
SEX	− 0.0194**	0.0076	0.0064**	0.0032
ELE	− 0.0058	0.0074	− 0.0129***	0.0027
SAV	0.0248**	0.0091	0.0184***	0.0045
FOR	0.0066	0.0086	− 0.0074*	0.0043
MEF	− 0.0180*	0.0098	− 0.0040	0.0038
LAF	0.0185	0.0190	0.0082	0.0134
AQS	− 0.0053***	0.0014	0.0003	0.0006
α	0.2208***	0.0170	0.1319***	0.0078
R-squared	0.0194		0.0330	
Adjusted R-squared	0.0168		0.0320	
F-statistics	7.42***		22.07***	

Where *** denotes significance at 1% and ** significance at 5%. NB: FOR denotes location in the forest zones = 1, 0 otherwise; SAV denotes location in the savannah zones = 1, 0 otherwise. The coastal zone, therefore, become the reference region

by some past studies (Senadza, 2011; Theis et al., 2018). The year of working used a proxy for work experience produced mixed results. During the 2005/6 period work experience induced reduction effect on the income inequality but it has turned out to be a source of rising inequality or income gaps among the rural farmers based on the 2012/13 survey. This could be attributed to changes in policies, economic activities and the related skills over the period (Colciago et al., 2019; Jones & Kim, 2018). The 2012/13 data also point out that locations in the savannah zones lead to increases in income inequality than being located in the coastal areas, implying that farmers in the savannah need special policy packages to mitigate income gaps between them and the other zones. On the contrary, the later survey data has shown that the location of farmers in the forest areas consistently depicts lessening effects on the income gaps (inequality) than to dwell in the coastal zones. The results also show that ownership of medium scale farms negatively influences the dispersion in the inequality among the households than cultivating small farms, specifically during the former survey period. Thus, as farm sizes increase from small to medium, income gaps could be bridged among farmers, since they may be better endowed than before. It also mean closing-up the social class segregation between small and medium land size farmers, (Rada & Fuglie, 2019). It could also reduce rural–urban income gaps and hence reduces income inequality (Ren et al., 2019).

Besides, the results in Table 6 reveal that the adult equivalent within a farm household has become less important in reducing inequality in the 2012/13 era. Moreover, whereas the access to national electricity grid as a proxy for infrastructure development was not an important factor as at 2005/6 period, it has become significant during the 2012/3 era for inequality reduction among the rural farmers. This might be attributed to some structural changes including, changes in policies and rural infrastructure and electrification over

**Table 6** Quantile regressions of factors influencing poverty among the households

GLSS 5

WCR	q35		q50		q75		Equality test
	Coefficient	Bootstrap Std. Err	Coefficient	Bootstrap Std. Err	Coefficient	Bootstrap Std. Err	Test
EDU	0.026***	0.003	0.031***	0.003	0.042***	0.005	4.840**
IDV	− 0.249***	0.049	− 0.326***	0.065	− 0.592***	0.102	6.600***
CDV	3.645**	1.447	4.894***	1.578	8.212***	2.219	2.130
AGE	0.001	0.001	0.001	0.001	0.001	0.002	0.010
YWK	0.002*	0.001	0.002	0.001	0.006**	0.002	1.890
SEX	0.098***	0.029	0.108***	0.037	0.153**	0.066	0.420
ELE	0.183***	0.029	0.238***	0.042	0.415***	0.077	5.180**
SAV	− 0.482***	0.036	− 0.525***	0.049	− 0.667***	0.081	3.090**
FOR	− 0.129***	0.038	− 0.143***	0.049	− 0.285***	0.080	2.340*
MEF	0.225***	0.040	0.307***	0.050	0.392***	0.105	3.370**
LAF	0.335***	0.068	0.306***	0.116	0.661***	0.188	2.800*
AQS	− 0.117***	0.007	− 0.134***	0.008	− 0.186***	0.010	29.430***
α	1.412***	0.064	1.700***	0.085	2.477***	0.142	
Pseudo R-squared	0.173		0.170		0.176		
Overall test							9.050***

GLSS 6

WCR	q35		q50		q75		Equality test
	Coefficient	Bootstrap Std. Err	Coefficient	Bootstrap Std. Err	Coefficient	Bootstrap Std. Err	Test
EDU	0.028***	0.002	0.032***	0.003	0.059***	0.006	18.750***
IDV	− 0.215***	0.045	− 0.269***	0.057	− 0.766***	0.104	19.230***
CDV	3.855***	0.880	4.144***	0.929	0.412	1.295	5.500***

Table 6 (continued)

GLSS 6

WCR	q35			q50			q75		Equality test
	Coefficient	Bootstrap Std. Err		Coefficient	Bootstrap Std. Err		Coefficient	Bootstrap Std. Err	Test
AGE	0.001**	0.001		0.002**	0.001		0.003*	0.001	1.580
YWK	−0.001	0.001		−0.001	0.001		0.003	0.002	1.940
SEX	0.009	0.024		−0.001	0.028		0.050	0.055	0.740
ELE	0.217***	0.019		0.262***	0.025		0.245***	0.043	0.035**
SAV	−0.352***	0.040		−0.398****	0.048		−0.686***	0.116	4.960**
FOR	−0.077*	0.040		−0.095*	0.049		−0.363***	0.118	3.720**
MEF	0.289***	0.025		0.363***	0.032		0.526***	0.057	12.330***
LAF	0.568***	0.095		0.670***	0.100		0.930***	0.222	1.760
AQS	−0.104***	0.004		−0.133***	0.005		−0.185***	0.008	77.650***
α	1.381***	0.062		1.726***	0.071		2.789***	0.149	
Pseudo R-squared	0.128			0.131			0.139		
Overall test									18.710***

Source: authors' estimations

Where *** denotes significance at 1% and ** significance at 5%. NB: FOR denotes location in the forest zones = 1, 0 otherwise; SAV denotes location in the savannah zones = 1, 0 otherwise. The coastal zone, therefore, become the reference region
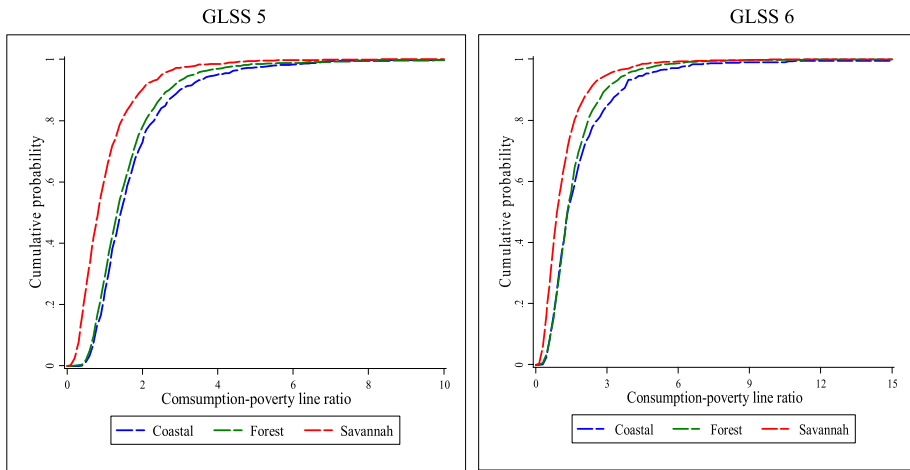
Fig. 5 Cumulative distribution curves of the per capita adult equivalents consumption–poverty line ratios by zones. Sources Authors calculations

the period. The occurrence might lead reduction income inequality (Lee & Vu, 2020). On the whole, evidence provided in this paper suggests that as policy makers targeting reducing income inequality in the rural farm sector by agro-ecological zones, much attention must be paid to the income and crop diversities, occupational dynamics, gender, accessible infrastructure by the rural farm households among others.

4.2 Determinants of dispersions poverty levels

In this subsection, the paper first examines the distribution of poverty dominance across the agro-ecological zones. It then investigates various factors that influence the variance or the spread in the poverty among the rural farmers. The study also compares factors that influence the economic well-being measure of poverty across selected quantiles so as to informatively distinguish the impacts at the extreme ends from the middle of the poverty levels. This means that farm households by virtue of their locations in the savannah comparatively experience greater poverty levels in rural farm economy of the country. These findings generally correspond with the higher income inequality among the farm households dwelling in the savannah and hence support the notion that higher income inequality leads to a greater poverty. The implication is that, in order to take more farmers out of poverty an utmost attention must be given to the savannah areas and by reducing inequality among households in such areas.

Next, the study has presented the graphical illustration of the first-order stochastic dominance test by comparing the plots of the cumulative distribution probabilities of the adult equivalent consumption per capita–poverty line ratios of the households by different zones (Fig. 5). In principle, first-order stochastic dominance occurs when a distribution, e.g. the consumption–poverty line ratios of both the coastal and the forest areas, dominates that of the savannah zones then the poverty level is lower for the locations of the dominating distributions, for instance, the rural farm households in the coastal zones experience lower poverty than the forest and the savannah, respectively. The graphical representations in Fig. 5 have also shown that though at some points of the distributions of both the coastal

and forest areas dominate the savannah zones, there is no complete dominance in the distributions, particularly at the extreme ends where the curves overlap. Thus, for instance, the savannah areas seem to be dominated by the other two zones at some percentage ranges and poverty seems to be greater in the savannah areas, and it as well appears greater in the forest than the coastal zones. These results can be linked to the income and crop diversity dominance curves to show that higher crop diversity dominance implies higher levels of poverty, whereas the larger the income the diversity dominance leads to lower the poverty dominance. Hence, we do not reject the null hypothesis that poorer agro-ecological zones are associated with higher crop diversity dominance (Figs. 1 and 5) and that poverty is lower where income diversity is dominant. Thus, the greater the crop diversity dominance the higher poverty, but the higher the income diversity dominance the lower the poverty. This means that the savannah zones are the poorest and this could explain why the crop diversity is dominant in such areas, but the coastal zone harbours the least of the poor households which could be attributed to the comparatively higher dominance diversity of the income sources. Contrarily, the forest zones exhibit fairly stable income and crop diversity and households in such locations experience quite a consistent poverty and income inequality levels. Hence, in order to reduce poverty in the savannah zones incomes must increase through crop diversity and productivity, while improving market outlets for rising farm outputs, as the coastal zone engages more in diversified income sources through skill training in addition to farm production.

As indicated above, the consumption–poverty line ratio significantly varies by the agro-ecological zones (Table 4), and so it is also expected that poverty varies across the quantiles. The paper, therefore, examined how various factors influence the poverty indicator across some selected quantiles. Thus, with respect to examining the marginal effects, various factors might have on the entire distribution of the poverty indicator at the middle, lower and the upper ends. These results are presented in Table 6 and comparatively illustrate the influences of the ecological locations as well as some other important factors on the poverty indicator. The study considers 35th, 50th and the 75th quantiles for easy comparison because they give adequate sample sizes per the quantiles. The coefficients of most of the regressors have the expected signs and are statistically significant; however, the magnitudes of a number of them differ across both the quantiles and the survey periods. It is observed that the explanatory variables exert greater influence on poverty indicator at the higher quantiles than the lower ones in most cases. Table 9 further reveals that the impacts of education on poverty are uniformly positive but increase in magnitude across the quantiles. This indicates that formal education is associated with decreasing levels of poverty for the two survey periods. Similarly, the longer the average years of working of the household, the less poor they become and the impacts are stronger at the higher quantiles.

Another observation is that the farm households that try to improve their economic welfare by increasingly diversifying their income sources end up being poorer. This finding agrees with a previous study that farm households that try to earn additional incomes to what they earn from farming are usually worse off and so strive to make ends meet than those engaging solely in farming (Tsiboe et al., 2016). On the contrary, the analyses reveal that, the farm households with larger crop diversity experience lower levels of poverty. Thus, the poorer farmers might be diversifying into cultivating multiple crops as the wealthier ones diversify their income sources. The analysis, in addition, reveals that farmers holding medium and large scales are less poor than smallholders. This occurrence might lead to income inequality among the farmers and a greater poverty among the rural households with lower income diversity since it has been asserted that nonfarm income sources are more prevalent among the wealthier households in Africa (Djido & Shiferaw,

2018; Asfaw et al., 2019), in this case, it is the coastal and the forest zones respectively, In other words, it is the rural farmers located in both the savannah and forest areas have greater poverty levels than being located in the coastal zones. It is, therefore, obvious that the agro-ecological locations, income and crop diversities exert some distributional effects of the rural farm poverty dispersions. Also, households with access to the national electricity grid infrastructure are likely to have lesser poverty than those without such access.

Moreover, households with male heads experience lower poverty levels than those of their female counterparts, however, this observation is limited to the 2005/6 survey period. Also, the greater the adult equivalent of the household the greater the poverty level of the household. Besides, in general, the impacts of the variables on the poverty indicator significantly vary across the quantiles.

5 Summary and conclusions

This paper primarily investigates how income inequality and poverty differ among rural farmers as a result of inhabiting various agro-ecological zones and what factors are responsible for the differences in their economic welfare. It uses a countrywide representative data on Ghana and various analytical methods to distinguish between the effects of agro-ecological zones, income and crop diversities among other factors on income inequality and poverty levels at the middle from the upper and the lower ends of the distributions of their welfare indicators. On the whole, this study has demonstrated that agro-ecological-based diversities, e.g. income and drop diversities, have some distributional effects on poverty and income inequality among rural farmers. The analyses have shown that the income inequality indices have some relationship with both the income and the crop diversity indices, such that a lower crop diversity index per the zones corresponds with a greater income inequality, and also a lower income diversity implies a higher income inequality. Thus, the paper has provided and empirical evidence that a rise in crop and income diversities could lead to lowering income inequality among rural farmers. In other words, the analyses have established that a rise in both income and crop diversities leads to a reduction in income inequality among the rural farmers, but crop diversity seems to have a greater impact. In general, the evidence provided in this study suggests that as policy-makers target reducing income inequality in rural farm sector by agro-ecological zones, much attention must be paid to disparities in income and crop diversities within and between the zones.

The findings suggest that as rural farm households try to improve their economic welfare by increasingly diversifying their income sources, they end up being poorer and this has been prior confirmed by some other studies. However, contrarily, the analyses have revealed that the farm households with larger crop diversity experience lower levels of poverty, meaning that the poorer farmers might be diversifying into cultivating multiple crops as the wealthier ones diversify their income sources, for instance, farmers dwelling in the savannah and the coastal areas, respectively. In addition, the paper has provided evidence that farmers holding medium- and large-scale farms are less poor than smallholders. This can be attributed to the fact that differences in farm sizes might lead to income inequality among the farmers and therefore, a greater poverty among the rural households with small farms which could be associated with a lower income diversity, since it has been asserted that nonfarm income sources are more prevalent among the wealthier households. We, therefore, find the rural farmers located in both the savannah and forest areas to be in a greater poverty than being located in the coastal zones, and it is obvious that the

agro-ecological locations, income and crop diversities have some effects of the rural farm poverty and income inequality dispersions.

Finally, the findings suggest that intra-zonal disparities are the main sources of income inequality and poverty. The implication is that in order to take more rural farm households out of poverty, a greater attention must be given to reducing inequality within and between the zones. Also, households' access to the national electricity grid infrastructure must be extended to poorer households. The paper recommends that policymakers in an attempt to reduce income inequality in the rural farm sector must pay attention to diversity in the agro-ecological environments, occupational dynamics, gender, accessible infrastructure in addition to changes in the diversities of crops production and income sources adopted by the farm households. The paper proposed tailored poverty alleviation policies for various classes of poverty, from the poorest to the least of the poor in order to cover every sect of rural farm households. Also, it is recommended that crop diversification must be intensified in the poorer rural areas, e.g. the savannah zones, whereas income diversification should be increased in the less poor areas, e.g. the coastal zones for more effective poverty reductions.

Data availability The GLSS 5 and GLSS 6 data can be made available from the Ghana statistical service upon request.

Declarations

Conflict of interest This paper has not been presented nor is it considered for publication anywhere. Also, no interest of conflict has been associated with this manuscript.

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