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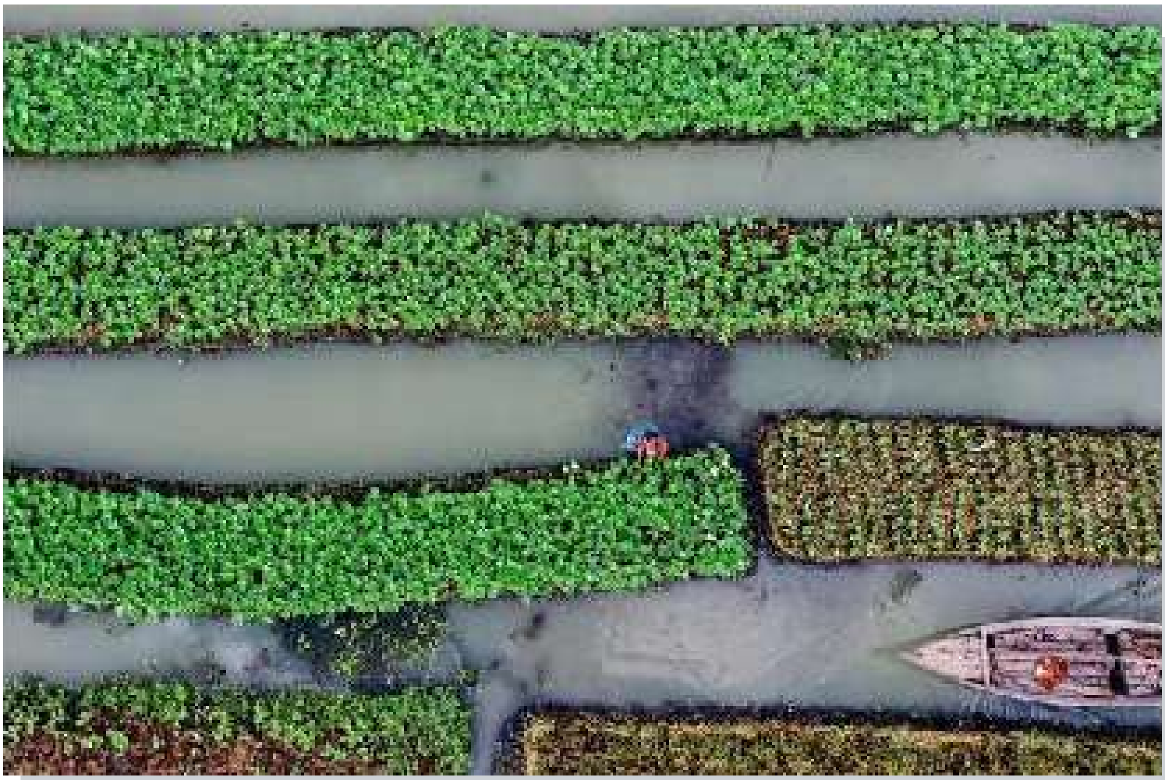

Cover Story

GIAHS (Globally Important Agricultural Heritage Systems): Floating Garden Agricultural Practices.
Site location: Gopalganj, Pirojpur and Barisal, South Center Bangladesh.
Area of GIAHS: 2 500 ha.
The floating garden practice is a local indigenous production system the successful in the wetland/submerged/flooded areas in the selected south and south-western districts of Bangladesh. Floating garden agricultural practices have been adopted by the local farmers for the past two centuries. This technology describes in detail how to construct and manage floating gardens for production of different crops (vegetables and spices).
Allowing the satisfaction of their living needs, floating gardens have also permitted to give an access to lands to the poorest communities. Last but not least, promoting their integration it has also improved the gender balance in these communities. This system is an example of the adaptation to hard climatic conditions but also to climate change.
The landscape with colourful diversified floating gardens has a unique aesthetic view. Dealing with nature and human needs, floating garden are integrated and sustainable in the Bengali landscape. In summer, flowers of water hyacinth bloom on the water. Contrast between light purple of flowers and deep green of leaves creates beautiful scenery.
(https://www.fao.org/giahs/giahsaroundtheworld)

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About the Journal

Agricultural & Rural Studies (**A&R**, **ISSN 2959-9784**) is a quarterly journal to be an international, multi-/inter-disciplinary platform for communicating advances in fundamental and applied studies on contemporary agricultural, rural and farmers' issues and policies, as broadly defined by the disciplines of economics, sociology, human geography and cognate subjects.

A&R is a digital-only, double-blind peer-reviewed, open-access (OA) journal. Article Publishing Charges (APC) are waived in the first four years. The journal publishes various materials – perspective, review, original research, and commentary articles – and it is dedicated to serving as an efficient, professional, and innovative platform for scholars in the field of agricultural and rural studies.

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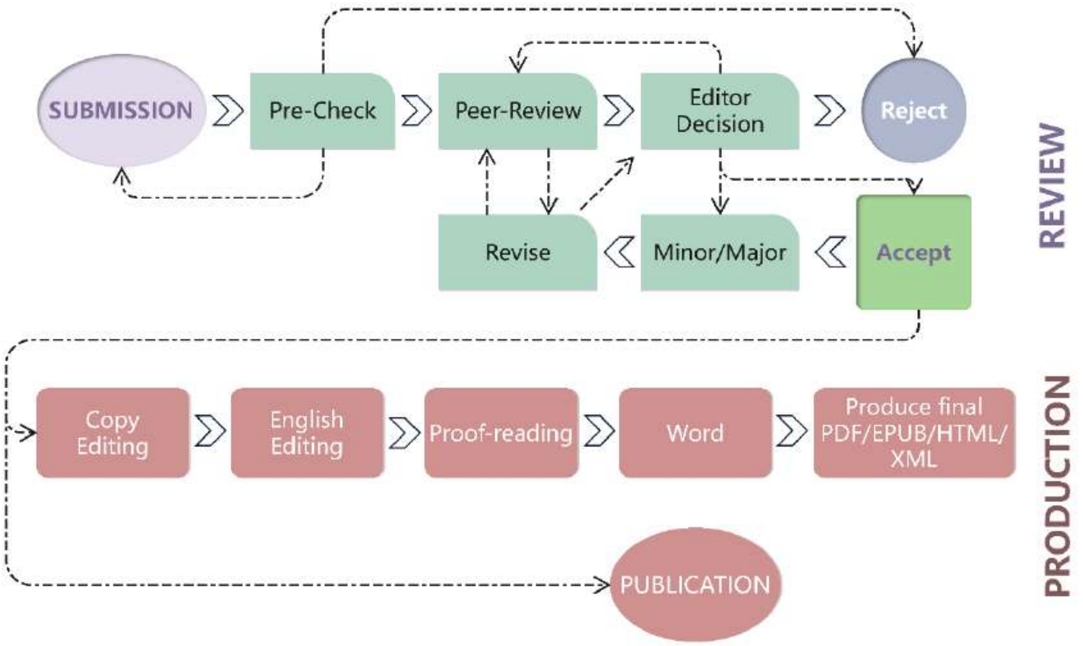

Agricultural & Rural Studies

Article

Role of Farmer Information and Advice Center in Providing Extension Services to Smallholder Farmers: Lessons From Bangladesh

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Abstract: The Farmer Information and Advice Centers (FIACs) are currently working to provide one-stop agricultural advisory services, including climate-friendly agriculture, to farming communities in rural Bangladesh, but their role has yet to be explored. Therefore, the aim of this study is to assess the role of FIACs in providing need-based extension services to the farming communities to create social innovation through transforming smallholders' agriculture into a farm business in rural Bangladesh. This study was conducted in Kishoreganj district, Bangladesh. The data were collected by questionnaire survey, semi-structured interviews, and focus group discussions (FGD). Both quantitative and qualitative (Trajectory Equifinality Model, TEM) analysis was applied based on the data obtained. It was found that the local FIAC approaches give farmers easy access to improved agricultural technologies. It is a needs-based service for farming households to improve their farming practices and livelihoods. Second, their resource use efficiency has increased, and their agriculture has diversified. This has improved institutional access on the ground and farmers feel empowered. So, we can call it social innovation. Third, FIAC interventions help farmers to develop farm business. Finally, farmer characteristics such as gender, farm size, farming experience, household income, and local institutional access are significantly positively related to access to FIAC services. Therefore, our policy implications suggest that FIAC should offer a gender-sensitive service approach. However, farmers faced some difficulties in obtaining services from FIAC, they needed more competent staff and female staff.

Keywords: Farmer Information and Advice Center; agricultural extension services; rural innovation; Bangladesh; farm business development

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1. Introduction

1.1. Background and Rationale of the Study

The majority of the poor live in rural areas worldwide. More than 60% of them live on subsistence farming. Most of them are small farmers and contribute about 80% to the world's food supply (Food and Agriculture Organization of the United Nations [FAO], 2014). Although agricultural productivity increases, it faces greater challenges from the impacts of global climate change (Rahman et al., 2022). In some regions of Bangladesh, farmers are producing more, while at the same time, poverty is increasing (Rana et al., 2022a). In addition, most of farmers (83.38%) are small farmers with farm sizes of less than 2.5 acres (Bangladesh Bureau of Statistics [BBS], 2021) in Bangladesh. Hence, it is very difficult for the farming community to meet the challenges with their limited resources. Thus, to reduce rural poverty, farming must be turned into a profitable business. Therefore, social innovation is necessary to address the issue. Because social innovation is viewed as a new process or product or service that meets social needs and overcomes problems inherent in society through the integration of organizations and the empowerment of local communities in a contextual manner (Moulaert & MacCallum, 2019).

Agricultural development in the rural regions is not possible without paying attention to the development of agriculture as an industry to diversify the rural economy (Kiminami & Kiminami, 2017). Furthermore, innovations are the main drivers for creating opportunities. Market-creating innovations have the power to change the culture of society along with economic growth (Christensen et al., 2019). In this case, agricultural extension services play an important role in the rural and agricultural development paradigm through creating innovations (Biswas et al., 2021). According to Torre et al. (2020) the different agencies also played a vital role in creating social innovation in different dimensions in rural Europe. At present 1621 Farmers' Information and Advice Centers (FIAC) have been established in the different regions of Bangladesh (Agricultural Information Service [AIS], 2022) to provide need based agricultural extension services to the farming communities at the grass-root level to transform subsistence farming into a farm business. However, the role of these FIAC centers in the farm business development of small farmers in view of sustainable rural and agricultural development in Bangladesh has yet to be explored. Therefore, the main purpose of this study is to assess the role of FIACs in creating social innovation through transforming smallholders' agriculture into a farm business towards sustainable agricultural and rural development in Bangladesh.

In the study area, it was empirically analyzed that entrepreneurship and social innovation play a significant role in regional development (Rana et al., 2022a). FIACs are established in rural areas of Bangladesh with the aim of increasing the country's agricultural productivity and improving farmers' livelihoods. The center also provides advice on market information and access to credit, as well as linking farmers to government services and programs. In addition to providing information and advice, FIACs also serve as a platform for farmers to exchange knowledge and ideas with diversified stakeholders (Rahman et al., 2019). Therefore, it is important to examine the role of FIAC in providing need based agricultural extension services to the farming communities and their farm business development. The results of this research will be useful for policy recommendations to support agriculture and rural development in developing regions.

1.2. Research Questions

Based on the regional socioeconomic characteristics of the target region and the literature review, we set the following research question.

What factors influence smallholders' access to FIAC services? How FIAC services strengthen local farm households? How will FIAC strengthen farm entrepreneurship in the haor region of Bangladesh?

2. A Selective Literature Review

Innovations are the main drivers to creat opportunities (Christensen et al., 2019). Agricultural extension services play a crucial role in promoting rural innovation and supporting the development of sustainable agriculture. These services bridge the gap between agricultural research, technology, and rural farmers, helping to disseminate knowledge, provide training, and facilitate the adoption of innovative practices (Van den Ban & Samanta, 2006). Nowadays it has struggled to account for socio-political factors especially rendering of power, place, and people inhibits effective agricultural extension (Cook et al., 2021). In addition, effort to improve agriculture may fail in practice due to constraints beyond farmer's control (Baur, 2021). According to Sarkki et al. (2021) social innovations can tackle various challenges in the rural communities including gender equity. Moreover, innovation in rural areas can come from new forms of collaboration; Policies that leverage rural assets and address critical service or product gaps; novel strategies for accessing financial capital; incorporating arts into aspects of community life; and maintaining networks that connect entrepreneurs, organizations and institutions (French, 2022).

2.1. FIAC Model in Rural Bangladesh

Farmers' Information and Advice Centers (FIAC) are set up at the Union Information and Service Center at the union level (the lowest level of local government and rural administrative unit) in Bangladesh. It is a one-stop agricultural extension service center in the Union Parishad (UP) office buildings in the rural areas of Bangladesh and equipped with necessary logistics support for providing extension services towards farming communities and reading materials such as booklets, technology leaflets etc. (PMU, 2021). The FIACs are established with financial support from the National Agricultural Technology Project (NATP), which is jointly funded by the World Bank, the International Fund for Agricultural Development (IFAD), the United States Agency for International Development (USAID) and the Government of Bangladesh (GoB) (PMU, 2021). The FIACs work in cooperation with the mainstream agricultural extension organizations of Bangladesh such as the Department of Agricultural Extension (DAE), the Department of Livestock Services (DLS) and the Department of Fisheries (DoF) at grassroots level. The representatives of DAE, DLS and DoF are respectively Sub-Assistant Agricultural Officers (SAAOs), Community Extension Agent for Livestock (CEAL) and Local Extension Agent for Fisheries (LEAF). The FIACs provide coordinated services to farming communities related to production, management and marketing of crops, livestock, and fisheries, enhancing a two-way flow of improved knowledge and farming technologies among farm households, extension workers, local NGOs, local governments and other stakeholders. As a result, many people in the rural areas receive one-stop agricultural extension services in the country's rural areas (Rahman et al., 2019) towards livelihood improvement.

2.2. Empirical Studies on Agricultural Extension and Advisory Services

According to Miah et al. (2020) the growth of the agricultural sector in Bangladesh has made a significant contribution to reducing rural poverty but has failed to accelerate the structural change in the development of the time-demand agricultural system. From the comprehensive review, numerous studies have been conducted on different aspects of agricultural extension services. Uddin et al. (2016) conducted a study on crop farmers' willingness to pay for agricultural extension services in Bangladesh. The study revealed that extension and advisory service transfers useful agricultural technologies and provide technical support services to improve the living standards of the farming community. Rivera (2011) conducted a study on public sector agricultural extension system reform and its challenges. The study reported that agricultural extension and advisory services mainly focus on technology dissemination, training and skill development of farmers and raising farm productivity and crop yield. Ragasa and Mazunda (2018) studied the impact of agricultural extension services in the context of a heavily subsidized input system in Malawi. The study found that agricultural extension and advisory services provide technical assistance to farming community to improve their socio-economic condition. Khan et al. (2017) measured the effectiveness of Agricultural Information and Communication Center (AICC) in technology transfer to the farmers in Bangladesh. The study found that more than one third of the respondents (37%) opined that effectiveness of AICC in technology transfer was high while 38% of the farmers perceived the effectiveness as moderate. Farmers' Information and Advice Center (FIAC) is the latest agricultural extension approach taken by the government of Bangladesh to provide demand driven extension and advisory services to rural farmers. Thus, it is crucial to explore the role of FIAC to create rural innovations with the aim of transforming agricultural extension service in Bangladesh.

3. Methodology

3.1. Study Area

This study was conducted in a rural area of Maria Union of Kishoreganj Sadar Upazilla in Kishoreganj District (Figure 1) of Bangladesh. A FIAC center was set up in the study area in 2012.

Figure 1. Map of Bangladesh mentioning the target area of this study.

This area was chosen because Bangladesh's agricultural policy pays special attention to the haor regions (DAE, 2018) and agriculture is the most important livelihood in the region (Rana et al., 2022a). The socio-economic situation of the study area is described in Table 1.

Table 1. Socio-economic situation of study area.

Socio-Economic Parameters	Kishoreganj District	National Average	Source
Population	2,911,907	144,043,700	BBS (2011)
Population percentage live in rural areas	83.20%	76.76%	
Population density/km^2	1,083	1,203	
Household size			
• Total	4.62	4.35	
• Rural	4.63	4.36	
• Urban	4.61	4.29	
Adults' literacy rate (15 years and above)			
• Total	41.18%	53%	
• Male	43.36%	56.8%	
• Female	42.78%	49.2%	
Poverty (Head Count Rate)			BBS (2016)
% of HH below the lower poverty line	34.1%	12.9%	
% of HH below the upper poverty line	53.5%	24.3%	

The residents of the study area have limited access to livelihood opportunities as agriculture is the main source of livelihood. In addition, due to regular flooding from May to October of the year, farming households have less opportunity to cultivate their land (Mohiuddin et al., 2022; Rana et al., 2022a). As a result, the cultivation intensity in the study area (167%) is below the national average (198%) (BBS, 2022). Although national-level poverty has been decreasing over time, it has been increasing in the study area (Figure 2).

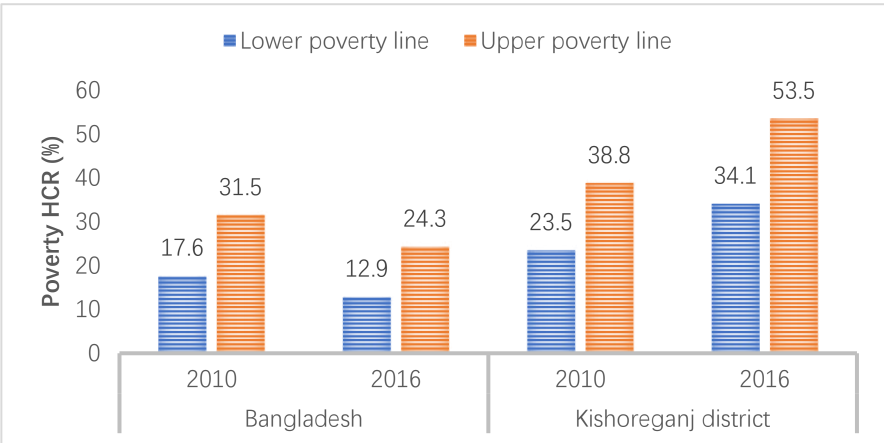

Figure 2. Poverty in study area as compared to national average (Source: BBS 2016).

3.2. Data Collection

Data were collected from the 150 respondents out of 4385 farm families from the study area through face-to-face interview using a pre-tested structured questionnaire from October to December 2022. A focus group discussion (FGD) was conducted with different stakeholders including local agriculture officer, agriculture extension officer, agriculture researchers, farmers, and local leaders, etc. to have a deeper understanding of the issues of this research.

3.3. Variable Settings and Analytical Methods

We set the following variables in our investigation (Table 2) based on literature review and socio-economic situations of farming communities in rural Bangladesh.

Table 2. Variables used in this study.

Variables	Definitions of the Variables in This Study	References
Age	The age of a respondent (years).	Mdoda and Mdiya (2022); Parmar et al. (2018)
Education	Formal year of schooling. But 0.5 score was assigned who can sign only.	Parmar et al. (2018); Mdoda and Mdiya (2022)
Sex	Female (0) and male (1)	
Farm size	Total farm land (Acre).	Parmar et al. (2018)
Farming experience	Duration of engagement in farming activities (years).	Parmar et al (2018)
Annual household income	The annual gross income of the household (thousand Taka).	Khalak et al. (2018); Syiem and Raj (2015)
Social capital	Respondents' social capital was assessed considering their community interaction (bonding social capital) and their connection to different strata of society (linking social capital).	Islam et al. (2011)
Access to the local institutions	It is considered the respondents' contact with different local institutions for receiving technological information and services to improve their livelihood. A four-point rating scale was used.	Mdoda and Mdiya (2022)
Training	The number of days participated in the training programs.	Khalak et al. (2018)
Access to FIAC	It is evaluated by taking into account the level of awareness of the FIAC, the frequency of visits to the FIAC, the services received from the FIAC and the satisfaction with the services provided by the FIAC.	

We introduced mixed method approach to both quantitative and qualitative investigations such as correlation analysis based on the results of structured questionnaire survey of farming families and trajectory equifinality modeling (TEM) analysis (Figure 2) based on case study results to examine the role of FIAC in the transformation of agricultural extension services and farm business development in the rural areas of Bangladesh. We introduced a correlation analysis that can represent the relationship between variables with correlation coefficients to understand the factors that influence access to FIAC services. To perform the correlation analysis, we used SPSS software version 25 (free). In addition, we applied TEM analysis to explain how an individual develops his farm business in society with the support of the FIAC approach.

3.3.1. Trajectory Equifinality Model (TEM)

Trajectory Equifinality Model (TEM) analysis is a qualitative analysis method in social sciences that can represent the variation of individual trajectories with respect to society in irreversible time (Sato et al., 2009; Sato & Valsiner, 2010). The TEM shows the irreversible period with a horizontal axis, but not in a concrete unit, in order to get similar results while following different paths. In this investigation, we analyze based on the analysis model shown in Figure 3.

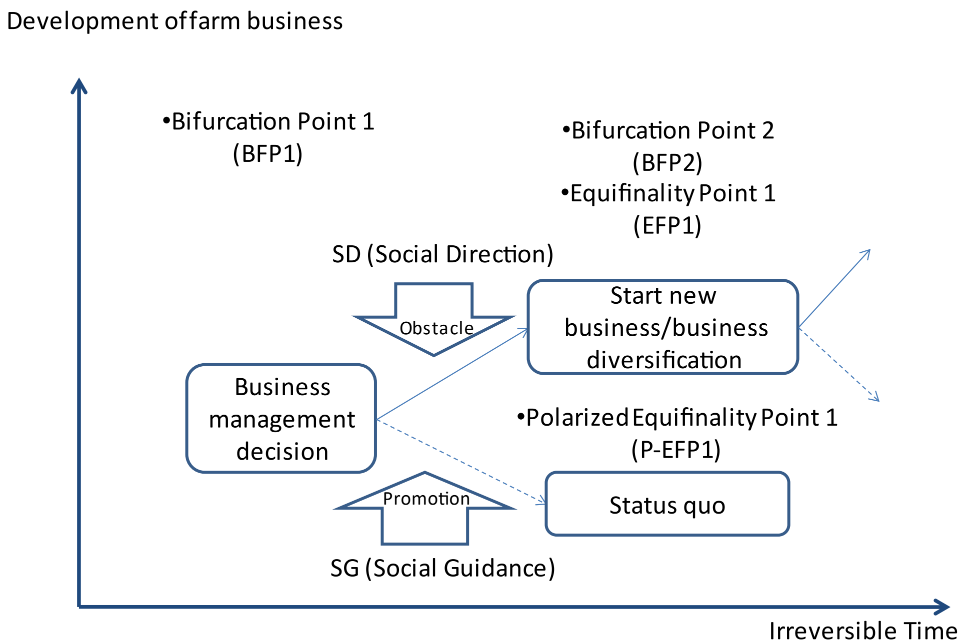

Figure 3. TEM analytical model of farm business development (Source: Based on Kiminami et al. (2020); Rana et al. (2022b).

Here, changes in management decisions that seem to have a significant impact on the development of farm business have been identified as major bifurcation points (BFP). In addition, the socio-economic factors that can influence the management decision, either positively termed as social guidance (SG) or negatively termed social direction (SD), are considered.

4. Results and Discussions

4.1. Major Characteristics of the Respondents

The salient features of the selected respondents' characteristics are presented in Table 3. Without making a detailed classification of the characteristics of the respondents, only mean values and standard deviations were shown to understand the centrality of the characteristics.

Table 3. Salient feature of the selected characteristics of the respondents.

Variables	Measuring Unit	Mean	SD	Min.	Max.
Age	Years	43.00	9.184	25.00	62.00
Education	Years of schooling	6.99	2.756	0.00	10
Sex	Male/female	0.93	0.250	0.00	1
Farm size	Acres	1.25	0.523	0.40	2.50
Farming experience	Years	23.26	9.914	2.00	45.00
Annual household income	Thousands BDT	725.66	293.638	100.00	1500.00
Social capital	Scale score	2.06	0.299	1.00	3.00
Access to the local institutions	Scale score	8.16	1.036	4.00	9.00
Training	Days	2.19	2.263	1.00	28.00
Access to FIACs	Scale score	10.24	0.858	8.00	12.00

4.2. Role of FIAC in Transforming Agricultural Extension Services in Rural Bangladesh

4.2.1. Farmers' Access to the Local Institutions

In Bangladesh, Upazila is the root level of local government and government officials in each section sitting at Upazila level. To serve the large number of farmers, one or two agricultural officials, animal husbandry officials, fisheries officials are not enough. In addition, they have many other public duties to perform besides their own department. It will not work without decentralizing agricultural advisory services to the union level. The establishment of FIAC at the union level has significantly improved farmers' access to local institutions and changed their perception of the services provided by local institutions in relation to farm advisory services. All the respondents mentioned that they visited FIAC in their locality even for a single time. Their frequency of visiting FIAC is shown in Table 4.

Table 4. Frequency of visit to FIAC.

Frequency	No. of Respondents (N)	Percentage (%)
Everyday	3	2.0
Once a week	111	74.0
2–3 times per month	16	10.7
Once a month	20	13.3
Not at all	0	0.0
Total	150	100

Source: Authors field survey 2022

4.2.2. Technology Adoption Through FIAC and Agricultural Diversification

The farmers participated in the technology demonstrations at the farmer's field level and in training programs organized by the local agricultural offices in cooperation with the FIACs. They received the technological information on the crop, livestock, and fisheries sectors (Table 5) from FIAC.

Table 5. Technology adoption of farmers through FIAC.

Areas of Technological Information Adopted	No. of Respondents (N)	Percentage (%)
Crops	3	2.0
Crops and Livestock	10	6.7
Crops, Livestock, and Fisheries	120	80.0
Crops and Fisheries	11	7.3
Livestock and Fisheries	6	4.0
Total	150	100

Source: Authors field survey 2022

As a result, farmers are receiving technical advice on how to diversify their farming practices. The traditional agricultural practice of the area is the cultivation of rice, but high value crops such as vegetables are now grown. In this way, the cropping intensity, and the use of resources (land and labor) become more efficient. This is supported by the agricultural production and agricultural diversification at the national level data (Table 6).

Table 6. Crop production and growth of Bangladesh.

Crop	Production (LMT)		Growth (%)
	FY 2008–09	FY 2020–21	
Rice	313.17	386.08	23
Wheat	8.49	12.34	45
Maize	7.3	56.63	775
Potato	52.68	106.13	101
Pulses	1.96	9.39	375
Oil seeds	6.61	11.99	81
Vegetables	29.09	197.19	578

Data source: Agricultural Information Service (AIS, 2022)

4.2.3. Factors Affecting Access to the FAICs

Among the selected farmer characteristics, gender (0.296**), farm size (0.329**), farming experience (0.181*), household income (0.375**) and local institutional access (0.204*) are significantly positively related to access to FIACs' services (Table 7). Female farmers face restrictions in accessing the FIACs due to local socio-cultural barriers. The larger farm size and agricultural experience are the influencing factors to gain access to the FIACs. This is due to their ability to innovate in farming practices. Local institutional access increases farmers' acceptance of technological services provided by FIACs, and FIACs also in turn increase farmers' local institutional access.

Table 7. Results of correlation modeling.

Dependent Variable	Independent Variables (Selected Characteristics)	Correlation Coefficient (r)
Access to the services of FIACs	Age	0.148
	Gender	0.296**
	Education	−0.104
	Farm size	0.329**
	Farming experience	0.181*
	Annual household income	0.375**
	Social capital	0.145
	Local institutional access	0.204*

Notes: ** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

4.2.4. Collective Empowerment of Farming Community Through FIAC

The collective empowerment of communities is an important dimension of social innovation (Moulaert & MacCallum, 2019). The FIAC approach equips farmers with updated technical knowledge and technologies as FIAC is an easily accessible rural grass-roots institution. Farmers are satisfied with FIAC's services to a remarkable level (Table 8). They get services from FIACs at free of cost. The majority of respondents said they were willing to pay for FIACs' services even if they had to pay. However, some of them point out that FIACs need to appoint more staff, especially female staff, to deliver services.

Table 8. Satisfaction of farmers to the services of FIAC.

Level of Satisfaction	No. of Respondents (N)	Percentage
Highly satisfied	91	60.7%
Satisfied	58	38.7%
Neutral	1	0.7%
Dissatisfied	0	0.0%
Highly dissatisfied	0	0.0%
Total	150	100%

Source: Authors field survey 2022

One of the respondents commented on the impact of the services provided by FIAC. He said:

"Having set up FIAC in our village, I can easily contact professional advisors for technical advice on how to improve farming practices. I attended several training programs and technology demonstration meetings organized by FIAC. Now I can advise my neighboring farmers on advanced farming practices if needed. I also feel honored and empowered."

In the following section, we will share the results of a case study using Trajectory Equifinality Modeling (TEM) analysis on how FIAC improves the development of an integrated agricultural business model in the study area.

4.3. Case Study Result of Mr. DM (Development of Integrated Farming Business Model)

The case of Mr. DM was chosen for this study because he developed an agricultural model of an integrated farming system in his area (Figure 4). He has transformed the traditional rice farming system into diversified crop farming along with livestock and fish farming, and through his innovative business model has improved local employment opportunities and food security in the region.

Mr. DM is a farmer from a poor farming family who lives in the Maria Union of Kishoreganj Sadar Upazila (sub-district) under the Kishoreganj district of Bangladesh. He is sixty years old and has no institutional education (SD1). He has been engaged with family farming since his childhood (BFP1). Now, he had 70 decimals of land of his own. However, he found that small-scale rice farming was hard to win in the competition for survival. Incidentally, Bangladesh Agricultural Development Corporation (BADC) has started demonstrations in this area to promote potato cultivation as it is a suitable crop for this area. Farmers receive training and demonstrations on potato cultivation from BADC (SG1) and he has participated in potato cultivation (BFP2). As a result, farmers are learning how to move out of traditional rice paddy farming (monoculture year-round). In 2012, FIAC was established in the study area with the support of NATP project. The FIAC provides technological services to local farmers in the crop, livestock, and fisheries sub-sectors. Mr. DM was trained by FIAC in vegetables.

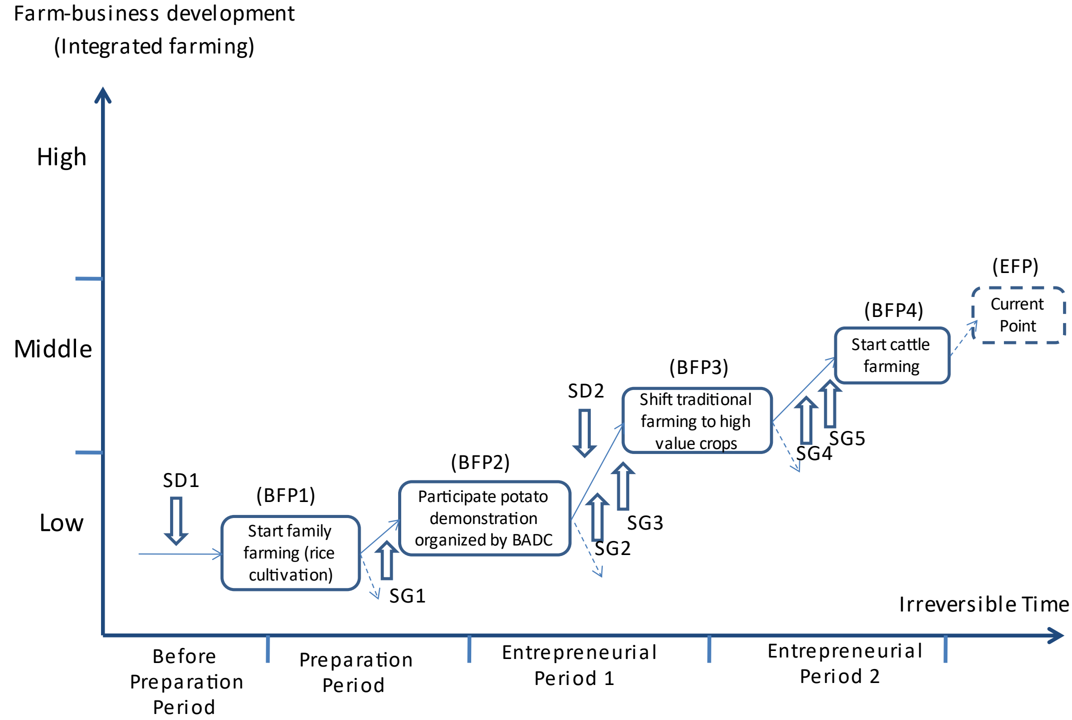

Figure 4. TEM analytical results of Mr. DM.

growing (SG2) and started growing various vegetables such as brinjal, beans, cucumbers, spinach and squashes, etc. (BFP3). With the help of FIAC, many farmers have switched their traditional rice cultivation to high-quality vegetable cultivation. As a result, farming households generate more income from growing vegetables than from growing rice. The inputs required for growing vegetables such as seeds, fertilizers, pesticides, etc. will be available in the area by then (SG3). He got a substantial amount of animal feed i.e. grass as a by-product from vegetable fields (SG4). Then he started cattle farming (BFP4) to diversify his farming model and increase income with the technical support of FIAC's (SG5) Community Extension Agent for Livestock (CEAL). Now its integrated farming model acts as a role model in the area (EFP).

The summary of the TEM analysis of the case is as follows. First, the FIAC approach gave Mr. DM more access to local institutions, which helped him develop the integrated farming model with the technological assistance from the FIAC center. Second, self-motivation and social capital are also important for the development of his integrated farming model. In order to develop a successful entrepreneurial model, coordinated measures are required (Santos & Neumeyer, 2021). Mr. DM receives training from local institutions and through this has developed his bonding and linking social capital with various stakeholders. According to Putnam (1993), trusts, norms and networks improve the efficiency of society in terms of social capital. He produced a variety of agricultural products for the local market. FIAC also helped him gain access to the local market value chain.

5. Conclusion and Policy Recommendation

Based on the analysis results, we made the following conclusions. First, local farmers have better access to improved knowledge and technology due to interventions of Farmer Information and Advice Center (FIAC). It is a need-satisfying service for the rural farming households to improve their farming practices as well as their livelihoods. Second, their resource use efficiency will be increased, especially land and labor with diversification of agricultural farming. It has improved institutional access locally and farmers feel empowered. So, we can call it social innovation. Third, farmers socio-economic attributes such as gender, farm size, farming experience, household income and local institutional access have a significant positive association with the access to FIAC services. Finally, the supports of FIAC help farmers to develop successful farm business enterprise. Therefore, our policy implications suggest that FIAC should support the formation and strengthening of farmer groups and cooperatives to enable collective action for better bargaining power, resource sharing and access to markets. Advisory services can be provided to organized groups more efficiently, promoting a multiplier effect. However, farmers experienced some difficulties in obtaining services from FIAC, particularly a lack of competent staff, including female employees. In addition, a gender-sensitive service should be provided to support women farmers to integrate into mainstream agriculture. Therefore, clear coordination mechanisms should be established between relevant government departments, NGOs, research institutions and private sector stakeholders to improve agricultural extension services and ultimately promote rural development by improving farmers' knowledge, productivity and income. FIAC can play an important role in this regard at the grassroots level. However, to generalize the results, similar studies should be conducted for other geographical regions in Bangladesh where the FIAC activities are carried out. This will be our future research agenda.

CRediT Author Statement: Sohel Rana: Conceptualization, Methodology and Writing – original draft; **Md Abdul Halim:** Conceptualization, Methodology and Writing – original draft; **Muhammad Mohiuddin:** Data collection, Visualization and Investigation; **Md. Shajidur Rahman:** Writing – review & editing; **Md Masud Rana:** Writing – review & editing.

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Agricultural & Rural Studies

Article

Effects of Government Price Policies on Major Agricultural Commodities in Andhra Pradesh, India

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Abstract: This study was concerned with analysis of export competitiveness and quantification of impact of price policies in Andhra Pradesh, using Policy Analysis Matrix and Partial Equilibrium Model in the Marshallian economic surplus framework. The findings from Policy Analysis Matrix revealed that, on the input side, the farmers are more subsidized for rice and maize, as Nominal Protection coefficient on Tradable Inputs are less than one across all the major importing countries (unlike for chickpea, cotton lint and chilies (dry)). On the output side (Nominal Protection coefficient on Tradable output), the farmers producing rice, maize and chilies (dry) are more protective compared to social prices. Considering both input and output policies together, the farmers are simultaneously protective (Effective Protection Coefficient) for rice and maize and hence, the overall transfer from society to farmers is positive (Subsidy Ratio to Producers). The findings from Partial Equilibrium Model showed that total net social loss was found to be positive implying protectionism favored the farmers across all the selected commodities. Further, the net social loss in production turned out to be positive confirming the main postulate of this study, a price greater than the equilibrium price will reduce the quantity demanded. The protectionist policies further led to a positive effect of trade liberalization on the welfare in the State and an increase in foreign exchange earnings, except for chickpea. Unlike farmers, consumers in Andhra Pradesh suffered welfare loss due to higher domestic prices over border prices for rice, maize and chilies (dry).

Keywords: price policies; protectionism; nominal protection coefficient on tradable output; welfare gains or loss; net social loss; trade liberalization; Andhra Pradesh

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1. Introduction

India is one of the major players in the agriculture sector world-wide and it is the primary source of livelihood for about 58 percent of its population. However, this sector's contribution to Government revenue is minimal, despite it enjoys net exporter status and contributes considerable foreign exchange. In 2020–21, the net agricultural exports from India accounted for Rs 1.54 lakh crore and the percent share of agricultural exports to national exports was 14.30 and these two parameters showed increasing trend since past one decade. Though the country experienced both weather-related challenges (drought, floods, etc.) and COVID-19 pandemic, still the agriculture sector showed resilience against these shocks, as it grew at 3.6 per cent in 2020–21 and improved to 3.9 per cent during 2021–22.

Andhra Pradesh is one of the top performing States in India in terms of consistency. The State is extending several landmark decisions for the welfare of farming community such as interest free loans, free crop insurance scheme, free electric power during daytime for crop cultivation, subsidized inputs, testing of Agri-inputs, direct money transfer, etc., so as to continue them in farm business. The valuation of agriculture exports from the State is around the 0.16 lakh crore and it accounts for 16.65 percent of total exports during 2020–21 (Statistical Abstract, 2021). Based on global export trends and considering agricultural exports as one of the engines for economic growth, the Government sees agricultural exports as the priority area for economic development of the State.

The trade liberalization offered several opportunities and challenges to the farmers and other stakeholders in the supply chain of agricultural commodities to ensure export competitiveness. Rice, maize, chickpea, cotton and chilies (dry) are the major food grains and commercial crops cultivated in Andhra Pradesh. These commodities should compete with the major importing countries, provided they are cost-effective, high quality, different from competing products, acceptable to consumers at affordable prices. The provision of input and output subsidies by the importing countries definitely contributes to their export competitiveness. So, in analyzing the competitiveness of commodities, it helps to ascertain whether their comparative advantage in the markets also has a competitive advantage. It also helps to identify incentive policy choices to further enhance the comparative advantage so as to become a competitive exporter of the selected commodities in the outside markets. Further, the Government's active participation in production, marketing and price policies in agriculture will certainly influence the welfare gains or losses to the farmers, consumers and also exert an influence on the Government revenue. In India, though agriculture is a state subject, agricultural policy is formulated at the national level and state formulates its policy accordingly. The agricultural policy starts from announcing Minimum Support Prices (MSP) for supporting production, procuring output and distributing the same to the public at issue prices. These price interventions are assumed to generate Government revenue, lead to internal price stability and supply of commodities at affordable prices to the population Below Poverty Line (BPL). From input side, the Government intervenes through subsidizing prices, crop insurance programs, liberal credit at low rates of interest, power and irrigation water subsidies etc., to make the farmers continue production. These price distortions are often followed as protectionist policies by the Government; but they exert considerable influences on welfare of farmers, consumers and Government. The body of literature highlights that the more the degree of protectionism, the more volatility in prices in the international market (Johnson, 1975; Johnson, 1950; Shei & Thompson, 1977). So, these protectionist policies frequently change suiting to international market environment and this requires quantification of their effects on the production and consumption of major agricultural commodities in Andhra Pradesh. Even the welfare and distribution effects of the consumers at the expense of farmers also should be addressed. In this context, this study analyzes the export competitiveness of selected commodities and impact of price policies of the State on welfare gains and losses for farmers, consumers and Government revenue.

2. Review of Literature

According to Ogbe et al. (2011), the findings from Policy Analysis Matrix (PAM) revealed that outputs are taxed for production of rice and maize in Nigeria. Both Effective Protection Coefficient (EPC) and Subsidy Ratio to Producers (SRP) confirmed that production of these two commodities is subsidized on the use of tradable inputs. This contributed towards higher competitiveness at the farm level (under irrigated rice, upland rice and upland maize) and a strong comparative advantage. PAM is used to analyze the impact of intensifying rice production systems in Southeastern Nigeria (Ugochukwu & Ezedinma, 2011) and profitability of rice farming in India (Kanaka et al., 2015). Souza et al. (2017) combine primary data from representative companies and secondary data to make economic and accounting evaluations of the rice production chain in Rio Grande do Sul (Brazil) and Uruguay. Soejono et al. (2020) analyzed the comparative and competitive advantages of Pronojiwo snake fruit using PAM. The results showed that Pronojiwo snake fruit farming has comparative and competitive advantages or strong competitiveness. So, the strategies to promote export competitiveness of Pronojiwo snake fruit are to maintain product quality and promote effective means of transportation. The study from Adesiyan et al. (2018) showed that yam, rice and cassava production generate a positive private and social profits with the highest in cassava and lowest in yam production. Similarly, government interventions have had a negative effect of about 20, 75 and 17 percent on prices of yam, rice and cassava, respectively below their world prices. This study concludes that the food production system is competitive and therefore profitable under the prevailing policy framework in Nigeria if value is added.

Raghavendra analyzed the price distortion effects on major crops viz., rice, maize and red gram in Karnataka through employing Partial equilibrium Model (PEM). The consequences of price distortion had positively influenced the welfare gains for producers, unlike consumers. The net effect of trade liberalization on the State was positive with respect to all the selected commodities. Reddy et al. (2005) studied the effects of price distortions on rice in Karnataka in the context of free trade. They concluded that loss to society due to free trade was Rs. 5,800 million and due to inefficient production from a price rise was Rs. 4,200 million. As rice is export competitive during the post-liberalization period (2001–02), there is increase in domestic production of rice by 0.453 million tonnes. Consequently, there is decline in rice consumption by 0.799 million tonnes. Rajesh et al. (2006) conducted cointegration tests and spatial integration of Indian major pepper and cardamom markets during pre- and post-liberalization era by using maximum likelihood method of cointegration. The results suggested that liberalization has improved the transmission of price signals of pepper both in domestic and international markets. On the contrary, the cardamom price is poorly integrated with the international prices, indicating its non-decisive role in influencing the trade at international level. Usharani (2008) concluded that the loss for consumers of rice due to liberalization was Rs. 267.1 million and for maize, it was Rs. 43.6 million. The welfare gains to producers were higher for cotton at 365.42 percent (Rs. 168380.7 million) of total value of production, from maize it was at 77.76 percent (Rs. 9646.5 million), for rice 45.82 percent (Rs. 60276.4 million) and for groundnut it was 23 percent (Rs. 54526.1 million). Fathelrahman et al. (2021) studied the impact of food trade liberalization in India, Egypt, Pakistan, Saudi Arabia, and the United Arab Emirates (UAE) using the PEM-World Integrated Trade Solution (WITS). The simulation results showed that welfare gains for consumers are higher for India, Egypt, and Pakistan with 2571, 340, and 25 million USD, respectively compared to Saudi Arabia and the UAE with 14 and 17 million USD. These findings reflected that with a reduction in tariffs, there are considerable welfare impacts for consumers across the selected countries.

3. Materials and Methods

3.1. Policy Analysis Matrix (PAM)

This technique was employed to measure divergences between private and social valuations of revenues, costs, and profits during TE 2020–21. In this study, the inputs for production of selected commodities were disintegrated into tradable inputs and non-tradable inputs. For this study, tradable inputs include - seeds, fertilizers (nitrogen, phosphate and potash), plant protection chemicals, and depreciation on machinery were considered, while non-tradable inputs include - human labor, bullock labor, machine labor, irrigation, farmyard manure, imputed rental value of land. In this study, the social price is computed based on the importable hypothesis.

Table 1. Illustrative PAM.

Year	Revenues	Costs		Profit
		Tradable inputs	Non-tradable inputs (Domestic factors)	
Private prices	A = $p_i^p q_i^p$	B = $\sum a_j p_j^p q_j^p$	C = $\sum b_k p_k^p q_k^p$	D = A–B–C = π^p
Social prices	E = $p_i^s q_i^s$	F = $\sum a_j p_j^s q_j^s$	G = $\sum b_k p_k^s q_k^s$	H = E–F–G = π^s
Divergences	I = A – E	J = B – F	K = C – G	L = D – H = I – J – K

Source: (Monke & Pearson, 1989).

In the above table, A = private revenue, B = tradable input cost (*e.g.,* fertilizer, herbicides, pesticides, seeds, and so on), C = domestic factor cost such as land, labor, capital, *etc*., D = private profit, E, F, G and H are social values of A, B, C and D respectively. The divergences denoted by letters I, J, K and L were explained in the ensuing pages. Quantities of inputs and outputs with their respective unit prices, exchange rate, Free on Board (FOB), tariff, transport costs *etc*. were inputted into PAM software, which produced the PAM results. Others are p_i^p = price of output in private prices, q_i^p = quantity of output in private prices, a_j = tradable input coefficients, p_j^p = price of tradable input in private prices, q_j^p = quantity of tradable input in private prices, b_k = domestic input coefficients, p_k^p = price of domestic input in private prices, q_k^p = quantity of domestic input in private prices, π^p = private profit, p_i^s = output price in social prices, q_i^s = quantity of output in social prices, p_j^s = tradable input price in social prices, q_j^s = quantity of tradable input in social prices, p_k^s = domestic input price in social prices, q_k^s = quantity of domestic input in social prices, π^s = social profit. These quantities in the PAM are used to compute the following measures of protection incentives that cast light on export competitiveness and how these are affected by Government policies:

Nominal Protection Coefficient on Tradable Inputs (NPCI) = B/F
Nominal Protection Coefficient on Tradable Outputs (NPCO) = A/E
Effective Protection Coefficient (EPC) = (A-B)/(E-F)
Subsidy Ratio to Producers (SRP) = L/E

For selected commodities, five competing countries (export competitiveness) based on leading imports from India were identified (Table 2) and the divergence was studied from the perspective of Andhra Pradesh.

Table 2. Selected competing countries for measuring divergence of exports from Andhra Pradesh (TE 2020-21).

Commodities	Major importing countries
Rice	Saudi Arabia, Iran, Benin, Nepal, Iraq
Maize	Bangladesh, Nepal, Vietnam, Bhutan, Malaysia
Chickpea	Algeria, UAE, Bangladesh, Nepal, Sri Lanka
Cotton	Bangladesh, China, Indonesia, Iran, Italy
Chilies (dry)	Chinese mainland, Bangladesh, Thailand, Sri Lanka, USA

The secondary data required for construction of PAM are crop yields, output, inputs used and their market prices, and output (domestic and export) prices. The data are collected from the Reports of Commission for Agricultural Costs and Prices (CACP), Cost of Cultivation Scheme of Commission for Agricultural Costs and Prices, Government of India; Directorates of Agriculture of selected States, www.indiastat.com, www.fao.org, etc. for the period 2017–18, 2018–19 and 2020–21 i.e., TE 2020–21. The domestic prices are obtained from the Agmarknet Portal, Agricultural Marketing Board, Government of India.

The social costs have been calculated using Value Marginal Product approach considering factor share (S_i) of inputs (X_i), mean values of inputs and outputs (Y) and prices (P_i) given by:

$$P_{Xi} = [(S_i / X_i)^* \mathrm{Y}]^* P_y$$

$$= \frac{X_i}{(\sum P_i X_i / n)} * \frac{Y}{X_i} * P_y X_i$$

3.2. Partial Equilibrium Model (PEM)

The welfare gains or losses both to producers and consumers are estimated using the PEM (Lutz & Scandizzo, 1980). It is known that protectionist policies of the Government show an impact on incomes of producers, consumers and Government revenues in the context of trade liberalization. In this context, PEM was employed to ascertain the welfare gains or losses to the producers, consumers and change in Government revenue. In Figure 1, supply and demand functions are drawn. It is assumed that due to price distortions, the border price (adjusted for transaction costs, OPb) is higher than domestic price, OPd. It is further assumed that OPd = consumer price (OPc). The difference between OPd and OPb i.e., PdPb represents the tax imposed on the imported commodity. Following this representation, we arrive at different formulae as given below.

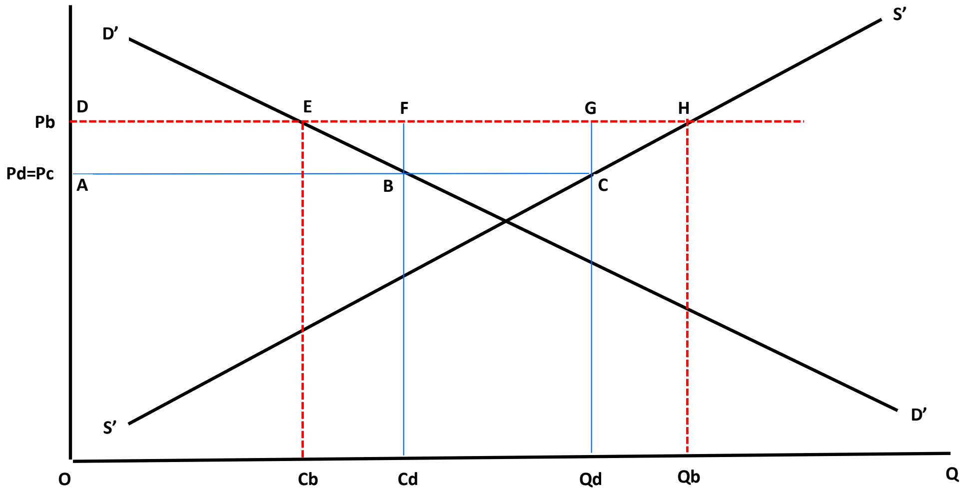

Figure 1. Partial equilibrium theory of trade (government price policy effects).

- Net Social (Economic) Loss in production (NSLp) = 1/2(Qb–Qd) (Pb–Pd) = CHG
- Net Social (Economic) Loss in Consumption (NSLc) = 1/2(Cb–Cd)(Pb–Pc) = BFE
- Total Net Social Loss (NSL) = NSLp – NSLc = CHG + BFE
- Welfare (Loss or) Gain of producers or farmers (WL/Gp) = Qd(Pd-Pb) – NSLp = ACHD (Loss)
- Welfare (Loss or) Gain of consumers (WL/Gc) =Cd(Pb-Pc) – NSLc = ABED
- Change in Government revenue (ΔG) = (NSLp + NSLc) – WGp – WGc = BCGF
- Change in Foreign Exchange Earnings (ΔFEE) = Pb(Qb-Qd+Cd-cb) = CbCFE & QdQbHG (Losses)
- Net effect of liberalization on welfare in the State = Qd(Pd-Pb) – Qd(Pb-Pc)
  where,

Qb = Quantity of production at border prices
Qd = Quantity of production at domestic prices
Pb = Border prices (adjusted for transaction costs)
Pd = Domestic market price
Pc = (Retail) price for consumers in the domestic market
Cb = Quantity of consumption at border prices
Cd = Quantity of consumption at domestic prices

For analysis, the demand and supply elasticities are assumed based on the past studies of Aayog (2018), Reddy (1997), and Lutz & Scandizzo (1980).To arrive at production values, Minimum Support Prices (MSPs) or wholesale market prices (chilies (dry) of selected commodities are considered, while for consumption values, retail prices were used. The border prices of selected commodities are derived from respective international prices after adjusting the transaction costs. The changes in quantities produced and consumed resulting from changes of domestic prices to their respective border price equivalents are calculated as follows:

$\Delta Q_i = nS_i * (\Delta P_i/P_i)*Q_i$
$\Delta C_i = nD_i * (\Delta P_i/P_i)*C_i$

where,

$\Delta Q_i = (Q_{ib} - Q_{id})$ = Change in quantity of commodity ‘i’ produced
$\Delta C_i = (C_{id} - C_{ib})$ = Change in quantity of commodity ‘i’ consumed
$\Delta P_i = (P_{ib} - C_{id})$ = Change in price of commodity ‘i’
ηS_i = own price elasticity of supply for commodity ‘i’
ηD_i = own price elasticity of demand for commodity ‘i’

The active intervention in the form of price policies by the Government in production, marketing and consumption of the above commodities is pervasive. Further, the level and nature of intervention vary across these crops, and this helps to evaluate their appropriateness in achieving policy goals. Accordingly, the concept of economic surplus was used in estimating the production and consumption effects, efficiency effects, welfare and distribution effects resulting from Government's policies with respect to selected crops. This helps to discuss the relevance of the findings to the formulated policies and thus, enable to design improved policy in the ensuing future.

4. Results and Discussion

4.1. Measures of Protection Incentives

4.1.1. Nominal Protection Coefficient on Tradable Inputs (NPCI)

The NPCI is less than one with respect to all the selected countries for rice (0.33) and maize (0.68) implying that the farmers are more subsidized or less taxed in Andhra Pradesh (Table 3). That is, both rice and maize farmers in Andhra Pradesh pay for tradable inputs lower than they should in a perfectly competitive market when compared to selected countries. However, NPCI is more than one with respect to all the selected countries for chickpea (5.19), cotton lint (3.17) and chillies (dry) (2.82) inferring that the farmers of above three crops are less subsidized or more taxed in Andhra Pradesh and hence, they pay for tradable inputs higher than they should in a perfectly competitive market when compared to respective competing countries. These findings are in agreement with the works of Adesiyan et al. (2018), Ahmed (2016), and Soejono et al. (2020).

Table 3. Measures of protection incentives of selected commodities from Andhra Pradesh across major importing countries (TE 2020–21).

Indicators	Rice					Maize					Chickpea				
	Andhra Pradesh & Saudi Arabia	Andhra Pradesh & Iran	Andhra Pradesh & Benin	Andhra Pradesh & Nepal	Andhra Pradesh & Iraq	Andhra Pradesh & Bangladesh	Andhra Pradesh & Nepal	Andhra Pradesh & Vietnam	Andhra Pradesh & Bhutan	Andhra Pradesh & Malaysia	Andhra Pradesh & Algeria	Andhra Pradesh & UAE	Andhra Pradesh & Bangladesh	Andhra Pradesh & Nepal	Andhra Pradesh & Sri Lanka
NPCI	0.33	0.33	0.33	0.33	0.33	0.68	0.68	0.68	0.68	0.68	5.19	5.19	5.19	5.19	5.19
NPCO	1.00	1.08	1.14	1.12	1.18	1.34	1.28	1.21	1.03	1.19	0.70	0.89	0.90	0.98	0.73
EPC	1.09	1.19	1.26	1.24	1.33	1.51	1.43	1.33	1.09	1.30	0.57	0.74	0.75	0.82	0.61
SRP	0.43	0.54	0.62	0.60	0.69	0.66	0.59	0.50	0.27	0.47	−0.70	−0.62	−0.62	−0.58	−0.69

Table 3. *Cont.*

Indicators	Cotton Lint					Chillies (Dry)				
	Andhra Pradesh & Bangladesh	Andhra Pradesh & China	Andhra Pradesh & Indonesia	Andhra Pradesh & Iran	Andhra Pradesh & Italy	Andhra Pradesh & Chinese mainland	Andhra Pradesh & Bangladesh	Andhra Pradesh & Thailand	Andhra Pradesh & Sri Lanka	Andhra Pradesh & USA
NPCI	3.17	3.17	3.17	3.17	3.17	2.82	2.82	2.82	2.82	2.82
NPCO	0.97	1.01	1.05	0.95	0.91	1.10	1.20	1.06	0.94	1.06
EPC	0.89	0.92	0.97	0.87	0.84	0.86	0.95	0.82	0.72	0.82
SRP	−0.31	−0.29	−0.26	−0.33	−0.35	−0.38	−0.33	−0.41	−0.48	−0.41

4.1.2. Nominal Protection Coefficient on Tradable Outputs (NPCO)

NPCO for Andhra Pradesh is ≥ 1.00 with respect to all the selected countries for rice, maize, chilies (dry) and cotton (China and Indonesia only), implying that the price policies offered by the Government of Andhra Pradesh are more protective to the above farmers thereby, they receive a higher price compared to social (shadow) price(s) (Table 3). For example, with respect to Iraq (1.18), the Government policy in Andhra Pradesh is able to maintain the price of rice at a rate of 18 percent higher than social (shadow) price. This shows that farmers in Andhra Pradesh get 18 percent higher profit than social price of Iraq. However, with respect to chickpeas for all the selected countries and cotton lint (Bangladesh, Iran and Italy), NPCO is <1.00, indicating that the price policies of Andhra Pradesh are less protective to these farmers. For example, with respect to Bangladesh (0.97), the Government policy in Andhra Pradesh is able to maintain the price of cotton lint at a rate of 3 percent lower than social (shadow) price. This indicates that the farmers in Andhra Pradesh get 3 per cent less profit than social price of Bangladesh.

4.1.3. Effective Protection Coefficient (EPC)

EPC is ≥ 1.00 across all the selected countries for rice and maize indicating that the policies in Andhra Pradesh are simultaneously protective (input and output side policies together) in the production of above two commodities (Table 3). For example, with respect to Iraq (1.33), the combination of input and output policies is more effective in protecting rice production in Andhra Pradesh, as the farmers derive 33 percent higher profits over social prices. However, for chickpeas, cotton lint and chillies (dry), EPC < 1.00 thereby, farmers are simultaneously less protective in terms of input and output side policies together. This also indicates that the farmers are more taxed. The empirical findings of NPCI, NPCO and EPC showed interesting resemblance with previous studies of Amao et al. (2015); Poernomo (2018); Saptana et al. (2022).

4.1.4. Subsidy Ratio to Producers (SRP)x

The SRP is positive for Andhra Pradesh with respect to all the selected countries for rice and maize. This indicates the overall transfer from society to farmers (Table 3). However, for chickpeas, cotton lint and chilies (dry), the SRP is negative indicating that these farmers are more taxed in their production and hence, there is decrease in gross revenue.

4.2. Impact of Price Policies of the Government

4.2.1. Welfare Gains or Losses to Producers and Consumers

The empirical estimates (Tables 4 – 6) are based on the supply and demand elasticities and on average NPCOs computed earlier. Unfortunately, estimates of the price elasticities of supply and demand for the selected commodities viz., rice, maize, chickpea, cotton and chillies (dry) are not readily available for Andhra Pradesh. Also, these elasticities could not be calculated because of data limitations. Therefore, assumptions about the potential ranges of these basic parameters were made by examining the substantial empirical evidence that is available for other States in India and developing countries. Furthermore, low and high ranges of the elasticities are used because of the wide variation in existing elasticities estimates in the available literature. Supply elasticities estimates for selected commodities range between 0.23 to 0.95 and demand price elasticities range between − 0.45 to − 0.70 (Aayog, 2018; Reddy, 1997; Lutz & Scandizzo, 1980) .Thus, these low and high ranges of supply and demand elasticities were adopted for the selected commodities in this study. The NPCO (average) estimates for the selected commodities are obtained from PAM calculated earlier under Section 4.1.

The net monetary effects (Table 4) revealed that the loss to society due to liberalization during TE 2020–21 in terms of consumption of rice was Rs. 4258.9 lakh (higher compared to 2004–05); for maize it was Rs. 394.7 lakh (lesser compared to 2004–05), Rs. 4.5 lakh for chickpeas and Rs. 657.1 lakh for chilies (dry). The loss to society due to inefficiency in production was Rs. 3774.9 from rice (lesser compared to 2004–05); Rs. 497 lakh from maize (lesser compared to 2004–05); Rs. 505.1 lakh from chickpeas; Rs. 11.5 lakh from cotton and Rs. 357.1 from chilies (dry). From the findings it is clear that the NSLP is highest for rice and least for cotton. Similarly, NSLC is highest for rice (Rs. 4258.9 lakh). The net social losses in production and consumption critically depend on production and elasticities. Regarding Total NSL, it was highest from rice (Rs. 8033.7 lakh) followed by chilies (dry) (Rs. 1014.3 lakh), maize (Rs. 891.7 lakh) and chickpeas (Rs. 509.6 lakh). So, distortion in domestic prices resulted in a change in revenue to producers and consumers. It is interesting that welfare gains for rice, maize and chilies (dry) producers are much higher than their respective Total NSL.

Table 4. Net monetary effects of price distortions in selected crops of Andhra Pradesh (TE 2020-21) (Rs. Lakh).

Crop	NPCO		NSL_P		NSL_C		Total NSL		Estimated WL/G_P		Estimated WL/G_C		Net Effect of Trade Liberalization on the Welfare in the State	
	2004–05*	TE 2020–21	2004–05	TE 2020–21	2004-05	TE 2020–21	2004–05	TE 2020–21	2004–05	TE 2020–21	2004–05	TE 2020–21	2004–05	TE 2020–21
Rice	0.57	1.11	13262.4	3774.9	2670.9	4258.9	19218.2	8033.7	602763.8	76368.7	587137.5	−94677.7	15626.3	189081.9
Maize	1.07	1.21	6474.6	497.0	436.0	394.7	6910.6	891.7	96465.0	5230.4	89554.4	−4942.9	6910.6	14308.9
Chickpea		0.84		505.1		4.5		509.6		−5808.4		42.9		−5698.2
Cotton#	0.35	0.98	372216.4	11.5	-	-	-	-	1683807.4	−1030.6	-	-	-	--
Chilies (dry)		1.07		357.1		657.1		1014.3		10277.3		−20225.3		32621.2

Note: # - Consumption gains and losses not calculated for cotton, since the product undergoes considerable transformation before reaching the consumer and per capita consumption data of each product are not available

* - Usharani (2008).

Table 5. Effect of liberalization on agricultural trade—Gross real effects of price distortions (TE 2020–21).

S.No	Crop	Domestic Price vs Border Price (%)		Consumer Price vs Border Price (%)	Increase/Decrease in Supply (Lakh Tonnes)			Increase/Decrease in Demand (Lakh Tonnes)			ΔG (Rs. Lakh)	ΔFEE (Rs. Lakh)
		2004–05*	TE 2020–21		2004–05	TE 2020-21 Low (0.23)	TE 2020-21 High (0.95)	2004–05	TE 2020–21 Low (−0.45)	TE 2020–21 High (−0.70)	TE 2020–21	TE 2020–21
1.	Rice	45	10.4	14.1	4.32	−2.84	−11.71	0.87	6.05	9.42	26342.7	12340.9
2.	Maize	72	21.0	31.5	2.97	−0.71	−2.94	0.20	1.02	1.58	604.2	2224.7
3.	Chickpea		−16.0	−1.2		0.23	0.96		−0.003	−0.01	6275.1	−5555.8
4.	Cotton	284	−2.2	−0.5	12.43	0.04	0.18	12.43	−0.02	−0.03	1042.1	−10.4
5.	Chilies (dry)		7.2	14.9		−0.12	−0.51		0.41	0.64	10962.3	1091.2

Note: * - Usharani (2008).

Table 6. Gains or Losses due to projected changes in prices of selected commodities in Andhra Pradesh (TE 2020–21).

Crop	Value of Production at Pd (Rs. Lakh)		% of Estimated WL/G_P in Value of Production at Pd		Value of Consumption at Pb (Rs. Lakh)		% of Estimated WL/G_C in Value of Consumption at Pb	
	2004–05*	TE 2020–21	2004–05	TE 2020–21	2004–05	TE 2020–21	2004–05	TE 2020–21
Rice	131533	850754.58	45.82	8.98	1889561.6	698017.24	37.84	−13.56
Maize	124046	33000.73	77.76	15.85	211962.8	22539.94	42.25	−21.93
Chickpea		27842.22		−20.86		39458.93		0.11
Cotton	460776	45306.33	365.4	−2.27				
Chillies (dry)		158334.78		6.49		137780.18		−14.68

Note: * - Usharani (2008).

4.2.2. Production and Consumption Effects

The gross real effects of the price distortions are often sizable. Since production and consumption effects have opposite signs, they are additive with respect to trade effects. Where no Government subsidies are involved, price distortions lead to a reduction in trade; but export or import subsidies cause an expansion of trade. For Andhra Pradesh, the liberalization of agriculture would result in change in production due to changes in prices. Border prices were lesser by 10.4, 21 and 7.2 percent compared to their respective domestic prices (Table 5) during TE 2020–21 for rice, maize and chilies (dry). This would result in an incremental decline in their domestic production i.e., reduction in rice production of between 2.84 lakh tonnes to 11.71 lakh tonnes; maize production between 0.71 lakh tonnes to 2.94 lakh tonnes and chilies (dry) production between 0.12 lakh tonnes to 0.51 lakh tonnes. This is because lower border prices would discourage domestic production of these crops. These low and high estimates correspond to the assumed low and high supply elasticities for each commodity. These findings for rice and maize are in contrast to the findings of 2004–05 (Usharani, 2008). Lower border prices would have a positive impact on domestic consumption levels, and this led to an increase in the consumption of rice between 6.05 lakh tonnes to 9.42 lakh tonnes; for maize between 1.02 lakh tonnes to 1.58 lakh tonnes and chilies (dry) between 0.41 lakh tonnes to 0.64 lakh tonnes. These low and high estimates correspond to the assumed low and high demand elasticities for each commodity. However, for chickpeas and cotton, border prices are higher than domestic prices by 16 and 2.2 percent respectively during TE 2020–21. This positively influenced their domestic production from 0.23 to 0.96 lakh tonnes for chickpeas and 0.04 to 0.18 lakh tonnes for cotton respectively considering low and high supply elasticities for these commodities. Further, there will be a decline in their domestic demand between 0.003 lakh tonnes to 0.01 lakh tonnes for chickpeas and 0.02 lakh tonnes to 0.03 lakh tonnes for cotton respectively considering low and high demand elasticities for these commodities.

The results from Table 6 further showed that welfare gain to farmers as a percentage of total value of production was highest for maize at 15.85 percent (Rs. 5230.4 lakhs) followed by rice (8.98% i.e., Rs. 76368.7 lakh) and chilies (dry) (6.49% i.e., Rs. 10277.3 lakh), as domestic prices outweighed their respective border prices. However, in 2004–05, similar findings were highest for cotton at 365.42 percent (Rs. 1683807.4 lakh) and lowest for rice i.e., 45.82 percent (Rs. 602763.8 lakh) due to lower domestic prices compared to border prices. Analogously, consumers in Andhra Pradesh incur substantial welfare loss due to rise in domestic prices of rice (−Rs. 94677.7 lakh); maize (−Rs. 4942.9 lakh) and chilies (dry) (−Rs. 20225.3 lakh), unlike chickpeas (Rs. 42.9 lakh) (Table 4). So, the estimated welfare loss of consumers as a percentage of total value of consumption at border prices from rice was at 13.56 percent, 21.93 percent for maize and 14.68 percent for chilies (dry).

On the whole, there is a substantial increase in Government revenue (ΔG) due to price distortions from across all the selected commodities in Andhra Pradesh (Table 5). Rice, maize and chilies (dry) have contributed foreign exchange (ΔFEE) positively worth of Rs. 12340.9 lakh from rice, Rs. 2224.7 from maize and Rs. 1091.2 from chilies (dry), unlike chickpeas (Rs. −5555.8 lakh) and cotton (Rs. −10.4 lakh). So, the net effect on Andhra Pradesh economy due to trade liberalization was substantial amounting to Rs. 189081.9 lakh from rice; Rs. 14308.9 lakh from maize and Rs. 32621.2 lakh from chilies (dry) during TE 2020–21, unlike for chickpeas (−Rs. 5698.2 lakh) (Table 4). In view of the net importer status of chickpeas and lower border prices compared to domestic prices, the net effect of trade liberalization was negative to the tune of Rs. 5698.2 lakh. So, Government of Andhra Pradesh is encouraging the farmers to cultivate pulses to meet domestic demand and nutrition security of the mounting population and also to check imports. However, consumption gains or losses have not been calculated for cotton, since cotton is used in several forms and average use of each form is not available. However, it can be inferred that cotton farmers would gain welfare, as the border prices were slightly higher than domestic prices.

4.2.3. Efficiency Effects

The estimates of efficiency losses in production and consumption in monetary values (gross monetary effects of price distortions) are given in Table 7. The total efficiency losses to the economy are simply the sum of the NSLp and NSLc. From the table, Andhra Pradesh suffered a total efficiency loss for selected commodities ranging from Rs. 4519.1 lakh to Rs. 10076.9 lakh during TE 2020–21. So, the distorted price policies led to an efficiency loss that account for 0.02 to 0.05 percent of Agricultural and Allied sector GVA of Andhra Pradesh for the TE 2020–21 (Base = 2011–12).

Table 7. Gross Monetary Effects of Government Price Policies (TE 2020–21) (Rs. Lakh)

Crops	NSLp		NSLc		Total NSL		Estimated WL/GP		Estimated WL/GC	
	Low#	High#	Low	High	Low	High	Low	High	Low	High
Rice	868.2	3586.1	2519.8	3919.6	3387.9	7505.8	79275.3	76557.4	−87899.0	−86499.2
Maize	114.3	472.2	244.9	380.9	359.2	853.1	5613.1	5255.2	−4303.3	−4167.2
Chickpeas	116.2	479.8	0.1	0.2	116.3	480.0	−5419.5	−5783.1	47.5	47.6
Cotton	2.6	10.9	0.3	0.4	2.9	11.3	−1021.8	−1030.1	236.6	236.8
Chilies (dry)	82.1	339.3	570.5	887.4	652.6	1226.7	10552.3	10295.2	−18997.7	−18680.8
		Total			4519.1	10076.9	88999.5	85294.7	−110915.9	−109062.8

Note: # - The low and high estimates correspond to the assumed low and high supply elasticities for each commodity.

4.2.4. Welfare and Distribution Effects

A major effect of the pricing policies of the selected commodities is the differential impact of the policies on farmers and consumers. The lower commodity (domestic) prices tax farmers and benefit consumers. Farmers suffer a welfare loss as measured by the change in producers' surplus, and the consumers' welfare gain is measured by the change in consumers' surplus.

During TE 2020–21, rice, maize and chilies (dry) farmers gained an increase of welfare between Rs. 76557.4 lakh to Rs. 79275.3 lakh; Rs. 5255.2 lakh to Rs. 5613.1 lakh and Rs. 10295.2 lakh to Rs. 10552.3 lakh respectively and this is because of higher domestic prices compared to border prices (Table 7). But chickpeas and cotton farmers suffered welfare loss of Rs. 5419.5 lakh to Rs. 5783.1 lakh and Rs. 1021.8 lakh to Rs. 1030.1 lakh, as the domestic prices are lower compared to border prices. Chickpeas farmers suffered more than cotton farmers because of the relatively larger deviations in domestic prices (−16 %) of chickpeas compared to its border prices. Across all the commodities put together, welfare gain for farmers was Rs. 85294.7 lakh to Rs. 88999.5 lakh during TE 2020–21.

Consumers gained an increase of welfare between Rs. 47.5 lakh to Rs. 47.6 lakh and Rs. 236.6 lakh to Rs. 236.8 lakh for chickpeas and cotton respectively over the same period. So, the magnitude of the welfare loss to farmers was larger than the consumers' welfare gains for these two commodities. However, the consumers of rice (14.1%), maize (31.5%) and chilies (dry) (14.9%) suffered welfare losses due to larger deviations of consumer (retail) prices compared to their respective border prices, unlike chickpeas (−1.2%) and cotton (−0.5%). Across all the commodities together, the total loss of consumers' welfare was Rs. 109062.8 lakh to Rs. 110915.9 lakh during TE 2020–21. So, the magnitude of net loss of consumers' welfare compared to welfare gain of farmers is approximately higher by Rs. 21916 lakh to Rs. 23768 lakh during TE 2020–21 and this implies welfare transfers from consumers to farmers.

Based on the evidence provided by the analysis, the above welfare transfers are 2.35 to 4.85 times less than the efficiency losses (Total NSL). Therefore, the largest impact of the pricing policies occurred as welfare transfers from consumers to farmers. Considering the Below Poverty Line (BPL) category population in Andhra Pradesh, (137 lakh families; Socio-Economic Survey, 2020–21), the price policies have alleviated the existing unequal income distribution. Farmers and rural people being the poorest sections of the population, the price policies have increased their income position of the poor and improved their standard of living.

The analysis further illustrates the existence of harmony between the Government's stated objectives and the policy measures undertaken. So, the objectives of increased production of rice, maize and chilies (dry), improved standards of living and welfare of farmers and increased nutritional well-being of the population from increased food production seem to have been furthered by the price policies pursued during the period TE 2020–21. However, the price policies reduced the production of chickpeas and cotton and especially the State still continued to be net-importer of chickpeas to adjust its domestic supply and demand. However, from consumers' side, it will be appropriate to offer more food subsidies on rice and explore other mechanisms for efficient supply of chickpeas to poor consumer groups (BPL) to ensure nutrition security.

5. Summary and Conclusions

The results from PAM revealed that NPCIs are < 1 for rice and maize and NPCOs are >1 for rice, maize and chilies (dry) and these reflect that the farmers are more protected compared to social prices. So, the Government can enhance subsidies for chickpeas, cotton lint and chilies (dry) to enhance comparative advantage through cost-effective and quality production. As the farmers producing chickpeas, cotton, lint and chillies (dry) are taxed on domestic input, the Government should reduce taxes and provide incentives for farmers to boost their comparative advantage. So, it is necessary to distribute certified superior seeds, complete and balanced fertilization, organic fertilizers, mechanization, etc., on subsidized basis to enhance quality output. However, unfavorable exchange rates, domestic and export price fluctuations need to be addressed to make the inputs and output available at favourable prices. It is essential that for the importing countries, where the market size for selected commodities is increasing, it provides Andhra Pradesh an incentive to increase their area and production and an opportunity to increase the exports. Hence, Government initiatives are needed to produce the commodities with desired international standards preferred by the importers.

The findings from PEM revealed that Government policy led to increase in domestic prices of rice, maize and chilies (dry) relative to their equivalent border prices. Consequently, domestic farmers were less taxed by the price policy, while the consumers lost from the increased prices. So, these price policies have led to increase in their production. However, in case of chickpeas and cotton, Government policy has lowered their domestic prices compared to their respective equivalent border prices and hence, domestic farmers were heavily taxed by the price policy, while the consumers gain from the lowered prices. Consequently, the price policies with respect to chickpeas and cotton have led to decrease in their production. The possibility of welfare gains accruing to the farmers of rice, maize and chillies (dry) appeared to be high in a free trade regime. Consequently, there will be welfare losses to the consumers of these commodities. However, welfare gains clearly outweighed the Total NSL for above three commodities. On the whole, there is a positive net effect of trade on the welfare in Andhra Pradesh. It is interesting that in case of chickpeas, free trade resulted in a reduction in farmers' prices, which as a consequence led to their welfare loss. Even again, the welfare gains to the consumers will outweigh the welfare loss to the farmers. So, the policy mechanism in Andhra Pradesh with respect to chickpeas has caused welfare loss to the farmer, thereby affecting his ability to invest in production. To correct this anomaly, the consumers will have to bear some of the burdens, as it is quite easy for them to shift the same through substitution (red or white rajma beans instead of chickpeas). It is essential to find alternative ways to expand chickpeas production. Instead of depending only on input subsidies, technological improvements are a better alternative, as they can raise its supply in the State and at the same time benefit both farmers (cost-effective production) and consumers in the form of lower prices. Even the Government intervention will serve as a price stabilizing mechanism in periods of oversupply and/or undersupply to reduce damaging price fluctuations to both farmers and consumers. Price policies offered by the Government should be in accordance with the international prices through considering the inflation rate and rational inter-product price relationships which would not cause farmers to switch resources from the socially desirable crop mix to more lucrative but less socially desirable enterprises.

This study suffers from a few limitations. Firstly, in general, high-quality products from the State will attract a higher domestic price and this alters the comparative advantage scenario. But, in this study, average prices have been used. Secondly, cross-substitution effects were not considered, while determining the welfare gains and losses. In general, the net loss in consumption and production could be exaggerated due to the omission of the substitution effects.

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Investigating the Effect of Trade Openness and Agriculture on Deforestation in Cameroon

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Abstract: This study aimed to measure the effect of trade openness and agriculture on deforestation in Cameroon from 1980 to 2021 by using a fully modified ordinary least squares (FMOLS) approach. Data used are from the World Bank and FAO. The results obtained indicate that when trade openness increases, deforestation also increases, but when trade openness increases up to a certain threshold, deforestation decreases. This study also reveals that agriculture is one of the major causes of deforestation in Cameroon. Agricultural output and agricultural value-added both have a positive and significant impact on deforestation. There is an inverted curve relationship between economic growth and deforestation in Cameroon, this shows that the EKC is respected with deforestation as it is postulated that at higher levels of income, GDP turns to reduce deforestation meaning a unit change in GDP^2 leads to a reduction of deforestation. We recommend the implementation of concrete actions and strict environmental policies focused on a green economy, to control the exploitation of natural resources with particular attention to the sustainable exploitation of wood. Sustainable agricultural practices should also be implemented, as well as more suitable liberal trade policies.

Keywords: trade openness; agriculture; deforestation; CEK; Cameroon

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1. Introduction

It is believed that trade openness or trade liberalization has brought about unsustainable exploitation and consumption of natural resources (Udeagha & Ngepah, 2022; Wu, 2022). That is, the world benefits from trade openness at the cost of the environment (Shahbaz et al., 2013; Tsurumi & Managi, 2014). Deforestation occurs when forest land changes to non-forest use (Baccini et al., 2012). Deforestation is seen as one of the consequences of trade openness and is considered globally to be among the primary causes of climate change most especially in tropical regions. Deforestation brings about negative consequences on the environment such as soil degradation, soil erosion, desertification, loss of habitats for many animals and loss of plant species amongst others (Ajanaku & Collins, 2021; Van der Werf et al., 2009). Deforestation is of great concern as forests act as a good storage mechanism for carbon reason why they have been suggested as part of the climate change mitigation strategy (Cramer, 2004).

According to Food and Agriculture Organization of the United Nations (FAO, 2015) over the past 25 years, Cameroon has declined with a loss of about 1% forest cover annually. This shows an increasing rate of deforestation for Cameroon in the Congo basin. This increase in deforestation has been linked mainly to timber exports, agriculture, unsustainable and illegal exploitation of timber, infrastructure and fuelwood exploitation (Alemagi & Kozak, 2010; Ewane et al., 2015; Lescuyer et al., 2016; Ngome et al., 2019; Rudel et al., 2005).

According to Tazeen (2021), agriculture is a major cause of deforestation and its impact on deforestation is huge. Due to the large population, the demand of food is high and in order to fulfill the demand of food of society, deforestation takes place on large scale. The high demand of food promotes commercial farming that leads to the acquisition of lands on large scale. Forests are converting into farmlands for large scale farming. This causes adverse effects on environment, climate and health. It also damages natural ecosystems and biodiversity. When trade policies were liberalized in the early 90s in Cameroon, new forest laws were adopted and ever since timber trade and logging has increased in Cameroon and it emerged as one of the main export commodities after agriculture. Today Cameroon's legal timber production for exports has reached approximately 3 million m^3; as a result, Cameroon has become a leading exporter of timber in Africa.

Unfortunately, this affects deforestation as timber exploitation and logging are yet to be done sustainably in Cameroon (Alemagi & Kozak, 2010; Dixon et al., 1996; Lescuyer et al., 2016).

Agricultural production which is the country's second main export commodity has increased remarkably since the liberalization of trade policies in the early 90s. From 2005–2015 agriculture contributed over 28.47% to the country's Gross Domestic Product (GDP). Cameroon is more of an agrarian economy; it employs over 70% of the Cameroonian population and agriculture is often referred to as the backbone of the economy. As the trade for agricultural commodities increases and generates remarkable revenue, so too does the level of deforestation increase in the country as farmers strive for both small and large scale commercial agriculture and exports by increasing or expanding their lands for cultivation and this is done mostly through tropical deforestation (Bele et al., 2011; Cerutti & Lescuyer, 2011; Schmitz et al., 2015; Zapfack et al., 2013). Illegal timber exploitation and logging and fuelwood exploitation for domestic trade are a growing problem in Cameroon and all these exert pressure on deforestation (Alemagi & Kozak, 2010; Ewane et al., 2015).

Up to about a third or 30% of the world is covered by the forest. Forests provide environmental services and benefits such as conservation of biodiversity, soil conservation, climate change prevention, hydrological cycle regulation amongst other benefits. Forest resources are important for the long-term economic development of many countries (Chakravarty et al., 2012; Zeller & Pretzsch, 2019). Due to increasing dependence on forest resources, the world's rainforest is facing threats of extinction because of deforestation. Deforestation is an issue of primary concern for countries of the tropics such as Cameroon, as it leads to the rapid destruction of the tropical forests, with visible effects on biodiversity loss and greenhouse gas effects (Chakravarty et al., 2012). Trade liberalization, measured by trade openness has been identified in the literature as a determinant for deforestation.

Trade openness is measured as the ratio of total trade (imports + exports) to GDP and is an indicator of trade liberalization and globalization. This ratio is also interpreted as a measure of economic policies that either restrict or promote trade among countries. The higher the trade to GDP ratio, the more open a country is to trade and vice versa. Restrictive trade policies were the main feature of underdeveloped economies from 1980 to 1990 after which most economies were liberalized.

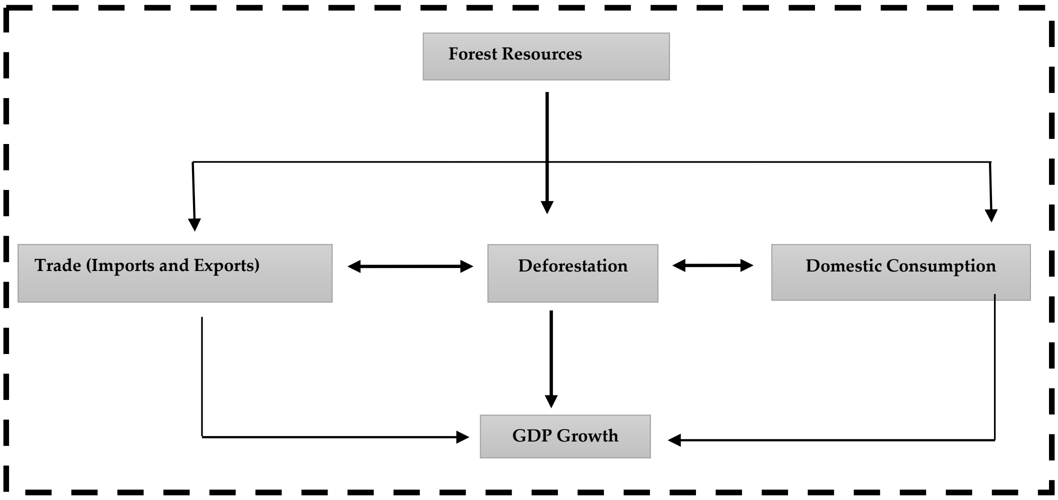

Figure 1. Conceptual link between trade openness and deforestation.
Source: Developed by Authors.

The conceptual framework linking trade liberalization to deforestation is presented in Figure 1. Forest resources are exploited for foreign and domestic consumption which all contribute to the country's GDP. An increase in both domestic and foreign demand for forest products leads to the permanent loss in forest cover. Deforestation reduces the number of forest products for trade and domestic consumption and hence GDP. Thus, it is seen that the more liberalized an economy is in terms of its openness, the more deforestation takes place, especially in countries where trade in natural resources constitutes a greater part of foreign trade. This has been confirmed in similar studies done across the world using different approaches.

Beckman et al. (2017) researched on international trade and deforestation in the United States of America and other six major exporting countries. They analyzed the patterns of deforestation and those commodities that contribute greatly to tropical deforestation. Using historic data with economic models, they found evidence that trade liberalization results to increase in deforestation; the prohibition of the exportation of illegally logged wood will reduce deforestation. Joshi and Beck

(2016) did a study on deforestation in different countries, their result showed that greater trade openness and agricultural lands impacted deforestation differently in different countries and regions. Oktavilia & Firmansyah (2016) did a similar study in Indonesia; they measured the impact of trade liberalization on environmental degradation and economic development. They used pollution as a proxy for environmental degradation. Using the econometric model and the Engel granger procedure of the error correlation model, it was statistically proven that trade liberalization indeed leads to environmental degradation and deforestation; trade liberalization partially increases pollution in the environment. Eskander et al. (2016) did a similar study on trade openness, domestic and foreign investment and the environment in Africa, Asia and other member countries of OECD. They found evidence of mixed effects of trade openness on the environment; it has positive effects in some countries and negative effects in others. Schmitz et al. (2015) researched on agricultural trade and tropical deforestation to investigate the impact trade, agriculture and trade policies have on tropical deforestation in future. They found out that trade liberalization leads to an increase in deforestation, and extensive clearing of tropical forests is partly assigned for agriculture. Tchatchou et al. (2015) carried out a study in the Congo basin (Cameroon, the Democratic Republic of Congo [DRC], Central Africa Republic, Equatorial Guinea and Gabon). Using ordinary least square method (OLS) they analyzed the causes of deforestation and its effects on carbon emissions and land degradation. From their findings, agriculture, fuelwood collection and infrastructure constructions are the principal causes of deforestation which leads to land degradation. This result is similar to the findings of Ewane et al. (2015) in a study conducted in Cameroon and Faria and Almeida (2016) who did a study on the relationship between trade openness and deforestation in the Brazilian Amazon. Tsurumi & Managi (2014) measured the environmental consequences of trade openness and economic development, using the Antweiler et al. (2001) model of decomposing environmental effects; he found evidence that the effects of trade openness are more in the long term than in the short term. Many papers underline the negative impact of agriculture on deforestation (Abman & Carney, 2020; Ajanaku & Collins, 2021; Angelsen & Kaimowitz,1999; Leite-Filho et al., 2021).

The main objective of this paper is, therefore, to measure the effect of trade openness and agriculture on deforestation in Cameroon over 42 years; from a period of pre-liberalization (1980–1994) to a period of post-liberalization from (1995–2021). This study is presented in 4 sections, section 1 is the introductory section followed by section 2 which is the materials and methods of the study, section 3, the results and discussion of the study, and section 4, conclusion.

2. Materials and Methods

2.1. The Model

In this study, we employ the Fully Modified Ordinary Regression Least Squares (FMOLS) regression with an econometric specification similar to the model used by Bhattarai and Hammig (2001) and Ogundari et al. (2017).

Following Bhattarai and Hammig (2001) the model in its general form can be given as:

$$E = f(Y, Y^2, Z), \tag{1}$$

Z is a vector of control variables that may contribute to environmental degradation

$$E = f(trade\ openness, Agriculture), \tag{2}$$

The following specification holds for deforestation.

$$Deforestation = f(trade\ openness, Agriculture), \tag{3}$$

Thus, the following functional relationship will be used:

$$Deforestation = f(economic\ growth + trade\ openness + Agriculture), \tag{4}$$

The indicator for deforestation was obtained from the variable forest cover, it was obtained by calculating the difference between forest cover for period t-1 and t expressed in terms of t-1, thus the following equation was used to obtain deforestation. This relationship can be specified as:

$$Deforestation_t = \frac{forest\ cover_{t-1} - forest\ cover_t}{forest\ cover_{t-1}} \tag{5}$$

$$\begin{aligned} &Deforestation_t = \alpha + \beta_1 gross\ domestic\ product_t + \\ &\beta_2 gross\ domestic\ product_t^2 + \beta_3 trade\ openness_t + \beta_4 trade\ openness_t^2 + \\ &\beta_5 agric\ capital\ formation_t + \beta_6 agric\ gross\ production_t + \\ &\beta_7 agric\ value\ added_t + \beta_8 permanent\ cropland_t + \end{aligned} \tag{6}$$

$\beta_9 forest\ area\ of\ land_t + \beta_{10} foreign\ direct\ investment_t +$
$\beta_{11} real\ effective\ exchange\ rate_t + \varepsilon_t,$

α is a constant and β_1 to β_{11} are regression coefficients.

Here, trade openness is used as a proxy for trade liberalization (Antweiler et al., 2001) calculated as:

$$Trade\ openness_t = {(export_t - import_t)}/{gross\ domestic\ product_t}, \tag{7}$$

The sign β_1 is expected to be positive, this depicts the Environmental Kuznets Curve (EKC) at the early stage of economic growth, the sign of β_2 is expected to be negative; GDP^2 is GDP per capital squared which depicts the curvature nature of the EKC (Wang et al., 2012). This same effect is expected for trade openness, β_3 is expected to be positive, when trade policies lead to increase trade, resources will be exploited in an unsustainable manner leading to increase deforestation, with increasing advocacy for environmental protection, actions will be taken to reduce deforestation thus leading to a negative impact, this is reflected by a negative value for β_4.

2.2. The Data

All the data used in this study is obtained from World Development Indicators (WDI) and Food and Agricultural Organization (FAO). The period of study is from 1980 to 1994 (a period of pre-liberalization) and from 1995 to 2021 (a period of post-liberalization).

Table 1. Summary statistics of variables.

Variables	Observation	Mean	Std. Dev	Min	Max
Deforestation	42	0.349	0.05	0.26	0.41
Gross domestic product	42	23.73	0.34	23.13	24.38
Trade openness	42	45.19	8.79	26.15	65.02
Agriculture capital Formation	42	213.70	176.47	21.73	580.92
Agriculture gross production	42	58.34	27.08	28.07	104.23
Agriculture value added	42	19.62	3.65	15.62	28.67
Permanent crop land	42	2.76	0.34	2.15	3.27
Forest area of land	42	214720.36	6907.82	202844.80	225000
Foreign direct investment	42	1.24	1.18	−0.91	4.06
Real effective exchange rate	42	113.89	23.12	90.28	169.20

Source: Authors using Eviews.

3. Results

3.1. The Trends in Trade Openness, Agriculture and Deforestation

Figure 2 shows that the trend displayed by trade openness is stochastic, with many fluctuations throughout the period. It represents a random walk process without drift since it does not have an intercept term. The implication is that its mean and variance is likely to be constant indicating that the first difference of this variable would be stationary. Though stochastic, it can be realized that the trend of trade openness was downward from 1980 to 1990 reflecting the restrictive trade policies that characterized that period. Economic policy in Cameroon was internally managed up to the early 90s when the economy of Cameroon was liberalized. From the early 90s, though fluctuations in trade openness continued, the trend displayed has been upward.

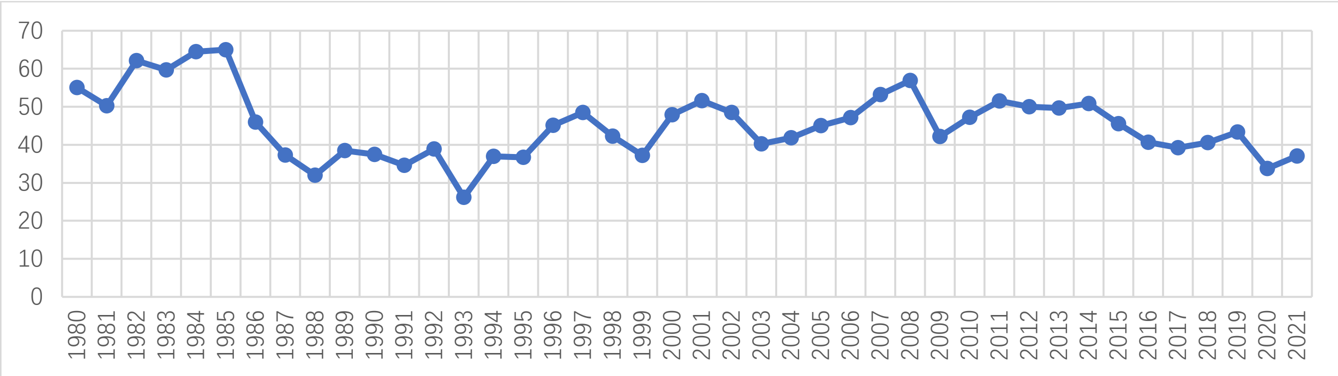

Figure 2. Trends in trade openness from 1980 to 2021.
Source: Authors compilation

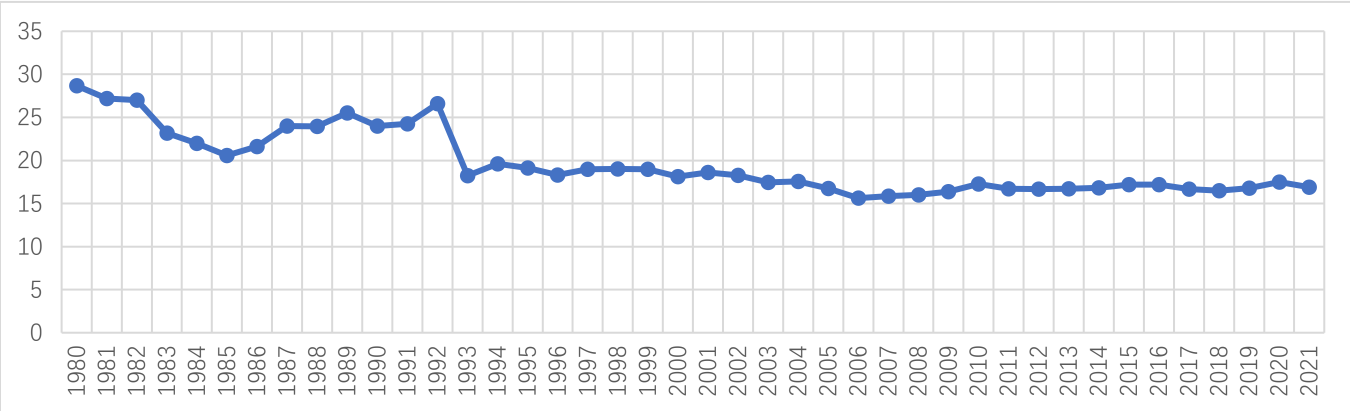

Figure 3. Trends in agricultural value added from 1980 to 2021.
Source: Authors compilation.

Figure 3 is a graphical presentation of trends in the key agricultural indicators over the years (1980–2021); a period of pre-liberalization (1980–1990) and post-liberalization (1991–2021). The agricultural value added evolves in the same direction with trade openness all over time after 1995; it illustrates how much agricultural value added took an ever-increasing turn with the implementation of trade policies after the 1990s.

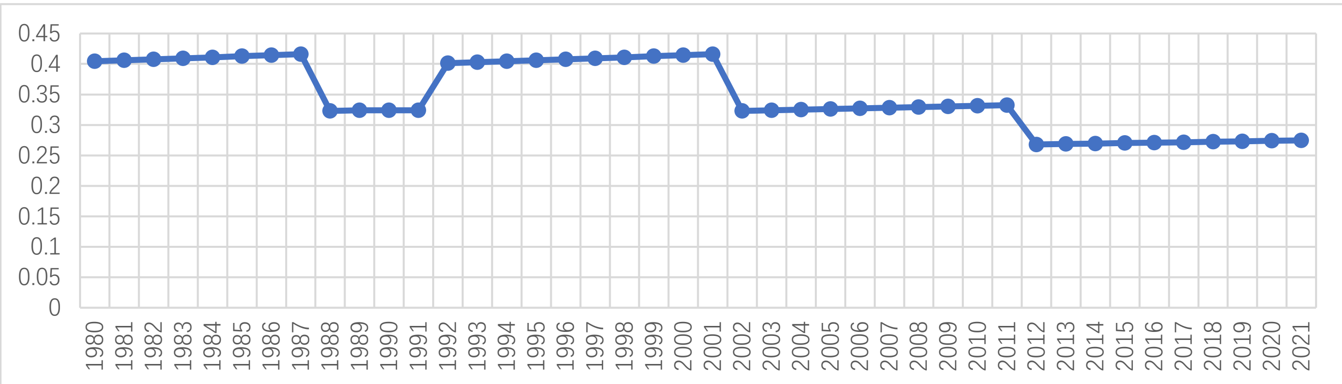

Figure 4. Trends in deforestation from 1980 to 2021.
Source: Authors compilation.

Figure 4 on the trend of deforestation in Cameroon displays two trends from 1980–2021: a downward trend from 1980–1990 and an upward trend from 1990–2021. From the graphical illustration, it is observed that in the years before liberalization, Cameroon depended mostly on agricultural production (excluding forestry) and petroleum for economic growth until the late 1980s when the world was hit by a drop in market prices of many products including agricultural commodities and oil. Again, huge fiscal deficits plunged the country into serious economic crises. Within the framework of the structural adjustment program (SAP) measures imposed on developing countries including Cameroon in the late 1980s and early 1990s was the liberalization of trade and investments. Since the adoption of liberalized trade policies in Cameroon in the early 90s, the rate of deforestation per year has been increasing steadily, showing that Cameroon is slowly becoming less of a forest dominant country over time. Also, with a fall in the world market prices of agricultural commodities, attention was shifted toward the forest sector; the reason why up to date, the rate of deforestation is on the rise. In econometric terms, the trend displayed by the graph on deforestation can be described as deterministic.

3.2. The Unit Root and Johansen Co-integration Tests

Table 2 shows that eight of the ten variables of study are integrated of the order 1. The other two notably forest area of land and foreign direct investment, are integrated at level. This result shows a long-run relationship might exist between trade openness and deforestation in Cameroon.

Table 2. Unit root test.

	Augmented Dickey-Fuller test				
	Level		**First Difference**		
Variables	**trend & inter**	**Probability**	**trend & inter**	**Probability**	**Decision**
Deforestation	−2.549152	0.3044	−6.288337	0.0000	I(1)
Gross domestic product	−2.098204	0.5310	−3.826330	0.0253	I(1)
Trade openness	−2.669977	0.2537	−6.866277	0.0000	I(1)
Agriculture capital Formation	−2.4044002	0.3722	−6.645736	0.0000	I(1)
Agricultural gross production	−1.781555	0.6954	−5.564408	0.0002	I(1)
Agriculture value added (% of GDP)	−3.152213	0.1083	−8.169255	0.0000	I(1)
Permanent cropland (% of land area)	−2.254916	0.4477	−7.694852	0.0000	I(1)
Forest Area of land	−20.06878	0.0000	−44.20255	0.0000	I(0)
Foreign direct investment	−5.57848	0.0002	−13.44724	0.0000	I(0)
Real effective exchange rate	−1.8227123	0.6732	−5.548626	0.0003	I(1)

Source: Authors compilation using E-views 9.

Table 3 shows the presence of co-integration between deforestation and trade openness. The trace statistic shows that there are six co-integrating variables significant at 5% and the maximum Eigenvalue statistic shows that there are four co-integrating variables. This shows that a linear combination of these variables gives a stationary series (I (0)), thus confirming the presence of a long-run relationship between the variables of the study.

Table 3. Johansen Co-integration test on deforestation.

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.939270	384.7455	197.3709	0.0000
At most 1 *	0.855820	272.6927	159.5297	0.0000
At most 2 *	0.815141	195.2248	125.6154	0.0000
At most 3 *	0.671400	127.6983	95.75366	0.0001
At most 4 *	0.560488	83.18172	69.81889	0.0030
At most 5 *	0.480931	50.29813	47.85613	0.0289
At most 6	0.359663	24.06940	29.79707	0.1975
At most 7	0.143223	6.238965	15.49471	0.6673
At most 8	0.001396	0.055877	3.841466	0.8131
Trace test indicates 6 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.939270	112.0529	58.43354	0.0000
At most 1 *	0.855820	77.46784	52.36261	0.0000
At most 2 *	0.815141	67.52647	46.23142	0.0001
At most 3 *	0.671400	44.51662	40.07757	0.0148
At most 4	0.560488	32.88360	33.87687	0.0653
At most 5	0.480931	26.22872	27.58434	0.0737
At most 6	0.359663	17.83044	21.13162	0.1363
At most 7	0.143223	6.183088	14.26460	0.5898
At most 8	0.001396	0.055877	3.841466	0.8131
Max-eigenvalue test indicates 4 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				

3.3. The Effect of Trade Openness and Agriculture on Deforestation

Table 4 shows a summary of the regression analysis. The adjusted R^2 shows that 67.1% of the variance of deforestation is affected by the variables under study, thus the variables are explicative enough. It also shows that the model is globally significant at 1%.

Table 4. Regression analysis.

Dependent Variable: Deforestation Method: Fully Modified Least Squares (FMOLS) Sample (adjusted): 1981 2021 Included observations: 41 after adjustments Cointegrating equation deterministic: C Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth Effect on deforestation				
	Coefficient	Std. Error	t-Statistic	Prob.
Gross domestic product	11.19764	3.075430	−3.640999	0.0011
Gross domestic product^2	−0.234945	0.064100	3.665283	0.0010
Trade openness	0.812403	0.634121	1.281148	0.0003
Trade openness^2	−0.098439	0.082271	−1.196524	0.0012
Agriculture capital Formation	0.000251	0.000103	−2.427701	0.0216
Agricultural gross production	0.002299	0.000751	−3.061976	0.0047
Agriculture value added (% of GDP)	0.007358	0.002698	−2.727367	0.0107
Permanent cropland (% of land area)	0.036562	0.029729	1.229832	0.2286
Forest Area of land	−3.30E-06	2.88E-06	−1.143048	0.2624
Foreign direct investment	−0.001645	0.003097	−0.531125	0.5994
Real effective exchange rate	0.000348	0.000486	−0.715123	0.4803
C	133.0599	36.46359	3.649115	0.0010
R-squared	0.825810	Mean dependent var		0.347417
Adjusted R-squared	0.759739	S.D. dependent var		0.057108
S.E. of regression	0.027992	Sum squared resid		0.022723
Long-run variance	0.000317			

Source: Authors using E-views 8.

From the results, trade openness has a nonlinear relation and a significant effect on deforestation. When trade openness increases, deforestation also increases, but when trade openness increases to the threshold of 8, 25% (turning point), deforestation decreases. With increasing trade and demand for timber, harvesting of forests and related products for exports, illegal logging and fuelwood exploitation; deforestation is on an increasing trend as affirmed by Ewane et al. (2015) and Faria and Almeida (2016). We also investigated if agricultural production affects deforestation in Cameroon that is if increasing agricultural production comes with increasing deforestation. The results reveal that agricultural output and agricultural value-added have a positive and significant impact on deforestation. A 1% increase in agricultural value-added will lead to a 0.007 % increase in deforestation all things being equal. This result is significant at 5%. This result is similar to research of Tchatchou et al. (2015) and Ordway et al. (2017) where agriculture is an overwhelming direct cause of deforestation in Cameroon. This is due to the felling down of trees by farmers to expand farmlands as they seek to increase agricultural production for consumption and trade (domestic and export trade). The regression results also show that agricultural capital formation has a positive and significant effect on deforestation. Precisely, a slight increase in agricultural capital formation will bring about a change of 0.0002 units increase in deforestation. Increasing investments in agricultural capital without taking adequate sustainable measures to ensure sustainable farming systems and resource exploitation will lead to deforestation. The regression result equally shows that the EKC is respected with deforestation as affirmed by Bhattarai and Hammig (2001) and Martínez et al. (2009), at higher levels of income, deforestation reduces. It can be seen from the regression table that a slight increase in GDP leads to a 11.197 unit increase in deforestation, but at higher levels of income (with GDP doubled) the effect on deforestation becomes negative. Thus, a slight increase in GDP^2 leads to a 0.234 unit decrease in deforestation. This result is statistically significant at 5%. This means that countries with higher levels of income turn to invest in environmental protection and deforestation measures, thus for Cameroon, increasing control of natural resource management will enhance the sustainable management of natural resources and less deforestation.

4. Conclusion

This study aimed to measure the effect of trade openness and agriculture on deforestation in Cameroon from 1980 to 2021. Trade openness influences deforestation. When trade openness increases, deforestation also increases, but when trade openness increases to the threshold of 8, 25% (turning point), deforestation decreases. This study also reveals that agriculture is one of the major causes of deforestation in Cameroon. Agricultural output and agricultural value-added both have a positive and significant impact on deforestation. A unit change in agricultural value-added will lead to 0.0002 units increase in deforestation. There is an inverted curve relationship between economic growth and deforestation in Cameroon, this shows that the EKC is respected with deforestation as it is postulated that at higher levels of income, GDP turns to reduce deforestation meaning a unit change in GDP^2 leads to a reduction of deforestation by 0.234 units. Forest area is also affected by deforestation; thus, forest cover is reducing. We recommend that to reduce the rate of deforestation in Cameroon concrete actions and stringent environmental policies with a focus on a green economy should be taken to control the exploitation of natural resources with special attention on sustainable exploitation of timber and sustainable logging activities. Sustainable agricultural practices should be implemented, and more suitable liberalized trade policies should be adopted and implemented in the country. We also recommend strict implementation of adopted forest laws and control of legal logging and prohibition of illegal logging. Reforestation should be encouraged in the country**.**

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Article

The Impact of Forestry Industry Integration on the Forest Farmers' Income in China: A Theoretical and Empirical Study

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Abstract: Transforming the forestry development model and promoting the development of forestry industry integration (FII) has become an important way for forestry to break through development bottlenecks and realize the increase of farmers' income. In this study, we use the inter provincial data from 2005 to 2019 to test the effect of FII on forest farmers' income with the help of fixed effect model, quantile regression model and spatial panel model. Results showed that, firstly, the level of FII is on the rise, with most provinces in the middle or high integration stage. Among them, the Northeast region is at the highest level. Secondly, there is a positive spatial correlation in the forest farmers' income, which is gradually increasing. The income of forest farmers in coastal provinces is relatively high, forming an HH cluster. Thirdly, the FII has significantly improved the income level of forest farmers, and there is a significant spatial spillover effect. Finally, the group heterogeneity is reflected in the increasing income effect of FII with the improvement of the income level of forest farmers. Regional heterogeneity shows that the FII in Northeastern, Eastern, and Central regions significantly promotes the increase of forest farmers' income. Efforts to boost integrated forestry industry development will broaden the income channels of forest farmers by leveraging high productivity of the agglomeration effects, diffusion effect and demonstration effect, and promoting integrated forestry industry development with adjacent regions. This work may help to understand this relationship and to creating effective regional forestry development income-enhancing policies.

Keywords: forestry industry; integrated development; income of forest farmers; heterogeneity testing; analysis of spatial effect

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1. Introduction

Promoting the sustained increase in farmers' income and continuously improve their sense of gain, happiness and security is a necessary part of China's comprehensive construction of a moderately prosperous society. Since 2004, the No. 1 document of the Central Government has continued to focus on the issues of "agriculture, rural areas and farmers". Accordingly, the per capita net income of farmers has rapidly increased from 2936.4 yuan in 2004 to 16021 yuan in 2019, achieving "16 consecutive increases" (Yao et al., 2022). However, in the face of the impact of the novel coronavirus epidemic, the downward pressure on the Chinese macro economy is increasing, the situation of farmers' income increase is not optimistic, and the momentum to continue to maintain a relatively rapid growth is insufficient. How to promote the sustainable and stable growth of farmers' income is still a major and difficult point. Forests often play a vital role in the lives of many poor people (Vedeld et al., 2007). Globally, nearly 735 million rural people live in or near tropical forests and savannas (FAO, 2006; World Bank, 2000). In China, most of the 592 poverty-stricken counties are located far from urban centers and in areas with poor transportation. At the same time, they tend to have relatively rich forests (Liu et al., 2009). In order to increase the income of rural residents, in the recent five years, the State Council government work report and the documents issued by the National Forestry and Grassland Administration mentioned several times to promote the integrated development of rural primary, secondary and tertiary industries, increase farmers' income through multiple channels. In this context, does the integration of forestry industry effectively promote farmers' forestry income? Will the effect be heterogeneous with subject endowment and regional differences? Will it affect the income of forest farmers in adjacent areas? These topics are in urgent need of research.

Research on industrial integration has a long history. In the 1960s, scholars represented by Rosenberg (1963) took the lead in summarizing the concept and type of industrial convergence with technology convergence as the core. Subsequently, the research on industrial integration is becoming more and more systematic, involving the connotation (Bally, 2005; Chen, 2010; Rosenberg, 1963), characteristics (Cao, 2015), motivation types (Chesbrough, 2007; Lemola, 2002), level measurement (Dong et al., 2021; Lemola, 2002; Lu et al., 2017) and effects of industrial integration (Gambardella & Torrisi, 1998; Li et al., 2021a), but mainly focusing on the secondary and tertiary industries and their internal integration analysis. Subsequently, a small portion of the academic community began to pay attention to research on the integration of the forestry industry. Li (2007) first defined the connotation of industrial integration in the forestry field. Jin et al. (2023a) measured the current status of forestry industry integration using the Herfindahl index method. However, research on the integration of the forestry industry is still in its early stages.

Among the diversified incomes of farmers, forestry income is a very important income (Charlie et al., 2007; Kendra & Bassett, 2002). For example, Reddy and Chakravarty (1999) founded that in northern India, forestry revenues can reduce the probability of poverty. There are many factors that affect farmers' income in forestry, which can be summarized into two aspects: i)The factors of the farmer household itself, such as the size of the household and the number of adult labor force (Pyi et al., 2015), the family cultivated land (Patricia et al., 2012), the forest land area (Lu et al., 2020), and the integration degree of forestry with agriculture and animal husbandry (Adriana et al.,2019; Roberto et al.,2015). ii) Factors other than the farmer's household, such as the state of forestry resources (Getachew et al., 2007), climatic conditions (Oscar & William, 2021), sudden natural disasters (Feng & Dai, 2019), forestry technology (Nambiar, 2021), forestry capital (Hari et al., 2017), and fiscal policy (Carlos et al.,2020).

Currently, there is a blank research stage on the relationship between industry integration and forest farmers' income in the forestry industry, which has weak characteristics. However, forestry, as a subsidiary industry of agriculture, can provide an important reference for scholars to study the relationship between forestry industry integration and forest farmers' income. The existing research mainly focuses on two aspects: the research on the relationship between rural three-industry integration and farmers' income (Gullette, 2014), and the mechanism analysis on how to promote rural three-industry integration to increase farmers' income (Li & Wang, 2019).

In summary, although a series of studies have been conducted on industrial integration and farmers' income, there are limitations regarding the knowledge of both: i) Existing studies have primarily explored forestry industry integration or farmers' forestry income from a unilateral perspective or explores the impact of agricultural industry integration on farmers' income from an agricultural perspective. However, there is no established theoretical system for researching the impact of forestry industry integration on farmers' forestry income from a forestry perspective, and there is a lack of empirical research on its effect. ii) Most of the existing empirical studies focus on the national level or a certain region level, and rarely involve all provinces in the country. Comprehensive analysis of individual differences, regional heterogeneity and spatial spillovers is even less.

Accordingly, this paper took 30 provinces in China from 2005 to 2019 as the research samples and explored the spatial distribution law of forestry industry integration and the forest farmers' income. We explored the impact of the former on the latter by used the panel fixed effect model, quantile regression model and panel spatial econometric methods, in order to comprehensively grasp the problems faced by forestry industry integration in promoting farmers' forestry income. Our analysis is comprehensive and can provide a basis for the scientific formulation of differentiated regional forestry development policies.

2. Mechanism Analysis and Research Hypotheses

2.1 Mechanism of Forestry Industry Integration on Farmers' Forestry Income

Forestry industry integration mainly increases the added value of forest products, promotes the optimal allocation of forestry production factors, reduces the opportunity cost of forestry industry development, and creates more employment opportunities by extending the industrial chain and cultivating new forms of forestry industry, so as to broaden the income channels of forest farmers and thus increase their incomes. The mechanism of forestry industry integration affecting farmers' forestry income (Figure 1) is described below.

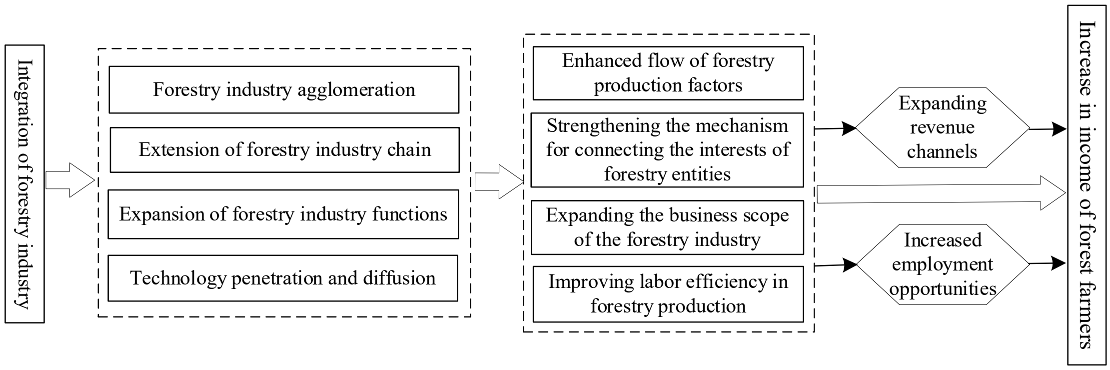

Figure 1. Mechanism of forestry industry integration on farmers' forestry income.

Specifically, firstly, forestry industry integration includes the integration of forestry technology, which is reflected in all aspects of forestry production and operation. The penetration and cross integration of high-tech industries such as biotechnology and information technology and their industries into forestry can break the technical barriers to the development of forestry industry and improve the original mode of production, which can promote the innovation of the mode and means of forestry production and management. This can not only save the cost of production and operation, improve the efficiency of forestry labor production, but also increase the forestry output, improve the quality and additional value of forest products, and thus greatly increase farmers' forestry income (Cubbage et al., 2007). Secondly, forestry industry integration can bring about the industrial agglomeration, the formation of new formats, and the extension of the industrial chain. For example, the integration of forestry and tourism, culture, education, medical care, health care, sports and other industries expand the scope of forestry business, improve the value creation ability of forestry and the added value of forest products, so that farmers have more job opportunities, expand the income channels, and thus increase their income (Sunderlin et al., 2003). Thirdly, the higher the level of integrated development of forestry industry, the more sufficient the flow of forestry production factors. The forestry management entities and foresters transform the forestry production mode into enterprise or stock cooperation through forms such as orders, land transfer or equity participation, and enterprise labor.

These interest linkage mechanisms share the risks and benefits of forestry production, thereby reducing the transaction costs of forest products in production and circulation and increasing the ability to resist natural risks, ensuring the stability of forest farmers' income. Moreover, forest farmers can also share the benefits of various links in the forestry industry chain, including sales and processing (Midgley et al., 2017). The more closely the interests of each forestry management body are connected, the more value-added forestry benefits farmers get. We propose the following accordingly.

Hypothesis 1: Forestry industry integration has a promoting effect on farmers' forestry income.

2.2 Heterogeneity of Forestry Industry Integration on Farmers' Forestry Income

The heterogeneity of the income increase effect of forestry industry integration is mainly reflected in two aspects: regional heterogeneity and individual heterogeneity. That is, the differences in the impact of forestry industry integration on farmers' forestry income in different regions and the differences in the impact of forestry industry integration on the income of heterogeneous farmers.

(1) Regional differences in farmers' forestry income affected by forestry industry integration

Due to China's vast territory, there are significant regional differences in the natural resource conditions, economic development level, and industrial structure of forestry among regions (Chen et al., 2020; Xiong et al., 2018), resulting in significant regional differences in the income level of forest farmers and the level of forestry industry integration. In recent years, although the income of forest farmers has shown a rapid growth trend, the regional income gap has also been widened. There are also Northeast-Central-West-East hierarchical differences in forestry industry integration (Jin et al., 2023a). The impact of forestry industry integration on farmers' forestry income may exhibit imbalanced characteristics at the provincial or regional level due to the high or low level of forestry industry integration. The integrated development of the forestry industry is a long-term, systematic, and dynamic complex project. Currently, China is still in the initial exploration stage, and its level of development is influenced by the external environment and supporting conditions (Jin et al., 2023b). Among them, the differences in economic development level, forestry resource endowment, and transportation infrastructure between different provinces and cities can lead to significant inter provincial differences in the integration level of regional forestry industry, which may lead to regional differences in the driving effect of increasing income for forest farmers in different regions. Specifically, the level of regional economic development to a certain extent determines the primitive accumulation of forestry industry development (Xiong et al., 2018), while infrastructure construction and forestry resource factor endowment determine the forestry production mode and operation scale to a certain extent. Scholars have found regional differences in the impact of rural integration of the three industries on farmers' income through research. Among them, the integration of rural industries in the eastern region has the strongest promoting effect on farmers' income, followed by the northeast and central regions, and the western region is the weakest. This is mainly due to the favorable geographical advantages and external environment in the eastern region. The higher the level of economic development, the more convenient transportation, complete facilities, and more channels for rural residents to obtain income, which is more conducive to the increase of farmers' income (Bai, 2023). Therefore, in areas with high levels of regional economic development, complete infrastructure construction, and abundant endowments of forestry resources, the stronger the foundation for the development of new industries and formats, the faster the growth rate of new forestry operators, and the higher the level of forestry industry integration, the more obvious the promoting effect on farmers' forestry income. We propose the following accordingly.

Hypothesis 2: The income increasing effect of forestry industry integration is characterized by regional heterogeneity due to differences in external environment and supporting conditions, with a strong Eastern region and a weak Western region.

(2) Individual differences in farmers' forestry income affected by forestry industry integration

The difference of the effect of forestry industry integration on the income of heterogeneous farmers can be explained from the main body difference of forestry industry integration effect caused by the heterogeneity of farmers' resource endowment. This is because there is a huge gap in the endowment of forestry resources among forestry management entities, mainly reflected in the differences in the occupancy and utilization efficiency of forestry production factors such as forest land, labor, capital, technology, and so on (Chen et al., 2020; Jin et al., 2023b; Lu et al., 2018). Although forestry industry integration can improve the efficiency of forestry production, increase the added value of forest products, generate more employment opportunities, and increase the level of farmers' forestry income, there are differences in the opportunity cost and marginal revenue of different forestry management entities in carrying out forestry production and management, which makes the same level of forestry industry integration may have different income effects on different entities. Generally speaking, the group with higher forestry income has more forestry production factors, and the scale effect and multiplier effect produced by forestry industry integration are more significant, resulting in more significant income growth. We propose the following accordingly.

Hypothesis 3: The income increasing effect of forestry industry integration has individual heterogeneity, and the marginal contribution increases with the increase of income level.3. Model Setting and Variable Selection.

3. Model Setting and Variable Selection

3.1 Model Setting

To verify the income increasing effect of forestry industry integration, based on reference to relevant influencing factors, a benchmark model is constructed as follows:

$$Y_{it} = \alpha_0 + \beta X_{it} + \sum_{j=1}^{n} \beta_j Z_{jit} + \varepsilon_{it} \tag{1}$$

where Y_{it} represents the income level of forest farmers of the ith-region in the tth-year; X_{it} and β represent the integration level of forestry industry and its coefficients, respectively; Z_{it} and β_j represent, respectively, the control variables and their coefficients; ε_{it} is the random error term.

There are significant inter provincial differences in China's forestry resource endowment and income level of forest farmers, making it difficult to describe the forestry income characteristics of different groups from the perspective of "average level" regression analysis. By using the quantile regression model proposed by Kendra and Bassett (1978) to estimate the independent impact of explanatory variables on the different points of the distribution of explanatory variables, we can more comprehensively and accurately reflect the heterogeneity structure of the entire sample distribution between the integrated development of forestry industry and the income of forest farmers in different regions of China. In addition, quantile regression can eliminate heteroscedasticity in the distribution of variables to a certain extent, and the estimation results are not easily affected by extreme values, so they are more robust. Therefore, the panel quantile regression model is constructed based on Formula (1) as follows:

$$Q_{FI_{it}}(\gamma|X_{it}) = \sigma_i + \varphi(\gamma)X_{it}, i = 1,2,3\cdots n; t = 1,2,3\cdots m \tag{2}$$

where $Q_{FI_{it}}(\gamma|X_{it})$ represents the γ conditional quantile of the interpreted variable Y under the given conditions of X; X is the explanatory variables, including the core explanatory variable (forestry industry integration) and the control variables; $\varphi(\gamma)$ represents the quantile regression coefficient, which can be obtained by solving the objective function Formula (3).

$$\min_{(\sigma+\varphi)} \sum_{k=1}^{q} \sum_{t=1}^{n} \sum_{i=1}^{m_i} \omega_k \rho_{\gamma k}(FI_{it} - \sigma_i - \varphi(\gamma)X_{it}) \tag{3}$$

where ω_k represents the corresponding weight of each quantile. This paper selects 10%, 25%, 50%, 75%, and 90% of the representative points based on the current research practice.

To further investigate the regional heterogeneity and influencing factors of forestry industry integration on forest farmers' income, Spatial Panel Lag Model (SPLM), Spatial Panel Error Model (SPEM), and Spatial Panel Dubin Model (SPDM) were selected to explore the spatial effects of forestry industry integration on forest farmers' income. Among them, SPDM is most often used to investigate the spatial correlation of geographical units. It contains both independent and dependent variables' spatial dependence effects, which is a more general form than SPLM or SPEM (Elhorst, 2003). It can be expressed as follows:

$$Y_{it} = \beta_0 + \rho\sum_{j=1}^{N} W_{ij}Y_{jt} + \beta_2 X_{it} + \varphi_1\sum_{j=1}^{N} W_{ij}X_{jt} + \beta_3 Z_{it} + \varphi_2\sum_{j=1}^{N} W_{ij}Z_{jt} + \mu_i + \nu_t + \varepsilon_{it} \tag{4}$$

where Y_{it} represents the dependent variable value of the ith-region in the tth-year; W_{ij} represents the normalized spatial weight matrix; $W_{ij}Y_{jt}$ represents the spatial lag dependent variable; ρ represents the spatial regression coefficient; X_{it} and β_1 represent the independent variables and their coefficients, respectively; $W_{ij}X_{jt}$ represents spatial lag explanatory variables; φ_1 represents the coefficient of spatial lag independent variables; Z_{it} and β_2 represent, respectively, the control variables and their coefficients; $W_{ij}Z_{jt}$ represents spatial lag control variables; φ_2 represents the coefficient of spatial lag control variables; μ_i and v_t represent spatial effect and temporal effects, respectively; ε_{it} is the random error term. When $\varphi_1 = 0$ and $\rho \neq 0$, Formula (4) refers to the SPLM model; when $\varphi_{1+}\rho\beta_1 = 0$, Formula (4) represents the SPEM model.

It should be noted that the spatial weight matrix adopts the adjacency spatial weight matrix W_{ij}, and spatial research is implemented using ArcGIS and GeoDA. To avoid the endogeneity problem of variables, the system generalized moment estimation (MLE) method is used to estimate the model.

3.2. Variable Selection

(1) Explained variable (Y). At present, there is no specialized yearbook data on farmers' forestry income. The existing research generally adopts two ways to deal with it: the first is to sample the net income of farmers in each province and measure the net income of farmers in forestry with the results of micro-household survey, which is generally used for the analysis of cross section data; the second method is to convert the corresponding data proportion, which is suitable for the analysis of panel data. Therefore, this paper refers to existing research (Chen & An, 2018; Liao & Zhang, 2014) and uses the net income of rural households multiplied by the ratio of forestry output value to the output value of agriculture, forestry, animal husbandry, and fishing industries to represent farmers' forestry income.

(2) Core explanatory variable (X_1). In this paper, the core explanatory variable is the degree (level) of forestry industry integration. Forestry industry integration is a dynamic development process in which forestry breaks through the original boundaries of different industries and gradually forms a new format or development model of forestry industry through phase penetration and cross between forestry and other different industries, or within the three forestry industries. This paper adopts the Herfindahl index method used by Jin et al. (2023b) in previous research to measure forestry industry integration. The specific formula and division criteria (Table 1) are as follows:

$$FIII = 1 - \sum_{i=1}^{N}\left(\frac{X_i}{X}\right)^2 \tag{6}$$

where $FIII$ represents Forestry Industry integration Index; $\sum_{i=1}^{N}\left(\frac{X_i}{X}\right)$ is the sum of squares and total proportion of all variable values, representing the Herfindahl index; X refers to the total output value of the primary, secondary, and tertiary forestry industries; and X_i represents the total output value of the *i*th-industry (Jin et al., 2023b; Lu et al., 2017; Qu et al., 2022). It should be noted that the broad integration of forestry industry includes both the integration between forestry and other different industries, as well as the integration of primary, secondary, and tertiary industries within forestry; The narrow definition of forestry industry integration only refers to the integration of primary, secondary, and tertiary industries within the forestry industry. The empirical part of this paper is limited by data and focuses on the narrow integration of the forestry industry.

Table 1. Integration level classification.

Fusion Interval	<0.20	0.20-0.40	0.40-0.60	0.60-0.80	0.80-1.00
Fusion level	I	II	III	IV	V
Type	Low fusion	Medium-low fusion	Medium fusion	Medium-high fusion	Deep fusion

(3) Control variables. Considering that farmers' forestry income is also influenced by other factors besides the forestry industry, and addressing the endogeneity problem caused by omitted variables, we selected a series of control variables based on relevant studies and the principles of availability, comparability, and quantifiability (Abdulai et al., 2016; Abhilash, 2018; Li et al., 2021a; Lin & Chen, 2020; Lu et al., 2018; Lu et al., 2020; Wei et al., 2022; Xiong et al., 2018; Zhang et al., 2019). Control variables refer to potential factors or conditions other than experimental variables in an experiment that affect the changes and results of the experiment. If you want to investigate the influence of an independent variable on the dependent variable, it is necessary to eliminate the influence of other independent variables on the dependent variable, that is, to control the influence of other independent variables-control variables. To this end, it is necessary to add the control variable affecting the dependent variable to the model and estimate the model together with the independent variable to be investigated, so that more accurate estimation results of the variable to be investigated can be obtained (Antonakis et al., 2010; York, 2018). The selected control variables follow.

①Farmers' forest land resource level (X_2). Forest land resources have a significant impact on farmers' forestry income and are an important form of farmers' participation in forestry income distribution. The amount of forest land resources for farmers is related to the level of forestry income (Lu et al., 2020). Therefore, the per capita mountainous area in the land management situation of rural households is used to measure the level of forest land resources for farmers, that is, the per capita forestry land area.

②Rural human capital level (X_3). Rural human capital, as an important input factor in forestry production and operation, has a significant promoting effect on the growth of farmers' forestry income (Wei et al., 2022). The per capita education years of rural residents are used to measure the level of rural human capital. Improved average educational attainment can enhance the ability of forestry enterprises to introduce, absorb, and apply new technologies, improve the management level of forestry departments, and thus improving the technical efficiency of forestry production and increasing farmers' forestry income (Abdulai et al., 2016).

③Forestry fiscal expenditure (X_4). Due to the weakness of forestry and the externality of public goods, the development of forestry industry depends on national financial support. Increasing financial support can improve forestry production and increase farmers' forestry income (Zhang et al., 2019).

④Level of economic development (X_5). The performance of industrial integration development effect is closely related to the level of regional economic development (Xiong et al., 2018), that is, when forestry industry integration affects farmers' forestry income, it may be affected by the level of regional economic development.

⑤Forest resource endowment (X_6). In regions with more abundant forest resources, it is more conducive to the integration and development of forestry industry and other related industries, generating new forms of business, such as forest health care, turning resources into capital, so as to improve farmers' forestry income in the region (Abhilash, 2018; Lu et al., 2018). The level of forest coverage is a direct reflection of forest resource endowment; therefore, forest coverage is chosen as the proxy indicator of forest resource endowment.

⑥Transport infrastructure conditions (X_7). Transport infrastructure has typical externality characteristics. On the one hand, the gradual improvement of transport infrastructure can promote the flow of production factors and reduce transaction costs (Lin & Chen, 2020), drive the integrated development of forest industry, increase employment opportunities related to forests, and increase farmers' forestry income. On the other hand, the large-scale and disorderly construction of transportation facilities has led to the destruction of the quantity and quality of forest resources, resulting in the deterioration of the living environment for forest farmers and a certain degree of loss of economic benefits (Li et al., 2021b). The traffic density value is used to measure the condition of transport infrastructure.

3.3. Data Declaration

Considering data availability, we selected panel data for 30 provinces (excluding Hong Kong, Macao, Taiwan, and Tibet due to lacking data) in China from 2005 to 2019. To test for regional heterogeneity, we also divided 30 provincial areas in China into four major regions according to the divisions of the National Bureau of Statistics: The Eastern region (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan), Central region (Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan), Western region (Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Inner Mongolia, and Guangxi), and Northeast region (Liaoning, Jilin, and Heilongjiang).The relevant data came from the *China Statistical Yearbook*, *China Forestry Statistical Yearbook*, *China Rural Statistical Yearbook*, *China Statistical Yearbook for Regional Economy*, and the *Statistical Yearbook* of each province.

Additionally, to eliminate impacts of inter-annual price changes, we used a comparable price index with 2005 as the reference year. Some missing data were supplemented by linear interpolation. In order to deal with the problems of heteroscedasticity and multicollinearity, all variables were logarithmized. This processing did not change the trend of the original time series, making our data analysis results more accurate and comparable. The descriptive statistics of the main variables are shown in Table 2.

Table 2. Definitions of relevant variables and descriptive statistics.

	Variables	Calculation Methods	Mean	Standard Deviation	Min	Max
Dependent variable	Farmers' forestry income (yuan)	$\frac{\textit{Forestry output value}}{\textit{Output value of agriculture, forestry, animal husbandry, and fishery}} \times \textit{Per capita disposable income of rural residents}$	9.547	0.367	8.600	10.615
Independent variable	Forestry industry integration level (/)	Herfindahl index method	−0.796	0.511	−3.930	−0.322
Control variables	Farmers' forest land resource level (hm^2/person)	$\frac{\textit{Forest land area}}{\textit{Rural population}} \times 100\%$	1.250	1.115	−2.416	3.878
	Rural human capital level (year)	(Number of illiterate persons×1+Number of primary school graduates×6+ Number of secondary school graduates×9+Number of high school and technical secondary school graduates×12+Number of college students and Bachelor's degree or above holders×16)/Total population over 6 years old	0.850	0.118	0.449	1.039
	Forestry financial expenditure (%)	$\frac{\textit{Expenditure on agriculture, forestry and water affairs}}{\textit{Budgetary expenditure}} \times 100\%$	−2.317	0.370	−3.847	−1.663
	Level of economic development (%)	$\frac{\textit{Forestry output value}}{\textit{Output value of agriculture, forestry, animal husbandry, and fishery}} \times 100\%$	−3.385	0.657	−5.024	−1.086
	Forest resource endowment (%)	$\frac{\textit{Forest coverage}}{\textit{Land survey area}} \times 100\%$	3.171	0.789	1.078	4.202
	Transport infrastructure conditions (/)	$\frac{\textit{Total mileage of highways, railways, and inland waterways}}{\textit{Land area}} \times 100\%$	−0.410	0.809	−3.189	0.749

4. Spatial-temporal Differences of Forestry Industry Integration Level and Farmers' Forestry Income

4.1. Spatial-temporal Features of Forestry Industry Integration Level

In 2005, the "Medium-high fusion" regions (IV) included 6 provinces (Figure 2a), mainly located in Northeast, Central, and Western regions, including Jiangxi, Hunan, Chongqing, Sichuan, Gilin, Heilongjiang. Among them, Hunan Province had the highest integration (0.631). The integration level of the forestry industry in the remaining provinces was at the "Medium fusion" level or below. In 2019, the number of provinces decreased to 18 with the "Medium fusion" level or below, but the number was still more than half of all provinces (Figure 2b). The provinces with IV or above levels were mainly in the Central, Southwest, and Northeast regions, among which Hunan and Hubei had the particularly high integration index values.

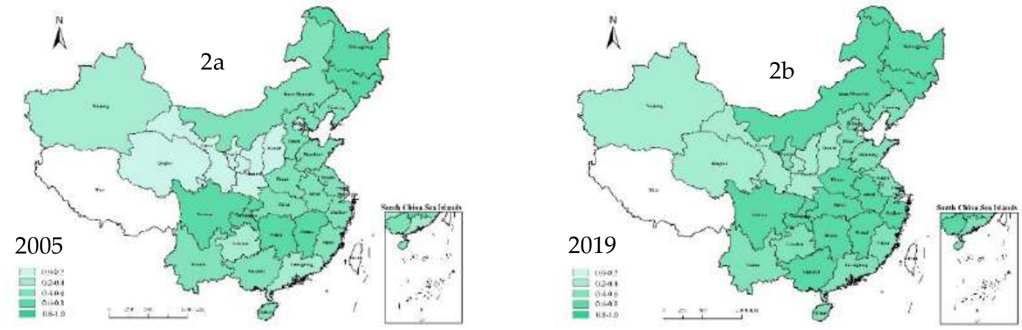

Figure 2. Regional distribution map of China's forestry industry integration level 2005−2019.

During the period 2005 to 2019, the levels of 14 provinces remained unchanged, while the levels of other provinces increased or decreased. Specifically, Tianjin dropped from II to I, Jilin slightly declined but the level did not change, and the integration index values of other provinces increased to varying degrees. As a whole, during the study period, the integration level of the forestry industry in all provinces was at "Medium fusion" or "Medium-high fusion", and the integration level of most provinces was improved while those of a few provinces was decreased. There was a hierarchical difference in the integration level between Northeast, Central, Western, and Eastern regions. The integration levels in Central and Northeast regions were higher than that of the Western and Eastern regions.

4.2. Spatial-temporal Features of Farmers' Forestry Income

4.2.1 Global Autocorrelation

According to the Tobler's (2004) first law of geography, everything is related, and things near each other are more related. Through global autocorrelation, spatial autocorrelation analysis can be carried out on a common attribute of different research objects in the same region, so as to determine whether the attribute is affected by the geographical location, and further explore its spatial evolution rule and spatial aggregation status. In this study, the spatial correlation analysis of the income level of forest farmers in China from 2005 to 2019 was carried out by using the global Moreland index, local Moreland index and Moreland scatter plot.

From 2005 to 2019, the global Moran's I index values of China's farmers' forestry income were all positive and passed the 1% significance level test, indicating that the global autocorrelation experiment was significant at a 99.9% confidence level, and the original assumption of random distribution should be rejected (Table 3). China's farmers' forestry income had a positive correlation in the overall space and exhibited agglomeration phenomenon. Overall, areas with high income from forest farmers were more likely to be adjacent to areas with high income from forest farmers, while areas with low income from forest farmers were more likely to be adjacent to areas with low income from forest farmers. From the data, the global Moran's I index was between 0.322 and 0.337, reaching its highest point in 2019, at 0.337, indicating that the clustering phenomenon of farmers' forestry income is most evident in 2019. From a dynamic perspective, the Moran's I index showed a fluctuating upward trend, indicating that the spatial agglomeration of farmers' forestry income is gradually strengthening.

Table 3. Moran’s I index value of farmers’ forestry income in China from 2005 to 2019.

Index	2005	2006	2007	2008	2009	2010	2011	2012
Moran’s I	0.322***	0.322***	0.324***	0.325***	0.322***	0.325***	0.325***	0.325***
Z value	3.007	3.004	3.012	3.022	2.993	3.014	3.018	3.019
P value	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Index	2013	2014	2015	2016	2017	2018	2019	
Moran’s I	0.324***	0.325***	0.327***	0.331***	0.334***	0.335***	0.337***	
Z value	3.005	3.020	3.031	3.064	3.09	3.099	3.121	
P value	0.003	0.003	0.002	0.002	0.002	0.002	0.002	

Note: ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level.

4.2.2 Local Autocorrelation

The Moran’s I scatter plot is divided into four quadrants, corresponding to four types of local spatial connections between regional units and their neighbors. IL>0 indicates that a high value is surrounded by a high value or a low value is surrounded by a low value, corresponding to two distribution modes: the first quadrant represents high-high clustering, and the third quadrant represents low-low clustering; IL<0 indicates that a low value is sur-rounded by a high value or a high value is surrounded by a low value, corresponding to two distribution modes: the second quadrant represents low-high clustering, and the fourth quadrant represents high-low clustering. According to the local Moran’s I scatter chart (Figure 3), during the study period, most of China’s provinces were distributed in the first quadrant and the third quadrant, that is, the HH mode and the LL mode dominated, showing obvious spatial dependence, and the spatial differentiation of farmers’ forestry income was serious. The aggregation of high value provinces indicates that each province can form a mutually promoting effect, while the aggregation of low value provinces indicates that each province can form a negative impact on each other, leading to a vicious cycle of constant difference.

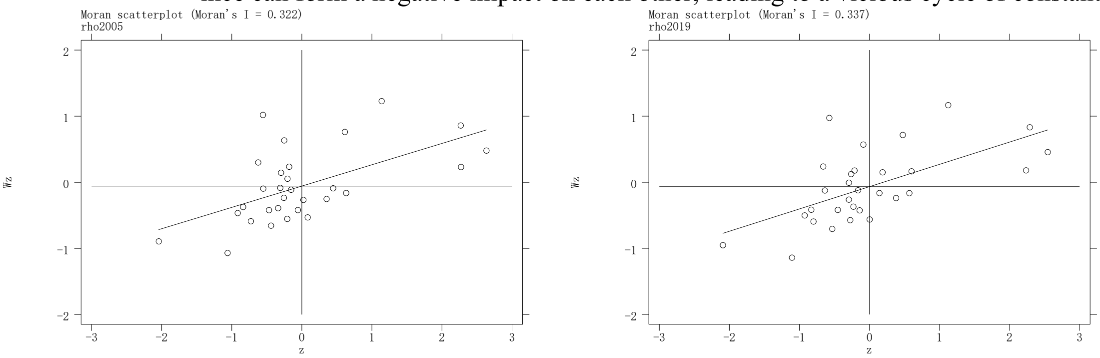

Figure 3. Moran’s I scatter plot of local farmers’ forestry income in China’s provinces.

Among the high-high concentration areas, there are mainly Tianjin, Shanghai, Fujian, Zhejiang and Beijing, etc. These provinces are located in the coastal economically developed provinces, and their own forest farmers’ income is higher, which can also drive the increase of forest farmers’ income in neighboring provinces. In the low-low agglomeration zone, Hunan, Ningxia, Shanxi, Shaanxi, Chongqing, Henan, Hubei, Inner Mongolia, Liaoning, Heilongjiang, Jilin, Guizhou and Anhui are mainly represented. These provinces are mainly located in economically underdeveloped areas in the central and western regions, adjacent to provinces with lower income from forest farmers. They not only have lower income from their own forest farmers, but also have mutual constraints with other neighboring provinces, which is not conducive to driving the increase in income from forest farmers in neighboring provinces. From a dynamic perspective, the number of high-high agglomeration areas increased from 5 in 2005 to 7 in 2019, the number of low-low agglomeration areas decreased from 14 in 2005 to 13 in 2019, and the number of low-high and high-low agglomeration areas decreased, which also shows that the spillover effect increased, and the driving role played by neighboring provinces was enhanced. Overall, the local autocorrelation relationship exhibits relatively stable performance, mostly exhibiting “high-high” and “low-low” clustering types.

5. Analysis and Discussion of Empirical Results

5.1. Full-sample Spatial Regression Discussion

In order to choose a more suitable parameter estimation model, this paper used F-statistics and Hausman test to make the optimal choice between the mixed regression model and the fixed effects model, as well as the random effects model and the fixed effects model (Table 4). The test results showed that both the F-test value and Hausman test value reject the original hypothesis at the significance level of 1%. Therefore, this paper used the panel fixed effect model to estimate the impact of forestry industry integration on farmers' forestry income. At the same time, in order to minimize the problem of abnormal model results caused by missing variables, this paper followed the modeling principle of "general to special" in econometrics and used stepwise regression to introduce control variables for analysis.

Table 4. Overall sample regression results.

Varia-bles	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)	FE (6)	FE (7)
X_1	0.065*** (4.786)	0.025*** (2.972)	0.020*** (3.458)	0.014*** (2.799)	0.020*** (3.916)	0.021*** (4.032)	0.015*** (3.106)
X_2		0.495*** (26.858)	0.238*** (14.079)	0.194*** (12.076)	0.200*** (12.821)	0.249*** (9.213)	0.222*** (8.706)
X_3			0.917*** (22.330)	0.783*** (19.652)	0.745*** (18.997)	0.740*** (18.930)	0.589*** (14.311)
X_4				0.134*** (9.517)	0.129*** (9.421)	0.130*** (9.523)	0.101*** (7.677)
X_5					0.045*** (5.410)	0.049*** (5.763)	0.052*** (6.566)
X_6						−0.058** (−2.232)	−0.042* (−1.724)
X_7							0.102*** (7.936)
_cons	9.604*** (727.060)	8.950*** (349.169)	8.487*** (313.747)	8.962*** (160.942)	9.133*** (146.250)	9.275*** (104.287)	9.368*** (111.829)
N	450	450	450	450	450	450	450
F	0.065***	0.025***	0.020***	0.014***	0.020***	0.021***	0.015***
Hausman	-	-	-	-	-	-	12.49*

Note: ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level.

In Table 4, FE (1) represents the "general" estimation results, while FE (2)–FE (7) represents the "special" estimation results of gradually introducing control variables. From the results of FE (7), it can be seen that the regression coefficient of forestry industry integration is 0.015 and passes the 1% significance test. Moreover, after adding other control variables, its promoting effect is still significant. Consistent with Sears et al. (2007) and Hou et al. (2017), we find that the improvement of forestry industry integration significantly promotes farmers' forestry income, thus rejecting the null hypothesis and validating "alternative" Hypothesis 1.

From the perspective of control variables, farmers' forest land resource level, rural human capital level, forestry financial expenditure, level of economic development and transport infrastructure conditions all significantly promote the increase of farmers' forestry income, while forest resource endowment has an inhibitory effect on the increase of farmers' forestry income at the significance level of 10%. This is mainly because although the forest resources in the region are relatively abundant, they are mostly in a state of protection and cannot be fully developed and utilized due to policy restrictions (Bai & Zheng, 2018; Wang et al., 2007; Yang et al., 2015), thus having no promoting effect on farmers' forestry income.

5.2. Heterogeneity Analysis and Discussion

5.2.1 Regional Difference Analysis and Discussion

There are significant differences in forestry industry integration and farmers' forestry income among different provinces in China. Considering the practical significance of regional differences on farmers' forestry income, based on the Eastern, Central, Western, and Northeastern regions of China, a fixed effect model is used to estimate the relationship between forestry industry integration and farmers' forestry income for regional difference discussions (Table 5).

Table 5. Regression results of sub regional samples.

Variables	Eastern	Central	Western	Northeastern
X_1	0.016*	0.022*	−0.001	0.304***
	(1.744)	(0.973)	(−0.147)	(3.145)
X_2	0.125***	0.741***	0.329***	0.846
	(3.344)	(12.401)	(8.296)	(2.955)
X_3	0.553***	0.255**	0.539***	0.347**
	(9.916)	(2.136)	(8.353)	(2.550)
X_4	0.084***	0.046**	0.111***	0.070
	(3.810)	(2.444)	(4.882)	(1.250)
X_5	0.075***	−0.001	−0.006	0.004
	(6.381)	(−0.037)	(−0.475)	(0.130)
X_6	−0.014	−0.155***	−0.046	0.146
	(−0.397)	(−3.027)	(−1.214)	(0.446)
X_7	0.153***	0.027	0.067***	0.052
	(5.711)	(1.646)	(3.862)	(1.460)
_cons	9.840***	9.105***	8.796***	7.626***
	(63.128)	(50.390)	(76.469)	(7.511)
N	450	450	450	450
F	501.92***	195.12***	265.98***	47.74***

Note: ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level.

In Table 5, the regression coefficients for forestry industry integration in the Eastern, Central, Western, and Northeastern regions are 0.016, 0.022, −0.001, and 0.304, respectively. Meanwhile, the regression coefficients in the Eastern, Central, and Northeastern regions are significantly positive, while the regression coefficient in the Western region is negative and not significant, indicating that the integration of forestry industry in the Eastern, Central, and Northeastern regions can significantly promote farmers' forestry income, and yet in the Western region, forestry industry integration has a restraining effect on farmers' forestry income, but it is not significant. These findings reject the null hypothesis and verify "alternative" Hypotheses 2. One possible reason for this is that compared to the Eastern, Central, and Northeastern regions, in the Western region, production factors such as capital, talent, and technology are relatively scarce (Chen et al., 2020), forestry infrastructure is relatively backward, the driving capacity of new business entities is weak, the resource constraints of integrated development are prominent, and the innovation of integrated content is insufficient, which to some extent hinders the promoting role of forestry industry integration on farmers' forestry income. Furthermore, the ecological environment in the Western region is fragile, with protection as the main focus, and as an ecological conservation area (Chen & Zhang, 2019), it also restricts economic development and utilization, leading to a decrease in opportunities for forest farmers to engage in forestry production and operation activities, which is not conducive to increasing their income.

In the Eastern, Central, and Northeastern regions, the coefficient of forestry industry integration in the Northeastern region is significantly higher than that in the Central and Eastern regions. This is mainly because in the Northeast region, there are abundant forest resources (Chen & Zhang, 2019). Forest industry enterprises and state-owned forest farms have overcome the barriers and obstacles that restrict the integration of the upstream and downstream industrial chains of the forestry industry in various aspects such as financing and circulation. This plays an important role in promoting the integration of the forestry industry, ensuring that the development of modern forestry is no longer limited by traditional forestry, releasing a large amount of surplus labor, and thus driving the increase of local farmers' forestry income.

5.2.2 Individual Difference Analysis and Discussion

In order to comprehensively reveal the impact of forestry industry integration on the income levels of different forest farmers, five typical quantiles of 10%, 25%, 50%, 75% and 90% were selected to correspond to the lowest, middle low, middle, middle high and highest groups of farmers' forestry income, respectively, to try to understand the marginal effect of forestry industry integration on farmers' forestry income under different income levels of forest farmers (Table 6). In addition, in order to make the estimation results more effective, the self-service repeated sampling technique is used to conduct 1000 repeated samples for each quantile regression.

Table 6. Panel quantile regression results.

Variables	10 Quantiles	25 Quantiles	50 Quantiles	75 Quantiles	90 Quantiles
X_1	0.013	0.014*	0.015***	0.016**	0.019*
	(1.095)	(1.735)	(2.710)	(2.259)	(1.800)
X_2	0.214***	0.218***	0.222***	0.226***	0.228***
	(2.874)	(4.383)	(6.577)	(5.308)	(4.155)
X_3	0.620***	0.604***	0.586***	0.571***	0.561***
	(6.235)	(9.104)	(13.004)	(10.060)	(7.674)
X_4	0.102***	0.102***	0.101***	0.101***	0.100***
	(3.147)	(4.692)	(6.866)	(5.423)	(4.191)
X_5	0.056***	0.054***	0.051***	0.049***	0.048***
	(2.875)	(4.131)	(5.785)	(4.393)	(3.312)
X_6	−0.008	−0.025	−0.045	−0.062	−0.072
	(−0.103)	(−0.496)	(−1.298)	(−1.420)	(−1.282)
X_7	0.120***	0.111***	0.100***	0.091***	0.086***
	(3.289)	(4.547)	(6.059)	(4.391)	(3.207)

Note: ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level.

In Table 6, the regression coefficients of forestry industry integration are all positive, and except for the 10th quantile, all other quantiles are significant at least at the 10% level, indicating that forestry industry integration has a promoting effect on increasing farmers' forestry income. In addition, with the increase of the quantile of farmers' income (10%→25%→50%→75%→90%), the regression coefficient of forestry industry integration continues to increase (0.013→0.014→0.015→0.016→0.019), indicating that the impact of forestry industry integration on farmers' income increases with the increase of income level. This also means that the income increase effect of forestry industry integration on areas with higher income level is greater than that on areas with lower income level (Fei et al., 2021), thus rejecting the null hypothesis and validating "alternative" Hypothesis 3.

On the one hand, forestry industry integration includes industrial activities such as understory planting and collecting industry, forest animal breeding and utilization industry, wood processing and manufacturing industry, forest ecotourism, and forestry production technology management industry. There is a certain threshold for investment in funds, technology, and other aspects, and people at high income levels can obtain more benefits from it. On the other hand, due to asymmetric information, farmers lack comprehensive control over market information, and are always in a disadvantaged position in the industry chain (Liao, 2015; Liao & Guo, 2015; Muriithi, 2011). In addition, in order to obtain excess profits, enterprises often reduce the proportion of interests of vulnerable forest farmers in the industry chain and try to realize the transfer of market value risks as much as possible. This long-term imbalance in interest distribution can undoubtedly affect the income of forest farmers and reduce their production enthusiasm. Therefore, although forestry industry integration has promoted the income increase effect of low-income forest farmers, it has not yet played a significant role.

As far as the control variables are concerned, the regression coefficient of farmers' forest land resource level is significantly positive, and the regression coefficient increases with the increase of the quantile, indicating that the income increasing effect of farmers' forest land resource level raises with the enhancement of income quantile. The regression coefficients of rural human capital level,

level of economic development, and transport infrastructure conditions are all positive at a significance level of 1%, and gradually decrease as the quantile increases, indicating that rural human capital level, level of economic development, and transport infrastructure conditions have a more significant income increase effect on low-income forest farmers. The regression coefficient of forestry financial expenditure is significantly positive at the 1% level, and there is no significant change at each quantile, reflecting the group neutrality principle of forestry finance. The regression coefficients of forest resource endowment are all negative at the significance level of 1%, and the absolute value of the coefficients increase with the increase of the quantile, which indicates that forest resource endowment inhibits farmers' forestry income and has a more significant effect on high-income groups. The possible reason is that the index of regional forest resource endowment is measured by the regional forest coverage rate. A good forest resource endowment means a high regional forest coverage rate, a large number of nature reserves and the area of returning farmland to forest (Chen et al., 2020; Zhang et al., 2019). These resources have not been effectively developed and utilized due to the restrictions of the current ecological protection policy, which also reflects that the advantages of regional forest resources have not yet been transformed into advantages of forest assets, and even some areas are still in the stage of suppression.

5.3. Spatial Effect Analysis and Discussion

To select a suitable spatial econometric model, we tested the spatial panel model (Chen et al., 2020). The results showed a significant positive spatial correlation between variables, as indicated by the significantly positive Moran's I statistic (Table 7). We also found a need to reject the original hypothesis (spatially independent residuals). Additionally, the LM-error test, Robust LM-error test, LM-lag test, and Robust LM-tag test were passed 1% significance level, which suggests that the selection of either the SPLM or SPEM model is appropriate. Further testing through LR and Wald tests led to rejection of the original hypothesis, indicating that the SPDM model was more suitable. A Hausman test was then used to screen between random effects and fixed effects models; the Hausman statistical value was 353.22 and passed the 1% significance level test, indicating that the fixed effects model was more appropriate. Finally, it can be judged from the F-test value that the spatiotemporal dual fixed effect model should be selected. Accordingly, we selected the SPDM model with spatiotemporal dual fixed effect.

Table 7. Results of spatial panel econometrics model.

Test type	Statistic	P value	Test type	Statistic	P value
Moran's I	6.184***	0.000	Wald-spatial lag	53.93***	0.000
LM-error	35.053***	0.000	LR-spatial lag	152.56***	0.000
Robust LM-error	16.593***	0.004	Wald-spatial error	215.11***	0.000
LM-lag	89.663***	0.000	LR-spatial error	187.04***	0.000
Robust LM-lag	71.203***	0.000	Hausman	353.22***	0.000

Note: ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level.

The estimated parameters of each index of the SPDM model with spatiotemporal dual fixed effect (Table 8) were analyzed to determine the following.

Table 8. Estimation results of spatial econometric model.

Variables	SPEM	SPLM	SPDM	LR_D	LR_I	LR_T	WX	Interaction effect
X_1	0.003** (2.186)	0.003* (1.935)	0.003** (2.412)	0.004** (2.476)	0.007* (1.268)	0.011** (1.686)	$W*X_1$	0.002** (0.661)
X_2	0.040*** (4.878)	0.037*** (4.600)	0.042*** (5.095)	0.043*** (5.137)	0.024 (0.769)	0.067* (1.923)	$W*X_2$	−0.010 (-0.585)
X_3	0.017 (1.212)	0.037** (2.466)	0.036** (2.439)	0.063*** (3.743)	0.289*** (4.160)	0.351*** (4.401)	$W*X_3$	0.132*** (4.000)
X_4	0.010* (1.878)	0.006 (1.186)	0.011** (2.033)	0.011** (1.977)	−0.003 (−0.198)	0.008 (0.431)	$W*X_4$	−0.007 (−0.817)
X_5	-0.008*** (−3.299)	-0.005** (−1.994)	-0.005** (−2.023)	-0.003 (−1.029)	0.027*** (2.686)	0.024** (2.069)	$W*X_5$	0.016*** (3.350)
X_6	-0.023*** (−3.170)	-0.021*** (−2.965)	-0.029*** (−4.004)	-0.026*** (−3.213)	0.028 (0.797)	0.002 (0.051)	$W*X_6$	0.031* (1.691)
X_7	0.014** (2.156)	0.016** (2.527)	0.011* (1.756)	0.016** (2.339)	0.058** (2.241)	0.074*** (2.598)	$W*X_7$	0.024* (1.680)
Rho/λ	0.568***	0.530***	0.512***					
sigma2_e	0.000***	0.000***	0.000***					
R^2	0.709	0.873	0.937					
Log_L	1358.973	1359.010	1377.047					

Note: ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level.

The estimated value of the forestry industry integration coefficient was 0.003, which is significant at the 10% level. This shows that the improvement of forestry industry integration significantly promotes farmers' forestry income, thus rejecting the null hypothesis and validating Hypothesis 1. Similar results have been reported in past analyses of industry integration in agriculture. For example, positive associations between farmers and industry integration were found by Das & Ganesh-Kumar (2018), Carillo et al. (2017) in places such as India and Italy. According to the theory of spatial economics, with the vertical development of national economic integration, inter-regional transaction costs will be reduced. Various input-output factors and production and management activities in the inter-regional development main body gather together in the spatial scope due to accidental factors, and thus form a "center-periphery" form of economic zoning. With the rapid development and wide application of network information technology, the supply and demand relationship between industries has already broken the restriction between regions, and the inter-regional flow of various production factors and the enhanced correlation of product trade will form the spatial agglomeration advantage of regional production factors, affecting the integration and cluster development of forestry industry and the formation of industrial chain, thus affecting the income of forest farmers. The results also show that it is necessary to study the effect of forestry industry integration on farmers' income from a spatial perspective. It should be noted that Rho/λ reflects the magnitude and direction of the spatial hysteresis effect, with a value between −1 and 1. In Table 8, Rho/λ is 0.512, passing the 1% significance level test, which means that the increase in forestry industry integration in adjacent regions has a positive effect on the increase of farmers' forestry income. That is, there is a significant spatial spillover effect of forestry industry integration on the growth of farmers' forestry income. sigma2_e represents the variance of the spatial error term, which is the degree of spatial autocorrelation error. In Table 8, sigma2_e is 0.0002, passing the 1% significance level test and indicating that the spatial autocorrelation error is small and the SPDM model fits well.

When using the spatial econometric model to explain the impact of forestry industry integration on farmers' forestry income and spatial spillover effect, in addition to point estimation, it is also necessary to decompose the spatial effect to further determine the direct effect, indirect effect and total effect of forestry industry integration on farmers' forestry income (Table 8). Among them, the total effect represents the overall impact of forestry industry integration on the income of forest farmers, the direct effect represents the impact of forestry industry integration on the income of local forest farmers, and the indirect effect represents the impact of local forestry industry integration on the income of nearby forest farmers (Elhorst, 2003).

The total effect, direct effect, and indirect effect coefficients of forestry industry integration on the income of forest farmers were all positive, and significant at the level of 1%, with values of 0.011, 0.004, and 0.007 respectively, which indicates that forestry industry integration has a significant income increasing effect on the income of forest farmers in both the local and adjacent regions, that is, the spatial spillover effect caused by forestry industry integration is significant. At the same time, the indirect effect coefficient of forestry industry integration was greater than the direct effect coefficient, indicating that the effect of forestry industry integration on the income increase of neighboring forest farmers is greater than that of local forest farmers. This is mainly because the upgrading of local forestry related industries has effectively broken the relatively single mode of low efficiency production, free flow of talents, capital and technology among industries, and the barriers to free flow of regional factors have gradually disappeared (Deichmann et al., 2016; Fu & Zhang, 2022; Jin et al., 2023b). Resources can flow freely and efficiently in the neighboring areas, and then rely on the spatial spillover mechanisms such as "factor flow effect", "scale economy ", "diffusion effect" and "learning imitation effect" to affect the neighboring areas (Ziyu, 2022), which has a positive spatial spillover effect on the income increase of forest farmers in the surrounding areas. However, it should be noted that the spillover effect coefficient of forestry industry integration was 0.007, which is at a relatively low level, indicating that China's forestry industry integration is still in the period of transformation and upgrading, some emerging industries related to integration are in the initial stage of development, and the diffusion effect generated by factor flow still needs to be strengthened.

5.4. Robustness Test

We conducted robustness tests based on gradually adding control variables (Table 4) and replacing the explained variable (Table 9).

Table 9. Robustness test results of proposed model.

Variables	SPDM	LR_D	LR_I	LR_T	WX	Interaction effect
X_1	0.007^{*} (1.207)	0.011^{**} (2.218)	0.046^{***} (2.693)	0.057^{***} (2.838)	$W*X_1$	0.021^{***} (2.187)
X_2	0.124^{***} (5.058)	0.101^{***} (3.919)	-0.260^{***} (−2.653)	−0.159 (−1.433)	$W*X_2$	-0.203^{***} (−3.998)
X_3	−0.021 (−0.474)	−0.039 (−0.789)	−0.260 (−1.367)	−0.299 (−1.361)	$W*X_3$	−0.133 (−1.334)
X_4	0.012 (0.718)	−0.007 (−0.433)	0.224^{***} (−4.429)	-0.231^{***} (−4.076)	$W*X_4$	-0.124^{***} (−4.570)
X_5	-0.040^{***} (−5.025)	-0.035^{***} (−4.022)	0.055^{*} (1.871)	0.021 (0.602)	$W*X_5$	0.048^{***} (3.229)
X_6	-0.155^{***} (−7.241)	-0.127^{***} (−5.222)	0.309^{***} (2.835)	0.182 (1.473)	$W*X_6$	0.247^{***} (4.471)
X_7	0.060^{***} (0.007)	0.093^{***} (4.446)	0.393^{***} (5.027)	0.486^{***} (5.622)	$W*X_7$	0.175^{***} (3.966)
R^2				0.517		
Log_L				881.595		

Note: ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level.

(1) Gradually adding control variables. In Table 4, we added control variables that affect farmers' forestry income, such as farmers' forest land resource level, rural human capital level, forestry financial expenditure, level of economic development, forest resource endowment, and transport infrastructure conditions, one by one. Not only does the goodness of fit of the model gradually increase, but the significance level of the main explanatory variable and control variables has not changed significantly, indicating that the research conclusion is robust and reliable.

(2) Salary of on-the-job employees in the forestry system as explained variable. In Table 9, the forestry industry integration level had a significant positive correlation with the salary of on-the-job employees in the forestry system. This is consistent with our conclusion that farmers' forestry income as the explained variable. The regression results in this case do not change substantially due to changes in the measures of the explained variable.

6. Conclusions and Implications

6.1. Conclusions

(1) Our results indicated that from 2005 to 2019, the forestry industry integration index value showed a positive trend at both the national and regional levels with varying levels of integration across the Northeast-Central-West-East cascade. Most provinces are currently in the stage of "Medium fusion" or "Medium-high fusion", with the level of integration improving in the majority of regions and declining in only a few areas.

(2) The spatial correlation analysis revealed that spatial factors have become an important factor affecting the income of forest farmers in various regions. The global autocorrelation showed a positive spatial correlation in the income of forest farmers, which is gradually increasing. Local autocorrelation revealed that provinces in the coastal area had high income from forest farmers, as indicated by the presence of HH clusters. In contrast, provinces such as Hunan, Ningxia had low income from forest farmers manifesting as LL clusters.

(3) Our empirical results indicated that the *FII* has a significant positive impact on the income of forest farmers. And it has spatial spillover effects, but at a relatively low level. At the same time, there were regional differences and individual differences in the income increase effect of forestry industry integration for forest farmers. Specifically, regional differences are mainly manifested in the integration of forestry industry can significantly promote farmers' forestry income in the Eastern, Central, and Northeastern regions, and yet in the Western region, forestry industry integration has a restraining effect on farmers' forestry income, but it is not significant. Individual differences are mainly manifested in the income increase effect of forestry industry integration on areas with higher income level is greater than that on areas with lower income level.

6.2. Implications

(1) In terms of the spatial-temporal evolution characteristics of forestry industry integration, the level of integration is mostly in the medium or medium-high stage and exhibits significant positive spatial correlation. Therefore, it is necessary to improve the level of forestry industry integration development and enhance its impact on adjacent regions. This can be achieved by promoting the primary processing and deep processing of forest products, linking primary and tertiary industries, and realizing the drive of industrial chain extension to extend the value chain. To make the most of the agglomeration effect of regions with high levels of forestry industry integration, it is important to improve the benefit-sharing mechanism of cross-regional cooperation and enhance the diffusion effect of forestry industry integration activities in a given region on other regions. By establishing successful cases, we can continue to build pilot areas and demonstration parks to drive the development of forestry industry integration in numerous regions.

(2) The spatial-temporal evolution of farmers' forestry income shows clear regional characteristics. To leverage the agglomeration effect of regions with high income, it is important to strengthen regional exchanges and cooperation and to promote the growth of farmers' forestry income. For regions with substantial differences in farmers' forestry income, regular experience exchange meetings can be organized to facilitate the flow of resources. Regions with high income can serve as a driving force for those with low income, ultimately promoting common development in all regions. In regions with similar income levels, organizing collective training for forestry scientific and technological personnel, as well as conducting friendly competitions, may encourage all regions to strengthen their forestry development.

(3) From the perspective of the function mechanism of forestry industry integration on farmers' forestry income, it is evident that integration can generally improve farmers' forestry income. Therefore, it is crucial to promote the development of forestry industry integration to boost farmers' forestry income. For instance, multiple regions can jointly create a batch of regional characteristic forestry industry integration enterprise brands, play a demonstration effect, bring more employment

opportunities to farmers, and expand the channels for increasing income for forestry farmers. At the same time, we should pay attention to regional economic development and individual differences, that is, formulate special support policies to promote regional coordinated development and the development of low-income groups' forestry industry in promoting the integrated development of regional forestry industry. However, it is necessary to follow the law of forestry economic development, not blindly promote the "curve overtaking" development mode in underdeveloped areas and avoid the possible rupture of new and old kinetic energy and the hollowing of forestry industry when upgrading the forestry industry. Moreover, we should guide the development of joint-stock cooperation. It is necessary to develop more forestland-based cooperation methods, include the forest contractors into the shareholders, and create a comprehensive interest linkage mechanism from the production stage to the operation stage through a variety of models such as "guaranteed income + dividend per share", so as to reduce the operational risks of disadvantaged forest farmers. Finally, it should also innovate the development of order forestry. Promote cooperation in the production and sales of forest products, establish a tracking system with information technology development, product standards and service quality functions, track the integrated products of the forestry industry, improve product quality and increase the income of forest farmers.

(4) It should be pointed out that the Herfindahl index, a previous research method, is used in this paper to measure forestry industry integration. Although it can better reflect the degree of cross-penetration and integration between industries within forestry, it cannot fully reflect the integration between forestry and other industries, resulting in relatively rough measurement results. However, the complete data that can be collected in China's forestry industry can only be used to measure the integration degree of forestry industry by using Herfindahl index method, which is also a commonly used method in more subdivided industries such as cultural tourism, major agriculture, forestry and animal husbandry. Therefore, this method is a very suitable method under existing conditions. In the future, with the increasingly complete data and the continuous improvement of measurement methods, we will further explore more reasonable and effective ways to improve our current work. And conduct smaller scope (such as county-level) research to enrich and improve the integration research of the forestry industry.

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Article

Securing Agro-Pastoral System and Rural Livelihood Through the Market Gardening in Niger: Unfolding Smallholders' Resilience to Interwoven Challenges

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Abstract: Market Gardening (MG) in Niger is a crucial tool for securing agro-pastoral systems and rural livelihoods amid interwoven challenges such as climate change, conflicts and insecurity, demographic pressure, and poverty, which could not be fully coped with only relying on the very limited availability of capital and modern technology. A study of 60 small garden farmers found that MG significantly enhances farmers' income and household food security. The average annual income from MG accounts for about 70 per cent of the farmers' total income. However, challenges like water scarcity, land insecurity, and limited access to credit and markets hinder their full socio-economic role. The farmers try to overcome those obstacles through cooperation, sending remittance from part-time off-farm activities, and mobilization of resources based on their social capital. Those who could not overcome the challenges left the village for a "safer" location. The study emphasizes the need for community collective action, rural-urban networking, and external support to improve MG for rural poverty reduction and food security improvement.

Keywords: Market Gardening; food security; rural livelihoods; Sub-Saharan Africa; Niger

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1. Introduction

Securing agro-pastoral systems and rural livelihoods in developing countries, particularly Sub-Saharan African (SSA) countries, has long been a critical concern due to the countries' dependence on subsistence agriculture and livestock production for sustenance and income generation (Minot & Sawyer, 2016; Ndimbo et al., 2023). The agro-pastoral system, characterized by the interdependent relationship between crop cultivation and animal husbandry, forms the backbone of Niger's rural economy (Zossou et al., 2020). This system faces numerous challenges stemming from environmental, socio-economic, and climatic factors that threaten the livelihoods of smallholder farmers and pastoralists (Adisa, 2020). Nevertheless, in recent years, market gardening (MG) has emerged as a potential solution to address the vulnerabilities and resilience of smallholders within the agro-pastoral system in some SSA areas, which relies on still very limited availability of capital and modern technology. MG involves intensively cultivating vegetables, fruits, and other high-value crops on a small plot of land, typically close to markets, to meet the growing demand for fresh produce (Orsini et al., 2013). The implementation of MG in Niger holds the potential to strengthen agro-pastoral systems and enhance rural livelihoods by offering alternative income sources, diversifying agricultural practices, and mitigating the impact of climate change.

MG has gained attention as a means to achieve sustainable agricultural practices in resource-constrained environments. Farmers can optimize land use, maximize yields, and reduce environmental degradation by adopting small-scale, intensive cultivation techniques. MG can also enhance soil fertility through organic waste recycling and composting, increasing productivity and resilience against climatic stressors (Razanakoto et al., 2021). Since Niger is highly susceptible to the adverse impacts of climate change, including prolonged droughts, erratic rainfall, and rising temperatures that threaten the agro-pastoral system, decreasing agricultural productivity and livestock losses (Zakari et al., 2022; Zossou et al., 2020). MG appears to be one of the resilient mechanisms for smallholder farmers in rural and peri-urban areas amid changing climatic condition and insecurities (Ndimbo et al., 2021; Keys et al., 1988). MG allows farmers to diversify income sources since it enables smallholders to capitalize on urban markets' demand for fresh produce, providing them with additional income streams beyond traditional livestock and crop sales (Goldman et al. 2016).

MG enables smallholders to reduce reliance on a single income source and cope better with income fluctuations, ultimately enhancing livelihood security (Dzanku et al., 2021). Women play a significant role in agricultural production and household choirs. However, they often face gender-specific barriers that limit their access to resources and economic opportunities. Market gardening has the potential to empower women by providing them with greater control over their income and resources. MG is transformative in challenging traditional gender roles and empowering women within agro-pastoral communities (Chiba and Thebe, 2023). Market gardening can significantly contribute to food security by increasing the availability of fresh, nutritious produce and reducing the reliance on food imports in areas facing food security like Niger. It also offers a pathway towards achieving food sovereignty and self-sufficiency in local food production (Razanakoto et al., 2021).

This study aims to explore the role of MG in securing agro-pastoral systems and rural livelihoods in Niger by providing a comprehensive understanding of how MG can contribute to smallholders' resilience in the face of interwoven challenges. As Niger grapples with the complexities of agro-pastoral sustainability, the knowledge derived from this research could inform policymakers, development practitioners, and stakeholders in crafting effective strategies to foster sustainable agriculture and livelihoods in the country. The study highlights that smallholders in Niger have a deep-rooted knowledge of their environment, climate conditions, and traditional farming techniques. By valuing and integrating this knowledge into MG practices, smallholders can develop context-specific strategies responsive to their unique challenges. This localized knowledge is a powerful tool for adapting to changing circumstances, enhancing productivity, and reducing vulnerability to external shocks.

2. Literature Review

2.1. The Interwoven Challenges Facing Agro-Pastoral Systems

The agro-pastoral system in Niger has long served as the backbone of rural livelihoods, sustaining communities through the interdependent relationship between crop cultivation and animal husbandry (Zakari et al., 2022). However, the agro-pastoral landscape in Niger is beset by a complex tapestry of challenges that threaten the sustainability and resilience of smallholders' livelihoods (Zossou et al., 2020). This section delves into the intricacies of these interwoven challenges, highlighting the multifaceted nature of the issues faced by agro-pastoral communities. The Niger's agro-pastoral system is intricately linked to the region's climatic conditions. The country's susceptibility to prolonged droughts, erratic rainfall patterns, and desertification significantly threaten crop production and livestock rearing fields (Zakari et al., 2022). Changes in precipitation patterns can reduce soil moisture, affecting crop growth and exacerbating water scarcity, which is crucial for livestock and irrigation.

Resource scarcity, particularly arable land and water, significantly challenges agro-pastoral communities (Osbahr et al., 2010). Overgrazing and unsustainable land management practices contribute to soil degradation and reduced land fertility, further undermining agricultural productivity. Unsustainable resource use can lead to a vicious cycle of declining yields, ultimately threatening food security and rural livelihoods. Gender inequalities persist within agro-pastoral systems, with women often having limited access to resources, decision-making power, and opportunities (Doss, 2013). The gender gap restricts women's participation in income-generating activities and their ability to adapt to changing circumstances, hampering rural development and diminishing the system's resilience in interwoven challenges. The agro-pastoral communities are highly susceptible to market fluctuations and price volatility, which can significantly impact household income and food security (Stewart, 2008). Reliance on a few agricultural commodities exposes smallholders to the risks associated with changing market dynamics. Price crashes or sudden fluctuations can destabilize livelihoods and limit the capacity to invest in resilience-building measures.

Inadequate access to financial services, including credit and insurance, hampers smallholders' ability to invest in improved agricultural practices and adapt to shocks (Cavatassi et al., 2011). Moreover, the absence of critical infrastructure such as irrigation systems, storage facilities, and transportation networks further constrains the agro-pastoral system's potential to cope with challenges. The impacts of climate change are limited to erratic weather patterns and extend to the shifting of agroecological zones (Sultan et al., 2013). Temperature increases and changing precipitation patterns lead to the northward migration of suitable agricultural areas, affecting traditional cropping calendars and challenging farmers' ability to predict growing seasons (Zakari et al., 2022).

Despite the agro-pastoral system's pivotal role, food insecurity and malnutrition persist in Niger (FAO et al., 2020). A lack of dietary diversity, driven by the limited range of crops cultivated and livestock reared, contributes to persistent malnutrition and limits the system's resilience against shocks. In conclusion, the challenges facing agro-pastoral systems in Niger are intricate and interconnected, requiring holistic approaches to secure rural livelihoods. The multifaceted nature of these challenges underscores the importance of addressing them comprehensively rather than in isolation. By understanding the intricacies of the interwoven challenges, stakeholders can design effective strategies that enhance the resilience of agro-pastoral communities, allowing them to navigate the complex landscape they operate within.

2.2. Role of Market Gardening in Securing Agro-Pastoral Systems and Rural Livelihoods

The agro-pastoral system, characterized by its intricate blend of crop cultivation and animal husbandry, is a means of subsistence and a way of life for millions of rural households. However, the vulnerabilities stemming from environmental uncertainties, climate change, and market fluctuations have prompted the exploration of innovative approaches to enhance the resilience of agro-pastoral systems (Ado et al., 2019). One such approach gaining prominence is the establishment of MG, which holds significant potential in securing rural livelihoods through diversified income streams, increased food production, and enhanced adaptive capacity. MG provides a unique opportunity for diversifying income sources for smallholder farmers and pastoralists. The reliance on a single income stream, often tied to livestock or staple crops, makes households vulnerable to market shocks and climatic uncertainties (Cooper & Wheeler, 2017). Diversification through market gardening allows smallholders to access urban markets and tap into the growing demand for fresh produce (Andres & Lebailly, 2011; Ndimbo et al., 2021). The additional income generated from MG is a buffer against income fluctuations and contributes to overall household resilience.

The nutritional diversity offered by MG has far-reaching implications for rural communities grappling with food security challenges. Traditional agro-pastoral systems may be limited in providing a balanced diet due to reliance on a narrow range of crops and animal products. MG introduces a variety of fruits and vegetables, enriching local diets with essential vitamins and minerals (Abdoulaye & Ramanou, 2015). This diversification contributes to improved nutrition and health outcomes, critical to overall household resilience. MG offers a pathway for smallholders to adapt to changing climatic conditions. The intensive nature of market gardening allows for greater control over production environments, including irrigation and shade netting, to mitigate extreme temperatures (Razanakoto et al., 2021). By integrating climate-smart practices into MG management, smallholders enhance their resilience to climate-induced shocks, safeguarding their agricultural production and livelihoods.

Establishing MG often involves collective community efforts, fostering social capital and knowledge exchange. Cooperatives and producer groups enable smallholders to pool resources, share experiences, and collectively address challenges (Gyau et al., 2014). These networks facilitate the dissemination of innovative techniques, such as improved irrigation methods or pest management strategies, enhancing the overall adaptive capacity of agro-pastoral systems. Besides, MG is crucial in advancing gender equity within agro-pastoral communities. Women often take on active roles in market gardening, gaining greater decision-making power and control over income (Sebastian et al., 2023). This empowerment improves women's socio-economic status and contributes to the resilience of households by diversifying income sources and enhancing resource management.

MG contributes to creating value chains that connect smallholders to larger markets. Its proximity to urban centers allows direct consumer access, reducing intermediaries and increasing profits (Gyau et al., 2014). Establishing strong market linkages bolsters income generation and exposes smallholders to diverse market opportunities, reducing their vulnerability to localized market fluctuations. Therefore, cultivating various crops contributes to preserving and enhancing local agrobiodiversity. Traditional crops that might otherwise be neglected gain prominence in MG, conserving genetic resources and improving the adaptive capacity of agro-pastoral systems (Abdoulaye & Ramanou, 2015). Integrating this agricultural practice into the agro-pastoral system emerges as a transformative strategy to bolster rural livelihoods and enhance resilience. The intricate interplay of challenges, from climate uncertainties to market fluctuations, necessitates holistic solutions. MG offers diversified income sources, improved nutrition, climate adaptation, and empowerment, collectively reinforcing the agro-pastoral system's resilience. Fostering community networks, preserving local agrobiodiversity, and linking smallholders to markets provide a multifaceted approach to addressing interwoven challenges. As many developing countries navigate the complexities of sustaining agro-pastoral systems, MG is a promising avenue to secure livelihoods and preserve ecosystem health while building the foundations of rural well-being (Razanakoto et al., 2021).

3. Materials and Methods

3.1. Description of the Study Area

The study was carried out in the eastern part of the Tillabérie region located between 14°23’08” and 15°41’49” north latitude and 3°35’40” and 4°15’38” east longitude. Created by law No. 2002-014 of 11/06/2002, it comprises the northeastern portion of the Abala department and has an area of 5,500 km2. It is bounded on the south by the communes of Kourfeye Centre, Soucoucoutane, and Dogon Kiriya, on the southeast by the commune of Bagaroua, on the east by the communes of Tébaram and Tillia, on the north by the Republic of Mali, and the west by the commune of Abala. The total population was about 111,358 inhabitants, of which 54,349 are men (48.80%) and 57,009 are women (51.20%). The active labor force aged 15 to 49 is 41,590 (39.14%), which means that the area has a very active human potential for agriculture practiced in all villages of the commune. The ethnic groups “Touaregs, Peulhs, and Djermas follow the Haoussas regarding population size”.

This region’s year is divided into dry and rainy seasons. The dry season begins from October to June. It includes a cold period (October to February) with temperatures dropping to 15℃ and a warm period (March to June) with temperatures of up to 45℃. As for the rainy season (July to September), the average temperature is around 27℃. The average annual rainfall in the area is 471.4 mm (Andres and Lebailly, 2011). The predominant economic activity among the population in the study area depends on agricultural practices, with small-scale MG also playing a critical role in facilitating food security. The cultivation of small plots of land to grow various types of crops, including cereals like millet and sorghum, legumes such as cowpeas and groundnuts, as well as cash crops like sesame, sorrel, voandzou, cassava, cucurbits, and okra is dominant. Millet and cowpeas are the predominant agricultural commodities under cultivation.

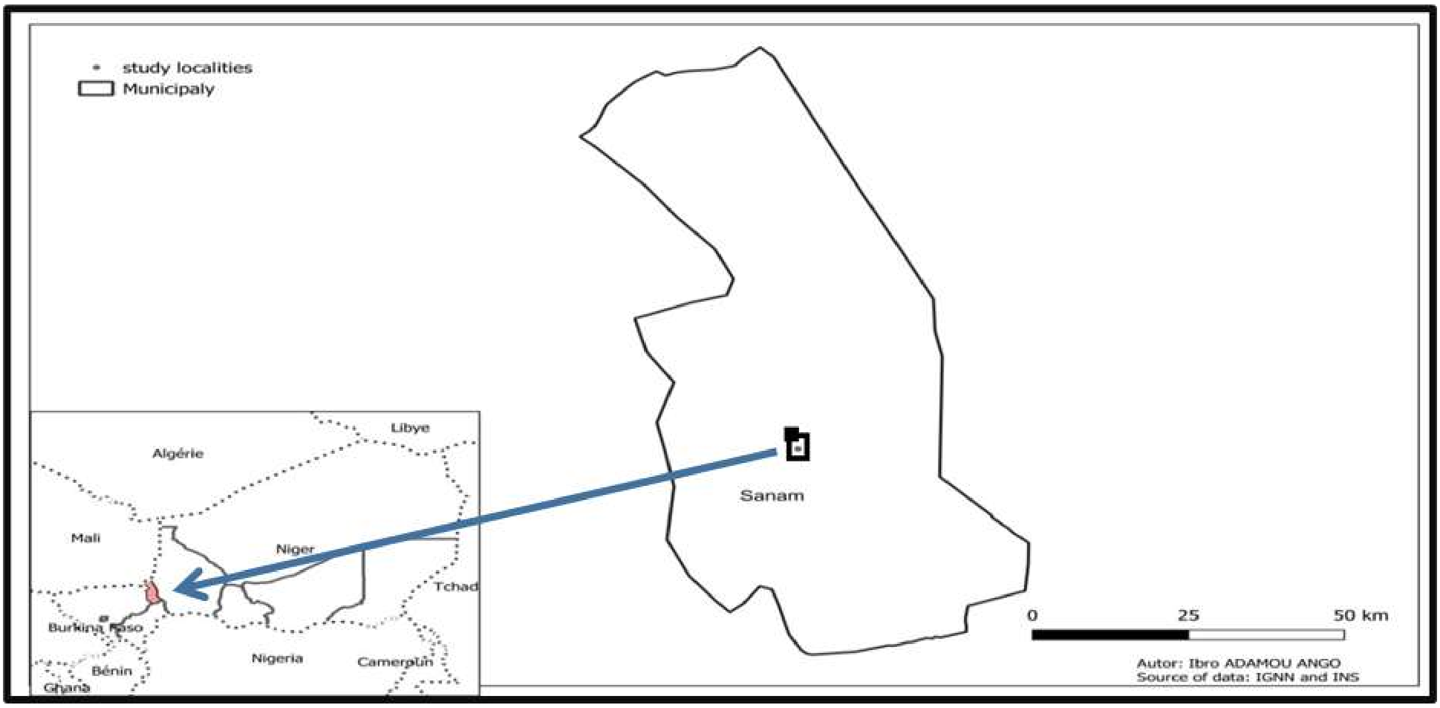

Figure 1. Map of the study areas.
Source: Created by authors.

3.2. Data Collection and Analysis

This article follows a qualitative research approach to explore the role of MG in securing agro-pastoral systems and rural livelihoods in Niger. The study unravels smallholders’ interwoven challenges to understand farmers’ resilience strategies to sustain their agro-pastoral activities and navigate market dynamics. Qualitative research approaches are highly used when there is little understanding, significantly if the current knowledge is fragmented (Kyngäs, 2020). It is uniquely positioned “to provide researchers with process-based, narrated, storied data that is more closely related to the human experience” (Stahl & King, 2020). The qualitative research approach enabled the researcher to learn about farmers’ experience in MG, particularly regarding challenges and adaptive strategies amid the interwoven challenges. Through a qualitative research approach, researchers were able to gain a deep understanding of some specific questions, such as: *What are the key challenges faced by small-scale MG farmers in Niger’s agro-pastoral societies? How do smallholders adapt and respond to the interwoven challenges? What role does MG play in securing the agro-*

pastoral system and rural livelihoods in Niger? How do smallholders engage with market forces and market opportunities in the context of agro-pastoral activities?

Purposive sampling was employed to select the information-rich respondents who effectively responded to the research question. Participant observation, semi-structured interviews, and key informant interviews were used to collect primary data from 60 small-scale farmers actively involved in MG activities, four development officers, and two local leaders from the study sites. Field trips and extended stays in the study sites facilitated the establishment of interpersonal connections with the respondents, hence facilitating the acquisition of detailed information to address the research question. A thematic analysis was undertaken to discover emerging patterns and themes (Byrne, 2022) on the problems faced, resilience mechanisms employed, and the significance of MG in ensuring the sustainability of livelihood strategies and household socio-economic characteristics.

3.3. Analytical Framework

The study's findings are analyzed using a sustainable livelihoods approach (SLA)—a framework that seeks to investigate how to improve the livelihood capabilities of individuals and communities. It acknowledges the significance of various capital assets, including natural, human, financial, physical, and social capital, as the basis for rural poverty reduction and sustainable development (Scoones, 2015; Serrat, 2017). The SLA is a comprehensive framework that aims to understand and enhance the lives and livelihoods of individuals and communities, which is the case in our study area. It emphasizes the importance of considering the interplay between various factors that shape people's livelihoods, such as different resources, social institutions, and economic opportunity. This approach recognizes that livelihoods are dynamic and influenced by multiple dimensions, and therefore, interventions need to address these complexities. By employing this methodology, policymakers and practitioners can better comprehend and promote strategies that strengthen livelihoods and support communities in overcoming challenges. As endorsed by Corsi et al. (2018), MG plays a significant role in ensuring the resilience of agro-pastoral systems. MG provides smallholders with diversified income sources, food security, and a potential pathway out of poverty. Smallholders can capitalize on market demand, generate additional income, and improve their living standards by cultivating high-value horticultural crops.

However, this study emphasizes the importance of smallholders' resilience to interwoven challenges such as climate change, market volatility, and limited access to resources. Scholars like Scoones (2015) argued that smallholders' resilience can be enhanced by adopting sustainable agricultural practices, building social networks, and accessing financial and technical support. MG contributes to income diversification and fosters knowledge exchange and community cooperation, enabling smallholders to cope with and adapt to these challenges effectively. Consequently, policy interventions are essential to promote the widespread adoption of MG to secure agro-pastoral systems. Borras et al. (2011) highlight the significance of empowering smallholders through land tenure security, access to credit, and participation in decision-making processes. Governments and development organizations must provide smallholders with essential support systems and a conducive environment for agricultural success.

Since smallholder farmers face numerous challenges ranging from climate change, market fluctuation, and limited access to agricultural information (Ndimbo et al., 2023), adopting different livelihood strategies such as MG is crucial to creating resilient and sustainable livelihoods. These external shocks can significantly impair agricultural productivity and livelihoods. In this case, we bring forth the neo-endogenous development approach that brings together local and external knowledge to facilitate development. Indigenous agricultural knowledge, passed down through generations within local communities, can offer valuable insights and practices for building resilience in the face of such challenges. Nevertheless, indigenous knowledge alone cannot bring changes and promote sustainable rural livelihoods. The framework below shows how neo-endogenous knowledge could help promote sustainable livelihoods and ensure security in agro-pastoral rural communities.

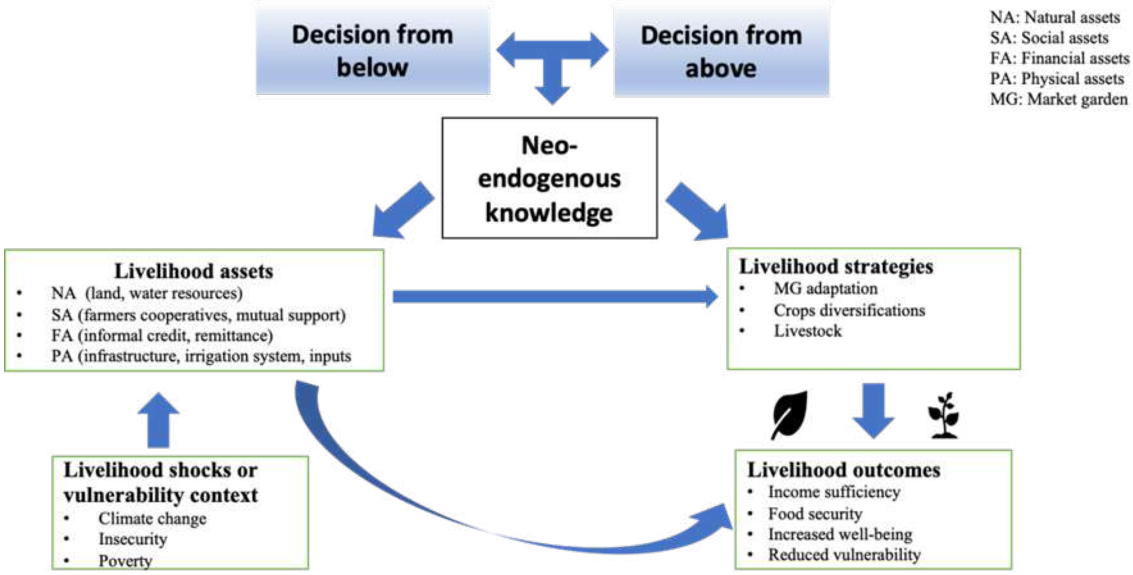

Figure 2. Sustainable livelihoods framework
Source: Modified from Scoones (2015); Serrat (2017)

4. Results and Discussion

4.1. Demographic and Socio-Economic Characteristics of the Respondents

It was essential to describe the demographic and socio-economic characteristics of the respondents, such as gender, education, age, marital status, and land ownership, since these variables determine farmers' participation in MG. This diversity in demographic characteristics can influence the methods employed in farming operations and farms' overall sustainability and profitability. As stated earlier, data for this study were collected from sixty MG producers (N=60) from the eastern portion of the Tillabérie region. According to the data shown in Table 1, it can be observed that a higher proportion of women (76.7%) are engaged in MG production compared to males (23.3%) within our sample, implying that there is higher women's representation in the MG than that of their men counterparts which is very minimal. Women's struggle for economic freedom and improving household food security drives them to engage in MG. On average, the mean age of the respondents is 49.00, where the maximum and minimum age of the respondents is 75 and 22, respectively. This observation suggests that adult individuals, mainly women, exhibit higher levels of involvement in MG than their younger counterparts.

Table 1. Demographic characteristics of the respondents.

Demographic Characteristics	No. of Respondents (N=60)	Percentage (%)
Gender		
Male	14	23.3
Female	46	76.7
Marital status		
Single	0	0.00
Married	33	55.00
Divorced	13	21.67
Widow	14	23.33
Age		
Below 22	13	21.66
23-35	7	11.66
36-55	25	41.66
56-75	15	25.00
Education		
No formal education	17	28.33
Primary	25	41.66
Secondary	16	26.66
Certificate/ Diploma	2	3.33
Bachelor's degree	0	0.00

The current study shows that vegetables are cultivated on minimal land within the production basins. In the Sanam region, most market gardeners (89%) possessed land ranging from 0.25 to 1 hectare. Conversely, a smaller proportion of those examined (11%, N=5) owned plots above one hectare. Most market gardeners operating on the Soubéra producing site possess relatively tiny land parcels, typically ranging from 0.15 to less than one hectare. The compact dimensions of plots in specific producing basins can be attributed, firstly, to the significant presence of market gardeners and, secondly (in the instance of Bassin de Soubéra), to the exclusive reliance on a solitary irrigation well and the acquisition of land through loans or donations. Market gardeners typically cultivate small plots to guarantee adequate upkeep and achieve desirable crop yields. However, in both locations, the land is owned by a limited number of people who inherited it from their parents. At the Sanam site, it can be observed that approximately two-thirds of the basin surrounding the pond was under the ownership of the royal family, which allocated land temporarily to individuals interested in participating in MG activities.

Table 2. Respondents' land size (ha).

Land size (ha)	Frequency (N=60)	Percentage (%)
0-0.25	39	65.00
0.26-0.5	13	21.66
Above 0.51	8	13.33

4.2. Resilience Building and Adaptive Strategies of Smallholders

Strengthening smallholders' adaptation and resilience strategies in the face of interwoven challenges is critical for their survival and long-term development. MG ensures food availability and access for smallholders and their communities, particularly during conflict-induced food shortages and climate-related risks. The diversification of crops and shorter cultivation cycles in MG enables farmers to harvest multiple times within a year, increasing their resilience to climate shocks and minimizing food insecurity (Gwan and Kimengsi, 2020). Market gardeners grow diverse products in the study sites rather than relying on a particular crop. Crop diversification enables farmers to mitigate potential risks associated with climate change, agricultural diseases, and market trends. Both research sites have a wide range of crops grown, with significant yields. Market gardeners in these communities specialize in producing a variety of mixed fruits and vegetables, including leafy greens and fruits. Based on the growers' responses and field observation, the market gardeners grow different horticultural crops, such as lettuce, carrot, cabbage, potato, and eggplant. Besides, vegetables such as zucchini, tomato, okra and moringa are produced by market gardeners, and the production of these crops varies to different degrees depending on farming practices.

Nevertheless, lettuce and cabbage are the most extensively grown commodities, contributing 17% and 16% of total crop production. These two crops are grown by nearly 90% of the surveyed growers at the designated locations. 14% comprises potatoes, making them the second-most prevalent crop. Tomatoes and moringa follow at 13% and 12%, respectively. Carrots and okra have the lowest representation, with 10% of the sample for each. Zucchinis comprise 5% of the sample, whereas eggplants account for 3%. Given the limited area of the facilities, agricultural producers choose to cultivate crops with a short life cycle. Multiple production cycles can be attained through the cultivation of short-cycle crops. Adopting sustainable farming practices, such as crop rotation, water management, and agroforestry, helps to improve soil fertility and withstand extreme climatic conditions. In the study areas, farmers utilized inputs consisting of seeds, fertilizers, and plant protection products. Market gardeners understand the dynamic nature of soil fertility, recognizing the necessity of cultivating multiple crops that sustain and enhance their productive capacity (Ruch et al., 2023).

The farmers utilize both organic and conventional fertilizers. All market gardeners exclusively employ organic manure derived from animal dung and domestic waste in the designated study areas. Inorganic fertilizers are commonly utilized, with the nitrogen phosphorus (NPK) components being sourced through contributions from development partners and local merchants. The neo-endogenous approach to MG is centered around the objective of optimizing agricultural productivity through the implementation of ecologically sustainable agriculture and the promotion of local resource use. Farmers also emphasize the significance of water management strategies in this arid region (Baker et al., 2012). Sonam's and Soubéra's smallholders have developed innovative water-saving techniques in MG, such as rainwater harvesting, small-scale irrigation systems, and efficient water use. These practices help farmers use limited water resources effectively, ensuring crop growth even during water scarcity.

The MG practice relies on the small-scale irrigation system. 95% (N=57) of the market gardeners use running water, defined as water originating from the waterhole and flowing through the minor bed of the waterhole. In comparison, only 5% (N=3) of the market gardeners use water from wells and boreholes. On the other hand, it makes it abundantly evident that all of the market gardeners located in the vicinity of the waterhole drew their water supply from the exact location. Nevertheless, the Soubéra market gardeners have had advantageous outcomes due to implementing a borehole, a vital resource for conducting their market garden-producing operations. Implementing this borehole has facilitated various local activities, including providing water for livestock and domestic use.

In the rural regions of Niger, the capacity to adapt and assume control of their destinies is reflected in the adoption of new farming strategies and agricultural varieties. Farmers are experimenting with and employing new crops, production techniques, and methods of organizing and marketing production to take advantage of their favorable environment. They demonstrate the capacity of African rural communities to establish innovative value-added strategies (Pritchard et al., 2019). In addition to MG, farmers generate income through other sources, such as rain-fed agriculture, livestock breeding, agri-food processing, or handicrafts, to reduce dependence on a single source of income. The rural community of Sanam is an agro-pastoral community par excellence, where agriculture and livestock breeding are the dominant activities. However, other activities of no less importance exist and contribute to increasing household incomes: trade, handicrafts and women's economic activities. These activities occur in a context marked by an upsurge in extreme phenomena known in the community as recurrent droughts, insecurity, and floods.

Generally, the MG plays a significant role in promoting food security, economic resilience, and social stability in conflict-affected Niger, particularly study area. In the study areas, MG contributes to the local production of fresh vegetables, agricultural job creation, community food security, and local economic stimulation. It also promotes sustainable farming practices and helps reduce dependence on imported vegetables. However, climatic factors, water management and other local considerations must be considered to ensure the success of MG in this region. The development of cash and food crops (CCS) was, therefore, a new necessity to avoid accelerated impoverishment of the area and simultaneously satisfy the increasing needs linked to demographic growth. MG significantly enhances food security in the study area regarding quantity and quality.

From an economic perspective, MG offers smallholders an opportunity to generate income and stabilize their livelihoods amidst conflict and climate-related insecurity. It provides a sustainable source of income and employment for smallholders, reducing their vulnerability to economic shocks. The sale of surplus produce supports farmers' families and contributes to local economic development. The examination of the study data reveals that the lowest amount received by farmers at the two sites under investigation was 35,000 XOF CFA (equivalent to 55.82 USD). In contrast, the highest amount per farmer reached 4,500,000 XOF CFA (756.29 USD). Each farmer received an average of 75,275 XOF CFA (or 126.51 USD).

4.3. Farmers' Access to Markets and Value Chains

Market access and value chain management are essential for market gardeners in Sanam, as in many agricultural regions. Proper access to MG and developing efficient value chains are vital for promoting agricultural output, improving local incomes, and ensuring food security. The local distribution network, training and empowerment, technology and digitization, and access to credit and marketing awareness are critical challenges to improving the study area's value chain and market access. However, local authorities, farmers' organizations, and development actors work together to implement measures and support mechanisms for market gardeners in Sanam and Soubéra to improve market access and value chains. Farmers also collaborate with other value chain actors to access broader markets, enhance the marketing of their produce and obtain fair prices. This enables market gardeners to grow and trade MG crops of diverse varieties and generate income.

Market access for MG is essential for farmers to utilize their resources effectively and contribute to the local economy. Both rural and peri-urban market gardeners rely on local and growing urban markets. This indicates the significance of MG access for small-scale farmers in meeting the growing demand for fresh produce in urban centers. Establishing efficient value chains further enhances the impact of MG access. Value chains encompass various stages, including production, processing, distribution, and marketing, that add value to agricultural products before they reach the end consumers. Enhancing these chains leads to increased farmer income, reduced post-harvest losses, and improved market access. A report by the International Institute of Tropical Agriculture IITA (2018) emphasizes the importance of strengthening value chains to ensure food security and alleviate poverty in Niger. This highlights the potential of value chains in enhancing the overall socio-economic development of the research areas and its surrounding regions.

Access to markets and well-functioning value chains also reduce hunger and malnutrition. The availability of fresh and nutritious produce through MG offers affordable and healthy food options for the local population. MG positively affects value chain improvements, dietary diversity and nutritional outcomes of both growers and consumers (Hantchi et al., 2022). This underlines the crucial role of these factors in tackling food insecurity and promoting a healthy diet among the population in Sanam. Nevertheless, stakeholders must work together to address existing challenges to ensure sustainable MG access and value chains in Sanam and Soubéra. These challenges include limited infrastructure, lack of proper storage facilities, and inadequate access to credit. Strategies such as supporting farmers' cooperatives, investing in infrastructure development, and promoting market information systems are essential for overcoming these obstacles (FAO, 2021). This is due to the paramount importance of MG in boosting agricultural productivity, improving livelihoods, and promoting food security. Through effective implementation of strategies, stakeholders can contribute to the sustainable development of the agricultural sector and improve the overall well-being of the local population.

4.4. The Contribution of Development Actors to Smallholders in Market Gardening

Development actors have played a crucial role in improving smallholders' agricultural practices, enhancing productivity, and facilitating market access. In the context of the MG, development actors play different roles. Firstly, development actors have provided technical assistance and training to smallholders in sustainable farming techniques, crop diversification, and water management. These interventions have helped smallholders in Niger to increase their agricultural productivity and improve their resilience to climate change. Secondly, development actors have facilitated the formation of farmer organizations and cooperatives, promoting collective action and market linkages. These organizations have assisted smallholders in gaining better access to inputs, credit facilities, and information on market opportunities. By providing smallholders with access to improved technologies, market information, and financial services, development actors have contributed to a shift from subsistence farming to market-oriented production.

The International Fund for Agricultural Development (IFAD) is a key actor in the study area. IFAD's projects in Niger, such as the Market Gardening and Small-Scale Irrigation Program (PMPADAI), implemented in collaboration with the Nigerien government, aim to improve the productivity and market access of smallholder farmers. These efforts involve training, technical support, and infrastructure development, enabling smallholders to adopt sustainable farming practices and increase their income. Besides, NGOs like Oxfam have also contributed significantly to developing smallholders in MG. Through their projects, such as the Sustainable Agriculture and Resilience Program, Oxfam has focused on building the resilience of small-scale farmers to climate change and market volatility. Their interventions include training on climate-smart agriculture, promoting sustainable farming techniques, and supporting the formation of farmers' cooperatives to enhance market access and bargaining power.

Moreover, development actors have facilitated the establishment of market infrastructures such as rural marketplaces, collection centers, and storage facilities. These interventions have helped smallholders in Niger to reduce post-harvest losses, enhance product quality, and negotiate better prices. Development actors have also played a significant role in policy advocacy and creating an enabling environment for smallholders. They have influenced government policies and programs, encouraging greater investment in agricultural research, rural infrastructure, and market development. This has led to improved market access, reduced trade barriers, and the formulation of supportive policies for smallholders. The contribution of development actors to smallholders in MG in Niger has been substantial. These actors have enhanced smallholders' productivity, income, and market participation through technical assistance, farmer organization formation, market facilitation, and policy advocacy. However, continuous efforts are required to ensure sustainable and equitable growth for smallholders in the MG sector in Niger.

4.5. Social Empowerment and Community Development Through Market Gardening Initiatives

MG initiatives in rural areas significantly influence social empowerment and community development. Market gardens provide local communities with direct access to fresh, nutritious produce. They reduce their dependence on external supplies and improve nutrition and food security. In Sanam and Soubéra, local people have preferences and often attach specific symbolic values to the essential foods they consume. The analysis of our interviews with farmers shows that the population appreciates fruit and vegetables because of the consideration they are given (sweets). Regarding job creation and income generation, MG initiatives offer employment and income opportunities to members of the local community, particularly women and young people. They improved their economic situation and strengthened their role in society. Income from MG has become a guarantor of food security when cultivated correctly. It can give growers more than enough income to outperform traditional crops (cereals, cowpeas). The MG is almost exclusively for market-oriented crops.

MG in Sanam and Soubéra (two neighboring villages) enables women to produce actively and market produce. It can significantly impact their economic autonomy, self-esteem and participation in decision-making within the family and community. An illustration in this regard is that young people and women play a significant role in the mutations that are taking place to reduce environmental constraints and food insecurity (Burney et al., 2010). Nevertheless, the recognition they receive needs to be more balanced. Women are heavily involved in soil restoration and MG. Certain crops, such as sesame, perceived as minor and reserved for women, are experiencing substantial expansion thanks to the efforts of female producers to organize. Women's positions have improved in the family, on the farm and in rural areas (Hassane, 2015). Nevertheless, despite the persistence of certain representations and constraints, they continue to suffer discrimination in several areas. Frequently, women are not considered as producers in their own right. The critical tasks they perform in food production are still often perceived as an extension of the domestic activities linked to their status in this locality.

This activity (MG) strengthens the social fabric by promoting cooperation and collaboration within the community. In both villages (Sanam and Soubéra), members work together to plant, cultivate and market produce, thus strengthening social ties and solidarity. Neo-endogenous theory encourages collaboration and cooperation between local players, producers, governments, research institutions and businesses. This collaboration can foster the sharing of knowledge and resources for the sustainable development of MG. The survey results showed the importance of producer collaboration at the sites studied. According to the head of the Sanam women's cooperative, "Producers have learned about production thanks to the support of the various partners and through their willingness to work as a team, sharing knowledge and using similar production techniques".

Furthermore, MG promotes environmental awareness by encouraging sustainable agricultural practices, which can raise environmental awareness within the community and contribute to preserving natural resources. Indeed, it should be remembered that neo-endogenous theory encourages this development approach, which valorizes local skills and resources to stimulate economic growth.

In the context of market gardeners, this would mean supporting their training, collaboration, and access to innovation to improve their competitiveness and contribute to the development of their local communities. In short, MG initiatives in rural areas have the potential to positively transform the lives of communities by strengthening their social and economic empowerment and promoting sustainable development on a local scale.

4.6. Smallholders Market Gardening Cooperatives and Mutual Support

MG cooperatives play a crucial role in improving smallholders' economic and social conditions. Cooperative structures enable smallholders to collectively access resources, such as land, water, and seeds, which would be difficult to attain individually (Burney et al., 2010). These cooperatives also facilitate collaborative decision-making, skill-sharing, and knowledge exchange (Abraham et al., 2022). Furthermore, cooperatives can strengthen the bargaining power of smallholders in the market, enabling them to negotiate better prices for their produce.

Mutual support is a key component of MG cooperatives in the study areas. This entails collaborative efforts among community members to enhance agricultural productivity and overcome common challenges (Jelsma et al., 2017). For instance, farmers within a cooperative can pool their resources to purchase irrigation equipment or secure credit collectively. This mutual support fosters resilience among smallholders, as they are better equipped to cope with the uncertainties of climate change and market fluctuations. Additionally, establishing cooperative savings and credit schemes helps members allocate resources effectively and invest in sustainable farming practices. MG cooperatives serve as platforms for community-led learning and knowledge exchange. Members benefit from shared learning experiences, such as training on sustainable farming techniques or marketing strategies (Marchesi and Tweed, 2021). This knowledge exchange empowers smallholders to adopt innovative practices, which can improve agricultural productivity and diversify income sources. Moreover, cooperative platforms provide opportunities for farmers to participate in decision-making processes and shape the development of their communities.

One remarkable example of a successful MG cooperative in the Sanam study area is the Sanam Cooperative of Women Farmers (SCWF). The SCWF has significantly improved the livelihoods of its members through collective marketing, skill development workshops, and microlending initiatives (Abraham et al., 2022). This cooperative allows female smallholders to overcome gender-based constraints and gain economic independence. The SCWF has been able to tap into local and regional markets, increasing its members' income and market share. The success of SCWF demonstrates the transformative potential of MG cooperatives and mutual support. MG cooperatives and mutual support are vital for smallholders in our case areas to enhance their resilience and livelihoods. Farmers can access resources, exchange knowledge, and increase their bargaining power by working collectively. The success of the SCWF exemplifies the positive impacts that can be achieved through cooperative initiatives. Therefore, it is crucial to foster an enabling environment that supports the establishment and growth of MG cooperatives, with a focus on mutual support and community-led learning.

5. Conclusions and Policy Implications

5.1. Conclusions

This paper has explored the role of MG as one of the viable approaches to securing agro-pastoral systems and rural livelihoods in Niger. Empowering smallholders and building on inherent resilience enables communities to address interwoven challenges and achieve sustainable development. The neo-endogenous approach recognizes the inherent knowledge, resources, and capabilities of smallholders in Niger. Instead of relying solely on external interventions and solutions, it leverages local assets and expertise to drive change. Through MG, smallholders can tap into their traditional agricultural practices, adapt them to modern challenges, and create innovative solutions that strengthen agricultural productivity and rural livelihoods.

The study findings revealed that MG has played a vital role in securing agro-pastoral systems and rural livelihoods in Niger. Through cultivating horticultural crops, smallholders have demonstrated their resilience in the face of interwoven challenges, such as climate change, political unrest, limited access to resources such as inputs and technologies, and market limitations. For instance, the study shows that MG is an adaptive response to climate change. Niger, a region highly vulnerable to the impacts of climate change, has witnessed erratic rainfall patterns, prolonged droughts, and increased temperature variability. In such a context, market gardening has emerged as a viable option for smallholders to mitigate climate-related risks. Innovative agricultural techniques, such as rainwater harvesting and efficient irrigation methods, have enabled smallholders to sustain agricultural production despite water scarcity. By diversifying crops through MG, smallholders have also reduced dependency on rainfall and improved resilience to climate uncertainties.

Furthermore, the research has underscored the significance of market gardening in addressing the limited access to resources smallholders face in rural Niger. Access to land, finance, and inputs, such as quality seeds and fertilizers, has historically challenged smallholders. However, MG has allowed smallholders to utilize micro plots of land effectively, making it possible to intensify their agricultural production, complementing the lack of large-scale production bases such as capital and modern technologies. Smallholders have overcome financial constraints through collective action and cooperation by pooling resources and accessing credit facilities. Collective actions and cooperation have improved agricultural productivity and empowered farmers to negotiate better prices and market produce effectively. The research sheds light on the role of MG in alleviating market limitations smallholders face. In rural Niger, smallholders often struggle with inadequate market infrastructure, limited market access, and price volatility. However, MG has enabled smallholders to establish direct linkages with wholesalers, retailers, and direct consumers, bypassing intermediaries and gaining better control over market transactions. Smallholders have developed collective marketing strategies by organizing themselves into producer groups and cooperatives, allowing them to negotiate fair prices and access higher-value markets. This has not only improved their income generation but has also enhanced their market power and reduced their vulnerability to price fluctuations.

5.2. Policy Implications

While MG has demonstrated its potential to enhance the resilience of smallholders, there are still areas for improvement and intervention. Firstly, access to resources remains a critical issue. Smallholders require improved access to land, water, finance, and inputs to optimize agricultural production further. This necessitates targeted government interventions, such as land reform policies, investment in irrigation infrastructure, and credit facilities tailored to the needs of smallholders. Additionally, smallholders would benefit from training and capacity-building programs that focus on sustainable agricultural practices, resource management, and entrepreneurship. Secondly, market integration and value addition need to be strengthened. Smallholders would benefit from increased market linkages with processors, exporters, and agribusinesses, providing them with opportunities for value addition and access to higher-value markets. This requires investment in market infrastructure and establishing value chain alliances that promote fair trade practices and support smallholder inclusion. Furthermore, research and development efforts should focus on developing appropriate technologies and techniques that improve MG produce's post-harvest handling, storage, and processing.

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Agricultural & Rural Studies

Commentary

It Is Not What We Eat, It's How We Produce It

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1. Exceeding Critical Thresholds in Food Production

The current food system is one of the main contributors to the environmental degradation of our planet (FAO, 2021). The disruption of phosphorus and nitrogen cycles, the release of greenhouse gases (GHGs), and the degradation of vital resources like water and soil serve as compelling examples and explain the overtaking of six planet boundaries (Rockström & Gupta, 2023) that a decade ago appeared distant and abstract.

Despite this prevailing consensus, there is a substantial divergence in the range of measures and proposals. Many focus on product analyses, emphasizing their water and carbon footprint (Mekonnen & Hoekstra, 2012; Petterson et al., 2021), as well as their relationship with health (Willett et al., 2019) often overlook the significance of production systems and our lifestyle. In an era marked by short-termism and the incessant flow of information, short and flashy messages are imposed, leaving aside essential nuances of the food system, such as the externalities of each form of production, the demand for very cheap food at any time, or the final form in which these products are delivered to us (ultra-processed, with a huge associated consumption of plastic and energy, or with working conditions that are in many cases appalling).

It is imperative to expand our perspective and take into account the diverse impacts—both positive and negative—across social, environmental, and economic dimensions of food systems. This is crucial as the same product can be cultivated and produced through various methods, each carrying distinct implications.

This viewpoint can be illustrated with two examples. One concerns the call to drastically reduce red meat consumption, and the other promotes so-called superfoods (Magrach & Sanz, 2020), such as quinoa. Initially, several data points indeed underpin the sustainability of this dietary shift. Beef production accounts for an average water consumption of 15,415 $m^3\ t^{-1}$ (Mekonnen & Hoekstra, 2012). 98% of this water footprint is due to the massive use of animal feed, the production of which requires the cultivation of cereals and legumes. The cultivation of these crops involves the deforestation of valuable primary forests (Martínez-Valderrama et al., 2021) and the depletion of aquifers, which are also affected by the discharge of animal slurry from large-scale farms. Another harmful effect associated with livestock farming is the emission of GHGs, mainly methane and nitrous oxide. It is estimated that this production sector is responsible for between 8 and 18% of total emissions (Herrero & Thornton, 2013); on average, meat carbon footprint is 41 kg CO_2eq kg^{-1} (Herrero et al., 2013). In addition, there are other undesirable effects of meat production and consumption, such as the conditions in which many of these animals live and the diseases associated with excessive consumption. Quinoa enjoys a favorable reputation. It's a food with deep roots in ancient cultures, which imparts a sense of exoticism in Western markets. Often hailed as a "superfood", quinoa is highly compatible with vegetarian diets, offering a rich blend of essential amino acids, micronutrients, vitamins, and is naturally gluten-free.

2. The Need for a More Integrated Vision of Food Systems

Is this always the case? It depends, we can argue the opposite. Let us first look at meat. There are many livestock production systems that are examples of sustainability, i.e., stocking rates are adjusted to the availability of pasture. Pastoralism is the most widespread land use around the world and has proven to be a secure livelihood for many societies for millennia (Manzano et al., 2021). In these livestock grazing systems, the ruminants graze in the open air, eating various types of vegetation that would otherwise not be utilized. In doing so, they achieve something unique: they convert lignin and cellulose into protein. No machine is capable of this process. In addition, they rid the landscape of flammable materials, reducing the risk of forest fires. As they move, they fertilize the countryside with their excrement, in line with the precepts of the circular economy: that the waste of one becomes the food of the other. The richness of breeds is the result of their adaptability to different environments and conditions, which translates into great agrobiodiversity

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and resilience of the territory. Finally, products derived from this type of livestock farming have nutritional and organoleptic properties far superior to those of processed products from industrial livestock farming (Wilkinson & Lee, 2018).

What are the downsides of quinoa's popularity? Its soaring demand has pushed it into large supermarket chains where competitive pricing is the standard. As a result, the traditional Andean production system has undergone significant alterations. Peru and Bolivia, the primary quinoa producers, have increased their production by 252% and 612%, respectively, over the last four decades, along with a 124% and 440% expansion in their cultivation areas (Magrach & Sanz, 2020). These changes have brought about noteworthy environmental and social consequences. In the high-altitude deserts where quinoa thrives, the conditions are harsh: minimal rainfall coupled with frigid and windy weather. For centuries, local communities sustained themselves on quinoa, cultivating it without the use of mechanical equipment and meticulously considering weather conditions to allow the soil to rest and regenerate with water and nutrients. The quinoa boom, which drove prices to unprecedented levels (sometimes reaching up to 60 times that of wheat), triggered the intensification and expansion of quinoa farming.

The use of heavy machinery, fertilizers and pesticides, the elimination of livestock that fertilized the soil, the invasion of pastures and the reduction of fallow have triggered soil erosion and deterioration. The selection of the most productive varieties (4 of which account for 90% of production) is leading to the loss of a rich gene bank. The local population, far from getting richer from this business, has lost its main sources of protein: Quinoa has prohibitive prices and most of it is exported -Peru went from exporting 60 t in 1995 to 36,000 in 2014 (Bedoya-Perales et al., 2018) and the llamas have less space to graze. To make matters worse, much of the land that was in the hands of local communities is now private property.

As evident, a plate of quinoa can have an environmental impact comparable to that of a hamburger. Concentrating solely on the product type, neglecting the social and environmental repercussions of its production system, may result in the formulation of policies that exacerbate rather than resolve issues. Therefore, adopting a more holistic perspective on food systems can empower stakeholders to devise more sustainable land-use plans.

3. Final Remarks

These two instances illustrate that consumption should be guided not solely by the type of food but also by the methods of its production. The main problem is related to large-scale production, which seeks to minimize production costs at the expense of social and environmental externalities (Martínez-Valderrama et al., 2023). This phenomenon of "Uberization" has permeated a significant portion of food systems, and this is where attention should be directed.

Quinoa can maintain its sustainability if cultivation respects local ecosystems and traditional production systems, such as fallowing, and refrains from encroaching upon marginal areas traditionally designated for grazing. On the other hand, livestock production requires substantial reforms, which may include the following guidelines: (i) By reducing animal protein demand for the nutritional reasons outlined above; (ii) By favoring pasture-based livestock systems, within the limits of adequate stocking rates; or (iii) by further technifying intensive production systems (i.e., macro-farms) through cultured meat and precision fermentation (Singh et al., 2022), which will reduce the environmental footprint and animal suffering.

Finally, it is necessary to understand that the elimination of negative externalities and the establishment of socially equitable food systems will result in higher food costs (Baker et al., 2020). The impact on society can be mitigated by redistributing these costs or by narrowing the profit margins of major distributors.

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