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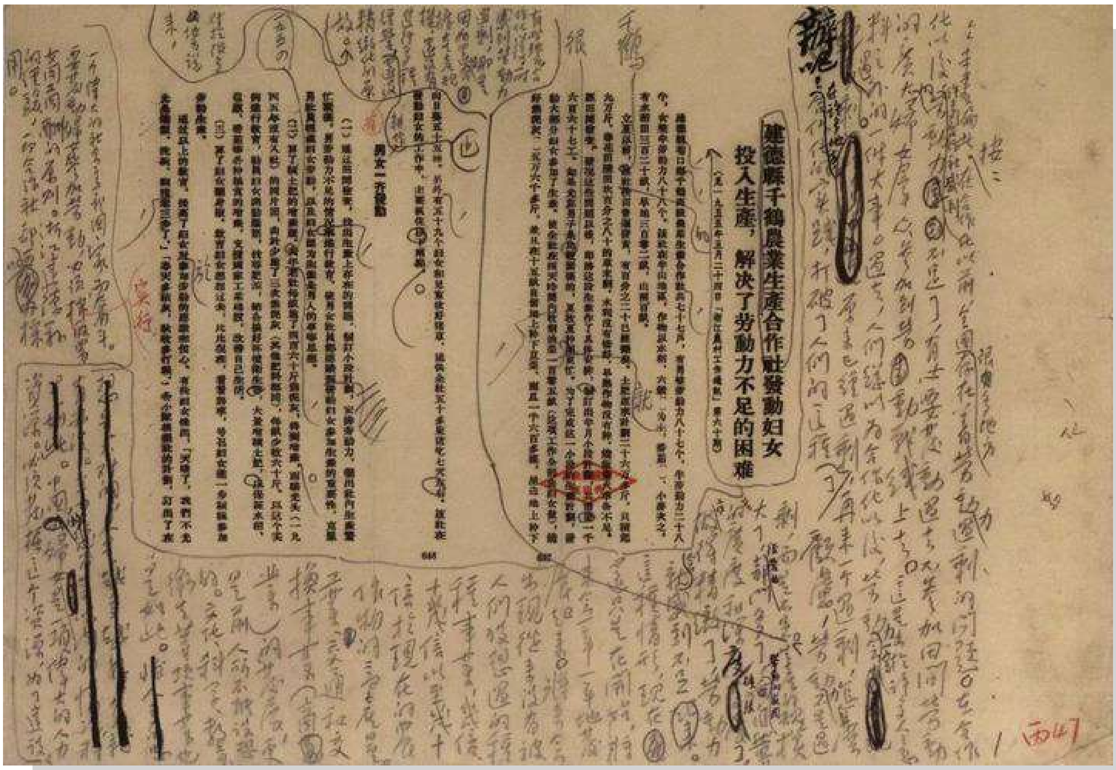

建德縣千鶴農業生產合作社發動婦女

投入生產，解决了勞動力不足的困難

# Cover Story

Qianhe Village is located in the east of Jiande City, Hangzhou, Zhejiang Province, China, with a population of 1370 people, 439 households, and a village area of 5.3 square kilometers. It has the Memorial Hall of Qianhe Women's Spirit, the Children'sHall of He Family, and Qianhe Study Hall and other venues, as well as Qianhe Guesthouse and the special industry of "Qianhe One Noodle".

At the beginning of the founding of New China, under the leadership of the Communist Party of China, the women of Qianhe Village broke with traditional customs, went out of their homes and into the fields, implemented the policy of equal pay for equal work for men and women, and devoted themselves to agricultural production and labor. They nurtured the "Qianhe Women's Spirit" of "not waiting and not relying on, daring to think and work, uniting and cooperating, and working hard".

In 1955, Chairman Mao Zedong made a 512-word commentary on "Qianhe Women'sMeritorious Deeds" and the important statement that "Chinese women are great human resources", making Qianhe an important birthplace of the thought that "women can hold up half the sky". This is a remarkable chapter in women's career of Jiande, and it is also a highlight in the history of modern China and its feminist movement.

(Zhenhong Xu, Chairwoman of the Women's Federation of Jiande City, Zhejiang Province, China.)

# Agricultural & Rural Studies

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Contents

# 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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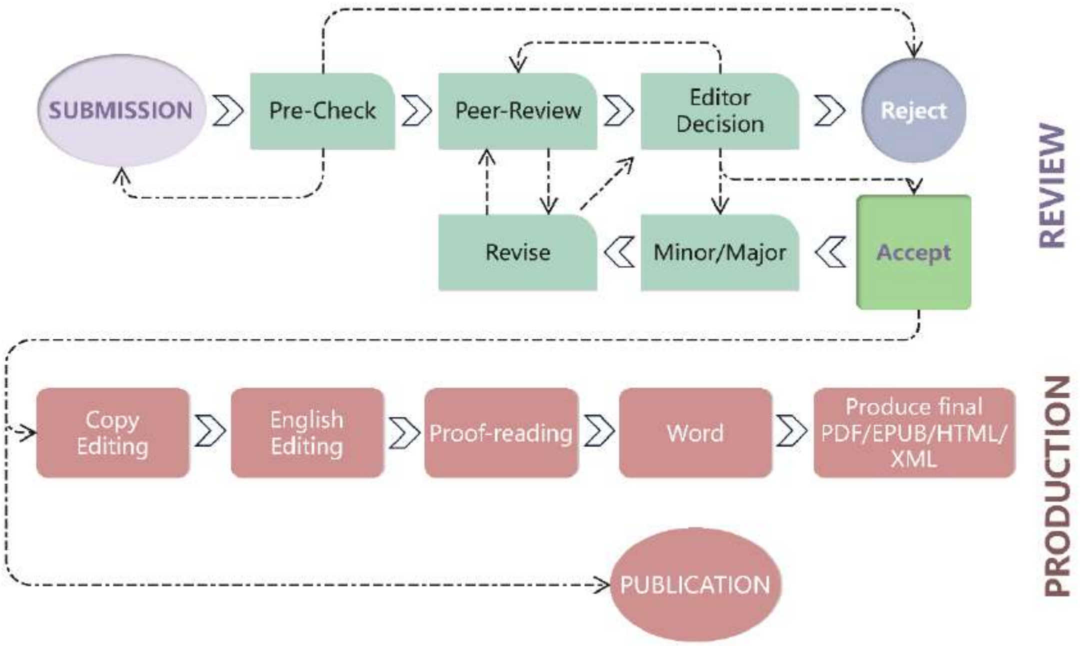

Agricultural & Rural Studies

*Perspective*

# Big Food Vision and Food Security in China

**Shenggen Fan, Yuchen Zhu and Xiangming Fang ***

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**Abstract:** Objective: The objective of this paper is to identify the key policy and strategic issues that need to be addressed to ensure national food security by using the big food vision. Design/methodology/approach: Based on China's specific national and agricultural characteristics, this paper discusses the current challenges and opportunities facing China's food security and identifies the key policy and strategic issues that should be addressed to ensure food security in China using the big food vision. Findings: Food supply in China has been significantly improved, and the food consumption has been significantly changed, but China still faces with multiple challenges, such increasingly unbalanced diets, unsustainable use of land and water resources, mismatch between supply and demand, and increased volatility in international trade environment. To ensure China's food security, China should focus on the following four aspects:(i) strengthening the support of agricultural scientific and technological innovation; (ii) reforming policy and institutions;(iii) nudging consumer behavior change; and (iv) fully utilizing international trade and cooperation.

**Keywords:** food security; nutrition; big food vision; policy and strategy

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## 1. Introduction

The current global food and nutritional security are severe challenges, and there has been little progress in reducing various forms of malnutrition including hunger, micronutrient deficiency and overweigh and obesity. It is estimated that in 2021, 702–828 million people (8.9–10.5%) have suffered hunger in 2021, and COVID-19 alone led to increase of 150 million; about 2.3 billion people are in moderate or severe food insecure state. Nearly 3.1 billion people cannot afford a healthy diet, an increase of 112 million over the previous year (Academy of Global Food Economics and Policy et al., 2023). Food insecurity is caused by a variety of reasons, including the continuing impact of the COVID-19 pandemic, the crisis in Ukraine, and climate change, among others. At the same time, the impact of reduced income and rising food prices have reduced the food purchasing and affordability of many, particularly low-income population. Thus, there is an urgent need for governments and multiple actors to take joint action to reverse the current trend to reduce or even end hunger and malnutrition.

Food security in China, a developing country with a population of more than 1.4 billion, will have a profound "knock-on effect" on the global food system. In recent years, the performance of food security in China has been recognized by the international community as a success. For example, in the 2022 global food security index, China ranks 25th in the world with a comprehensive score of 74.2, up nine places from 2021 (The Economist Intelligence Unit, 2022).

Facing "new period of turbulent change", "tight balance of food", "hard constraint of resources and environment" and "high demand of diversified food consumption" in the new development era, however, China is facing unprecedented risk in its food systems. In the face of multiple demands concerning food security, national nutrition, market efficiency, and systemic resilience, the task of ensuring food security in China continue to be a top priority for the government and the society. This article analyzes the current state of food security in China, summarizes the challenges faced by the country in both food supply and demand, and explores the pathways for ensuring food security from the perspectives of food production, consumption, and trade using the big food vision.

## 2. Challenges Facing Chinese Food Security

### 2.1. Food Supply

Under the impetus of policies from both the central and local governments, China has witnessed a remarkable enhancement in its comprehensive grain production capacity and the ability to supply major agricultural products. From 2004 to 2021, the supply capacity of agricultural products has been continuously strengthened in both quantity and quality (Han, 2023). With a mere 9% of the global arable land and access to only 6% of the world's freshwater resources, China has effectively tackled the formidable task of nourishing 18% of the global population, thus making a momentous contribution towards the eradication of hunger and the assurance of worldwide food security.

More specifically, the goal of "grain is basically self-sufficient and absolutely secure" has been achieved. According to data from the National Bureau of Statistics, China's total grain output increased from 305 million tons in 1978 to 687 million tons in 2022, with an average annual increase of 1.86%. The per capita food increased from 319kg in 1978 to 486kg in 2022, with an average annual increase of 0.96%. At the same time, China's agricultural supply has been continuously diversified. From 1982 to 2021, China's meat output increased by 5.6 times, and reached to nearly 90 million tons in 2021; milk production increased by 21.8 times, poultry egg production increased 11.1 times, and aquatic products increased by 11.5 times. In 2021, the output of Chinese poultry eggs and aquatic products reached 34.088 million tons and 64.637 million tons, respectively. From 1996 to 2021, vegetable production in China increased from 300 million tons to 780 million tons, an increase of 1.6 times; fruit output increased from 46.53 million tons to 300 million tons, an increase of 5.4 times; and edible oil increased from 22.11 million tons to 36.13 million tons, an increase of 63.4% (Han, 2023).

While China has made a series of achievements in the supply of important agricultural products, it is still faced with difficulties such as prominent structural imbalance between supply and demand, excessive external dependence of a variety of products with highly concentrated import sources, unstable supply market prices. In particular, domestic feed grain supply is chronically insufficient, and imports have increasingly become significant, especially feed grain mainly composed of corn and soybean falls short of demand. It is predicted that by 2035, the self-sufficiency rate of corn will drop to 82%, and the gap between soybean production and consumption will remain at about 9000 tons (Huang, 2021). The self-sufficiency rate of main crops is shown in Table 1. Corn, soybeans, pork and beef, dairy products, and edible vegetable oil are too dependent on the imports, and the sources are highly concentrated (Zhu et al., 2023). At the same time, scarcity of agricultural resources and environmental constraints has limited the growth of the supply capacity of agricultural products. The rapid progress of urbanization has increased production costs, and the lack of supporting capacity of agricultural science and technology has also led to low production efficiency of agricultural production. The deterioration of the international trade environment has led to the instability of the agricultural imports, and the supply of important agricultural products are at great risks.

**Table 1.** The self sufficiency rate of major farm crops.

| Item | 1991 | 2000 | 2010 | 2022 |
|---|---|---|---|---|
| Wheat | 88.4 | 84.5 | 99.1 | 99.3 |
| Rice | 100.9 | 99.3 | 103.7 | 98.9 |
| Corn | 116.5 | 132.9 | 103.1 | 96 |
| Soybeans | 110.9 | 54.7 | 21.7 | 18 |
| Edible Vegetable Oil (Domestic oilseed pressing) | 82.8 | 69.4 | 32.9 | 29 |
| Sugar Crops | 142.6 | 65.5 | 78.8 | 64.8 |
| Pork | 101.2 | 100 | 101 | 99.8 |
| Poultry | 101 | 98.1 | 100.9 | 100 |
| Beef | 120 | 100.9 | 101.8 | 101 |
| Mutton | 100.4 | 99.5 | 99.7 | 98.8 |
| Poultry Eggs | 100.4 | 100.3 | 100.4 | 100.4 |
| Milk | 100 | 100.3 | 100.2 | 100 |
| Aquatic Products | 102.8 | 103.8 | 108.6 | 109 |

### *2.2. Food Consumption*

With the improvement of income, China has achieved quick progress in reducing hunger and malnutrition, and the dietary structure has undergone rapid changes. People are no longer satisfied with food consumption demand for "being able to eat" and "can be satisfied", but pay more attention to "nutrition, high-quality, healthy, and safe" (Chen, 2019). Residents' consumption of starchy staple foods such as rice and wheat has gradually decreased, the consumption of nutritious foods such as fruits, eggs, aquatic products and milk has gradually increased (AGFEP et al., 2021), and the consumption of animal foods such as red meat and poultry has increased steadily, and the consumption of refined grains and edible oils has increased significantly. The diets of Chinese population have become increasingly imbalanced, such as excessive consumption of refined cereals and meat, and insufficient consumption of vegetables, fruits and milk (AGFEP et al., 2022).

As a result, overweight and obesity, chronic diseases are increasingly prominent in China (He et al., 2019). In 2020, the rate of overweight and obesity aged 18 and over was 50.7%, chronic non-communicable diseases such as cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes account for 88% of all deaths in China, and the prevalence of diabetes among adults is as high as 11.9% in 2020, nearly double that of 2002. In 2020, nearly one-third of the residents suffered from high blood pressure, and the prevalence rate of hypertension was nearly 10% higher than that in 2002. Vitamin A, calcium, iron, zinc and other important micronutrient deficiencies also affect the health of Chinese residents, especially children, pregnant women (AGFEP et al., 2023).

## 3. Food Security Under the Big Food Vision

The traditional concept of food security mainly focuses on the supply capacity of grains such as rice, wheat and corn. With the improvement of people's living standards, the quantity and diversity of food consumption increase. The consumption level and structure of Chinese residents are changing from adequate food and clothing to well-off in an all-round way, from "grain and vegetables" to "grain, meat, vegetables and fruits" and from traditional family cooking to modern convenience (Xin, 2021). The food security concept based on "having enough to eat" should be gradually changed to the diversified food security concept of "eating well", "eating healthily" and "eating at ease". In the face of the imbalance between the structural supply and, it is difficult to meet the upgrading and diversified consumption demand, restrict the goal of nutrition and health, and the high degree of external dependence of agricultural products. China food should be more nutritionally diversified and safe under the overall goal of "basic self-sufficiency of grain and absolute security of food rations". In 2015, the China's annual central rural work conference proposed for the first time "establishing big agriculture and big food vision." In 2017, Chinese President Xi Jinping further pointed out at the China's annual central rural work conference, "It is necessary to develop food resources to cultivated land, grassland, forests, marine, plants, animals, microorganisms, and develop food resources in all aspects." In 2022, he further explained in detail the big food vision, pointing out that "it is necessary to establish a big food vision, meet the needs of the people's better life, grasp the changing trend of the people's food structure, and ensure the effective supply of all kinds of food, such as meat, vegetables, fruits, and aquatic products, while ensuring food supply. Any of these factors are indispensable." The big food vision reflects the transformation of China's agricultural development goals from focusing on grain security to food security, nutritional health, dual carbon targets, and common prosperity.

The big food vision is closely in line with China's national multiple development goals in the new development period, regarding meeting the diversified food consumption and better life of the people as the basic starting point, guiding the construction of food supply system guided by the demand for nutritious and healthy food, and expanding food resources in an all-round way (Fan & Zhang, 2023). The development concept of the big food vision requires to meet the diversification of diets and food supply, and to optimize the allocation of the whole landscape resources from a broader perspective, so we must pay attention to the sustainability of the whole food system, deal with the relationship between man and nature, and realize the common health of human beings and the earth. The development concept of the big food vision is a major strategic thinking to deal with the challenges of food supply and demand in the future and to ensure food security, and it is also the development of the concept of food security under the new situation.

## 4. Paths to Ensure Food Security Under the Big Food Vision

### *4.1. Strengthen Infrastructure Investment and Science and Technology Innovations*

Facility agriculture should be developed to break through resource constraints. Facility agriculture is an integrated application of various technologies that use light and temperature resources to create a growing environment for crops, which will effectively use arable land resources and make it possible to grow crops in the Gobi, deserts, tidal flats, saline-alkali lands, etc. Facility agriculture has a high degree of intensification, high yield, and high efficiency, but unfortunately, the current development of facility agriculture in China is large but not strong, so it is difficult to meet the requirements of the development of the big food vision. In the future, facility agriculture should be regarded as an important source of food, and scientific development planning of facility agriculture should be made according to resource endowment, ecological conditions and industrial foundation, guide funds, technology and talents, improve the level of science and technology, develop special equipment, break through resource restrictions, optimize the layout of facility agriculture, and enhance comprehensive production capacity, and thereby satisfying the food consumption needs of residents.

The food potential in the future should be developed. Alternative protein is an important direction to deal with climate change, environmental degradation and achieve sustainable development. Plant-based meat can reduce the health risks caused by excessive meat consumption and can reduce greenhouse gas emissions and resource consumption. In the future, the country should strengthen the research, development, promotion, and application of future foods such as alternative protein, and actively tap the potential of future food. First of all, the country should increase the investment and technological innovation of the alternative protein industry, solve the current technology and cost problems, and develop diversified categories to fully meet the needs of consumers for taste and taste. Secondly, the government should strengthen supervision, formulate product standards, and ensure the quality of alternative protein products, which is particularly important to promote the development of the industry. Finally, public publicity should be strengthened to allow more consumers to scientifically choose alternative protein products.

The agriculture and food sector should be transformed to green and low-carbon production mode. At present, the over-intensive mode of agricultural production is not sustainable. The green and low-carbon mode of production should be promoted by establishing an incentive mechanism to encourage the main bodies of the food supply chain to adopt green and low-carbon technology, adopt technical measures such as climate change adaptability, water, fertilizer and medicine, increase investment in environmental pollution control, further improve agricultural ecological compensation policies, and reduce environmental pollution. At the same time, ecological resources should be protected by, by allowing cultivated land, grasslands, forests, rivers, and lakes to recuperate, and thereby providing high-quality and nutritious food for residents. The diversity of agricultural production helps to protect biodiversity and the ecological environment, and a good natural ecological environment can enhance the sustainability and resilience of the food supply system to enhance the ability to respond to various risk challenges.

The work of damage reduction in food production and transportation should be further promoted. At the present stage, key links should be strengthened along the whole food supply chains such as production, post-natal treatment and storage, and key varieties such as vegetables and fruits by strengthening infrastructure, cold chain, science and technology, and other measures in food production, circulation, food manufacturing and processing, and consumption, so as to reduce food loss in the whole industry chain. In the process of food production, seed saving, and damage reduction machinery and intelligent green and efficient harvesting machinery should be popularized and applied, by training farmers to operate agricultural machinery to reduce the loss of growing grain and harvesting in the field. In the links of food manufacturing, supply and transportation, reforming the food labeling system, making use of advanced technologies such as the internet of things and artificial intelligence must be carried out to promote the accurate matching of production and demand, improve the efficiency of the food system, and reduce food waste in the process of food supply and transportation.

### *4.2. Explore Innovative Policies and System Support*

The development concept of the big food vision focuses on big food and wide resources, which goes far beyond the traditional staple grain and cultivated land. The current agricultural support policy is difficult to meet the needs of the development of the big food vision. In the future, it is necessary to expand the scope of food support policies, increase support efforts and optimize the support structure.

The first is to expand the range of food that receives the agricultural support. That is, the policy support for nutritional and healthy foods such as fruits, nuts, vegetables, aquatic products, milk, etc. should be added, the production potential of various foods is tapped, and the supply of various specialty forest foods, grassland foods and marine foods is enriched. The second is to support the development and utilization of various food resources. Specifically, infrastructure investment and resource utilization research and development of resources such as forests, grasslands, and oceans should be increased, the investment of social capital investment is leveraged, the potential of various resources in food production, and coordinating the governance of landscapes, forests, lakes and sand systems. The third is to extend agricultural support policies from agricultural production to the entire food supply chain. The government should support not only agricultural production, but also agricultural and food-related enterprises in all sectors such as inputs, circulation, storage, processing, and trade, through tax breaks for small and medium-sized enterprises to improve their profitability, improve the income level of employees and their ability to pay for healthy food.

The direction of agricultural policy support should be optimized. The first is to increase policy support for nutritional health, increase subsidies to produce nutritious and healthy food, promote the supply of nutritious and healthy food, reduce or abolish policy support for unhealthy food, or even levy taxes. The second is to strengthen support for sustainable development. Specifically, we should establish an incentive mechanism to encourage the main body of the food supply chain to adopt green and low-carbon technology, further improve the agricultural ecological compensation policy, and continue to increase ecological protection policies such as subsidies and incentives for returning farmland to forests and grassland ecological protection. The third is to improve the risk management policy of food supply chain. That is, infrastructure construction such as high-standard farmland construction and agricultural product supply chain should be strengthened to reduce the costs of production, warehousing, transportation, processing and consumption; establish and improve the risk monitoring and emergency plan system of the whole food industry chain, provide subsidies and support for agricultural disaster insurance and reinsurance systems, improve the ability of early warning of natural disasters and emergency management of the food supply chain, and enhance the supply capacity of diversified food under multiple risks.

The mechanism of large-scale collaborative management should be innovated. The management departments and industries involved in the greater food approach are diversified, and the promotion of institutionalized and effective “cross-border” cooperation is an important guarantee for jointly promoting nutritional health and sustainable development. The first is to establish an inter-departmental coordination and cooperation mechanism, break through the administrative boundaries between different departments, and establish a coordination mechanism among the Ministry of Agriculture and Rural Affairs the National Health Commission, the Ministry of Ecology and Environment, the Ministry of Education, the Ministry of Finance and other departments, establish a steering committee on the greater food approach, and apply the concepts and indicators of nutrition and health and green and low-carbon development to the work of all departments. The second is to give full play to the role of the market mechanism in optimizing the allocation of resources, improve the determination of the rights of cultivated land, woodland, grassland and other resources and the market-oriented reform of factors, promote the standardization and institutionalization of the factor transfer market, stimulate the transaction of production factors among different subjects, effectively promote the appropriate scale of agricultural operation, strengthen non-agricultural employment, entrepreneurship and other supporting policies, and guide small-scale farmers to withdraw from agricultural management activities in an orderly manner.

### *4.3. Promote the Change of Consumer Behavior*

In view of the current health and environmental difficulties caused by residents’ unbalanced diet, the big food vision should be used as an opportunity to improve residents’ food consumption and promote the transformation of the national dietary structure from “something to eat” to “diet is rich, balanced, healthy and sustainable”, and thus, promoting the National Nutrition Plan and the rational Diet Action in healthy China.

Promoting food education for all and cultivating the concept of sustainable and healthy diets should be a top priority by establishing food education programs in schools, providing professional nutritionists in communities(villages), and using information and communications technology for public awareness campaigns can be effective tools to bridge the “last mile” gap in nutrition knowledge and guide consumers in forming healthy dietary habits.

Creating a healthy and enabling food environment is critical in promoting sustainable and healthy dietary habits among consumers. Appropriate industry regulations can foster an industry that adheres to standardized labeling, certification, and general standards for the food industry. Additionally, behavioral interventions can guide and enable shifts in consumer choices toward healthy and sustainable food.

The concept of life of cherishing food and rational consumption should be respected. Guidance should be strengthened to promote the transformation and upgrading of the dietary structure of residents, improve the problem of excess nutrition, and then reduce the waste of food from the consumer side; advocate preparing and ordering meals on demand, reduce extravagance and waste, and make rational use of leftovers; actively create a good atmosphere of saving and honoring, shameful waste, and refusing to compare, strengthen the propaganda of "saving and cherishing grain" through various channels, strengthen the propaganda of "strict economy and opposing waste," and raise the residents' awareness of saving food. create a shameful atmosphere of waste in the whole society.

Increasing policy coordination and incentives for a healthy and sustainable food industry is critical. A multi-sectoral collaboration framework should be created to improve the food business chain toward health and sustainability. Improved laws and regulations and clear guidance and oversight roles of government departments could help this system. Financial policies, tax subsidies, and other measures should encourage the production and consumption of sustainable and healthy foods to meet the nutritional needs of vulnerable groups. Providing training and encouraging sustainable procurement and central kitchens can help administrators understand and implement sustainable and healthy diets.

Implementing a national nutrition improvement plan through targeted interventions is essential. To implement precise interventions, policymakers should design targeted dietary intervention strategies that consider differences in regions, demographic groups, and consumption scenarios. Food assistance programs that meet the food needs of low-income urban populations should be considered.

### *4.4. Strengthen International Trade and International Cooperation*

Due to the limited domestic resources, the output of Chinese agricultural products cannot completely satisfy the increase in food consumption demand for residents, and it is necessary to meet the growing food consumption needs of domestic residents by importing agricultural products. In the future, China should promote the high level of agricultural opening up with the concept of open sharing, make good use of international market resources, establish a stable diversified international food supply chain, strengthen international investment and technological cooperation, actively participate in global food security governance, address global climate change and other common challenges, and jointly promote Chinese and global food security.

Maintain moderate imports, optimize the trade layout, and dispersed trade risks. China is the largest importer of agricultural products. Most of the food demand exceeds the total world exports, and the imported varieties and sources are highly concentrated. In 2021, grain imports accounted for 13% of the world's total exports, soybean imports accounted for 60%, pork and beef imports accounted for 22%, and mutton imports accounted for 28%. Therefore, in the face of a hundred-year-old change, COVID-19 major popularity, continuous international trade friction, the prevalence of global trade protectionism, and the risk of agricultural trade, China is required to formulate a diversified strategy of importing agricultural products, do a good job of importing agricultural products, optimize the trade layout of agricultural products, strengthen international cooperation with trading partner countries, use the global agricultural trade rules, and establish a stable cooperation and win-win trade relationship.

Cultivation and growth of China's multinational agricultural enterprises must be scaled up to improve the construction of international food supply chain and enhance the ability of international supply guarantee. In China, agriculture-related enterprises represented by Sinochem and Cofco are gradually involved in the global industrial chain of processing, trade, and transportation of agricultural products. For example, Cofco has formed a new camp of "Seven Grain Merchants" with the four major international grain merchants, Fengyi International and Viterra. In the future, multinational agriculture-related enterprises should be supported to build a stable international supply chain and enhance their ability to invest abroad and seek food overseas.

Finally, we should actively participate in global food security governance, jointly address global challenges, and promote global food security. To achieve the United Nations sustainable development goal of less than 2.5 percent of global malnutrition, there is a need to increase productivity at the global level, especially in middle-and low-income countries. Therefore, bilateral agricultural cooperation with "Belt and Road Initiative" countries and developing countries should be strengthened through global multilateral and bilateral cooperation mechanisms. In addition, food production capacity should be increased, cooperation at the global and regional levels in disaster prevention and mitigation of the food system and emergency response should be strengthened to jointly address challenges such as climate change and extreme disasters. In addition, we should enhance China's right of speech in global agricultural governance and enhance the international influence of China's agriculture.

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*Review*

# A Review of Sampling and Modeling Techniques for Forest Biomass Inventory

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**Abstract:** Forest biomass is the energy base and material source of forest ecosystem cycle, which is expressed by the dry matter weight or energy accumulated per unit area and time. It is also an important index to study the structure and function of forest ecosystem, and is the premise and basis of scientific management of forest ecosystem. In this paper, the concept, development history, and research status of forest biomass were reviewed. The sampling methods, model construction methods of forest biomass survey were analyzed. Finally, the research prospects and summaries of key technologies of forest biomass inventory and monitoring were put forward.

**Keywords:** biomass sampling; estimation model; remote sensing; biomass inventory

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## 1. History and Methodologies

### *1.1. History*

According to the time line clustering view of forest biomass studies, the first biomass studies were conducted by Ebermayer (1876) in Germany to measure the amount of branches and leaves and the weight of wood in several forests, and the results have been cited by geochemists in calculating the chemical elements in the biosphere for more than 50 years. Before the 1950s, the study of forest biomass received little attention (Boysen, 1910; Kitterge, 1944). It was not until the 1950s that researchers from various countries around the world began to pay attention to the study of forest biomass. Researchers in Japan and the United States successively carried out the study of forest productivity, and began to conduct actual investigation and data collection on the biomass and productivity of major forest ecosystems. In the early 1970s, with the implementation of the International Geosphere and Biosphere Program (IGBP), the study of vegetation biomass and productivity introduced the perspective of ecosystem, grasped the process of ecosystem material production from an overall level and combined with environmental factors, and greatly developed the study of forest biomass and productivity.

After the 1980s, some scholars established regression equations of biomass using easy measurement factors of stand to study the biomass in different areas (Brandeis et al., 2006; Montes et al., 2000; Nascimento & Laurance, 2002). Others have studied the distribution patterns of forest structure and biomass in Northern Europe and America, and the dynamics of forest biomass changes after disturbance (de Wit et al., 2006; Giese et al., 2003; Kauffman et al., 2003; Lehtonen et al., 2004). With the mature application of satellite remote sensing technology in geography, some scholars have used the TM, ETM+ remote sensing data (Dong et al., 2003; Labrecque et al., 2006; Suganuma et al., 2006) and satellite Radar data (Austin et al., 2003; Hyde et al., 2007; Lucas et al., 2006) for studying forest biomass in a different area. With the accumulation of time, the remote sensing data volume is increasing, which brings new opportunities and challenges to the study of biomass estimation by remote sensing. the initial research on forest biomass started from the forest ecosystem and forest succession, and a large number of studies on forest biomass and carbon density were carried out from the 1990s to 2000. In the first decade of the new century, a large number of scholars carried out research on remote sensing and carbon sequestration, which are closely related to continuous inventory and management of forest resources, as shown in Figure 1.

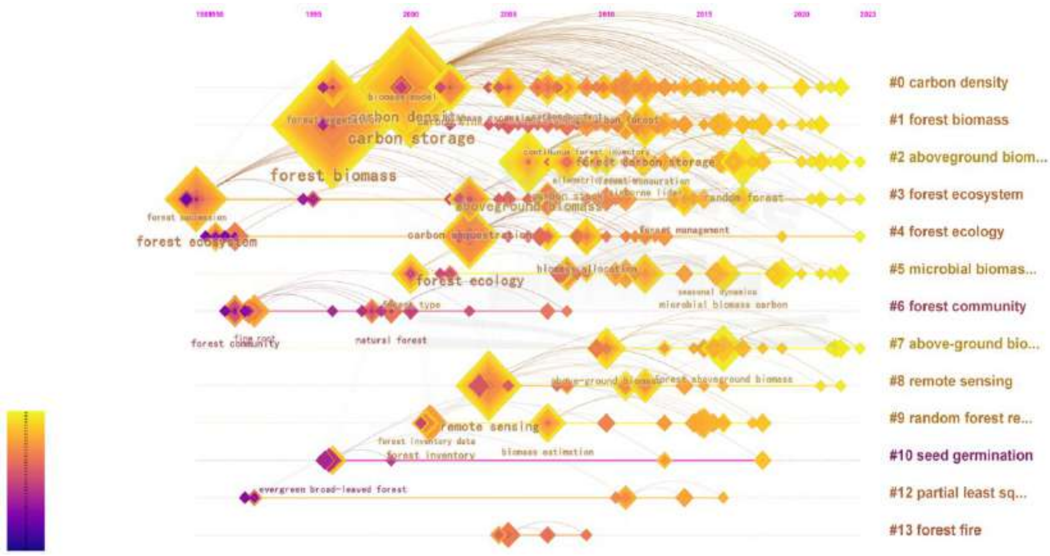


**Figure 1.** Time line clustering view of forest biomass studies.

*1.2. Methodologies*

The traditional methods of biomass inventory and estimation are still dominant. These traditional methods could be divided into carbon dioxide balance method, micrometeorological field method, direct harvest method and expansion factor method (Wu et al., 2023). The direct harvest method is the most accurate survey method and the most practical method for terrestrial forests. Direct harvest method can be divided into average wood method, clear cutting method, and relative growth method. The traditional methods of biomass investigation and estimation are heavy in workload, complicated in process, poor in representativeness, and have not formed a system of measurement techniques. Therefore, the traditional methods cannot timely reflect the quick changes of macroscopical ecosystems and ecological environment conditions, which could not meet the practical requirements. With the development of "3S" (GIS, RS, and GPS) technology, studies on vegetation productivity and biomass based on remote sensing technology have developed from the traditional ground measurement on a small scale and two-dimensional scale to the estimation of a large scale and multidimensional space-time, so that forest biomass at different spatial scales from stand to region can be estimated quickly (Hill et al., 2018), accurately.

## 2. Sampling Techniques

Sampling is a method based on probability theory. The random selection of samples can ensure the representativeness of samples, avoid human interference and deviation, and estimate the sampling error (Wu et al., 2023). Different sampling methods should be used for different purposes (Hou et al., 2021). In practical problems, a specific sampling scheme is mostly composed of a variety of basic sampling methods (Bagaram & Tóth, 2020). The methods of systematic sampling, stratified sampling and random sampling are used in biomass inventory at various levels. As a classical sampling method, equal probability sampling has been widely used (Hawbaker et al., 2009), and methods such as unequal probability sampling, remote sensing based sampling and sparse population distribution sampling (Lei & Tang, 2007; Sterba, 2009) are more targeted in biomass inventory. The study of forest biomass sampling mainly focuses on two keywords, measurement and estimation (Perez-Cruzado et al., 2021), which are closely related to forest carbon storage. The study of forest biomass sampling is gradually extended to survey design and estimation model, as shown in Figure 2.

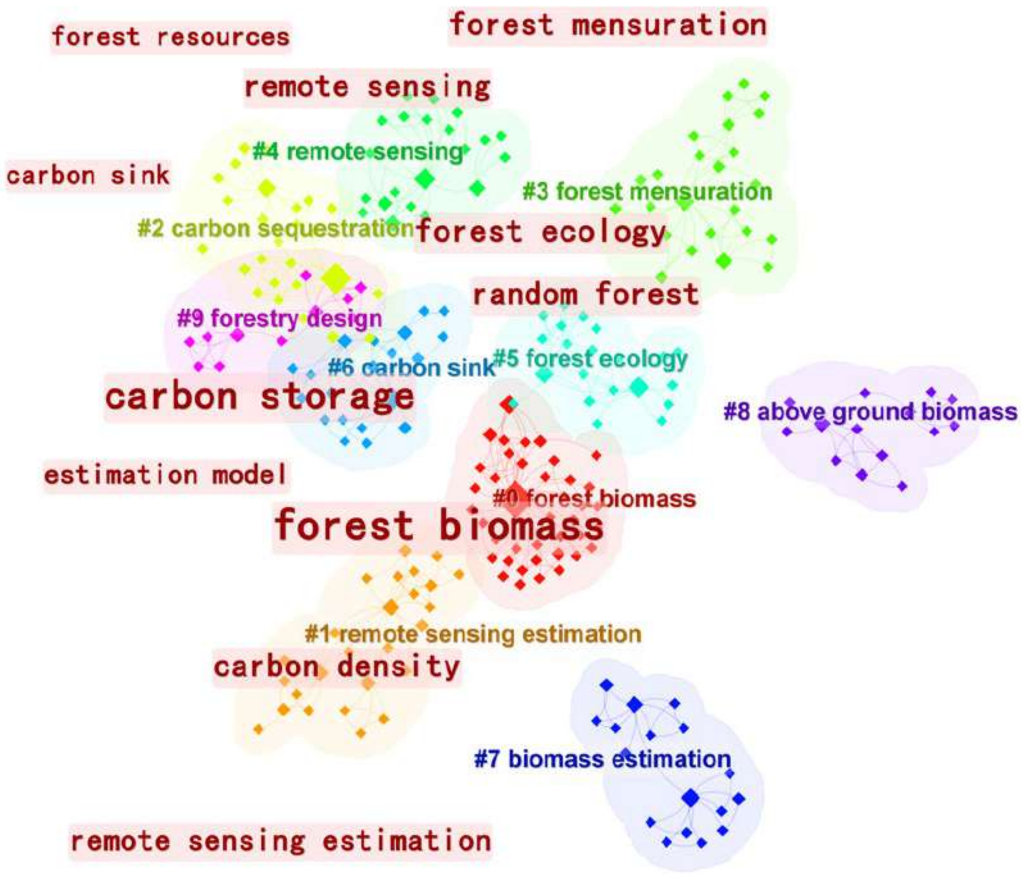


**Figure 2.** Cluster view of forest biomass sampling studies.

*2.1. Equal Probability Sampling*

2.1.1. Random Sampling

The sample units obtained by random sampling are scattered, which is not conducive to the development of actual forest resources investigation (Yu, 1974), and the accuracy depends on the number of sample units (Jin & Zhao, 2001; Meng et al., 1995). When the standard deviation of biomass between the sample units of systematic sampling is large, even if the samples are organized according to the method of systematic sampling, the estimated result is closer to the random sampling. To ensure the accuracy of sampling inventory results, it is necessary to increase the sample units. At present, the most common approach to estimating provincial forest biomass is by using data from continuous forest resource inventory plots data (Qin et al., 2017). However, the biomass estimation of this method is summarized from the level of individual trees to the level of plot, and then estimated the total biomass of the region. In the process, there are a large number of errors from different sources (McRoberts et al., 2013) and uncertainties, such as measurement errors, model uncertainties, and young trees that do not measure, which could lead to underestimation of forest biomass data (Poudel et al., 2015). The error sources of forest biomass estimation are diverse, and there are interaction and error conduction effects among them, so scientific sampling design is particularly important (Montesano et al., 2015).

2.1.2. Stratified Sampling

Compared with random sampling, stratified sampling often has significant efficiency for estimation. The effect of stratified sampling depends on the accuracy of prior information. The key point is that according to the classification of attribute characteristics, the variance between sample units in the same layer should be as small as possible, while the variance between sample units in different layers should be as large as possible. When the standard deviation of total biomass is large and the standard deviation between subpopulations is small, the estimation accuracy of using stratified sampling is greater than that of the random sampling (Zeng et al., 1995). Stratified sampling is often used to investigate forest volume in forest resource planning and design investigation (Yang, 1993). Cluster sampling divides the survey population into disjoint groups and then surveys the whole. By increasing the number of investigation units of adjacent samples to improve the accuracy and sampling efficiency and has been widely used in some forest resource surveys distributed in clusters (Li et al., 2019; Shi, 2012).

2.1.3. Cluster Sampling

Since adaptive sampling design was proposed in the 1990s (Thompson, 1991), sample organization method, estimation method and practical application have all been improved and perfected. Since traditional sampling methods do not consider the inconsistent contributions of different clusters, traditional methods such as systematic sampling may lead to the reduction of sampling efficiency and estimation accuracy (Gao & Gao, 2018; Hua et al., 2014; Huang, 2018; Zeng et al., 2018). Adaptive sampling design for sparse distribution population relying on the correlation between sample units can effectively reduce the number of sampling units (Hero et al., 2013; Lin et al., 2009); Traditional cluster sampling for aggregate distribution may lead to estimation bias (Xiao, 2004). The combination method of applying the results of biomass spatial distribution pattern analysis to adaptive sampling is unequal probability sampling (Holmberg & Lundevaller, 2015). Different distribution patterns should have different sampling probabilities. Adaptive sampling combined with unequal probability sampling can fully consider the spatial distribution difference of biomass, the status difference of different clusters, to carry out adaptive unequal probability sampling.

*2.2. Unequal Probability Sampling*

The advantage of unequal probability sampling is to improve the estimation accuracy and reduce the sampling error. The process of preparing the sampling frame is more complicated. PPES (sampling with probability proportional to an estimate of size) and PPP (probability proportional prediction) in forest resource inventory is the practical application of unequal probability sampling theory. In the 1970s, the forestry inventory began to use an unequal probability sampling design (Shi et al., 2009). Angular gauge for tree measurement is a typical application of unequal probability sampling in forest resource investigation. Different sample organization forms and unequal probability sampling combine to form different sampling design schemes (Good et al., 2001; Zhou & Sun, 2004). The sample sizes in cluster sampling are often different, the sampling probabilities of groups of different sizes are specified, and sampling with unequal probabilities can ensure the accuracy of sampling estimation under the requirement of fewer sampling units (Peng, 1998). Unequal probability sampling is more complicated than equal probability sampling in sampling frame design and sampling probability determination, but it can effectively improve the sampling efficiency (Li, 2000).

*2.3. Other Sampling Methods*

Unequal probability sampling is applicable to situations where the status of sampling units in the population is inconsistent or the units surveyed are inconsistent with those of the sampled population. The prerequisite of unequal probability sampling is that the sampling probability of sample units can be determined by the auxiliary information of each unit. Based on the prior information of the distribution pattern of forest biomass, the original sampling proportion was set, and the sampling adaptation was conducted according to the sampling probability of neighborhood sample units, so as to improve sampling efficiency. The Ripley's K($d$) analysis, aggregation index analysis, nearest neighbor analysis and spatial autocorrelation analysis are the main spatial pattern analysis methods (Jiang et al., 2009). The nearest neighbor analysis selects and measures the distance between each base unit and its nearest base unit in turn, then calculates the mean value of the nearest neighbor distance of all base units in the region, and compares it with the expected mean value of random distribution. Aggregation index is used to calculate and analyze the distance between adjacent sample units to describe the spatial distribution and aggregation state of biomass. The spatial autocorrelation analysis among sample units can effectively reduce sample redundancy and reduce investigation cost (Zhao et al., 2022).

**3. Modeling Techniques**

Stand growth model refers to a mathematical function or a group of mathematical functions describing the relationship between stand growth and site conditions, which is used to estimate the development process of a stand under certain conditions (Gao et al., 2017). The main uses of model include updating forest biomass data, evaluating the benefits of different forest management measures, evaluating the impact of disturbance activities on forest ecosystem, predicting the yield of forest sustainable management. Models can be classified into various types according to their purpose of use, model structure, and object of reflection. The correlation between forest carbon storage and aboveground biomass is still the main research of forest biomass model. Random forest and support vector machines are widely used in forest biomass model research, and forest measurement is combined, as shown in Figure 3.

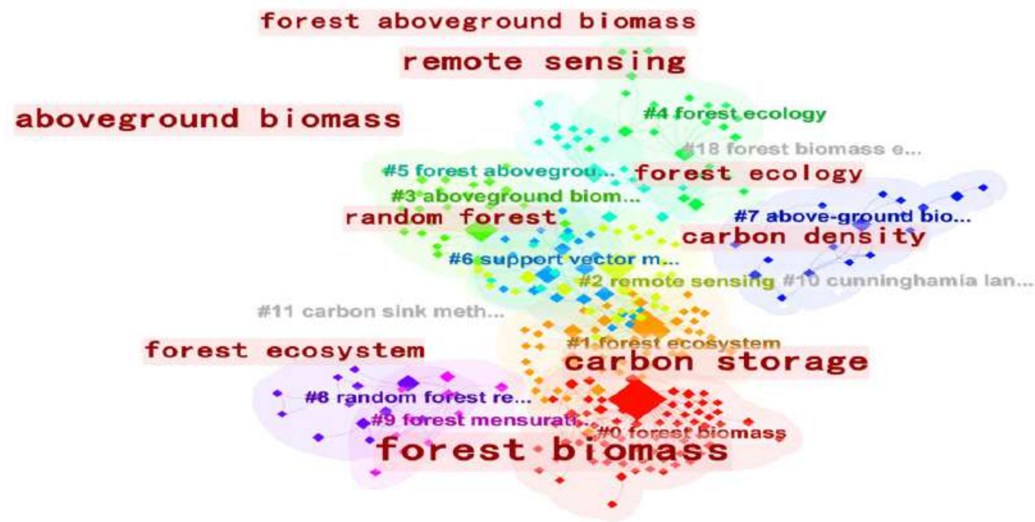


**Figure 3.** Cluster view of forest biomass modeling studies.

### *3.1. Empirical Model*

#### 3.1.1. Tree Level

The biomass model of individual trees is a kind of model based on simulating the dry matter weight of each component (trunk, branch, leaf, bark, root, etc.) of each tree in the stand. More than 3000 biomass models have been established globally, involving more than 100 tree species (Basuki et al., 2009; Case & Hall, 2008; Chojnacky, 2002; Jenkins et al., 2003; Muukkonen, 2006). In the modeling process, it is necessary to measure the biomass of a certain number of sample trees as the basic data. Once the model is established, the continuous forest inventory data can be used to estimate the biomass of the whole stand in the same kind of stands with a precision. Therefore, the research of biomass model of individual trees has always been a hot spot (Kleinn et al., 2020).

According to the number of independent variables, tree level biomass models can be divided into unitary, binary and multivariate biomass models (Zeng & Tang, 2010). Models can be divided into linear, nonlinear and polynomial models, according to the form of tree level biomass models. Parameter estimation methods for biomass model construction of tree level biomass model mainly include traditional regression method (Basuki et al., 2009; Vallet et al., 2006), nonlinear likelihood uncorrelated regression method (Bi et al., 2004), linear or nonlinear joint estimation method (Tang et al., 2000), dummy variable method (Fu et al., 2012), mixed effects model method (Fehrmann et al., 2008), measurement error model method (Zeng & Tang, 2012), spatial regression method (Ou et al., 2014), and so forth.

In the research and application of biomass models, the component model is incompatible with the aggregate model (Parresol, 1999; Xu & Zhang, 2002). Tang et al. (2000) proposed a compatible tree level biomass model and estimation method combined with the current forest volume resources inventory method, namely the nonlinear joint estimation method. Compatible biomass models mainly include two types, namely the biomass model compatible with volume, and the biomass model compatible with total and component.

#### 3.1.2. Stand Level

With the proposal of the IGBP, the results of previous ecological research systems and biomass data at stand level have been extended to landscape, regional and even global scales in the study of global climate change (Xu & Zhang, 2002). According to the independent variables, stand level biomass model can be divided into the model based on stand factor and the model based on volume. The biomass model based on volume can be subdivided into biomass expansion factor (BEF) and continuous biomass conversion functions (CBCF).

The dependent variable of the stand biomass model is usually the biomass per unit area of each organ of the stand, while the independent variable is the total basal area, dominant height, and average height of the stand to construct the stand biomass model of each dimension (Luo et al., 2009). Because the measurement of biomass at stand level rarely uses clear-cutting to obtain measured data, mostly obtains the biomass data based on the calculation of biomass model of individual trees or the measurement of standard trees (Dong & Li, 2016). Uncertainty analysis in the process of conversion from individual tree to stand level is also an important aspect of stand biomass research (Qin et al., 2017).

Scholars began to study to improve the accuracy of forest biomass estimation, and thus proposed a series of research methods (Fang et al., 2001). Among them, BEF is a method to obtain the total biomass of stand by multiplying the average biomass of stand by the total volume of the forest types (Kauppi et al., 1992). The shortcomings of the BEF method are mainly reflected in the conversion factors, such as wood density and conversion ratio of total biomass and aboveground biomass, which are taken as constants. Fang et al. (1998) pointed out that stand biomass and volume were related to forest type, age, site conditions, stand density and other factors, and that the use of constant biomass conversion factor could not accurately estimate forest biomass. The continuous function method of conversion factors changes the constant average conversion factor into an age-graded conversion factor to achieve a more accurate estimation of forest biomass at the national or regional scale (Edgar et al., 2019; Kauppi et al., 1992; Turner et al., 1995). The conversion model between biomass and volume is a hot topic in recent years, which needs to be further verified from the region and tree species, and the model relationship should be established comprehensively and systematically.

### *3.2. Nonparametric Model*

Traditional statistical regression methods could not effectively describe the complex nonlinear relationship between forest biomass and measured data in certain situation, as well as practical problems such as high dimension, and the derived relationship is usually only applicable to this region. Although the accuracy can be improved by the learning method, the “black box” operation only shows their complex action process through the simulation of some training data sets, which is difficult to reflect the mechanism between biomass and remote sensing parameters. In order to improve the nonlinear prediction ability of biomass model, data mining and machine learning methods were applied to forest biomass estimation, including decision tree, K-NN method, support vector machine and artificial neural network.

#### 3.2.1. Artificial Neural Network

Artificial neural network (ANN) is based on spectral information, vegetation index and texture characteristics as input variables of neural network, forest aboveground biomass of sample plot survey as output variables, select part of the sample data input neural network system for training to obtain a model algorithm, and then estimate the forest aboveground biomass according to the model algorithm (Foody et al., 2003; Xu et al., 2011).

#### 3.2.2. Decision Tree

Decision tree (DT) is a method to approximate discrete value function, which can be regarded as a tree prediction model. The basic algorithms include random forest and gradient lifting decision tree. Decision tree integration methods can remove noise interference well, training complexity is low, prediction is accurate, and the model is easy to display, but there may be problems with over-fitting of training data (Carreiras et al., 2012).

#### 3.2.3. K-NN Method

K-nearest neighbor (K-NN) classification algorithm is also known as the reference plot method. The forest aboveground biomass value of a certain pixel of remote sensing image is obtained by weighted value of K measured sample points closest to the pixel in feature space (Chirici et al., 2008; Tuominen, et al., 2010), and then monitored forest aboveground biomass according to the sample plot data. The K-NN method can estimate the forest biomass and maintain the heterogeneity and similarity characteristics of the spatial distribution of carbon density, but its estimation results are often higher than those estimated by using the sample plot data (Labrecque et al., 2006).

#### 3.2.4. Support Vector Machine

The principle of support vector machine (SVM) can be summarized, the nonlinear transformation defined by the inner product function is used to transform the input space into a high-dimensional space, and then the optimal classification surface is obtained in this space. Each intermediate node corresponds to a support vector, and the output is a combination of nodes (Zhang, 2000). Support vector regression machine is a special form of SVM and a kernel theory of regression analysis and equation approximation (Englhart et al., 2011). It overcomes the defects of insufficient data and over-learning of traditional prediction methods and has unique advantages in solving small sample and high-dimensional problems. However, improper selection of kernel function would cause errors in estimation results.

### *3.3. Remote Sensing Inversion Model*

#### 3.3.1. Based on Tree Structure Parameters

As for the structural parameters of trees, it is difficult to obtain the DBH by satellite remote sensing because the trunk is heavily shielded by the crown. As the vertical structure parameter of trees, height can be accurately measured by active lidar remote sensing. The height can be calculated based on the time interval between the echo signal received by the lidar and the echo signal from the ground. Then, the biomasses were calculated by the tree height or stand average height. Many space-borne full-waveform tree height inversion models have been developed (Lefsky et al., 2005).

3.3.2. Based on Vegetation Feature Index

Spectral information analysis of optical remote sensing images of forests can reflect the biophysical characteristics of forests. A variety of vegetation indices can be applied for modeling based on forest optical remote sensing data. Commonly used vegetation index is usually a linear or nonlinear combination of spectral reflectance ratio of two or more bands (Zeng et al., 2022), which can compress multi-dimensional spectral information into one index channel. By statistical regression of various vegetation indices, structural parameters such as canopy density and leaf area index can be further estimated. Based on the statistical regression method, the relationship between the spectral reflectance provided by optical remote sensing images and the vegetation biomass can be established, and then the regional vegetation biomass can be estimated.

3.3.3. Based on Physical Mechanism

The mechanism model (or process model) is used to describe the vegetation growth process at different spatial-temporal scales, such as photosynthesis, respiration, decomposition and oxygen cycle, etc. It simulates the process of solar energy conversion into chemical energy, and the process of plant body and soil water loss accompanied by canopy evapotranspiration and photosynthesis according to the principles of plant physiology, to achieve the estimation of forest productivity. The mechanism model is incorporated into models of global change and nutrient cycling, with biomass being only one of the model's output variables, taking CENTURY, CARAIB, TEM and so forth as Examples. The disadvantage of these models are often too complicated and need more input variables, the application of the model often depends on the quality of the data. The mechanism model emphasizes more on the description of various action processes within the ecosystem, and the estimation results are generally more reliable (Xu & Cao, 2006).

## 4. Research Prospects

The biomass inventory sampling should make full use of the existing spatial data for distribution pattern analysis, and carry out sampling design based on the results of spatial distribution pattern analysis (Wu & Xu, 2021). Spatial sampling technique can carry out with unequal probability sampling based on the spatial distribution pattern of forest biomass, which can effectively improve the investigation efficiency (Li et al., 2009; Wu et al., 2004). At the same time, in order to monitor large scale macroscopic changes and development trends of forest biomass, remote sensing data were used as sampling basic data and auxiliary survey data, and the method of aerial sampling was used to arrange sample plots on remote sensing maps to estimate forest biomass (Liu, 2001; Liu, 2016) to meet the practical requirements of biomass estimation at different regional scales and spatial distribution characteristics (Hetzer et al., 2020; Zhu et al., 2020).

In recent years, scholars have presented the biomass models of various tree species, and carried out the study of forest biomass at multiple scales, such as individual, population, community, ecosystem, region and biosphere (McRoberts, 2001). It is necessary to study the biomass of individual tree deeply, including different geographical provenances, different development stages, and different natural zones, so as to establish a weight index model of biomass to achieve a more accurate estimation of biomass in different stand types. At present, there is still a lack of research on multi-level stand models. Only the biomass of standing trees with a certain diameter in forest was estimated, while the biomass of trees with a smaller diameter, understory shrubs and herbaceous plants was ignored. Therefore, the relationship between the total stand biomass and the biomass of living trees was clarified, and the biomass model of understory vegetation was established to solve the problem that the existing model neglected the biomass of smaller trees, understory shrubs, and herbs. In the future, model development, the effects of forest biological factors and non-biological factors on forest biomass should be considered comprehensively, especially the effects of stand volume, age, and climate factors on forest biomass estimation.

Remote sensing has the characteristics of macroscopical, comprehensive, dynamic, rapid and repeatable, and its band information has a certain correlation with forest biomass, so it has become the main method for estimating regional forest biomass (Wirasatriya et al., 2022). Each remote sensing data has certain limitations in spatial, spectral and radiative resolution, which affects the ability of remote sensing technology to estimate forest biomass. These factors result in the instability of the accuracy of estimating ground forest biomass with different remote sensing data (Yu et al., 2022). Combining ecological factors, topographic factors, environmental factors, and remote sensing data to build a forest biomass estimation model with multi-source data can inhibit the influence of these factors. When the optical remote sensing data are used to estimate the areas with high forest biomass, the problem of remote sensing information saturation comes out. As a result, the changes of biomass cannot be accurately reflected, which becomes the bottleneck of forest biomass estimation by remote sensing method. Steininger (2000) found that LandSatTM images had a saturation problem when estimating biomass. Its saturation threshold was 15kg/m$^2$. Lu (2005) also found this problem when estimating the Amazon basin in Brazil. Similar problems exist in estimating forest biomass with radar data (Wang et al., 2006). Multi-sensor data integration and estimation methods can solve this problem to some extent. Multi-source remote sensing image by multi-sensor to estimate forest biomass has become a developing trend to address the saturation threshold issue (Zhu et al., 2020). Combining remote sensing data of different sensors, different time, different spatial resolution different spectral resolution, and selecting the optimal information to estimate forest biomass is a problem that needs to be studied in data assimilation, as well as a problem faced by contemporary remote sensing development (Zeng et al., 2022). There is a certain gap between field sampling data and remote sensing image data, which is also a problem faced by remote sensing data assimilation.

## 5. Summary

The change of ecological environment caused by climate warming is becoming more and more obvious. It is affecting the pattern of ecological system and the sustainable development of human society. It has become a global environmental problem recognized by the international community. Forest is one of the main terrestrial ecosystems, which has an important carbon sink function. Forest carbon reserves account for about 80% of the above-ground part of the land and 40% of the underground part of the land, and the annual carbon fixed amount accounts for more than 2/3 of the whole terrestrial ecosystem. Forest in China will become a large carbon sink, which will play a positive role in mitigating the rise of global atmospheric carbon dioxide concentration.

It is a research hotspot and technical difficulty in the field of natural resources investigation and monitoring that efficiently and accurately monitors the annual dynamic change of forest biomass. National forest and grassland ecological comprehensive monitoring in 2021 and 2022 has optimized survey organization. The number of sample units to be investigated by equiprobability sampling is still quite large, under the specified accuracy and reliability. The estimation of forest biomass below the provincial level takes the regional total carbon storage as the control number and divides them into small populations according to the principle of hierarchical control to produce the biomass data. Due to the lack of precision and the inability to sensitively reflect the dynamic changes of forest biomass at different scales, the application of the monitoring results in forest carbon sink accounting and other work is limited.

Based on the multi-stage sampling framework, researchers adopted the three-phase sampling method, combined with the characteristics of the regional distribution pattern of forest biomass, and carried out multi-scale unequal probability spatial stratified complex sampling design. The model sampling inference assisted by randomization inference was used to solve the problems of the limited sample size and small area estimation, data missing and measurement error under the specified precision, and the complicated sampling design uncertainty analysis and reliability evaluation were carried out. It is expected to form a set of complex sampling design and data inference technology for annual monitoring of forest biomass under hierarchical control, so as to meet the low-cost, rapid and accurate annual counting demand of forest biomass to be applied in practical work.

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Agricultural & Rural Studies

*Article*

# Emigration and Common Agricultural Policy in Romanian Rural Areas: An Analysis of Patterns of Inefficiency

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**Abstract:** Romanian rural areas have suffered a significant permanent emigration since the early 1990s and the European Union by the Common Agricultural Policy has tried to slow down this negative phenomenon. The main research question was to assess if the Common Agricultural Policy has been a leverage of socio-economic development in Romanian rural areas reducing the permanent emigration from the countryside since 2010 to 2020. The quantitative approach has used the Data Envelopment Analysis and the Multi-directional Efficiency Analysis in order to assess the patterns of inefficiency due to an excess of some variables impacting to the permanent rural emigration.

**Keywords:** MEA; DEA; excess of input-output; second pillar; CAP; efficiency

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## 1. Introduction

Romania's agriculture went through major structural, social and institutional changes since the early 1990s with intense migration from urban to rural areas consequence of a restitution of agricultural land capital and the loss of jobs in urban areas (Gavrilescu et al., 2020). According to these authors there has been a lack of available labor in small and medium-sized farms that are predominant in Romanian primary sector. Furthermore, since the collapse of the Berlin Wall Romania has suffered an intense permanent emigration to other European countries and other countries outside the Europe such as USA and Canada (Sandu, 2005). Romania in the European Union countries is characterized by one of the highest values in out-migration hierarchy (Mitrică et al., 2022). These authors have argued as a high magnitude of out-emigration is correlated to a low level of the social-economic and technological endowment which is typical and distinguishing in several counties of Southern Romania.

In many European Union countries, the emigration is the most important factor in population change but in Romania this phenomenon is something new that has made an appearance in the nineties of the past century. Nevertheless, a recent study carried out in 42 Romanian counties has underlined as the out-migration persists with a dichotomy between regions such as Southern ones and Western and Central regions due to a different social and technological degree (Mitrică et al., 2022).

Mitrică et al. (2019) in previous research have investigated the Romanian out emigration and the effect of the emigration to the social development underling as in the recent year 4.4 million people have left Romania to other European Union (EU) member states while on the contrary at least 3.1 million emigrants left an EU member state. The EUROSTAT reported as Germany has had 917.000 immigrants, United Kingdom 644.200 and Italy 343,400 (EUROSTAT, 2019).

Recent research has pointed out as the out-emigration in Romania can been investigated in 5 different stages since 1990 to 2007 year of the enlargement of the EU to Romania and Bulgaria (Mitrică et al., 2019; Roman & Voicu, 2010; Tomescu-Dumitrescu, 2017). After the fall of the Berlin Wall, more than 90.000 people left Romania (Tomescu-Dumitrescu, 2017). Since the EU enlargement the free access to all EU countries lots of people left Romania to Italy and Spain in order to improve their living conditions by a free access to the European labor market(Anghel, 2016; Anghel et al., 2017; Mitrică et al., 2019; Botezat et al., 2016; Ianoş, 2016; Ianoş et al., 2016).

Sandu in 2005 has argued as in order to investigate the permanent emigration it is fundamental to use a multidimensional approach both in the micro and also in the macro domain to take into account different variables involved in the emigration. As proposed by Sandu (2005) the permanent emigration could be a life strategy for Romanian population aimed at facing with some major challenges of the post-communist Romanian environment where human and social capital have been two important driving factors impacting the emigration in particular in rural areas. It is important to underline as Romanian rural areas have suffered mostly the phenomenon of permanent emigration than the urban territories. In the last two decades, the migration into the EU countries has become an important issue because it is a factor influencing population changes in Europe. Since 2007 a free access to the European labor market has stimulated the permanent emigration in Romania which is related to social development (Iordache & Titan, 2022; Mitrică et al., 2019). Both the permanent emigration and also the temporary emigration are very important drivers acting in a loss of human capital and in labor-migration flows.

According to Mitrică et al. (2019), almost 10% of the EU's highly-skilled population are living abroad and in two poorest Romanian regions such as South-West and South-Muntenia the migrants tend to be low-skilled. It is interesting to underline as the permanent emigration is typical of qualified people, for example, more than 26% of Romanian physicians work and live abroad and most permanent emigrants come from urban areas, while from rural areas emigrated people with a low level of social development and low-qualification and these people are employed in agriculture, sanification and construction (Mitrică et al., 2019).

The main driving factors that have pushed Romanian people to emigrate are characterized by a socio-economic nature (Mitrică et al., 2019). In general, more favorable economic conditions in terms of wages, better opportunities for employment and wealth creation have been very attractive aspects in the emigration process compared to unfavorable conditions at the place of origin such as poverty, poor infrastructures, lack of job opportunities (Mitrică et al., 2019; World Economic Forum, 2017).

The EU policy has tried by the Common Agricultural Policy (CAP) to slow down this negative phenomenon of emigration in the countryside stimulating by specific funds and initiatives the local economic development (Galluzzo, 2016). The impact of Common Agricultural Policy subsidies diverges in function of the type of financial subsides allocated such as first or second pillar subsidies and financial aids of the CAP. In fact, recent research's findings in literature review have highlighted out a positive correlation between rural emigration and financial payments allocated by the first pillar of the CAP. On the contrary, the impact of financial supports allocated by the second pillar of the CAP to the rural development did not imply any effects in reducing emigration from Romanian countryside. In general, less favored rural areas, characterized by a low level of assets and investments have had the highest level of permanent emigration hence, drawing some conclusions, the Rural Development Plan that every EU country has proposed and stimulated should implement the financial allocation towards rural areas which recently are involved in an intense process of counter-urbanization from urban space (Galluzzo, 2016, 2021a, 2021b, 2021c). In other new member states of the EU such as Slovenia and Hungary CAP subsidies disbursed in the framework of the first pillar have had positive effects on farm employment (Bojnec & Fertő, 2022) and consequently to the permanent emigration from rural areas where Pillar II and investment subsidies have pointed out mixed effects (Garrone et al., 2019; Minviel & Latruffe, 2017). The creation of new job opportunities and maintenance of working chances in rural areas has been a traditional Common Agricultural Policy target (Bojnec & Fertő, 2022; Kuiper et al., 2020).

Some quantitative studies carried out in Romania aimed at investigating links between financial subsides allocated by the Common Agricultural Policy and permanent emigration in this country have highlighted out a positive correlation between rural emigration and financial payments allocated by the first pillar of the CAP and no effects have been assessed in financial supports allocated by the second pillar of the CAP to the reduction of permanent emigration in Romania (Galluzzo, 2021b, 2021c). Furthermore, this latter author has argued as less favored rural areas, characterized by a low level of assets and investments, have had the highest level of permanent emigration in Romanian counties.

## 2. Aim of the Research

As mentioned before in the introduction, the permanent emigration is driven by a combination of economic, environmental, political and social factors (Mitrică et al., 2022; Mitrică et al., 2019). The main purpose of this research was to assess by a quantitative approach if the Common Agricultural Policy by the different allocation of financial subsidies has been a leverage of socio-economic development in Romanian rural areas reducing the permanent emigration from the countryside. In fact, in literature there is a lack of studies addressed in estimating the relationship between CAP subsidies and permanent emigration in Romanian rural areas (Galluzzo, 2021b).

A literature review has investigated as other driver factors classified as push and pull factors and relative economic prosperity and political stability of the European Union have had a significant pull effect on the demographic flows in some EU countries as reported by EUROSTAT in 2019 (Mitrică et al., 2022).

The main purpose of this research seeks to break the pattern of the classic investigation of the relationship between permanent emigration, public policies such as the CAP and socio-economic development addressing the attention to the role of exogenous variables such as risk of poverty, subsidies allocated by the CAP to the rural development and living population in rural areas in 8

Romanian regions (NUTS2) since 2010 to 2020. The analysis has investigated which socio-economic variables have impacted to the permanent emigration which has been estimated as an output in a model of assessment of the efficiency, that has to be minimized in an approach input-oriented, assessing consequently in a second stage of this study the patterns of inefficiency in each variable investigated in the model namely which variables can increase or reduce the efficiency in terms of emigration defining some measures of policy to contrast to permanent emigration in rural areas.

## 3. Methodology

In this study using the data published by the Farm Accountancy Data Network (FADN) and by the Romanian National Institute of Statistics it has been estimated since 2010 to 2020 in rural areas which variables have acted to the emigration. The quantitative approach has used a new estimation approach of the permanent emigration and the relationships to all investigated variable (Table 1) by an assessment of the variable permanent emigration in terms of the technical efficiency with the aim of minimizing this latter variable or rather Romanian permanent emigration from rural areas (output variable), acting on the socio-economic variables of input.

In general, there are two different methodologies aimed at assessing the technical efficiency; one through a parametric or stochastic modelling (SFA) and another by a non-parametric modelling using the Data Envelopment Analysis (DEA) method (Coelli et al., 2005; Galluzzo, 2021a, 2021b; Kumbhakar et al., 2015). The DEA had the positive aspect to estimate multiple inputs and multiple outputs without a priori defined functions of production and other specifications in the model (Coelli et al., 2005; Galluzzo, 2021a, 2021b, 2021c).

**Table 1.** Input and output variables used in the estimation of the efficiency in Romanian regions.

| Variable | Unit | Description |
|---|---|---|
| Land | ha | Usable agricultural area |
| People in agriculture | N° | Workers in the primary sector |
| Employed | N° | People working in all economic sectors |
| Poverty | % | Percentage of people at risk of poverty and social exclusion |
| Emigration | N° | Permanent emigrated people from rural areas |
| Farm income | € | Total income for farmers |
| RDP | € | Total payments and subsidies allocated by the second pillar of the CAP |

In this research, the DEA approach has been used in an input oriented variable returns to scale (VRS) model with the aim of minimizing inputs in all farms included in the Romanian Farm Accountancy Data Network dataset.

One of the main bottlenecks of the DEA is due to the incapacity in identifying and consequently estimating the inefficiency and inefficient patterns in each input and output variables and this weakness of DEA is effectively overcome by the Multi-directional Efficiency Analysis or MEA (Asmild et al., 2003; Bogetoft & Hougaard, 2003; Hansson et al., 2020). According to these authors, MEA has the advantage of simultaneously estimating efficiency in multi-input and multi-output models and assessing inefficiency in each of inputs and outputs used in the production process (Manevska-Tasevska et al., 2021). The MEA approach makes possible to identify those deviations from the production frontier, expressed in terms of productivity change, that are due to variables not incorporated in the analysis of technical efficiency (Bogetoft & Hougaard, 2003; Hansson et al., 2020). In the assessment of the patterns of inefficiency by the MEA the analysis has evaluated the excess in some variables able to impact to the permanent rural emigration from Romanian rural areas.

MEA scores take a value between zero for totally inefficient farms and 1 for totally efficient farms without any excess in inputs or outputs. Scores of values 1 indicate that there is no potential for improvement on the input/output variable in question while an input efficiency score of less than unity, e.g., 0.7, indicates that farms could reduce the input in question by 30 percent to be efficient. The estimation of the technical efficiency in this research has used for the DEA estimation and MEA approaches the R software packages corrplot, deaR, rDEA and Benchmarking.

## 4. Results and Discussion

The main results in all investigated Romanian regions have pointed out since 1990 to 2021 a significant amount of people leaving the country. Addressing the analysis to the years of the time series of departure from the residence statistical data published by the Romanian National Institute of Statistics have underlined an intense phenomenon after the collapse of the Berlin wall in particular in rural areas than in urban ones (Figure 1). While the departure from the residence in rural areas since 1999 has stabilized in urban areas statistical data have underlined as the emigration has been higher than in rural areas.

Analyzing in depth the departures from the residence in Romanian rural areas during the time 1990–2021 it emerges as from the North-East region there has been the most significant emigration from the countryside and by contrast from Bucharest-Ilfov there has been the lowest level of emigration from rural areas and this trend has been steady since 1992 (Figure 1). In order to assess if the emigration has a link to the socio-economic fabric, it is useful to use the data about the people employed in the primary sector and the percentage of people at severe risk of poverty and social exclusion.

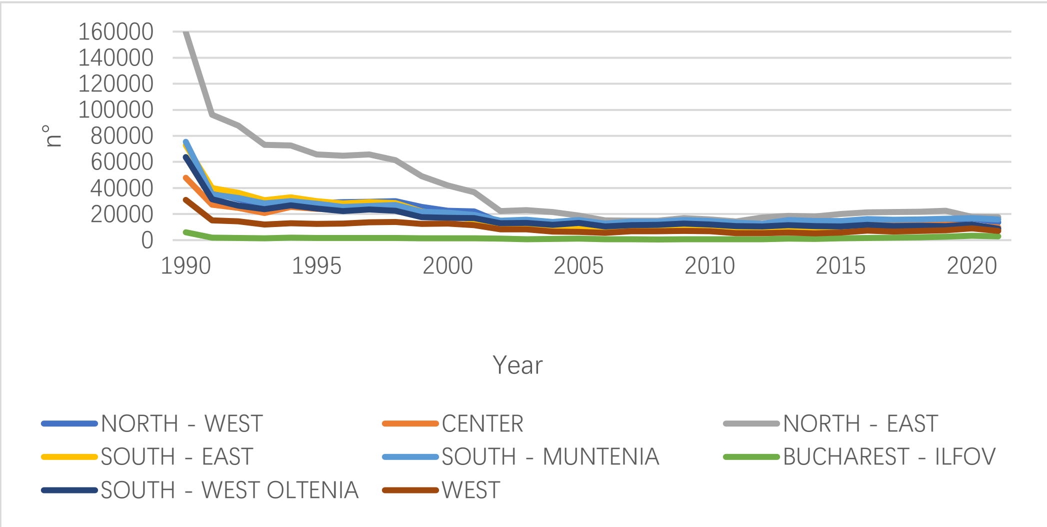


**Figure 1.** Departures from the residence in Romanian rural areas during the time 1990–2021.

Figure 2 has pointed out as from 2007 to 2020 in all Romanian regions there has been a significant drop of the rate of severe material deprivation. In fact, if in 2007 more than 35% of people was at risk of severe deprivation in the recent years the situation is changed and less than 15% of people is at risk of severe deprivation.

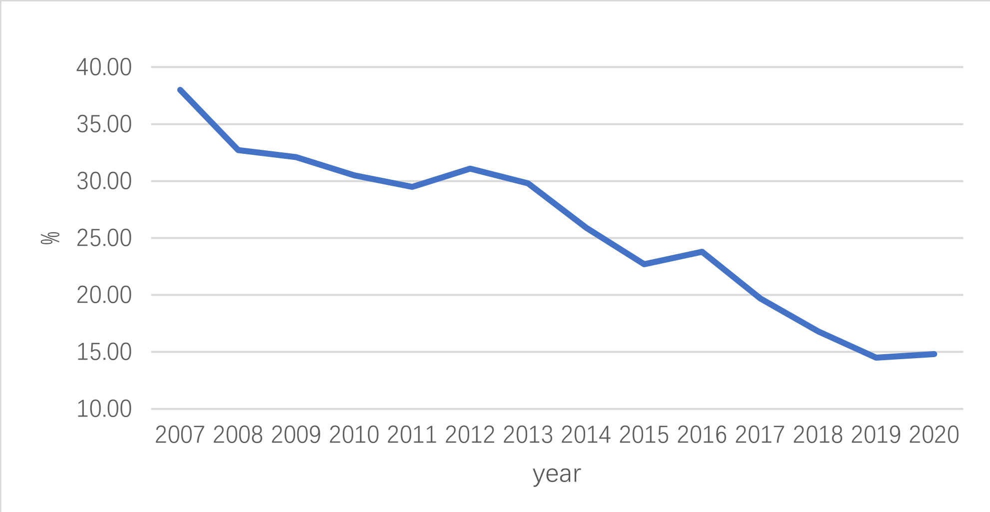


**Figure 2.** Severe material deprivation rate in all Romanian regions over the time.

Comparing different Romanian regions there are significant disparities over the time of investigation (Table 2). In fact, North-East, South-East and South-Muntenia regions have had the highest value of rate of people at risk of severe deprivation and these regions have pointed out the highest level of permanent departure from rural areas. The West region has had the lowest value of people at risk of poverty and severe deprivation in Romania which is halved in the last years of investigation with a modest increase in 2020 during the Sar-Cov 2 pandemic time.

**Table 2.** Evolution of percentage of people at risk of severe deprivation in all Romanian regions.

| Region | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | *Average region* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North - West | 30,4 | 25,0 | 24,3 | 21,8 | 24,2 | 22,7 | 21,9 | 18,0 | 16,5 | 17,6 | 11,9 | 9,3 | 9,0 | 9,1 | *18,6* |
| Center | 29,7 | 27,3 | 21,2 | 19,7 | 18,9 | 23,5 | 27,2 | 25,0 | 21,9 | 18,3 | 13,2 | 10,4 | 9,2 | 12,6 | *19,8* |
| North - East | 43,5 | 40,5 | 41,9 | 40,3 | 38,6 | 37,5 | 34,5 | 30,4 | 26,7 | 23,8 | 22,4 | 19,8 | 17,9 | 19,4 | *31,2* |
| South - East | 43,9 | 34,3 | 31,1 | 38,4 | 35,2 | 36,8 | 38,7 | 34,4 | 32,0 | 29,9 | 25,8 | 22,3 | 20,7 | 22,7 | *31,8* |
| South - Muntenia | 43,6 | 36,5 | 36,9 | 32,2 | 33,2 | 35,9 | 30,0 | 28,4 | 26,8 | 27,5 | 25,8 | 23,0 | 21,7 | 20,6 | *30,1* |
| Bucharest - Ilfov | 34,6 | 30,8 | 36,7 | 30,2 | 27,4 | 28,6 | 27,3 | 19,8 | 13,7 | 25,4 | 19,1 | 19,3 | 11,2 | 10,1 | *23,8* |
| South - West Oltenia | 46,7 | 39,2 | 38,1 | 32,7 | 31,7 | 32,6 | 27,1 | 25,3 | 20,8 | 24,4 | 22,0 | 17,8 | 14,9 | 14,7 | *27,7* |
| West | 25,2 | 22,8 | 20,6 | 22,8 | 20,4 | 26,4 | 28,8 | 22,7 | 16,4 | 22,0 | 13,8 | 7,8 | 7,4 | 8,6 | *18,9* |
| *Average year* | *37,2* | *32,1* | *31,4* | *29,8* | *28,7* | *30,5* | *29,4* | *25,5* | *21,9* | *23,6* | *19,3* | *16,2* | *14,0* | *14,7* | |

In the same time, it is possible to observe as the rate of people employed in agriculture on the total employees is increased over the time of investigation in Romania (Figure 3). Focusing the attention on the different Romanian regions data have pointed out significant differences even if the highest rate of people working in the agriculture has been found in the counties of South-east and North-East characterized by the highest level of people at risk of severe deprivation and departure (Figure 4).

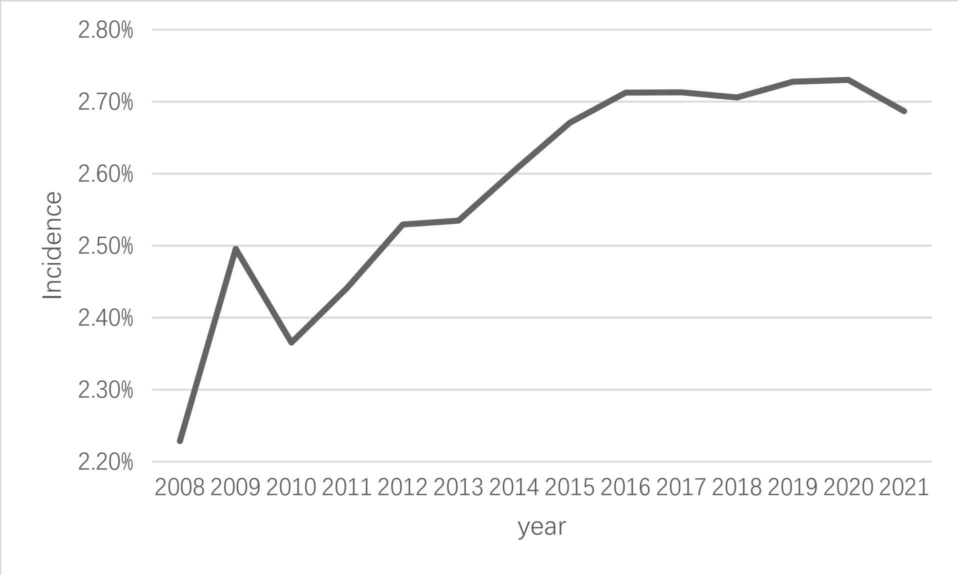


**Figure 3.** Rate of employees in the primary sector on the total employees at level of CANE Rev.2.

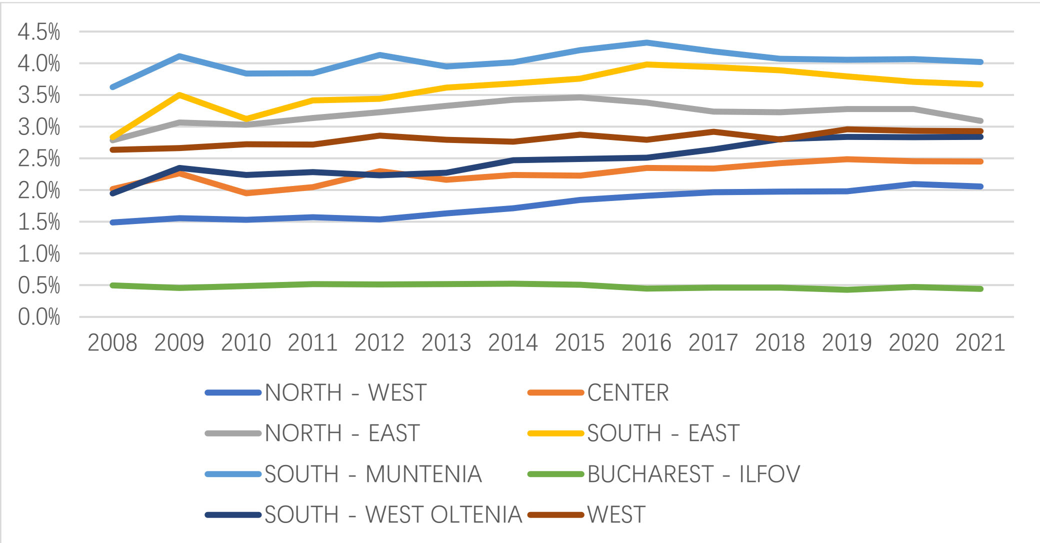


**Figure 4.** Rate of employees in the primary sector on the total employees in all Romanian regions.

In terms of permanent emigration all Romanian regions the research's findings have pointed out a significant decrease after the collapse of the Berlin wall and an increase, with some fluctuations over the time of investigation 1990–2021, even if since 2010 there has been a constant increase of permanent emigration (Figure 5).

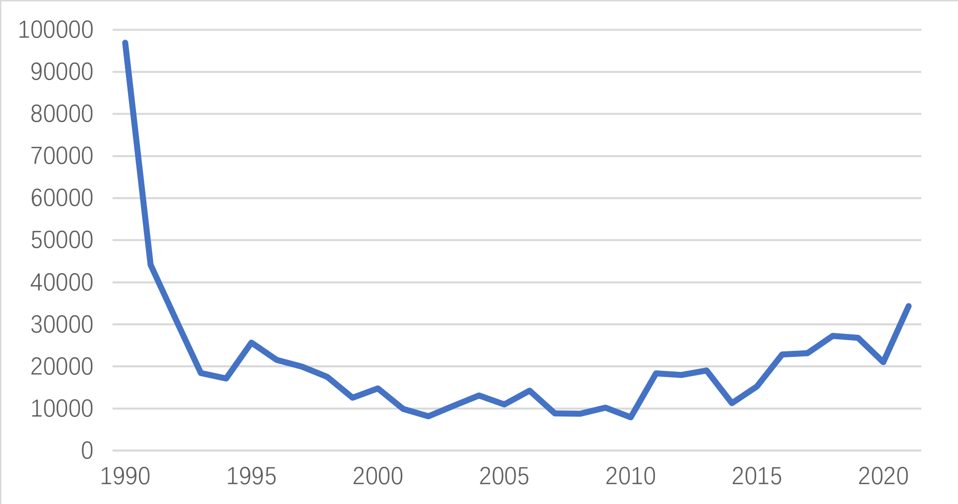


**Figure 5.** Permanent emigration in Romania over the time of investigation.

Focusing the attention to the main Romanian counties it emerges significant fluctuations over the time of study in particular in South-East, North-East and in Bucharest Ilfov regions (Figure 6).

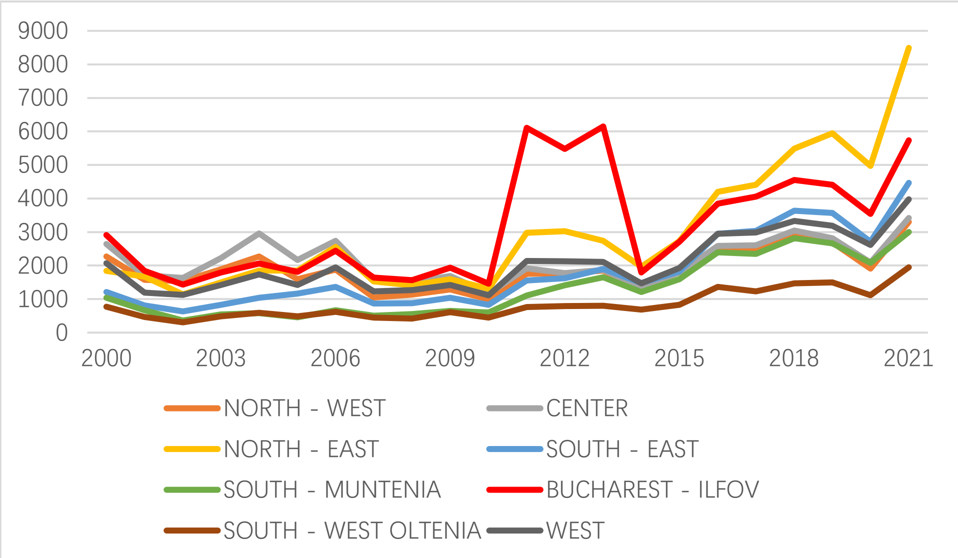


**Figure 6.** Permanent emigration in the main Romanian regions.

The analysis of descriptive statistic in data published by the Romanian Institute of Statistics and by the FADN dataset have pointed out as the total CAP subsidies are predominant and both the financial subsides allocated by the second pillar of the CAP and also the payments to farms located in disadvantaged rural areas (LFA payments) represented a poor share close in average value in a range between 0−381 euro (Table 3). The average value of land capital is close to 12.5 hectares under the average value of the European Union which is close to 16 hectares. It is important also to underline as the people employed in the primary sector is 25% of the total employed people in Romania even if it is fundamental to observe as the share of people at risk of poverty and severe social exclusion is on average close to 38%.

**Table 3.** Main descriptive statistics in all investigated variable used in the estimation of efficiency.

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Less Favored Areas subsidies | 22.36 | 53.54 | 0 | 381 |
| RDP payments | 86.88 | 160.14 | 0 | 1295 |
| Land Capital | 12.49 | 6.14 | 5.44 | 38.28 |
| Total CAP subsidies | 2613.46 | 1601.59 | 662 | 6991 |
| Emigrated people | 1131959 | 504901.2 | 223521 | 1921582 |
| Employed people | 1048.15 | 174.39 | 657.6 | 1425 |
| People employed in agriculture | 253.57 | 127.33 | 15 | 508.4 |
| Rate of employment | 65.17 | 9.65 | 49.3 | 90.4 |
| Rate of people at risk of social exclusion | 37.87 | 9.86 | 12.6 | 56.6 |

Table 4 showed the main descriptive statistics assessed in all 8 Romanian regions. Research's findings have pointed out as the highest value of payments allocated by the rural development program has been assessed in South-East, North-East and Centre regions. In North-East has been found the lowest level of land capital in farms that has been under the 8 hectares. In Bucharest-Ilfov region farmers have received the highest number of total payments and subsides allocated by the CAP while farmers in South-West-Oltenia have got the poor level of CAP financial subsidies. Apart from the Bucharest-Ilfov, North-East and South-Muntenia regions, the analysis has pointed out as the higher is the level of emigration the higher is people employed in agriculture and people at risk of severe social exclusion and deprivation.

The analysis of the correlation in the main investigated variables has pointed out as between emigration people and people employed in the primary sector there is a significant direct correlation on the contrary between emigrated people and employment rate there is an indirect correlation hence, a poor level of emigration is linked to a high level of employed people (Figure 7). Drawing some conclusions, the higher is the percentage of people at risk of social exclusion and poverty the higher is the emigration.

**Table 4.** Main descriptive statistics in all Romanian regions.

| Region | RDP payments (€) | Land Capital (ha) | Total CAP subsidies (€) | Emigrated people (n°) | People employed in agriculture (000) | Rate of people at risk of social exclusion (%) |
|---|---|---|---|---|---|---|
| Bucharest-Ilfov | 0 | 17.90 | 3918.92 | 253358.5 | 31.37 | 26.94 |
| Center | 172.42 | 11.14 | 2929.64 | 991437.5 | 203.77 | 31 |
| North-East | 43.07 | 8.45 | 1571 | 1879028 | 409.52 | 48.83 |
| North-West | 170.57 | 9.08 | 2095 | 1219218 | 304.77 | 29.23 |
| South-East | 156.28 | 16.96 | 3441.92 | 1141837 | 276.57 | 29.23 |
| South-Muntenia | 48.28 | 12.88 | 2523.78 | 1809253 | 356.53 | 41.54 |
| South-West-Oltenia | 18.21 | 7.81 | 1391.64 | 1062861 | 275.36 | 45.24 |
| West | 80 | 16.07 | 3129.07 | 698679 | 170.63 | 33.33 |
| *Total* | *86.88* | *12.49* | *2613.46* | *1131959* | *253.57* | *37.87* |

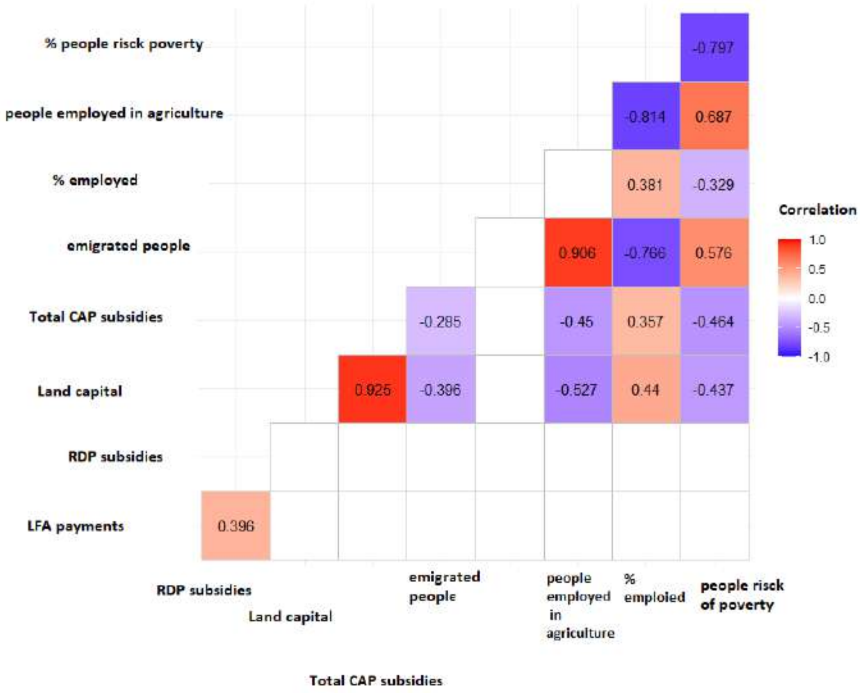


**Figure 7.** Main correlations with a significant at 5% in all investigated variables since 2010–2020 time. In white there are no correlations among variables.

The elaboration of the estimation of efficiency and the patterns of inefficiency in all Romanian counties have pointed out as in general the level of efficiency is almost high close to 0.95 (Table 5).

**Table 5**. Main results of efficiency estimated by DEA and MEA in all Romanian regions.

| Variable | Mean | Std. deviation |
|---|---|---|
| DEA | 0.947 | 0.093 |
| MEA Land Capital | 0.953 | 0.094 |
| MEA people working in agricul-ture | 0.961 | 0.110 |
| MEA total employment | 0.993 | 0.014 |
| MEA risk of poverty | 0.988 | 0.021 |
| MEA emigrated people | 0.976 | 0.045 |
| MEA farmers income | 0.965 | 0.059 |
| MEA RDP subsidies | 0.738 | 0.367 |

The patterns of inefficiency have underlined as the variable RDP subsidies has been the less efficient than the other inputs and output used in the estimation; in particular the total employment and the people at risk of poverty and severe deprivation have been less inefficient. By some maps it has been possible to compare the differences in terms of efficiency and in the patters of inefficiency in all Romanian regions. In this case we used three different colors green to show the highest level of efficiency and the poor level of inefficiency and red for the highest level of inefficiency and lowest level of efficiency, the yellow color indicates a middle way.

The highest level of efficiency has been assessed in four Romanian regions out of height and in particular in Centre, North-East, South-Muntenia and North-West with value above 0.97 (Figure 8). The lowest value of efficiency has been found in West, Bucharest-Ilfov and South-West Romanian regions with a value above 0.90.

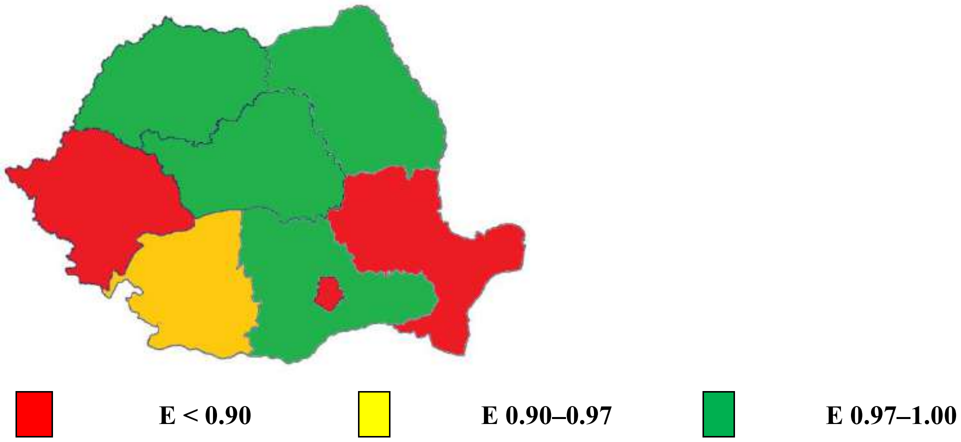


**Figure 8.** Efficiency (E) estimated by the DEA approach in each Romanian region.

Addressing the attention to the pattern of inefficiency in the input land capital (Figure 9) research's findings pointed out as the highest value in terms of efficient use of this input in Center, North-East, North-West and Bucharest-Ilfov regions, on the contrary West and South- West Romanian regions have underlined an inefficient use of this input.

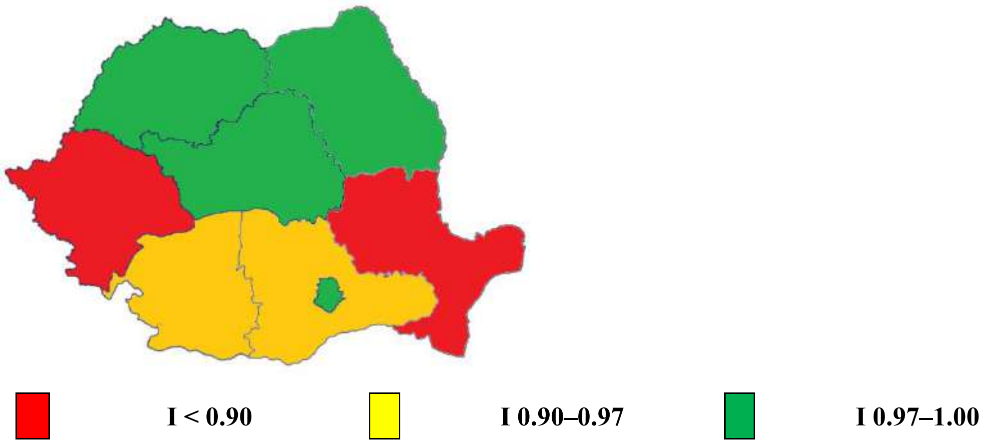


**Figure 9.** Estimation of inefficiency patterns (I) by the MEA approach in land capital variable.

Farm net income has had the lowest value of inefficient use both for the variable farm's income and also for the variable people at risk of poverty hence, over the time of investigation there has been an intense drop of the people at risk of severe deprivation and exclusion (Figure 10). Figure 10 showed also as except for the region of Bucharest-Ilfov and South-West in all Romanian regions people employed in agriculture is a variable which is not able to cause an inefficient use of this variable and the same results have been found addressing the attention to the percentage of employed people in all Romanian regions.

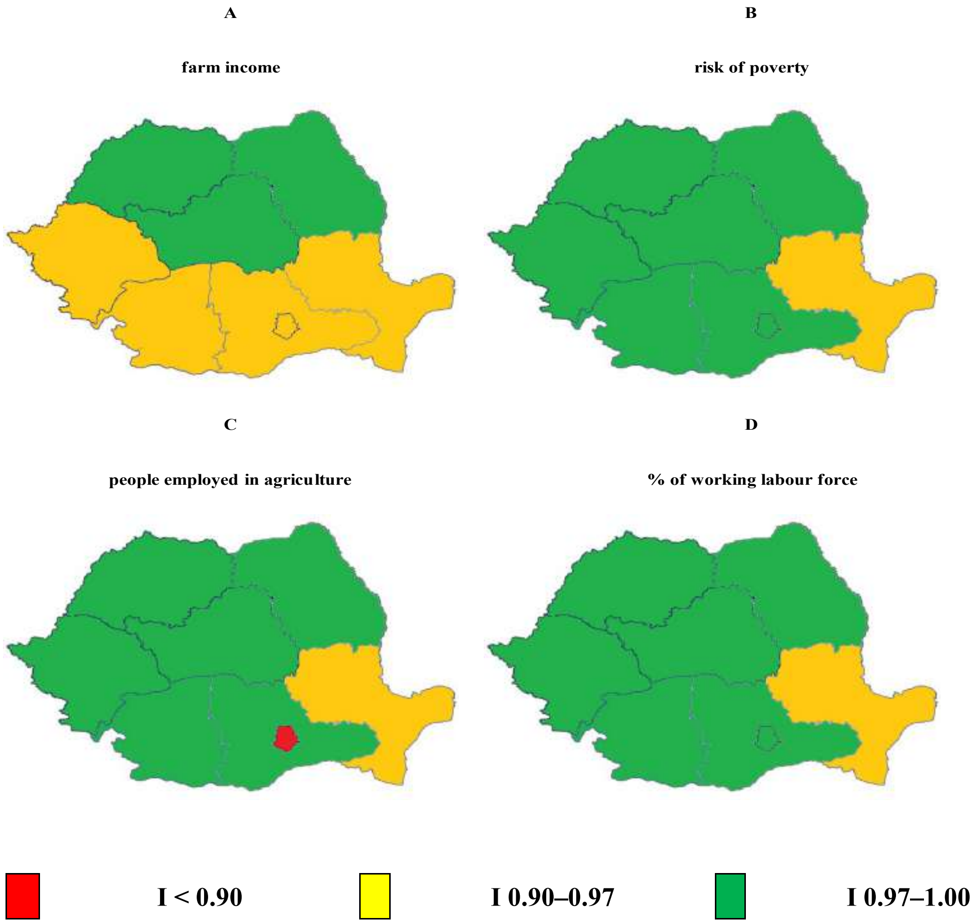


**Figure 10.** Main results of the inefficient (I) estimated by MEA in the use of farm income, risk of poverty, people employed in agriculture and percentage of working labor force variables.

In five counties out of eight the variable people emigrated has not inefficient apart from the South-West regions that has had the highest level of inefficiency in this variable which implies a significant action in order to halt this phenomenon of emigration from the rural areas (Figure 11). On the contrary, the allocation of subsides by the second pillar of the CAP in order to stimulate the rural development in Romanian rural areas has pointed out a mixed result. In fact, only in the Central region it has been possible to find a low level of inefficiency and in South-West-Oltenia, Bucharest-Ilfov and in South-West it has been possible to assess the highest level of inefficiency in the allocation of these kind of subsidies.

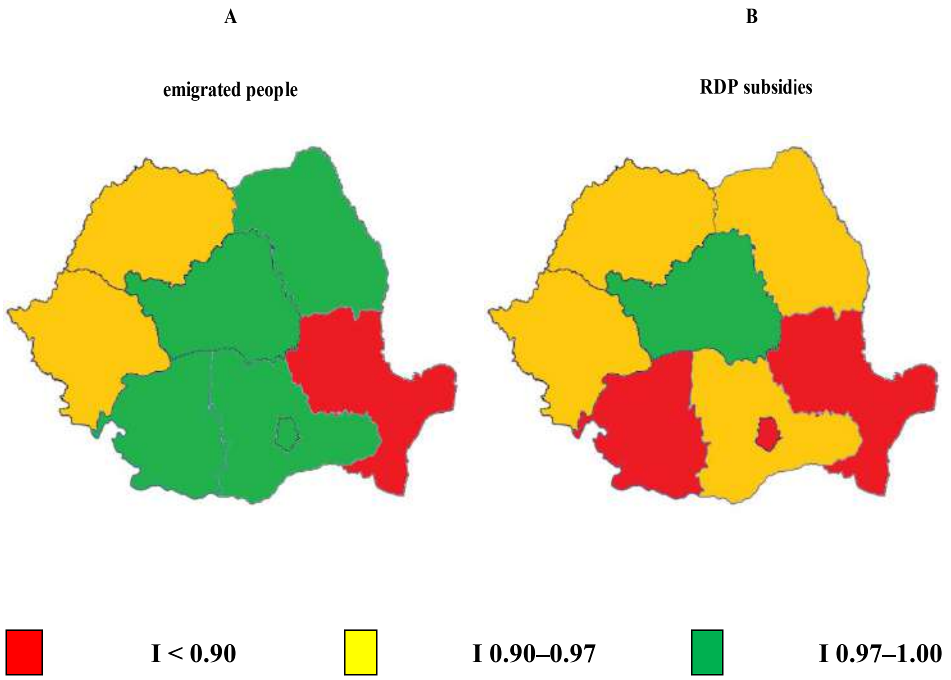


**Figure 11.** Main results of the inefficient patterns (I) in two investigated variables such as emigrated people and total subsidies allocated by the second pillar of the CAP.

## 5. Discussion and Conclusions

The present study has corroborated as the emigration in Romanian rural areas is a multidimensional topic that needs of different quantitative approaches of investigation as carried out in this paper. In fact, results have corroborated the theoretical hypothesis proposed by Sandy in 2005 in using a multidimensional approach in order to face with studies about permanent emigration.

The research's findings have underlined as the CAP subsidies are a fundamental tool for the socio-economic development of Romanian regions because of the financial subsidies and payments have had a significant impact to the emigration from the countryside as argued by other studies (Galluzzo, 2021a, 2021b; Mitrică et al., 2022).

As proposed by Mitrică et al. in 2022, the emigration has been typical of southern Romanian regions which seem to be very sensitive to some socioeconomic variables used in this study such as risk of poverty, employed people and subsidies allocated by the CAP. Results have pointed out as people emigrated from the South-West and South-Muntenia are typical of regions characterized by small farms with a modest impact of financial subsidies allocated by the second pillar of the CAP and by the highest share of people at risk of poverty and social exclusion and this has been in line with something proposed by other studies (Mitrică et al., 2019, 2022) according to which in these two regions higher has been the emigration and people seem to be characterized by low skills. This has corroborated as the variable people at risk of social exclusion is one of the main drivers able to push people to emigrate.

This study held the light about the role of subsidies allocated by public policy such as the Common Agricultural Policy and the emigration, underlining the fundamental role of subsided in less favored areas in order to reduce the emigration from rural areas even if the impact of CAP and emigration can be mixed at this stage of investigation (Galluzzo, 2016, 2021b). For the future it is important to boost the financial subsidies to rural areas with a specific and well-defined approach addressed to small farms located in rural areas at risk of marginalization where the diversification by agritourism can be a strategic leverage in reducing the emigration form the Romanian countryside.

In general, this study has underlined as there are some unbalances among all Romanian regions with the Bucharest-Ilfov receiving the highest amount of CAP subsidies. Drawing some conclusions, this research has pointed out as an increase of subsidies allocated by the second pillar of the CAP is not efficient as corroborated by the MEA approach. Furthermore, regions with a significant share of people at risk of poverty and people employed in agriculture have suffered a significant increase of permanent emigration as corroborated by the analysis of patter of inefficiency as well. Hence, it is important to improve the efficiency of the subsidies allocated by the Rural Development Program that has pointed out a different effect in all investigated Romanian regions. In particular, the Nort-East region has had the worst results in terms of efficiency in all investigated variables and where very intense has been the permanent emigration from the rural areas. In conclusion, South-West and North-West regions have been the areas where higher has been the poverty rate and the share of people working in agriculture that has been able to demonstrate as the higher is the deprivation in socio-economic way and the higher is the emigration in rural areas than in urban ones. For a correct management of policy of emigration and immigration in Romanian rural areas it is crucial to define specific measures in the rural development program with the purpose to reduce the marginalization of the rural space and to improve job opportunities in farms and in other enterprises well-rooted in the countryside. In this perspective, measures of farm's diversification, on-farm activities, rural tourism and agritourism are fundamental strategic leverages of development versus permanent emigration in Romanian rural areas.

**CRediT Author Statement:** This is a single author paper and the author was solely responsible for the content, including the concept, design, analysis, writing, and revision of the manuscript.

**Data Availability Statement:** The data supporting the findings of this study are openly avai-lable at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html; http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table and https://ec.europa.eu/eurostat/data/database.

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*Article*

# Rural Women's Participation and their Decision Making Behavior in Livestock Management and Household Activities in Central Dry Zone Area of Myanmar

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**Abstract:** The study aimed to assess the factors affecting on women's participation level and decision-making behavior of rural women in livestock management and household activities in particularly 60 randomized respondents from three villages of Natmauk township, central dry zone area, Myanmar. Descriptive analysis, Chi-Square test and stepwise regression methods were applied to analyze the relationship of women's participation and decision-making behavior of respondents. Results of the KII and FGD were used to further explains in survey. Respondents are middle-aged group, small-sized farmers, busy with domestic chores and had no formal schooling. They mostly grow sesame, groundnut and other tropical crops and rear small sizes of adult cattle males in the study. Men are chief decision makers in their households because they have access to more resources. Ownership of land and access to information is highly affected on decision making of when to buy/sell livestock, what to feed and when medical treatment of livestock. Information got especially from friends, family and traders are helpful in the decision making of buying/selling livestock, spending money earned from livestock and feeding the food for the livestock. Spearman's rho correlation was used to identify and streamline women's activities that need to be focused on so that to make good decisions in livestock farming.

**Keywords:** women-households; livestock management; household activities; decision making description

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## 1. Introduction

Livestock is generally considered as a key asset for rural livelihoods (Bhanotra et al., 2015) and livestock management is a gendered activity as both men and women are involved in it (Ali, 2007). Within the agriculture sector of Myanmar, livestock plays a critical role in smallholder mixed crop-livestock systems that dominate the sector (Food and Agricultural Organizations, 2016). According to the GDP contribution data, the livestock and fishery sector grew by 4.1 percent in 2019 (Statista Research Department, 2019). Central dry zone (CDZ) is a major hub for crop and livestock production with almost 50% of Myanmar's livestock population being reared in this area. Livestock production is a major income source for farmers in the CDZ but there is an eminent lack of information on livestock husbandry practices, nutrition, animal health problems, the socio-economic impact of livestock production and the current trading system (Oo, 2010).

Rural women play an important role in both livestock and household activities. They are the good livestock caretakers and undertake various activities of livestock management like fodder cutting, watering, and feeding of animals, animal shed cleaning and milking (Arshad et al., 2013). Women's participation in livestock management is productive and saves money to be spent in hiring labor. The role of women participation and contribution of women in livestock management is appreciated and women spend on an average about 5 to 6 hours a day on various livestock activities which include cleaning of sheds, washing of animals, feeding, and milking (Taj et al., 2012).

Despite the women's incredible role in livestock sector, their involvement in decision-making regarding livestock management is still seeming questionable (Bhanotra et al., 2015). Male dominance in decision making of the household and economy has continued even in areas where women are the key providers of labor because the influence of women has not been recognized and they are kept out of all important decision making processes, while the responsibilities ultimately impinge on them (Bhanotra et al., 2015). They have no or very little power to take decisions due to many reasons like lack of education, lack of mobility, lack of control over resources, low level of awareness of their civic/ human rights, lack of credit facilities from the Government (Food and Agricultural Organizations, 2003).

The importance women's participation in family decision-making among third world countries is limited to some extent (Sultana, 2010). The discriminatory social norms across societies, imbalanced gendered power within households and communities, unequal access to resources and opportunities impact on women's participation at all levels of decision making (Paudel, 2019). The participation of women in decision making of major household purchases has a strong significant association with socio-background characteristics in outcome (Acharya et al., 2010). There is a lack of confidence to contribute to public decision making of women prevents many women from trying to take on leadership roles in Myanmar (Minoletti, 2014). Women in Myanmar have a high burden of work, which includes both productive and reproductive work. Thus, the participation of Myanmar women in the development, implementation, monitoring, and evaluation of policies and programs can develop their qualities and leadership roles (Asian Development Bank, 2016a).

Nowadays, it is often argued that women's contributions are undermined and their involvement in decision making is minimal. Information about women's extent of participation and decision-making power in livestock and household management is still lacking in Myanmar. There is no study and research about women's participation and activities in livestock management related to their decision-making behavior. Thus, the study was conducted to assess the factors affecting on rural women's participation level and decision-making behavior of rural women in livestock management and household activities. Specifically, the study aimed to:

### *1.1. Objectives*

(1) Analyze the livelihood status, social norms and beliefs related to livestock production of rural women in study area.
(2) Assess rural women's participation level and decision-making behavior of rural women in livestock management and household activities.
(3) Explore the factors affecting on rural women's participation level and decision-making behavior of rural women in livestock management and household activities.

## 2. Materials and Methods

Livestock development is the driving force for rural development in Myanmar. According to Census in 2019, there are 112,891 populations of cattle, 70 populations of dairy cattle, 15,849 populations of sheep, and 29,455 populations of goats. Livestock is playing a crucial role in the fulfillment of basic subsistence requirements of the country's poor. The livestock farmers embark on various activities of livestock management like watering and feeding of animals, cleaning activities and milking (Bhanotra et al., 2015). Women are the household managers, but their work is considered as non-productive, unorganized, undocumented and their contribution in agricultural labor force in developed countries is 36.7% while, it is about 43.6% in developing countries (Lemlem et al., 2010). As compared to men, contribution of women in livestock care and management is higher and they contribute 60 to 80% of labor in the animal husbandry (Younas et al., 2007). Women carry out their livestock production to their household commitments or duties, which include food preparation, child-care, water collection, gathering firewood, milling grains, cleaning, sewing and embroidery. The success of livestock enterprise relies heavily on effective involvement of women because they are closely involved in animal husbandry sort of activities (Ahmad, 2013).

On the other side, male dominance in the decision-making of the household has continued in the gender biases of some areas even if women are the key providers of the labor perform the most of all (Tulachan & Karki, 2000). Male dominance and traditional belief system are the main factors which had affected the involvement of rural women in decision making process (Bhanotra et al., 2015). Men are taking the lead role in the decision-making of their households (Lemlem et al., 2010). The reasons women are kept out of all important decision-making processes are due to lack of education, lack of mobility, lack of control over resources, low level of awareness of their human rights, and lack of credit facilities from the Government (Bhanotra et al., 2015).

## 3. Results

### *3.1. Data Collection and Analysis*

The Number of households, about 60, were selected from three villages in Natmauk township, central dry zone area, Myanmar. A survey was collected quantitative, numbered data using questionnaires or interviews and statistically analyze the data to describe trends about responses to questions and to test research questions or hypotheses. Interview using a structured questionnaire; key informant interviews; focus group discussions and desk review of relevant secondary documents were used in the study. Descriptive analysis and inferential statistics were used through the aid of the SPSS software for Chi-Square test with the use of Goodman and Kruskal's Lambda Coefficient correlation and stepwise regression methods to determine the relationship between the dependent and independent variables.

## 4. Results and Discussion

### *4.1. Demographic Factors*

Data of livelihood status, social norms and beliefs related to livestock production of the respondents were included in these factors.

#### 4.1.1. Age

The mean age of the respondents was 51 years within the range of 17–73 years (see in Table 1). Besides, the age of the respondents was categorized into three groups such as young, middle, and old. Most of the respondents are middle age group (70%) and they are between 38–64 years old. This was followed by the young group under 38 years, the old group64 years and above in the same percent (15%), respectively. This finding is similar with the finding of Australian Center for International Agricultural Research (2011), which described that the average age of the farmers in CDZ of Myanmar is 48.8 years.

#### 4.1.2. Educational Attainment

Nearly about half (46%) of the respondents had no formal schooling, however, about 26% of them had primary level education and 20% had middle level education (Table 1). More than 6% of the respondents had the monastic education. This finding agrees with the statement of Food and Agricultural Organizations and Yezin Agricultural University (2021) that most Myanmar people had in the primary education. On this regard, Myanmar Education Consortium (2015) reported that monastic education was the first education system of both men and women in Myanmar despite its chequered and politically sensitive history, it is still in demand today and currently provides education for 3% of school-aged children.

#### 4.1.3. Occupation

All respondents are involved in livestock farming (Table 1). However, respondents are cooperate-working in other jobs such as agricultural works (35%), construction sites, standing as the hired labor, and selling in grocery. Respondents (55%) spent all their working time in the livestock activities of their houses including fodder cutting, watering, and feeding of animals, animal shed cleaning and milking as their main occupation. A few respondents (3.3%) said that they are grazing in pasture because they have enough food for their livestock. The National Consultative Committee (2001) also pointed that about 86% of the Myanmar people live in rural areas and are engaged in livestock farming.

**Table 1.** Demographic factors of the respondents.

| **Variables**<br>**Age Group** | **Frequency** | | **Percentage** |
|---|---|---|---|
| Young | 9 | | 15 |
| Middle | 42 | | 70 |
| Old | 9 | | 15 |
| Total | 60 | | 100 |
| Mean | | 51 | |
| Std Dev | | 13 | |
| Total | | | |
| **Education Attainment** | | | |
| Illiterate | 7 | | 46.7 |
| Primary | 4 | | 26.7 |
| Middle | 3 | | 20.0 |
| Monastery | 1 | | 6.7 |
| Total | 15 | | 100 |
| **Occupation** | | | |
| Agriculture | 21 | | 35.0 |
| Construction worker | 1 | | 1.7 |
| Laborer | 2 | | 3.3 |
| Livestock activities | 33 | | 55 |
| Livestock grazing | 2 | | 3.3 |
| Selling | 1 | | 1.7 |
| Total | 60 | | 100 |
| **Household Size** | | | |
| Small (below mean) | 28 | | 46.8 |
| Large (above mean) | 32 | | 53.2 |
| Mean | | 4.6 | |
| Std Dev | | 1.7 (Range 1–8) | |

Age (young = ≤38; Middle = 38–64; Old = ≥64 )

4.1.4. Household Size

More than 53% of the respondents fall within 5–8 household size followed by 46.8% is within the size of 1–4 members. As per Table 1, the average household size in this study is 4.6. According to the 2014 Myanmar Population and Housing Census Thematic Report on Housing Conditions and Household Amenities, the average Myanmar national household size is 4.4 (United Nation Development Programme, 2016). Study area is similar to Myanmar's national household size.

### *4.2. Land Holding of the Respondents*

There are three kinds of crop growing seasons in the study area: pre-monsoon, monsoon and post-monsoon. Thus, the respondents have different farm sizes in the three seasons (see in Table 2). According to the data gathered, more than 56% of the respondents have 1–5 acres, while nearly 12%have 6–10 acres, and 1.7% have 16–20 acres in pre-monsoon, respectively. When it comes to monsoon season, 60% of the respondents have 1–5 acres followed by 3.4% of the respondents and 1.7% of the respondents have 6–10 acres and 16–30 acres, respectively.

**Table 2.** Land holding of the respondents.

| Pre-Monsoon (Acres) | Frequency | Percentage | Monsoon (Acres) | Frequency | Percentage | Post-Monsoon (Acres) | Frequency | Percentage |
|---|---|---|---|---|---|---|---|---|
| 1–5 | 34 | 56.8 | 1–5 | 36 | 60 | 1–5 | 10 | 16.6 |
| 6–10 | 7 | 11.7 | 6–10 | 2 | 3.4 | 6–10 | 2 | 3.4 |
| 11–15 | - | - | 11–15 | - | - | 11–15 | - | - |
| 16–20 | 1 | 1.7 | 16–20 | 1 | 1.7 | 16–20 | - | - |
| Total | 42 | 70.2 | Total | 39 | 65.1 | Total | 12 | 20 |

As to post-monsoon season, the respondents have 1–5 acres and 6–10 acres for 16.6% and 3.4%. When compared with the country's average rainfall level, CDZ receives limited rains and the farmers in this region are mostly grown in pre-monsoon and monsoon crops. In contrast, their farm sizes of pre-monsoon and monsoon are also higher than post-monsoon farm size and post-monsoon crops are lack of rainfall. According to the results of FGD, the respondents mostly cultivated their crops during pre-monsoon and monsoon because they got low profits for post-monsoon crops during lack of rainfall in the study area. Hein et al. (2017) pointed out that the main two farmland categories: lowland (paddy land; le), and "upland" (ya) for pre-monsoon, monsoon, and monsoon crops in the central dry zone, and he also described that the landholding of the intermediate farm households is within 1–5 acres.

Majority of the respondents cultivated sesame (86.7%) and groundnut (73.3%) while some cultivated sorghum (33.3%) and Cotton (33.3%) in the pre-monsoon season as per in Table 3. A few respondents (5%) has pigeon peas during this season. Asian Development Bank (2016b) approved that sesame and groundnuts are the two principal oilseeds produced commercially in the CDZ, Myanmar.

**Table 3**. Pre-monsoon, monsoon, and post-monsoon crops.

| Pre- Monsoon Crop | Frequency | Percentage | Monsoon Crop | Frequency | Percent | Post-Monsoon Crop | Frequency | Percent |
|---|---|---|---|---|---|---|---|---|
| Sesame | 52 | 86.7 | Sorghum | 33 | 55.2 | Cotton | 20 | 33.3 |
| Groundnut | 44 | 73.3 | Cotton | 25 | 41.7 | Chickpea | 20 | 33.3 |
| Sorghum | 20 | 33.3 | Groundnut | 21 | 35 | Sorghum | 18 | 30.0 |
| Cotton | 20 | 33.3 | Rice | 20 | 33.3 | Sunflower | 16 | 26.7 |
| Pigeon pea | 3 | 5.0 | Sesame | 20 | 33.3 | | | |
| | | | Chilli | 17 | 28.3 | | | |
| | | | Pigeonpea | 7 | 11.7 | | | |
| | | | Greengram | 4 | 6.7 | | | |

When it comes to monsoon season, more than 55% of the respondent's cultivated sorghum and nearly 42% of them cultivated cotton. Besides, the rest of them are cultivated groundnut (35%), rice (33.3%), sesame (33.3%), Chilli (28.3%), pigeon pea (11.7%) and greengram (6.7%). Naing (2017) approved that rice, sesame and groundnut are the most widely cultivated crops in central dry zone area during monsoon season. Results also show that most of the respondents cultivated cotton and chickpea at the same percent (33.3%) while others cultivated for sorghum (30%) and sunflower (26.7%) in post-monsoon areas. In this regard, Oxfarm (2014) also reported that the farmers in the dry zone are mostly grown cotton, pulses including chickpea and other oilseed crops including sunflower. According to JICA report of the central dry zone in 2010, the farmers in the dry zone area cultivated sorghum for the marginal cost effectiveness.

### *4.3. Demographic Factors*

The ownership of livestock depends on a herd or flock size in the study area. According to the categorization of livestock guide in ACIAR research project in 2019, the livestock were categorized based on the lifespan and tercile analysis. In fact, the livestock were classified into two groups of young and adult for male and female in this study. Two years of male cattle were counted in adult and less than 2 years are in young male cattle. Likewise, one and half years of female cattle were counted in adult and less than one and half years are in young female cattle. Based on the terciles analysis, the 33rd, 66th and 100th percentiles were used to describe the herd/flock sizes (Table 4).

**Table 4**. Cattle group of the respondents.

| **Cattle Male Young Group** | **Respondents (n = 60)** | |
|---|---|---|
| | **Frequency** | **Percent** |
| Small (1–3) | 11 | 18.3 |
| Medium (4–6) | 2 | 3.3 |
| Large (6≤) | 1 | 1.7 |
| Nil | 46 | 76.7 |
| Total | 60 | 100 |
| **Cattle Male Adult Group** | Frequency | Percent |
| Small (1–3) | 33 | 55 |
| Medium (4–6) | 11 | 18.3 |
| Large (6≤) | 1 | 1.7 |
| Nil | 15 | 25 |
| Total | 60 | 100 |
| **Cattle Female Young Group** | Frequency | Percent |
| Small (1–3) | 16 | 26.6 |
| Medium (4–6) | 1 | 1.7 |
| Nil | 43 | 71.7 |
| Total | 60 | 100 |
| **Cattle Female Adult Group** | Frequency | Percent |
| Small (1–3) | 19 | 31.5 |
| Medium (4–6) | 11 | 18.3 |
| Large (6≤) | 5 | 8.5 |
| Nil | 25 | 41.7 |
| Total | 60 | 100 |

According to the data, the herds/flocks were classified into three sizes (small, medium, large), corresponding to these terciles for each livestock species: cattle herds-small (1–3), medium (4–6) and large (> 6); small ruminants' flocks-small (1–20), medium (21–40) and large (> 40). The respondents mostly had the small size of adult cattle male (55%) and female (35.5%) while the small size of young male group (18.3%) and female group is (26.6%). Likewise, the medium size of adult cattle male and female is the same percent (18.3%) followed by the medium size of young male group (3.3%) and female group is (1.7%). When it comes to the large size, the adult cattle male group (1.7%) and female group (8.5%), however, the respondents have only young male group (1.7%).

This categorization results of cattle herd are agreed with the finding of Win et al. (2019), that the number of animals kept per herd or flock was examined by terciles analysis, and the adult and young groups were categorized based on the life span in the central dry zone area. The small ruminants were also categorized based on their lifespan and ten months of male are added in adult group and less than ten months are in young male group. Likewise, eight months of the female small ruminants are added in adult group and less than eight months are in young female group.

In the flock size of goat, the respondents have only the small young size of male (16.7%) and female (18.3%) (see in Table 5).

**Table 5**. Goat group of the respondents.

| Goat Male Young Group | Respondents (n = 60) | |
|---|---|---|
| | **Frequency** | **Percent** |
| Small (1–20) | 10 | 16.7 |
| Nil | 50 | 83.3 |
| Total | 60 | 100 |
| **Goat Male Adult Group** | Frequency | Percent |
| Small (1–20) | 13 | 21.6 |
| Medium (21–40) | 1 | 1.7 |
| Nil | 46 | 76.7 |
| Total | 60 | 100 |
| **Goat Female Young Group** | Frequency | Percent |
| Small (1–20) | 11 | 18.3 |
| Nil | 40 | 81.7 |
| Total | 60 | 100 |
| **Goat Female Adult Group** | Frequency | Percent |
| Small (1–20) | 9 | 15 |
| Medium (21–40) | 1 | 1.7 |
| Large (40≤) | 2 | 3.3 |
| Nil | 48 | 80 |
| Total | 60 | 100 |

In terms of adult groups, the small size of male (21.6%) and female (15%) while the medium size of male and female groups has the same percent (1.7%). There has only adult large size of female (3.3%) in the study.

When it comes to the flock young sizes of sheep, the respondents have only the small size of male (20%) and female (18.3%) (Table 6).

**Table 6**. Sheep group of the respondents.

| Sheep Male Young Group | Respondents (n = 60) | |
|---|---|---|
| | **Frequency** | **Percent** |
| Small (1–20) | 12 | 20 |
| Nil | 48 | 80 |
| Total | 60 | 100 |
| **Sheep Male Adult Group** | Frequency | Percent |
| Small (1–20) | 11 | 18.4 |
| Medium (21–40) | 2 | 3.3 |
| Large (40≤) | 2 | 3.3 |
| Nil | 45 | 75 |
| Total | 60 | 100 |
| **Sheep Female Young Group** | Frequency | Percent |
| Small (1–20) | 11 | 18.3 |
| Nil | 49 | 81.7 |
| Total | 60 | 100 |

In case of sheep flock adult sizes, they have the small size of male (18.4%) and female (8.4%); the medium size of male (3.3%) and female (8.4%); and the large size of male (3.3%) and female (5%) in this study. This is similar with the categorization of Win et al. (2019) in the small ruminants' flocks' size and life-span analysis. Key informant interviews revealed that the respondents used lifespan and tercile analysis to categorize their herd or flock sizes of livestock.

*4.4. Women's Participation in Decision-Making Behavior of Livestock Management and Household Activities*

As per Table 7, it was found that the breakdown of the gendered division of labor in terms of livestock chores. The respondents' participation in the livestock rearing activities was found in this table. Results show that women are responsible for performing livestock chores, especially around the house. A greater percentage of women feed livestock (31.7%), provide water (38.3%), care for young animals (46.7%), clean shelters (83.3%), care for sick animals (53.3%) and purchase forage (45%), than men. This finding is agreed with the reports of Awan et al. (2021), the participation of women in livestock management activities is higher than men's contribution in various livestock activities including clean livestock shelters, care for sick livestock, care for young animals etc.

**Table 7**. Livestock rearing activities.

| Activities | Activity is performed by (hrs/day) | | | | |
|---|---|---|---|---|---|
| | **Neither** | **Men** | **Both** | **Women** | **Other** |
| Take the livestock grazing | 25.0(15) | 36.7(22) | 8.3(5) | 30.0(18) | |
| Feed livestock | 6.7(4) | 28.3(17) | 33.3(20) | 31.7(19) | |
| Provide livestock with water | | 28.3(17) | 33.3(20) | 38.3(23) | |
| Care for young animals | 10.0(6) | 20.0(12) | 23.3(14) | 46.7(28) | |
| Buy livestock | 48.3(29) | 36.7(22) | 6.7(4) | 8.3(5) | |
| Sell livestock | 11.7(7) | 58.3(35) | 11.7(7) | 18.3(11) | |
| Clean livestock shelters | | 6.7(4) | 10.0(6) | 83.3(50) | |
| Care for sick livestock | 3.3(2) | 20.0(12) | 23.3(14) | 53.3(32) | |
| Buy forage for livestock | 23.3(14) | 26.7(16) | 5.0(3) | 45.0(27) | |
| Chop and carry forage for livestock | 8.3(5) | 26.7(16) | 43.3(26) | 21.7(13) | |
| Agricultural work for forage crops | 15.0(9) | 51.7(31) | 30.0(18) | 3.3(2) | |
| Collect milk from livestock | 98.3(59) | 1.7(1) | | | |
| Sell milk collected from livestock | 98.3(59) | | | 1.7(1) | |
| Sheep Shearing | 75.0(45) | 5.0(3) | 3.3(2) | 15.0(9) | 1.7(1) |
| Take manure to fields for fertilizer | 8.3(5) | 50.0(30) | 35.0(21) | 6.7(4) | |

Cutting and carrying forage (43.3%) is a chore that is shared equally between men and women and for those households that own sheep. This finding agrees with Fischer et al. (2018) finding, that the forage chopping is the highest done with both husbands and wives in domestic groupings and male households are mostly found in chopping machine while female households are chopping with manual. Men are more influenced in decision making of sale of livestock (58.3%), agricultural work for forage crops (51.7%) and take manure to fields for fertilizer (50%) than women. This finding is agreed with the results of Arshad et al. (2010) that about 74% of the male dominance has in decision making of livestock activities including sale of animals, fodder cultivation, sale of animals' produce to get useful. If shearing (1.7%) is performed by someone in the households, it is more likely to be a chore for women. The result was assumed that respondents are seldom to shear their sheep in this region. In the reports of WorkSafe New Zealand (2014) and National Centre for Farmer Health (2023), which pointed that shearing and crutching are high-risk jobs that need a lot of manual effort workers, who shear or crutch thousands of sheep each year, can be at high risk of being injured.

Data shows that both men and women seldom to collect the milk from their livestock (98%) and seldom to sell their livestock milk (98%) in this study because they used milk for their home consumption. van der Lee et al. (2014) approved that dairy milk is the source of livestock milk production and only 6% of dairy cattle milk production has in the central dry zone. This finding agrees with van der Lee's finding that the livestock farmers in the dry zone area seldom to collect their livestock milk and seldom to sell out them in the market.

The domestic chores who actively performed in the household see in Table 8. Apart from agricultural work, where duties are predominantly performed by men or shared by men and women, women disproportionately bear the responsibility for performing all other domestic chores. Women are mostly involved in the four of five household chores such as clean house (100%), wash clothes (98.3%), cook for family (96.7%) and prepare donations for monks (96.7%). This is agreed with the report of Alliance for Gender Inclusion in the Peace Process (2016), which described that men are seen as responsible for hard-, productive- and outside work while women are seen as responsible for work taking place inside and domestic works.

**Table 8**. Domestic chores time constraints.

| Activities | Activity is performed by (hrs/day) | | | |
|---|---|---|---|---|
| | Neither | Men | Both | Women |
| Do agricultural work | 8.3% (5) | 43.3% (26) | 41.7% (25) | 6.7% (4) |
| Prepare donations for monks | | 1.7% (1) | 1.7% (1) | 96.7% (58) |
| Cook for family | | | 3.3% (2) | 96.7% (58) |
| Wash clothes | | | 1.7% (1) | 98.3% (59) |
| Clean house | | | | 100% (60) |
| Care for seniors | 40% (24) | 1.7% (1) | 1.7% (1) | 56.7% (34) |
| Care for children | 26.7% (16) | | 5% (3) | 68.3% (41) |
| Make clothes | 45% (27) | | | 55% (33) |
| Rest or enjoy time with friends and family | | | 100% (60) | |

Although agricultural work is done jointly by men and women (41.7%), men (43.3%) are also involved in this domestic chore. Result is similar to the findings of FAO (2012) and Singh and Srivastava (2016), they stated that most agricultural activities are done jointly by men and women, in which, men are more involved in agricultural activities. Besides, they all spend their leisure time together with their friends and family (100%). This finding is approved by the report of the United Nations Office for Project Services (2022) in Myanmar, in which, Myanmar farmers can spend their free time with their families todays because they get more free time due to changing mechanized farming.

The gendered patterns of access to the resources required to care and manage livestock are seen in Table 9. Results indicate that women appear to have more access to the financial resources, that required to manage livestock than men based on access to household income to spend on expenses (68.3%) and access to credit either from formal institutions or friends and family (53.3%). Razzaq et al. (2018) also approved that male and female respondents can manage their households' finances.

But the animals and equipment are more likely to be owned by men (31.7%) or co-owned by both parties (50%). The report of United Nations Women Watch Information and Resources on Gender Equality and Empowerment of Women (2012) explained that, in fact, women's lack of ownership over assets that can be used as collateral to leverage loans also constrains them more than men.

**Table 9**. Access to resources.

| Activities | Indicate access or ownership | | | | |
|---|---|---|---|---|---|
| | Other | Men | Both | Women | Neither |
| Access to household income to spend on expenses? | | 18.3% (11) | 13.3% (8) | 68.3% (41) | |
| Access to credit either from formal institutions or friends and family? | 16.7% (10) | 20% (12) | 6.7% (4) | 53.3% (32) | 3.3% (2) |
| Who in the household owns the livestock? | | 31.7% (19) | 50% (30) | 18.3% (11) | |
| Who in the household owns livestock shelters or equipment? | | 31.7% (19) | 50% (30) | 18.3% (11) | |
| Ask friends or family for help managing or caring for livestock? | 43.3% (26) | 16.7% (10) | 10% (6) | 30% (18) | |
| Access to a local trader when they want to buy or sell livestock? | 10%(6) | 50% (30) | 13.3% (8) | 25% (15) | 1.7% (1) |
| Had information in agricultural or livestock rearing practices? (animal help worker/friend/community) | 28.3% (17) | 31.7% (19) | 10% (6) | 28.3% (17) | 1.7% (1) |
| Access information about markets when they want to buy or sell livestock? | 11.7% (7) | 51.7% (31) | 11.7% (7) | 25% (15) | |
| Owns the land that crops are grown on? | 11.7% (7) | 41.7% (25) | 30% (18) | 16.7% (10) | |
| Access to communal grazing land when they need? | | | 100% (60) | | |

Men have more access to traders (50%) and information about markets (51.7%) while women have access to traders (25%) and they got information about market when they want to buy or sell their livestock (25%). In contrast, women have no opportunity to get traders and information to know about market in this study. This agrees with the findings of García (2013) that rural women in developing countries face difficulties to get information and difficulties in the process of negotiating prices with buyers and lack of mobility due to access to markets. The assessment results of FAO and WFP (2021) report also pointed that, farmers did not access traders, their crops will get low price with lower demand than usual. Men predominantly own cropping land (41.7%) but women have 16.7% of land as their own. This finding is agreed with the report of SasaKawa Global (2000), that women have less access to land than men for a variety of legal and cultural reasons. Legislation has affirmed women's basic right to land but other customary practices and laws limit women's land rights in some cases. Some legislations restrict rural women in developing countries. Both men and women have access to communal grazing land (100%). This means everyone has the right to graze livestock on a common pasture. The result is agreed with the report of Gilles and Jamtgaard (1981), that most of the world's grazing lands is the publicly owned.

### *4.5. Factors Affecting on Rural Women's Participation on Decision-Making Behavior in Livestock Management and Household Activities*

As per Table 10, the participation in decision making is a commonly used indicator of women's agency in the gender literature. It was found that women's decision-making behavior affected their domestic chores and livestock management activities in this table. Results from our study concur with evidence from other Asian countries, in which, women are often in control of the family finances (65%). Half said that they make decisions on when to borrow money (50%) and many are either unilaterally or jointly involved in decisions on how to spend the money earned from selling livestock (45%). While the tasks of feeding and caring for sick animals are the responsibility of women, men are more dominant in decision making on these matters including when to get medical treatment (50%), when to sell/buy livestock (50%) and what to feed the livestock (46.7%). However, a third of women (33.3%) stated that they unilaterally make decision on providing treatment to animals. Arshad et al. (2013) approved that caring for diseased and sick animals, was one of the main activities performed by rural women.

**Table 10**. Decision making discretion.

| Activities | Decision made by | | | | |
|---|---|---|---|---|---|
| | **Neither** | **Men** | **Both** | **Women** | **Others** |
| When to buy/sell livestock? | 10.0% (6) | 50.0% (30) | 16.7% (10) | 23.3% (14) | |
| How to spend the money earned from livestock? | 10.0% (6) | 16.7% (10) | 28.3% (17) | 45.0% (27) | |
| What to feed/graze the livestock? | | 46.7% (28) | 38.3% (23) | 15.0% (9) | |
| When to get medical treatment for livestock? | | 50.0% (30) | 16.7% (10) | 33.3% (20) | |
| When to seek medical treatment for family? | 1.7% (1) | 25.0% (15) | 21.7% (13) | 50.0% (30) | 1.7% (1) |
| How to educate children? | 3.3% (2) | 15.0% (9) | 43.3% (26) | 38.3% (23) | |
| How to manage household finances? | | 16.7% (10) | 18.3% (11) | 65.0% (39) | |
| When to borrow money? | 18.3% (11) | 20.0% (12) | 11.7% (7) | 50.0% (30) | |
| How to organize the marriage of children? | 53.3% (32) | 15.0% (9) | 10.0% (6) | 21.7% (13) | |

Table 11 shows the important values and meanings for understanding women's motivations and purpose of their activities to encompass a range of different factors such as social and cultural beliefs and norms that guide behavior and to gauge religious and social values and norms for women's mobility that guide livestock rearing.

**Table 11.** Values and meanings.

| Value Statement | Response | | | | |
|---|---|---|---|---|---|
| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
| I don’t like selling animals to traders because they will be killed | 13.3% (8) | 46.7% (28) | 21.7% (13) | 16.7% (10) | 1.7% (1) |
| I give livestock or the earnings from livestock as a donation to the Monastery | 1.7% (1) | | 13.3% (8) | 48.3% (29) | 36.7% (22) |
| I don’t sell livestock because I am not allowed to go to the market | 35.0% (21) | 21.7% (13) | 38.3% (23) | 3.3% (2) | 1.7% (1) |
| There are places in or outside the village where I am not allowed to go | 21.7% (13) | 23.3% (14) | 13.3% (8) | 11.7% (7) | 30.0% (18) |
| I like to take the livestock grazing because I meet friends to chat | 3.3% (2) | 3.3% (2) | 45.0% (27) | 20.0% (12) | 28.3% (17) |
| I love our livestock because they provide us with power and income | 1.7% (1) | 6.7% (4) | 15.0% (9) | 30.0% (18) | 46.7% (28) |

While there is little evidence suggesting that women follow Buddhist norms of abstaining from killing animals and eating meat, livestock are commonly used to pay for donations to the Monastery for rituals (48.3%). Mowe (2011) explained about Buddhist teachings on killing animals and abstaining from meat in Buddhist review of tricycle and Mon (2014) recommended that Myanmar farmers hold their donation festivals after harvesting their crops and selling livestock based on their rituals.

In terms of mobility many women can go to the market but there is a spread in terms of limitations in mobility in and outside the village (30%). It is also recommended that women frequently have poorer access to markets than men and play a limited role in the commercialization of livestock to sell out in market by themselves and livestock products in the management of livestock assets (FAO, 2013). Nearly half said they enjoy the social benefit of meeting friends to chat while taking animals grazing. This is agreed with the finding of Undeland (2008) that women graze animals jointly with the relatives and have no problems with access to good pastureland and water sources. Analysis of local values and meanings allows extension services to provide benefits to participants beyond income.

*4.6. Relationship of Variables*

To determine the relationship between the independent variables (decision making discretion) and the dependent variables (access to resources) of the women-headed households on the livestock rearing in the study area. Specifically, the non-parametric Chi-Square test with the Goodman and Kruskal’s Lambda correlation coefficient was used to analyze the variations.

Table 12 shows the significant and highly significant correlations between access to resources and decision-making descriptions of the women-headed households on the livestock rearing in this study. The ownership of land, information about markets, access to traders, and the information about livestock are highly significant correlated with time to buying or selling livestock, what to feed for livestock and when medical treatment. According to the results, the ownership of land is highly correlated with the decision making description of when to buy/sell livestock (.001**), what to feed (.050*) and when medical treatment (.050*). It is approved in the report of Hernández-Jover et al. (2019) that ownership of livestock can take health records of animals and engage with the surveillance system for animals. The United Nations Development Programme (2013) recommended that if the farmers have their own land, they can be considerable capability in managing small scale livestock enterprises covering the whole livestock program and they also pointed that even some landless households have demonstrated considerable capability in managing small scale livestock enterprises. When it comes to access to information about market, it is highly correlated with when to buy sell and livestock (.003**) and what to feed (.024*). This finding is similar with the finding of García (2013), that access to market information can provide the information of suitable food and process of negotiating prices with buyers to know the exact time of selling and buying due to lack of mobility.

**Table 12.** Relationship between decision making discretion and access to resources.

| Decision making discretion | When to buy/sell livestock? | | What to feed? | | When to get medical treatment for livestock? | | How to spend money earned from livestock | |
|---|---|---|---|---|---|---|---|---|
| | λ | P | λ | P | λ | P | λ | P |
| - Ownership of animal | .209 | .155 | .302 | .064 | .062 | .637 | .129 | .183 |
| - Access to income- | .143 | .188 | .038 | .478 | .148 | .038* | .085 | .408 |
| - Ownership of land | .181 | .001** | .265 | .050* | .265 | .050* | .093 | .231 |
| - Information about markets | .415 | .003** | .230 | .024* | .079 | .408 | .118 | .262 |
| -Access to trader | .424 | .000** | .242 | .026* | .109 | .231 | .246 | .034* |
| - Information about livestock rearing practices | .338 | .000** | .329 | .007** | .187 | .133 | .138 | .159 |
| - Information from friends and family | .319 | .008** | .188 | .313 | .143 | .183 | .280 | .013* |

*Chi-Square test with the use of Goodman and Kruskal's Lambda Coefficient for discriminate analysis of variation.*

Access to traders is highly correlated with when to buy and sell livestock (.000**), what to feed (.026*) and how to spend money earned from livestock (.034*). In fact, the report of ACIAR, FAO and WFP (2021) and Win et al. (2019) explained that access to traders can support to access feed, to get veterinary services and inputs including when to buy and sell livestock and manage of their livestock income. Access to Information about livestock rearing practices is also highly correlated with when to buy sell and livestock (.000**) and what to feed (.007**).

UNDP (2016) pointed that access to information on livestock can be the extent of official livestock rearing processing and practicing and exports livestock and livestock products. Access to information from friends and family is highly correlated with when to buy/sell livestock (.008**) and how to spend money earned from livestock (.013*). This finding is agreed with the report of Animal Welfare Institute (2022), the livestock information sources and services such as the activities performed to facilitate any stage of the livestock life cycle information, that were available to farmers from their friends, family, neighbors, and co-workers and social media. García (2013) also approved that rural women in developing countries face the most challenges in financial resources due to a lack of information.

### *4.7. Multiple Regression Analysis*

Multiple Regression Analysis the statistical findings of Spearman's rho correlation not only established the relationship between women households' livestock activities, access to resources, and decision-making discretion in the study area but also identified the possible predictors for the multiple regression analysis. Multiple regression analysis was used to further streamline the predictors (women households' activities and livestock management) of decision-making discretion to guide the researcher in formulating the recommended appropriate livestock management practices to access the better resources.

The prediction formula of multiple regression analysis is:

$Y = \beta 0 + \beta 1X1 + \beta 2X2 +----+ \beta kXk$

X = Independent variables (livestock activities, domestic chores, and access to resources)

Y = Dependent variables (decision making description)

a = Y-axis intercept

β = regression coefficient

k = number of predictor variables

Stepwise regression method was used to ensure the significant predictors remain after iterative model building using the set of predictors as variables. The predictors are the women households' livestock activities and their accessing resources that have strong significance with their decision-making discretions. Those predictors that have p-values less than the significance level of 0.05 and less than highly significant level 0.01 have statistically significant impacts.

The multiple regression analysis results in Table 13 reflect that care for young animals ($p = 0.030$*), livestock feeding ($p = 0.039$*), livestock buying ($p = 0.028$*), livestock selling ($p=0.000$**), caring for sick livestock ($p = 0.032$*), sheep shearing ($p = 0.001$**), cutting and carrying forage for livestock ($p = 0.005$**) of women households' livestock farming practices, and access to income ($p = 0.003$**), access to credit either from institutions/friends/family ($p = 0.004$**), livestock ownership ($p = 0.002$**), livestock shelters or equipment ownership (0.002**), access to a local trader (0.003**), access information from friends and family (0.000**), access information about market (0.002**) of the resources, will have the highest impact on decision making discretion of livestock farming.

**Table 13.** Regression analysis of women households' decision-making discretion, their activities and access to resources.

| Model | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| -Care for young animals | .267 | .120 | .271 | 2.226 | 0.030* |
| - Livestock Feeding | .298 | .141 | .272 | 2.117 | 0.039* |
| - Livestock buying | .282 | .125 | .252 | 2.252 | 0.028* |
| - Livestock Selling | .535 | .122 | .499 | 4.377 | 0.000** |
| -Caring for sick livestock | .319 | .144 | .279 | 2.204 | 0.032* |
| -Sheep Shearing | .316 | .090 | .418 | 3.501 | 0.001** |
| -Cutting and carrying forage for livestock | .360 | .125 | .353 | 2.891 | 0.005** |
| -Access to income | .486 | .159 | .376 | 3.057 | 0.003** |
| -Access to credit either from institutions/friends/family | .529 | .176 | .362 | 3.005 | 0.004** |
| -livestock ownership | .305 | .094 | .385 | 3.248 | 0.002** |
| - livestock shelters or equipment ownership | .305 | .094 | .385 | 3.248 | 0.002** |
| -Access to a local trader | .242 | .078 | .372 | 3.114 | 0.003** |
| -Access information from friends and family | .721 | .102 | .693 | 7.078 | 0.000** |
| -Access information about market | .396 | .121 | .394 | 3.282 | 0.002** |

Dependent Variable- Decision Making *Significant**

Not taking these predictors altogether will not have the expected high impact on improving the women's participation and their decision-making behavior in the study area. In essence, it points out that the participation of women in livestock farming practices and their access to resources in livestock management will have the highest impact on their decision-making discretions in this area.

The results imply that women's participation in livestock farming and their decision-making discretion could clearly improve the activities in caring young and sick animals, livestock feeding, livestock buying and selling, sheep shearing, cutting, and carrying forage for livestock. Ahmad (2013), Arshad et al. (2013) and Fischer et al. (2018) approved that women are actively involved in animal husbandry sort of activities including livestock feeding and caring, watering, fodder cutting, milking and animal shed cleaning etc. Result also shows that some products of livestock are commercialized when the benefits can be switched to women. Furthermore, FAO (2013) also mentioned that women-headed households are responsible to large and small animals marketing including by-products in practical, but they need the decision-making power over sale of livestock. The result shows women can be more actively participate and they can make the good decisions to access income if they access resources of credit, trader, market information and information from friends and families. FAO (2013) agreed that access to good market, access to credit, the high status and education, the high levels of customary practices can support women in the decision-making power over rural assets. Additionally, Win et al. (2019), and FAO and WFP (2021) highlighted that access to traders can be benefit in getting animal feed, veterinary services, time to sale of livestock, and manage of their livestock income.

On the other side, shearing is performed by one of the household members and it is more likely to be a chore for women. Result shows that the respondents seldom to shear their sheep in this region. WorkSafe New Zealand (2014) and National Centre for Farmer Health (2023) pointed out that shearing and crutching are high-risk jobs that need a lot of manual effort contractors who shear or crutch thousands of sheep each year can be at high risk of being injured. According to the results, the respondents need to be the owners in their livestock farming to manage their livestock and livestock equipment. UNDP (2016) pointed out that the farmers with their own lands can manage small scale livestock enterprises covering the whole livestock program.

## 5. Conclusions

The role of women's participation becomes important not only in livestock management but also households' activities. Even the respondents are in the middle-aged, but they did not get the lead role in decision making due to lack of access to resources and poor education of no formal schooling. Almost 60% of the respondents are small-sized farmers with the average household size is 4.6 and they mostly grow sesame, groundnut, and other tropical crops. The respondents mostly rear small sizes of adult cattle male and they categorized their livestock based on the tercile analysis and lifespan of livestock. Besides, the respondents serve as the good housewives with domestic chores. In case, men households are chief of the decision makers in the households because they access to resources more than women's households, however, access to financial resources and household income to spend on expenses are stronger on the women.

Access to resources contributed substantially to the decision-making descriptions of the households. The respondents also need to be the owners in their livestock farming to manage their livestock and livestock equipment. The information got especially from friends, family and traders are helpful in buying/selling livestock, spending money earned from livestock, taking medical treatment of the livestock, and feeding the food for the livestock. In fact, women can be more actively participate and they can make the good decisions to access income if they access resources of credit, trader, market information and information from friends and families. This implies that the higher access to resources, the decision making will be more prominent. Thus, women can improve their decision-making in livestock activities for the household by empowering women in livestock farming.

Since the correlation and multiple regression analyses were able to identify and streamline women activities that need to be focused on so that to make good decisions in livestock farming, this should be taken as a concrete guide for the involved villages, their officials, the Government of Myanmar, and all project implementers to follow. For longer-term outlook, participation of women and access to resources are important to achieving decision making behavior in livestock farming. In addition, providing the necessary resources to women in livestock farming, they can easily facilitate their livestock activities and their performance will be improved. Policy makers have to consider these constraints identified in this study to provide the necessary resources to women in livestock farming, to train women as the female leaders in their households and to develop guidelines for sustainable livestock production not only in the central dry zone but also the whole country. The gender-based equal opportunity can be initiative through a policy to enhance the participation of women and achieve development of women decision-making behaviors at the national scale.

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## Appendix A

**Individual Survey Questionnaire**

**Levels of Participation and Constraints that women face while developing their livestock production in the Central Dry Zone**

**Section A: (1) Demographic factors and Livelihood typology in study area.**

| | | | |
|---|---|---|---|
| Township | | Village Tract | |
| Interviewer | | Village | |
| Date | | Contact No. | |
| Interview Duration | | | |

| No. | Name | Relation with HHH | Age | Education Level | Primary occupation | Secondary occupation | Remark |
|---|---|---|---|---|---|---|---|
| 1. | | | | | | | |
| 2. | | | | | | | |
| 3. | | | | | | | |
| 4. | | | | | | | |
| 5. | | | | | | | |
| 6. | | | | | | | |
| 7. | | | | | | | |
| 8. | | | | | | | |
| 9. | | | | | | | |
| 10. | | | | | | | |

**(2) Cropping patterns.**

| **Pre-monsoon** | | **Monsoon** | | **Post-Monsoon** | | **Remark** |
|---|---|---|---|---|---|---|
| Crop | acre | Crop | acre | Crop | acre | |
| | | | | | | |
| | | | | | | |

**(3) Farming experiences.**

1. Crop production --------------------yrs

2. Livestock production ---------------------------yrs

**(4) Livestock access**

| | **Livestock size** | | **Quantity** | **Remarks** |
|---|---|---|---|---|
| Cattle | Male | Young **(<2 yrs)** | | |
| | | Old **(>2 yrs)** | | |
| | Female | Young **(<1.5 yrs)** | | |
| | | Old **(>1.5 yrs)** | | |
| Goat | Male | Young **(<10 months)** | | |
| | | Old **(>10 months )** | | |
| | Female | Young **(<8 months)** | | |
| | | Old **(>8 months )** | | |
| Sheep | Male | Young **(<10 months )** | | |
| | | Old **(>10 months )** | | |
| | Female | Young **(<8 months )** | | |
| | | Old **(>8 months )** | | |

**Section B: Levels of participation.**

| **Activities** | **Activity is performed by** | | | **Family member** |
|---|---|---|---|---|
| | **Men** | **Women** | **Both** | |
| Take the livestock grazing | | | | |
| Feed livestock | | | | |
| Provide livestock with water | | | | |
| Care for young animals | | | | |
| Buy livestock | | | | |
| Sell livestock | | | | |
| Clean livestock shelters | | | | |
| Care for sick livestock | | | | |
| Buy forage for livestock | | | | |
| Cut and carry forage for livestock | | | | |
| Agricultural work for forage crops | | | | |
| Collect milk from livestock | | | | |
| Sell milk collected from livestock | | | | |
| Sheep Shearing | | | | |
| Take manure to fields for fertilizer | | | | |

**Section C: (1) Constraints – time.**

| Activities | Activity is performed by | | | Family member |
|---|---|---|---|---|
| | Men | Women | Both | |
| Do agricultural work | | | | |
| Prepare donations for monks | | | | |
| Cook for family | | | | |
| Washing clothes | | | | |
| Clean house | | | | |
| Care for seniors | | | | |
| Care for children | | | | |
| Make clothes | | | | |
| Rest or enjoy time with friends and family | | | | |

**(2) Constraints – access to resources.**

| Activities | Indicate access or ownership | | | | Family member |
|---|---|---|---|---|---|
| | Men | Women | Both | Neither | |
| Access to household income to spend on expenses? | | | | | |
| Access to credit either from formal institutions or friends and family? | | | | | |
| Who in the household owns the livestock? | | | | | |
| Who in the household owns livestock shelters or equipment? | | | | | |
| Ask friends or family for help managing or caring for livestock? | | | | | |
| Access to a local trader when they want to buy or sell livestock? | | | | | |
| Had information in agricultural or livestock rearing practices? (Animal help worker/friend/community) | | | | | |
| Access information about markets when they want to buy or sell livestock? | | | | | |
| Owns the land that crops are grown on? | | | | | |
| Access to communal grazing land when they need? | | | | | |

**(3) Constraints – decision making.**

| Activities | Decision made by | | | Family member |
|---|---|---|---|---|
| | Men | Women | Both | |
| When to buy/sell livestock? | | | | |
| How to spend the money earned from livestock? | | | | |
| What to feed/graze the livestock? | | | | |
| When to get medical treatment for livestock? | | | | |
| When to seek medical treatment for family? | | | | |
| How to educate children? | | | | |
| How to manage household finances? | | | | |
| When to borrow money? | | | | |
| How to organize the marriage of children? | | | | |

**(4) Constraining or enabling factors – values and meanings.**

| Value Statement | Response | Remark |
|---|---|---|
| I don't like selling animals to traders because they will be killed | Strongly disagree disagree Neutral agree strongly agree | |
| I give livestock or the earnings from livestock as a donation to the Monastery | Strongly disagree disagree Neutral agree strongly agree | |
| I don't sell livestock because I am not allowed to go to the market | Strongly disagree disagree Neutral agree strongly agree | |
| There are places in or outside the village where I am not allowed to go | Strongly disagree disagree Neutral agree strongly agree | |
| I like to take the livestock grazing because I meet friends to chat | Strongly disagree disagree Neutral agree strongly agree | |
| I love our livestock because they provide us with power and income | Strongly disagree disagree Neutral agree strongly agree | |

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*Article*

# Research on Evaluation of Financial Risks in Agricultural Product Supply Chains Based on An Improved DEMATEL Method

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**Abstract:** In order to improve the rationality, accuracy, and timeliness of decisions on financial risks in agricultural product supply chains, it is necessary to evaluate and control these risks sensibly. In this paper, research is conducted on financial risk factors in agricultural product supply chains, and on this basis a financial risk evaluation index system for such supply chains is built in four identified dimensions – credit risk, market risk, pledge risk, and supply chain relation risk. Next, the weights of risk indexes are measured by means of combined weighting based on subjective F-AHP method and objective CRITIC method. The final risk weight coefficients are then derived with EDAS method. With the aid of an improved DEMATEL method, the agricultural product supply chain financial risk factors are analyzed, and comprehensive impact degrees of different risk factors in agricultural product supply chains are calculated. The calculation results show that financial risks in agricultural product supply chains are highly influenced by cooperation level, performance record, and financial standing and repayment history of borrowing organization. Based on the findings of this paper, appropriate financial risk management and control measures can be developed in light of the key risk factors identified in agricultural product supply chains, thereby providing a valuable reference for financial risk control in agricultural product supply chains.

**Keywords:** improved DEMATEL method; EDAS method; supply chain finance; risk evaluation

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## 1. Introduction

Internet-based supply chain finance mainly covers the business fields of credit ex-tension and financing. Using Internet as a platform, it serves core enterprises in supply chains as well as those operating in upstream and downstream links. With a long history behind it, supply chain finance is now in 3.0 Era, which is characterized by close connections between Internet, finance systems, and industrial chains that spur rapid social and economic development, and also by more prominent issues related to risk management and control.

Research on agricultural product supply chain finance has gained traction in the academic world with ever-increasing popularity in recent years. Financial risk control in agricultural product supply chains is intended to guarantee healthy and balanced development of agricultural product supply chain finance through effective risk prevention and mitigation. To achieve this, it stands to reason that a "unified front" for governing agricultural product supply chain finance should be built (Peng, 2018; Xu, 2020; Yu, 2018). More specifically, a risk measurement system needs to be put into place to evaluate and predict financial risks in agricultural product supply chains, to accurately quantify major comprehensive impact of various risk factors, and to determine prerequisites for effective control of such risks.

In the present study, in order to achieve more meaningful and logical evaluation of financial risks in agricultural product supply chains, F-AHP method and CRITIC method are used to obtain subjective and objective combined weights of risk indexes respectively. Following that, EDAS method and an improved DEMATEL method are adopted to analyze financial risks in agricultural product supply chains. Based on calculation of com-prehensive impact degrees, an agricultural product supply chain financial risk measurement model is developed, and risk measurement data is derived. An agricultural product supply chain financial risk control model is subsequently created with the data thus obtained. Measures for controlling these risks are also proposed.

## 2. Materials and Methods

The Materials and Methods should be described with sufficient details to allow others to replicate and build on the published results. Please note that the publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Interventionary studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

### *2.1. Development of Agricultural Product Supply Chain Financial Risk Measurement Indexes*

545 Internet users were polled through questionnaire survey or expert interview. To make the survey data more targeted, authoritative, and practical, 78 experts in relevant fields were interviewed, including 22 professors and researchers, 26 adjunct professors and associate researchers, and 30 doctoral students. Among 623 questionnaires distributed, 578 were recovered, with a recovery rate of 92.78%. The specific questionnaire survey flowchart is summarized below in Figure 1, covering the survey plan, expert interviews, and relevant studies (Dan et al., 2016; Jin, 2016; Xu et al., 2018; Q. Yang et al., 2016; Zeng et al., 2018; Zhao, 2021).

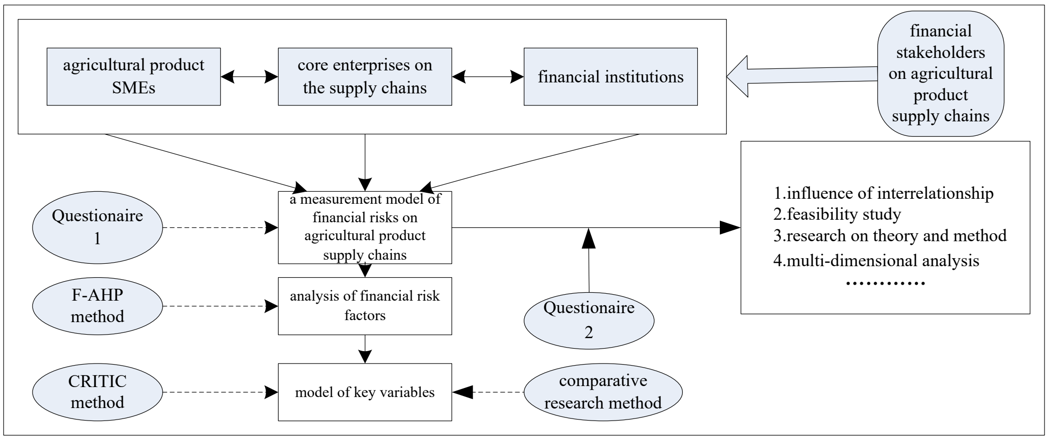


**Figure 1.** Low chart of questionnaire survey on agricultural product supply chain financial risks.

Based on the above questionnaire survey, expert interviews, and relevant studies (Fang et al., 2017; Higgins, 2010; Huo et al., 2011; Lan et al., 2021; Li et al., 2021; D. Liu et al., 2013; Shi et al., 2019; SZNAJD-WERON & SZNAJD, 2000; Xia et al., 2012; Q. Yang, et al., 2020; Zhang & Zhang, 2009; Zhao & Wang, 2013) four evaluation dimensions, including credit risk, market risk, pledge risk, and supply chain relation risk, are identified as Level 1 indexes, and 13 Level 2 agricultural product supply chain financial risk indexes are defined as well. The system of agricultural product supply chain financial risk measurement indexes is given in Table 1 below.

**Table 1.** System of agricultural product supply chain financial risk measurement indexes.

| Target level | Level 1 index | Level 2 index |
|---|---|---|
| Agricultural product supply chain finance risk measurement indexes (B) | Credit risk (B1) | Financial standing and repayment history of borrowing organization (B11) |
| | | Enterprise scale of borrowing organization (B12) |
| | | Management system of borrowing organization (B13) |
| | | Core corporate credit risk (B14) |
| | Market risk (B2) | Natural risk (B21) |
| | | Risk arising from deterioration of external operation environment (B22) |
| | | Risk due to price change of agricultural products (B23) |
| | Pledge risk (B3) | Stock status (B31) |
| | | Status of orders (B32) |
| | | Status of accounts receivable (B33) |
| | Supply chain relation risk (B4) | Supply chain robustness (B41) |
| | | Cooperation level (B42) |
| | | Performance record (B43) |

*2.2. Creation of an Agricultural Product Supply Chain Financial Risk Evaluation Model Based on An Improved DEMATEL Method*

2.2.1. Calculation of Subjective Weight with F-AHP Method

As a fuzzy analytic hierarchy process, F-AHP method features a combination of qualitative and quantitative techniques, and consequently provides both fuzziness and consistency properties. It is capable of quantifying expert assessments objectively and turning qualitative problems into quantitative ones through layer-by-layer decomposition. This method, therefore, adds to the reliability of agricultural product supply chain finance evaluation.

Step 1: Starting from the agricultural product supply chain financial risk measurement indexes, a $n \times n$ fuzzy judgment matrix $B = (b_{ij})_{n \times n}$ is built in consideration of the subjective preferences of experts for n ( $n = 13$ ) risk measurement indexes and the relative importance values assigned to the indexes with F-AHP method as shown in Table 2.

**Table 2.** Relative importance values assigned to indexes with F-AHP method.

| Value | Meaning |
|---|---|
| 0.5 | Two elements are equally important |
| 0.6 | One element is slightly more important than the other |
| 0.7 | One element is significantly important compared with the other |
| 0.8 | One element is very important compared with the other |
| 0.9 | One element is extremely important compared with the other |
| 0.1, 0.2, 0.3, 0.4 | Comparison in reverse order: $b_{ij} + b_{ji} = 1, j = 1,2,3,\cdots,n$ |

Step 2: In regard to satisfaction consistency and order consistency of the fuzzy matrix, a fuzz consistency matrix $F = (f_{ij})_{n \times n}$ is built out of matrix $B$ , where

$$f_{ij} = \frac{\sum_{j=1}^{n} b_{ij} - b_{ij}}{2n} + 0.5 \tag{1}$$

Step 3: Subjective weights $\chi = (\chi_1, \chi_2, \chi_3, \cdots, \chi_n)$ are calculated, where $\chi_j$ represents the weight of the $j$ th risk index. The following equations are then derived:

$$c_j = \frac{2\sum_{i=1}^{n} f_{ji} - 1}{n(n-1)} \tag{2}$$

$$\chi_j = \frac{c_j}{\sum_{j=1}^{n} c_j} \tag{3}$$

2.2.2. Calculation of Objective Weight with CRITIC Method

As an objective weighting process, CRITIC method takes into account not only the information volume of indexes, but also the level of comparison between indexes. It, therefore, leads to more objective, reasonable, and accurate index weight calculations.

Step 1: The agricultural product supply chain financial risks are processed through relativization. High-priority indexes are transformed with Equation (4):

$$g_{ij} = \frac{y_{ij} - \min y_{ij}}{\max y_{ij} - \min y_{ij}} \tag{4}$$

Low-priority indexes are transformed with Equation (5):

$$g_{ij} = \frac{\max y_{ij} - y_{ij}}{\max y_{ij} - \min y_{ij}} \tag{5}$$

Step 2: Negative indexes are converted into positive ones since they need to have the same sign. The conversion is realized with Equation (6):

$$y_{ij}^{'} = \frac{1}{\eta + \max\left|Y_j\right| + y_{ij}} \tag{6}$$

where $\max\left|Y_j\right|$ denotes the maximum of the $j$ th risk index, namely the maximum of the $j$ th row in matrix $Y$, and $\eta$ is a coordination coefficient ($\eta = 0.1$ in normal cases). This process yields a positive matrix $Y'$.

Step 3: Since the meaning of the positive matrix $Y'$ varies with the units adopted, dimensionless treatment of the risk indexes using Equation (7) is required:

$$y_{ij}^{''} = \frac{y_{ij}^{'}}{\sqrt{\sum_{i=1}^{n} (y_{ij}^{'})^2}} \qquad i = 1,2,3,\cdots,m \tag{7}$$

where $m$ is the number of schemes, and $n$ is the number of risk indexes in each scheme. In this way, a standard dimensionless matrix $Y''$ is generated.

Step 4: Calculation of risk index objective weight. From the standard dimensionless matrix $Y''$, standard deviation $\sigma_j$ and correlation coefficient $\kappa_{ij}$ of different risk indexes can be derived as follows:

$$\sigma_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (y_{ij}^{''} - \bar{y}_j^{''})^2} \tag{8}$$

$$\kappa_j = \frac{\mathrm{cov}(Y_j^{"}, Y_i^{"})}{\sigma_i \sigma_j} \tag{9}$$

where $\bar{y}_j^{"}$ is the average of the $j$ th risk index, and $\mathrm{cov}(Y_j^{"}, Y_i^{"})$ denotes the covariance between the $j$ th row and the $i$ th row of the standard matrix $Y^{"}$.

$R_j$ is used to represent the information volume of agricultural product supply chain financial risk indexes. It is calculated as follows:

$$R_j = \sigma_j \sum_{i=1}^{n'} (1 - \kappa_{ij}) \qquad i = 1,2,3,\cdots,n' \tag{10}$$

where $\sum_{i=1}^{n'} (1 - \kappa_{ij})$ is a quantitative indicator of the degree of conflict between the $j$ th risk index and other risk indexes. The higher the value of $R_j$, the larger weight of the risk index.

The objective weight $w_j$ is calculated with Equation (11).

$$w_j = \frac{R_j}{\sum_{i=1}^{m} R_j} \qquad (j = 1,2,3,\cdots,n) \tag{11}$$

2.2.3. Method for Determining Combined Weight

The subjective weigh $\chi = (\chi_1, \chi_2, \chi_3, \cdots, \chi_n)$ and objective weights $w = (w_1, w_2, w_3, \cdots, w_n)$ of the measurement indexes can be obtained with F-AHP method and CRITIC method respectively, where $\sum_{j=1}^{n} \chi_j = 1, 0 \le \chi_j \le 1$; $\sum_{j=1}^{n} w_j = 1, 0 \le w_j \le 1$

Assuming $W_h$ is the combined weight of a risk index, the equation $W_h = c_1 w + c_2 \chi$ holds true, where $c_1 + c_2 = 1, c_1 \ge 0, c_2 \ge 0$. By expressing the weighted measurement value of an agricultural product supply chain financial risk with $FD_i$ and the standard value of the $j$ th item of the $i$ th scheme with $d_{ij}$, the following equation can be established:

$FD_i = \sum_{j=1}^{n} \left[ (c_1 w_j + c_2 \chi_j) \times d_{ij} \right]^2$. $W_h$ should be selected in such a way to achieve maximum value of $FD_i$.

$$\max F = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[ (c_1 w_j + c_2 \chi_j) \times d_{ij} \right]^2 \tag{12}$$

where $c_1 + c_2 = 1, c_1 \ge 0, c_2 \ge 0$. A Lagrange multiplier function is created as follows based on Equation (12):

$$K(c_1, c_2, c_3) = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[ (c_1 w_j + c_2 \chi_j) \times d_{ij} \right]^2 + c_3 (c_1 + c_2 - 1) \tag{13}$$

The partial derivatives of $c_1, c_2, c_3$ are solved with Equation (13):

$$
\begin{cases}
\dfrac{\partial K(c_1,c_2,c_3)}{\partial c_1} = 2\sum_{i=1}^{m}\sum_{j=1}^{n}\left[(c_1 w_j + c_2\chi_j)\times d_{ij}\right]\times w_j d_{ij} + c_3 \\
\dfrac{\partial K(c_1,c_2,c_3)}{\partial c_2} = 2\sum_{i=1}^{m}\sum_{j=1}^{n}\left[(c_1 w_j + c_2\chi_j)\times d_{ij}\right]\times \chi_j d_{ij} + c_3 \\
\dfrac{\partial K(c_1,c_2,c_3)}{\partial c_3} = c_1 + c_2 - 1
\end{cases} \tag{14}
$$

The following results can be derived from Equation (14):

$$
\begin{cases}
c_1 = \dfrac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[(\chi_j^2 - \chi_j w_j)\times d_{ij}^2\right]}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[(\chi_j^2 - \chi_j w_j)\times d_{ij}^2\right] + \sum_{i=1}^{m}\sum_{j=1}^{n}\left[(w_j^2 - \chi_j w_j)\times d_{ij}^2\right]} \\
c_2 = \dfrac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[(w_j^2 - \chi_j w_j)\times d_{ij}^2\right]}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[(\chi_j^2 - \chi_j w_j)\times d_{ij}^2\right] + \sum_{i=1}^{m}\sum_{j=1}^{n}\left[(w_j^2 - \chi_j w_j)\times d_{ij}^2\right]}
\end{cases} \tag{15}
$$

In the second round of survey, the data derived from the agricultural product supply chain financial risk measurement index system and corresponding evaluation criteria were supplied to the above-mentioned experts. 78 questionnaires were distributed in this survey, and 69 were recovered, with a recovery rate of 88.46%. The experts were asked to give their measurement of different risk indexes, and their feedback was combined with pertinent literature data for further research (Blackman et al., 2013; Cheng et al., 2016; Z. Liu, 2021; Trkman & McCormack, 2009; Tseng et al., 2021; X. Yang, et al., 2020; Yao & Qin, 2021). 2009AHP method and CRITIC method are used to determine the subject weight and objective weight of different finance risk indexes for agricultural product supply chains respectively, based on which a combined weight $W_h = c_1 w + c_2\chi$ is obtained for each index. Finally, from the combined weights of different risk indexes, combined weight coefficients are obtained through MATLAB operation, as shown in Table 3.

**Table 3**. Weights of different indexes in the agricultural product supply chain financial risk measurement index system.

| Level 1 index | Level 2 index | Subjective weight | Objective weight | Combined weight |
|---|---|---|---|---|
| Credit risk ($B_1$) | Financial standing and repayment history of borrowing organization ($B_{11}$) | 0.09 | 0.10 | 0.096 |
| | Enterprise scale of borrowing organization ($B_{12}$) | 0.05 | 0.03 | 0.038 |
| | Management system of borrowing organization ($B_{13}$) | 0.07 | 0.06 | 0.064 |
| | Core corporate credit risk ($B_{14}$) | 0.03 | 0.03 | 0.030 |
| Market risk ($B_2$) | Natural risk ($B_{21}$) | 0.03 | 0.04 | 0.036 |
| | Risk arising from deterioration of external operation environment ($B_{22}$) | 0.06 | 0.08 | 0.072 |
| | Risk due to price change of agricultural products ($B_{23}$) | 0.04 | 0.04 | 0.04 |
| Pledge risk ($B_3$) | Stock status ($B_{31}$) | 0.05 | 0.04 | 0.044 |
| | Status of orders ($B_{32}$) | 0.08 | 0.07 | 0.074 |
| | Status of accounts receivable ($B_{33}$) | 0.03 | 0.04 | 0.036 |
| Supply chain relation risk ($B_4$) | Supply chain robustness ($B_{41}$) | 0.08 | 0.07 | 0.074 |
| | Cooperation level ($B_{42}$) | 0.21 | 0.23 | 0.222 |
| | Performance record ($B_{43}$) | 0.18 | 0.17 | 0.174 |

2.2.4. Method for Determining Index Weight Based on EDAS

Because experts may find it very difficult to evaluate the agricultural product supply chain financial risk measurement index system objectively and accurately, an index weight determination method based on EDAS is proposed in the present study, thus realizing more objective, reasonable, and logical measurement results.

In this method, a probabilistic language term set is introduced and expressed as follows: $Q(p)=\left\{Q^{(k)}(p^{(k)})\middle|Q^{(k)}\in S, p^{(k)}\geq 0, k=1,2,\cdots,\kappa Q(p), \sum_{k=1}^{\kappa Q(p)} p^{(k)}\leq 1\right\}$ , where $Q^{(k)}(p^{(k)})$ is a language term $Q^{(k)}$ containing probabilistic information $p^{(k)}$. $\kappa Q(p)$ denotes the number of language terms in $Q(p)$, and $\kappa Q(p)=K$. Then the entropy of $Q(p)$ needs to meet the following requirements:

(1) $0\leq E\,(Q(p))\leq 1$;

(2) When $g\,(Q(p))=0$ or $g\,(Q(p))=1$, if $p^{(k)}=1$, $E\,(Q(p))=0$;

(3) When and only when $\kappa Q(p)=2$, if $p^{(1)}=p^{(2)}=\frac{1}{2}$ and $g(Q^{(1)})+g(Q^{(2)})=1$, $E\,(Q(p))=1$.

Probabilistic language entropy can be defined based on hesitant fuzzy language entropy and probabilistic language equivalence transformation function:

$$E\,(Q(p))=\frac{1}{K\,(\sqrt{2}+1)}\sum_{k=1}^{K}(\sin\frac{\pi p^{(k)}}{2}+\cos\frac{\pi p^{(k)}}{2}+\sin\frac{\pi(g(Q^{(k)})+g(Q^{(K-k+1)})}{2} +\cos\frac{\pi(1-g(Q^{(k)})-g(Q^{(K-k+1)})}{2}-1) \quad (16)$$

It is assumed in this study that 13 risk evaluation indexes are selected by an agricultural product supply chain finance emergency department, their weight being denoted by $\upsilon=(\upsilon_1,\upsilon_2,\cdots,\upsilon_{13})^T$,

Eight experts with relevant background can be selected and asked to assign language evaluation values to the 13 risk measurement indexes, and a decision maker can make use of the following set to measure agricultural product supply chain financial risk indexes:

$$S=\begin{Bmatrix} s_{-4},s_{-3}=\text{very low},s_{-2}=\text{low},s_{-1}=\text{slightly low},s_0=\text{medium} \\ s_4=\text{extremely high},s_3=\text{very high},s_2=\text{high},s_1=\text{slightly high} \end{Bmatrix}$$

Based on the language evaluation values offered by the experts, a probabilistic language decision matrix $R=[Q_{ip}(p)]_{m\times n}$ can be created, as shown in Table 4.

**Table 4.** Probabilistic language decision matrix based on expert evaluation.

| Expert | $B_{11}$ | $B_{12}$ | $B_{13}$ | $B_{14}$ | $B_{21}$ | $B_{22}$ | $B_{23}$ | $B_{31}$ | $B_{32}$ | $B_{33}$ | $B_{41}$ | $B_{42}$ | $B_{43}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $S_1, S_2$ | $S_2,S_3$ | $S_0,S_1$ | $S_{-1},S_0$ | $S_3,S_4$ | $S_0,S_1$ | $S_{-4},S_{-3}$ | $S_{-1},S_0$ | $S_{-2},S_{-1}$ | $S_0,S_1$ | $S_2,S_3$ | $S_{-3},S_{-2}$ | $S_{-1},S_0$ |
| 2 | $S_{-1},S_0$ | $S_3,S_4$ | $S_0,S_1$ | $S_{-4},S_{-3}$, | $S_2,S_3$ | $S_0,S_1$ | $S_{-1},S_0$ | $S_3,S_4$ | $S_0,S_1$ | $S_3,S_4$ | $S_0,S_1$ | $S_0,S_1$ | $S_{-4},S_{-3}$, |
| 3 | $S_0,S_1$ | $S_{-1},S_0$ | $S_{-2},S_{-1}$ | $S_0,S_1$ | $S_{-1},S_0$ | $S_0,S_1$ | $S_0,S_1$ | $S_2,S_3$ | $S_{-3},S_{-2}$ | $S_{-1},S_0$ | $S_3,S_4$ | $S_{-4},S_{-3}$ | $S_{-4},S_{-3}$ |
| 4 | $S_0,S_1$ | $S_0,S_1$ | $S_{-1},S_0$ | $S_0,S_1$ | $S_{-4},S_{-3}$ | $S_0,S_1$ | $S_3,S_4$ | $S_0,S_1$ | $S_3,S_4$ | $S_{-4},S_{-3}$ | $S_2,S_3$ | $S_0,S_1$ | $S_0,S_1$ |
| 5 | $S_{-2},S_{-1}$ | $S_0,S_1$ | $S_{-4},S_{-3}$ | $S_{-3},S_{-2}$ | $S_0,S_1$ | $S_{-2},S_{-1}$ | $S_0,S_1$ | $S_{-4},S_{-3}$ | $S_2,S_3$ | $S_0,S_1$ | $S_0,S_1$ | $S_0,S_1$ | $S_0,S_1$ |
| 6 | $S_{-1},S_0$ | $S_3,S_4$ | $S_0,S_1$ | $S_{-4},S_{-3}$ | $S_0,S_1$ | $S_{-1},S_0$ | $S_3,S_4$ | $S_0,S_1$ | $S_2,S_3$ | $S_0,S_1$ | $S_0,S_1$ | $S_2,S_3$ | $S_3,S_4$ |
| 7 | $S_{-4},S_{-3}$ | $S_2,S_3$ | $S_0,S_1$ | $S_{-1},S_0$ | $S_0,S_1$ | $S_2,S_3$ | $S_2,S_3$ | $S_3,S_4$ | $S_0,S_1$ | $S_0,S_1$ | $S_3,S_4$ | $S_0,S_1$ | $S_2,S_3$ |
| 8 | $S_0,S_1$ | $S_{-1},S_0$ | $S_0,S_1$ | $S_0,S_1$ | $S_3,S_4$ | $S_0,S_1$ | $S_{-1},S_0$ | $S_0,S_1$ | $S_0,S_1$ | $S_{-3},S_{-2}$ | $S_0,S_1$ | $S_{-4},S_{-3}$ | $S_0,S_1$ |

Next, the probabilistic language decision matrix is standardized. Equations (17) and (18) are then used to calculate weights of risk evaluation indexes, and the results obtained in the present research are listed in Table 5.

$$\begin{cases} \max H(w)=\sum_{i=1}^{m}\left(\frac{1}{m-1}\sum_{l=1,l\neq i}^{n}CE(Q_{ij}(p),Q_{lj}(p))+(1-E(Q_{ij}(p))w_j\right. \\ \sum_{j=1}^{n}\upsilon_j^2=1,0\leq w_j\leq 1 \end{cases} \tag{17}$$

$$\upsilon_j=\frac{\sum_{i=1}^{m}[(\frac{1}{m-1}\sum_{l=1,l\neq i}^{n}CE(Q_{ij}(p),Q_{lj}(p))+(1-E(Q_{ij}(p))]}{\sum_{j=1}^{n}\sum_{i=1}^{m}[(\frac{1}{m-1}\sum_{l=1,l\neq i}^{n}CE(Q_{ij}(p),Q_{lj}(p))+(1-E(Q_{ij}(p))]} \tag{18}$$

where $\sum_{j=1}^{m}\upsilon_j=1,0\leq\upsilon_j\leq 1$.

**Table 5.** Weights of the risk measurement index system based on EDAS.

| $B_{11}$ | $B_{12}$ | $B_{13}$ | $B_{14}$ | $B_{21}$ | $B_{22}$ | $B_{23}$ | $B_{31}$ | $B_{32}$ | $B_{33}$ | $B_{41}$ | $B_{42}$ | $B_{43}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0934 | 0.0312 | 0.0571 | 0.0268 | 0.0334 | 0.0626 | 0.0265 | 0.0435 | 0.0664 | 0.0315 | 0.0667 | 0.2789 | 0.1820 |

In order to make these expert-derived weights more rational, accurate, and logical, and to reduce randomness, the following combined weight equation concerning expert evaluation is adopted:

$$w_z'=\alpha_\alpha w_h+\beta_\beta\upsilon_i \tag{19}$$

Delphi method is used again to analyze the weight coefficients of $\alpha_\alpha,\beta_\beta$ based on data provided by the eight experts, following which the data from every expert is reviewed and corrected. The revised data is then delivered to the experts so that they can offer opinions on data refinement. This process occurs iteratively until the result of $\alpha_\alpha=0.6,\beta_\beta=0.4$ is achieved unanimously.

The resulting final combined weight coefficients of the agricultural product supply chain financial risk indexes in our study are shown in Table 6.

**Table 6.** Final combined weights in the risk measurement index system.

| **B11** | **B12** | **B13** | **B14** | **B21** | **B22** | **B23** | **B31** | **B32** | **B33** | **B41** | **B42** | **B43** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.09496 | 0.03528 | 0.06124 | 0.02872 | 0.03496 | 0.06824 | 0.0346 | 0.0438 | 0.07096 | 0.0342 | 0.07108 | 0.24476 | 0.1772 |

2.2.5. Calculation of the Comprehensive Impact Matrix Based on an Improved DEMATEL Method

Shaped by a variety of factors, financial risks in agricultural product supply chains have uncertainties. In order to reduce the number of elements in the agricultural product supply chain financial risk system and to simplify relations between elements, we perform general evaluation from a holistic perspective using an improved DEMATEL method with the following steps:

Step 1: The values of 0, 0.2, 0.4, 0.6, 0.8, and 1 are used to represent "no impact", "very weak impact", "weak impact", "average impact", "strong impact", and "very strong impact" respectively, and the values of 0.1, 0.3, 0.5, 0.7, and 0.9 correspond to impact degrees between them. By correcting these values based on expert evaluation results and relevant weights, an original matrix of agricultural product supply chain financial risk factors can be generated.

Step 2: The data in the agricultural product supply chain financial risk factor matrix also receives dimensionless treatment. Initial value operators are used to generate an initial value matrix. Let $X_\hbar = (x_\hbar(1), x_\hbar(1), \cdots, x_\hbar(13))$ be the behavior sequence of factor $X_\hbar$ with $D_1$ being an operator in the sequence, and we can calculate as follows:

$$X_\hbar D_1 = (x_\hbar(1)d_1, x_\hbar(2)d_1, \cdots, x_\hbar(13)d_1) \tag{20}$$

where $x_\hbar(k)d_1 = \dfrac{x_\hbar(k)}{x_\hbar(1)}, x_\hbar(1) \neq 0, k = 1,2,\cdots,13$. Here $D_1$ is called initial value operator. The behavior sequence of the main system risk factor is denoted by $X_0$, and that of relevant agricultural product supply chain financial risk factors are denoted by $X_\hbar$ and $X_j$. If $r_{0\hbar} \geq r_{0j}$ holds true for the corresponding grey relation degree, we say $X_\hbar$ precedes over $X_j$, and this relation is expressed as $X_\hbar \succ X_j$, where "$\succ$" is the grey relation sequence derived from the grey relation.

Step 3: Calculation of maximum and minimum in the initial value matrix of agricultural product supply chain financial risk factors.

$\Delta_{0\hbar}(s) = \left|x_0(s) - x_\hbar(s)\right|$, where $s = 1,2,\cdots,13$; $\hbar = 1,2,\cdots,13$

Step 4: Calculation of correlation coefficient and derivation of direct impact matrix. $\rho$ is used to denote the identification coefficient. In the value range of (0, 1), the lower the $\rho$ value, the higher degree of identification. If $\{x_0(s)\}$ corresponds to a data column of optimal value, a larger $\varsigma_\hbar(s)$ is desired. If $\{x_0(s)\}$ corresponds to a data column of worst value, a smaller $\varsigma_\hbar(s)$ is desired. Suppose $\rho = 0.5$, and we can obtain the following result:

$$\varsigma_\hbar(s) = \frac{\min\limits_\hbar \min\limits_s \left|x_0(s) - x_\hbar(s)\right| + \rho \cdot \max\limits_\hbar \max\limits_s \left|x_0(s) - x_\hbar(s)\right|}{\left|x_0(s) - x_\hbar(s)\right| + \rho \cdot \max\limits_\hbar \max\limits_s \left|x_0(s) - x_\hbar(s)\right|}, \text{ where } s = 1,2,\cdots,13 \tag{21}$$

The values of $\varsigma_\hbar(1)$, $\varsigma_\hbar(2)$, ……, $\varsigma_\hbar(13)$ are calculated for $\hbar = 1$. Similarly, correlation coefficients for $\hbar = 2,3,\cdots,13$ are all derived. A direct impact matrix of agricultural product supply chain financial risk factors can then be generated, as shown in Table 7.

**Table 7.** Direct impact matrix of agricultural product supply chain financial risk factors.

| No. | B11 | B12 | B13 | B14 | B21 | B22 | B23 | B31 | B32 | B33 | B41 | B42 | B43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B11 | 0.0000 | 0.1997 | 0.1807 | 0.1997 | 0.6467 | 0.0571 | 0.1443 | 0.5952 | 0.2071 | 0.0810 | 0.2933 | 0.8467 | 0.8265 |
| B12 | 0.8745 | 0.0000 | 0.1499 | 0.1885 | 0.5408 | 0.4048 | 0.3453 | 0.2743 | 0.4267 | 0.7600 | 0.2386 | 0.6500 | 0.6345 |
| B13 | 0.7349 | 0.1718 | 0.0000 | 0.1718 | 0.4833 | 0.7971 | 0.1374 | 0.1569 | 0.5408 | 0.6267 | 0.2871 | 0.7967 | 0.6978 |
| B14 | 0.6633 | 0.6467 | 0.2414 | 0.0000 | 0.3453 | 0.7867 | 0.2414 | 0.3586 | 0.4333 | 0.2157 | 0.3471 | 0.8629 | 0.7552 |
| B21 | 0.7967 | 0.6754 | 0.4048 | 0.4894 | 0.0000 | 0.6544 | 0.4048 | 0.5833 | 0.4533 | 0.3667 | 0.6643 | 0.8933 | 0.6136 |
| B22 | 0.8633 | 0.6467 | 0.6033 | 0.1600 | 0.7867 | 0.0000 | 0.0571 | 0.2667 | 0.2414 | 0.0810 | 0.2667 | 0.7500 | 0.7667 |
| B23 | 0.6600 | 0.1810 | 0.4892 | 0.4373 | 0.0000 | 0.0910 | 0.0000 | 0.6444 | 0.4048 | 0.7944 | 0.6444 | 0.8300 | 0.3129 |
| B31 | 0.7680 | 0.2643 | 0.6544 | 0.7899 | 0.3453 | 0.4333 | 0.2071 | 0.0000 | 0.2186 | 0.7643 | 0.7643 | 0.7720 | 0.6233 |
| B32 | 0.6964 | 0.5952 | 0.4543 | 0.6000 | 0.1374 | 0.3810 | 0.2933 | 0.7136 | 0.0000 | 0.7842 | 0.7136 | 0.5714 | 0.7515 |
| B33 | 0.5680 | 0.4267 | 0.7871 | 0.3386 | 0.2414 | 0.5873 | 0.0012 | 0.6544 | 0.4048 | 0.0000 | 0.4533 | 0.6967 | 0.7598 |
| B41 | 0.4129 | 0.1200 | 0.6000 | 0.5733 | 0.4048 | 0.4043 | 0.3453 | 0.6467 | 0.0571 | 0.2667 | 0.0000 | 0.8885 | 0.7269 |
| B42 | 0.8133 | 0.4000 | 0.5408 | 0.6267 | 0.2871 | 0.7871 | 0.1374 | 0.6544 | 0.4048 | 0.4833 | 0.4533 | 0.0000 | 0.6157 |
| B43 | 0.6129 | 0.2543 | 0.2871 | 0.7600 | 0.2386 | 0.2667 | 0.2414 | 0.0810 | 0.7971 | 0.4592 | 0.6433 | 0.7512 | 0.0000 |

Step 5: Construction of a comprehensive impact matrix: Assuming $G_x$ is the direct impact matrix of agricultural product supply chain financial risk factors, standardization of this matrix will lead to a standard direct matrix $G_{xy}$.

$$f_x = \frac{1}{\max\limits_{1 \le \hbar \le n} \sum_{j=1}^{n} G_{x_{\hbar j}}}, \quad G_{xy} = f_x G_x \tag{22}$$

A comprehensive impact matrix $B_{xy}$ can then be built:

$$B_{xy} = G_{xy}(I - G_{xy})^{-1} \tag{23}$$

where $I$ is a unit matrix. With the aid of MATLBA software, the comprehensive impact matrix of $B_{xy}$ is obtained, as shown in Table 8.

**Table 8.** Comprehensive impact matrix of agricultural product supply chain financial risk factors.

| No. | B11 | B12 | B13 | B14 | B21 | B22 | B23 | B31 | B32 | B33 | B41 | B42 | B43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B11 | 0.3278 | 0.2093 | 0.2369 | 0.2553 | 0.2709 | 0.2394 | 0.1241 | 0.2997 | 0.2193 | 0.2260 | 0.2705 | 0.4670 | 0.4264 |
| B12 | 0.5151 | 0.2240 | 0.2826 | 0.2956 | 0.3027 | 0.3311 | 0.1705 | 0.3129 | 0.2886 | 0.3582 | 0.3112 | 0.5234 | 0.4783 |
| B13 | 0.5078 | 0.2559 | 0.2675 | 0.2983 | 0.3037 | 0.3908 | 0.1447 | 0.3010 | 0.3088 | 0.3435 | 0.3217 | 0.5507 | 0.4967 |
| B14 | 0.5193 | 0.3265 | 0.3092 | 0.2868 | 0.2974 | 0.4007 | 0.1667 | 0.3366 | 0.3053 | 0.3060 | 0.3412 | 0.5792 | 0.5203 |
| B21 | 0.6110 | 0.3700 | 0.3818 | 0.4041 | 0.2933 | 0.4378 | 0.2122 | 0.4198 | 0.3491 | 0.3763 | 0.4350 | 0.6681 | 0.5778 |
| B22 | 0.5165 | 0.3089 | 0.3341 | 0.2904 | 0.3393 | 0.2796 | 0.1358 | 0.3052 | 0.2669 | 0.2710 | 0.3120 | 0.5366 | 0.4944 |
| B23 | 0.4866 | 0.2449 | 0.3315 | 0.3310 | 0.2310 | 0.2971 | 0.1223 | 0.3621 | 0.2827 | 0.3667 | 0.3632 | 0.5473 | 0.4396 |
| B31 | 0.5752 | 0.3007 | 0.3968 | 0.4222 | 0.3231 | 0.3951 | 0.1752 | 0.3220 | 0.3039 | 0.4031 | 0.4260 | 0.6232 | 0.5529 |
| B32 | 0.5730 | 0.3449 | 0.3757 | 0.4047 | 0.2982 | 0.3881 | 0.1893 | 0.4200 | 0.2767 | 0.4163 | 0.4266 | 0.6038 | 0.5742 |
| B33 | 0.5096 | 0.2969 | 0.3844 | 0.3362 | 0.2864 | 0.3825 | 0.1349 | 0.3741 | 0.3043 | 0.2796 | 0.3577 | 0.5633 | 0.5263 |
| B41 | 0.4597 | 0.2408 | 0.3417 | 0.3493 | 0.2860 | 0.3399 | 0.1710 | 0.3548 | 0.2430 | 0.2963 | 0.2783 | 0.5563 | 0.4893 |
| B42 | 0.5559 | 0.3049 | 0.3626 | 0.3815 | 0.3032 | 0.4161 | 0.1578 | 0.3866 | 0.3112 | 0.3509 | 0.3682 | 0.4919 | 0.5252 |
| B43 | 0.4767 | 0.2586 | 0.2967 | 0.3674 | 0.2597 | 0.3162 | 0.1573 | 0.2867 | 0.3319 | 0.3168 | 0.3584 | 0.5316 | 0.3929 |

Step 6: Analysis of agricultural product supply chain financial risk factors: From the comprehensive impact matrix of agricultural product supply chain financial risk factors, centrality degree ($\mathrm{Lm}_\hbar$) and causality degree ($\mathrm{Lu}_\hbar$) are derived through the following equations, where $\mathrm{LD}_\hbar$ and $\mathrm{LR}_\hbar$ represent impact degree and vulnerability degree respectively.

$$\mathrm{LD}_{\hbar} = \sum_{j=1}^{n} t_{\hbar j} \quad (\hbar = 1,2,\cdots,13) \tag{24}$$

$$\mathrm{LR}_{\hbar} = \sum_{j=1}^{n} t_{j\hbar} \quad (\hbar = 1,2,\cdots,13) \tag{25}$$

$$\mathrm{Lm}_{\hbar} = \mathrm{LD}_{\hbar} + \mathrm{LR}_{\hbar} \quad (\hbar = 1,2,\cdots,13) \tag{26}$$

$$\mathrm{Lu}_{\hbar} = \mathrm{LD}_{\hbar} - \mathrm{LR}_{\hbar} \quad (\hbar = 1,2,\cdots,13) \tag{27}$$

## 3. Results

Based on the above analysis, the impact degree and vulnerability degree values of agricultural product supply chain financial risk factors are calculated with Equations (24) - (27), as shown in Table 9, and the centrality degree and causality degree values are given in Table 10.

**Table 9.** Impact degree and vulnerability degree of agricultural product supply chain financial risk.

| **No.** | **$B_{11}$** | **$B_{12}$** | **$B_{13}$** | **$B_{14}$** | **$B_{21}$** | **$B_{22}$** | **$B_{23}$** | **$B_{31}$** | **$B_{32}$** | **$B_{33}$** | **$B_{41}$** | **$B_{42}$** | **$B_{43}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Impact degree | 3.5726 | 4.3942 | 4.4909 | 4.6951 | 5.5364 | 4.3906 | 4.4059 | 5.2194 | 5.2914 | 4.7363 | 4.4063 | 4.9160 | 4.3509 |
| Vulnerability degree | 6.6341 | 3.6862 | 4.3017 | 4.4228 | 3.7950 | 4.6142 | 2.0615 | 4.4815 | 3.7917 | 4.3107 | 4.5701 | 7.2423 | 6.4941 |

**Table 10.** Centrality degree and causality degree of agricultural product supply chain financial risk.

| **No.** | **$B_{11}$** | **$B_{12}$** | **$B_{13}$** | **$B_{14}$** | **$B_{21}$** | **$B_{22}$** | **$B_{23}$** | **$B_{31}$** | **$B_{32}$** | **$B_{33}$** | **$B_{41}$** | **$B_{42}$** | **$B_{43}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Centrality degree | 10.2067 | 8.0805 | 8.7926 | 9.1179 | 9.3314 | 9.0048 | 6.4674 | 9.7009 | 9.0831 | 9.0470 | 8.9764 | 12.1583 | 10.8450 |
| Causality degree | 3.0615 | 0.7080 | 0.1893 | 0.2723 | 1.7414 | 0.2236 | 2.3444 | 0.7379 | 1.4998 | 0.4256 | 0.1638 | 2.3264 | 2.1432 |

With the centrality degree and causality degree values, a causal relation graph is plot ted, as shown in Figure 2:

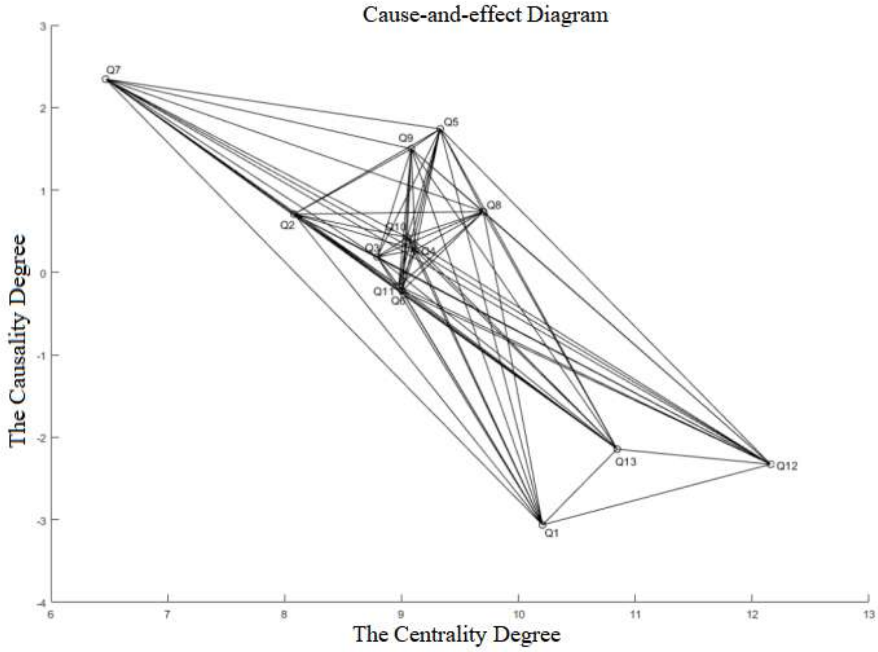


**Figure 2.** Causal relation of comprehensive impact of agricultural product supply chain financial risk factors.

Based on the combined weight coefficients and calculation results of DEMATEL method, the product of a centrality degree and corresponding weight of an agricultural product supply chain financial risk factor is calculated as the comprehensive impact degree of that risk factor. The comprehensive impact degree serves as an accurate measure of the importance of risk factors, and helps reduce subjectivity of combined weight coefficients and improve DEMATEL method. The multiplication operation is expressed as follows:

$$z_{\hbar} = Lm_{\hbar} \cdot w_z^{'} \quad (\hbar = 1,2,\cdots,13) \tag{28}$$

where $w_z^{'}$ is a weight of an agricultural product supply chain financial risk measurement index in the final combined weight coefficient method. The calculation results are given in Table 11:

**Table 11.** Comprehensive impact degree of agricultural product supply chain financial risk factors.

| **Impact factor** | **$B_{11}$** | **$B_{12}$** | **$B_{13}$** | **$B_{14}$** | **$B_{21}$** | **$B_{22}$** | **$B_{23}$** | **$B_{31}$** | **$B_{32}$** | **$B_{33}$** | **$B_{41}$** | **$B_{42}$** | **$B_{43}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $z_{\hbar}$ | 0.9692 | 0.2851 | 0.5385 | 0.2619 | 0.3262 | 0.6145 | 0.2238 | 0.4249 | 0.6445 | 0.3094 | 0.6380 | 2.9759 | 1.9217 |
| Ranking | 3 | 11 | 7 | 12 | 9 | 6 | 13 | 8 | 4 | 10 | 5 | 1 | 2 |

Centrality degree reflects the importance of different impact factors in the course of agricultural product supply chain financial risk evaluation. It can be seen from Figure 2 that the risk indexes of cooperation level, performance record, financial standing and repayment history of borrower organization, and stock status have a high centrality degree that exceeds 9.5. They belong to supply chain relation risk, credit risk, and pledge risk respectively. This indicates that these risk factors play a more significant role in agricultural product supply chain financial risk evaluation.

Based on the comprehensive degrees of agricultural product supply chain financial risk factors listed in Table 9, cooperation level, performance record, financial standing and repayment history of borrower organization, status of orders, supply chain robustness, and risk arising from deterioration of external operation environment are main agricultural product supply chain financial risk impact factors, among which cooperation level, performance record, financial standing and repayment history of borrower organization have a higher comprehensive impact degree. Hence, stricter control of supply chain relation risk and credit risk is required.

**4. Discussion**

Current management of agricultural product supply chain financial risks is still confronted with many challenges, such as difficult risk warning, delayed risk monitoring, and lack of coordination by financial regulatory authorities for agricultural product supply chains. It is therefore imperative for the government to reinforce agricultural product supply chain financial risk control (Fan et al., 2017; Jing et al., 2021; J. Liu et al., 2019). The government should build and refine a financial information sharing platform for agri-cultural product supply chains, and improve warning, intervention, response, and post-event accountability mechanisms for relevant risks, thereby laying systematic groundwork for control of such risks. It is advisable for the government to make use of block chain technology to help agricultural product SMEs improve their risk management capabilities, and to refine the government regulatory system. The block chain concepts and principles may aid optimization of financial models in agricultural product supply chains (Song et al., 2017; M. Yang et al., 2021), and may be coupled with experiences of managers to facilitate risk control in agricultural product SMEs. The specific risk control mechanisms are illustrated in Figure 3:

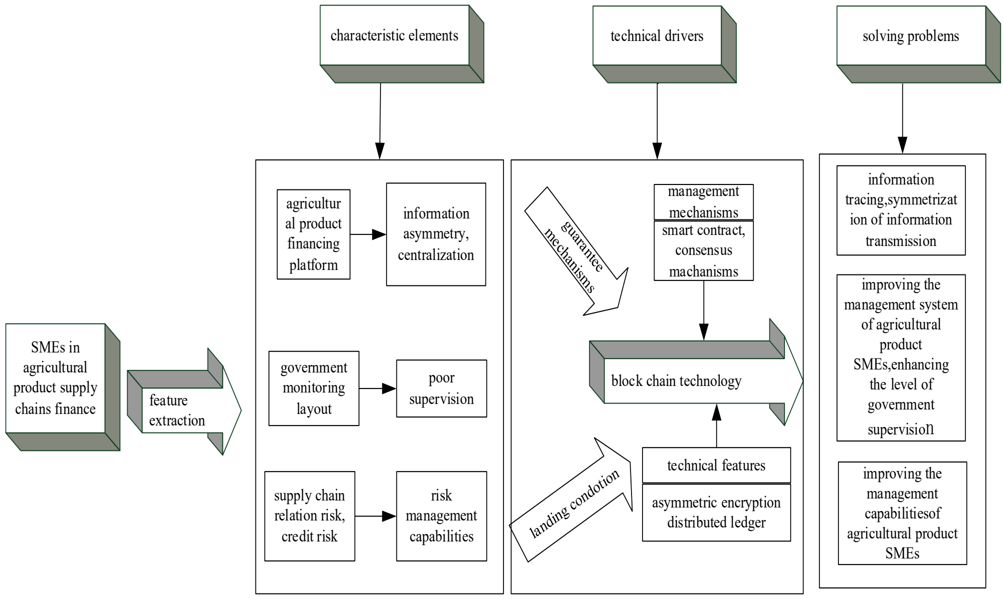


**Figure 3.** Finance risk control mechanisms based on block chain technology for agricultural product supply chains.

Block chain technology can give full play to network effects and application syner-gies between users, and help build a real-time information sharing database. Conse-quently, a more flexible and practical knowledge configuration can be created to provide assurance for agricultural product SMEs in their risk prevention and control. The intelli-gent coordination of risk control between banks, core enterprises, and agricultural product SMEs will also be boosted (Y. Liu & Cui, 2016; Luo & Chen, 2016; Wu et al., 2022). Moreover, block chain technology contributes to effectiveness and confidentiality of risk control, as well as traceability and efficient transmission of pertinent knowledge and information. Thanks to tamper-proof functions and intelligent contracts enabled by block chain technology, the government is able to provide agricultural product SMEs with different paths for mitigating various risks, improving their risk immunity and making sure that all supply chain financial risks are controllable and manageable.

**5. Conclusions**

Based on research on agricultural product supply chain financial risk impact factors, four dimensions of the agricultural product supply chain financial risk measurement in-dex system are identified – credit risk, market risk, pledge risk, and supply chain relation risk. Weight measurement is performed on the risk indexes with subjective F-AHP method and objective CRITIC method, and the final risk weight coefficients are obtained with EDAS method. Next, an improved DEMATEL method is adopted to analyze agri-cultural product supply chain financial risk factors, and the comprehensive impact de-grees of different risk factors are calculated. According to findings of the present research, cooperation level, performance record, financial standing and repayment history of bor-rower organization, status of orders, supply chain robustness, and risk arising from de-terioration of external operation environment are main financial risk impact factors for agricultural product supply chains.

Recommendations for the government: In the context of Finance 4.0 for supply chains, the government can make use of fintech such as block chain to help agricultural product SMEs improve their risk monitoring, prevention and control capabilities. By exploiting the tamper-proof and de-centralized nature of block chain technologies, the government may create a supply chain financial risk monitoring system to enable transaction tracking and automatic monitoring among agricultural products SMEs, which will mitigate the credit risks confronted by them. In the meanwhile, it is necessary to grant stronger sup-port to agricultural product SMEs by creating a favorable financing environment and improving the credit extension system to solve their financing difficulties. Besides, given the unstable operation of some agricultural product SMEs, the government should promote establishment of associations of SMEs and micro enterprises. The members of such associations may support and cooperate with each other for mutual benefit. Through creation of credit guarantee funds, it is possible to make up for core enterprise credit guarantee losses. Recommendations for financial institutions: A risk monitoring and punishment management system should be set up to urge agricultural product SMEs to share information effectively. This will contribute to better un-derstanding of the operation and financial status of agricultural product SMEs. Recommendations for agricultural products: They should give priority to financial and accounting transparency and improve credibility of information disclosure to ensure standard statement of their internal financial information.

The present research makes certain breakthrough and innovation in highlighting re-search viewpoints, promoting research concepts, and integrating research methods. The scope of the re-search extends to the realms of agricultural product supply chain man-agement, risk management, information economics, and supply chain finance. In partic-ular, the in-depth research on supply chain risk management may provide more experi-ences and reproducible risk control patterns and paths for financial institutions. On the other hand, there are certain aspects in this research that need to be improved in the future, and a more insightful research outlook needs to be developed.

Future research direction and outlook: The research on agricultural product supply chain fi-nancial risks may evolve from QCA analysis to MEM study. While QCA analysis involves relevant risk impact factors, MEM analysis covers collection, calculation, and visualization of credit data of research objects. These two methods may be combined in the future to enable deep study on some risk indexes that are hard to quantify, to better verify correctness of conclusions, and to give birth to long-term mechanisms for preventing and mitigating risks.

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Agricultural & Rural Studies

*Commentary*

# Some Considerations for Research on Smart and Novelty Villages in Global Rural Areas

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## 1. Introduction

At present, rural geography is a melting pot of options, dominant or secondary, that coexist in the study of rural spaces, which is also projected in the orientations of the rural global (Woods, 2007). Since the sociocultural turn, rural geography has been dominated by minor theory, where the rural locality is a locus for processes of social change between locals and newcomers. In this context, smart and novelty villages are two focuses of growing and renewing geographic attention in recent years (Paniagua, 2020; Zhang & Zhang, 2020).

This contribution argues that the new rural materiality of smart and novelty villages is a hybrid and inclusive route of study of material histories and sociocultural stories in rural environments, which allows amalgamating the life of people in the core of new material artifacts in the analysis of, renew spatial process of rural areas in the world. Places and peoples are governed by processes and flows, which generate fluid materials. Initially, the rural houses could be considered fixed materialities governed by the dialectic and the structural geography that generates opposite geographies. But, the histories of houses and the stories of houses of the smart and novelty villages perform better with the relational postmodern geography, which combines forms, culture and dwelling. In renovated traditional houses there is a tension or a dialectic between external renovation versus internal renovation, between the urban style with/and the old structure.

## 2. Stories and/or Histories of Novelty and Smart Experimental Materialities and Lives

Since the beginning of the 2000s, the study of heterogeneous realities and the hybridization processes of multiple geographic realities have been a permanent concern in human and rural geography. In this theoretical context, it is possible to situate the individual and community experience in the processes of loss, recovery and transformation of agrarian or rural realities towards smart and novelty villages.

In the context of rural geography, materiality can be a notable way of studying new smart and novelty spatial processes with a socio-material expression through micro encounters (Paniagua, 2022, 2023). Traditionally, the study of rural houses is framed mainly in rural politics or plans, through housing provision in a dialectic people-houses relationship. In particular, in the remote rural areas the houses of smart and novelty villages are key for new population.

In the process of change from traditional society to postmodern societies, smart materials are malleable fluids. Classic contributions to rural studies put houses provision and house transformation as a central theme. In the context of the socio-economic transformation processes of rural areas and the arrival of new social groups. The need for housing and the transformation of traditional houses were linked in the geographical perspective of political-economy. Materiality is relevant in the renewal of the social micro composition of smart rural communities, since it suggests styles of social recomposition around processes of social inclusion or exclusion that acquire their plasticity in the forms of new smart and novelty materialities.

The encounter with the smart and novelty rural material suggests different temporalities and spatialities in the form of histories and stories of intimate encounters. Through human/material experimentality, smart artifacts are reproduced and reinvented over time as individual elements in a field of material heterogeneous networks in the form of affective materialism (Lu & Qian, 2020). In this sense, smart small settlements constitute novelty hybrid forms of heterogeneous realities with different levels of experimental relations, or as suggested by Harvey (2016) there are “formed totalities” that dominate the construction and dissolution processes of the place, where the intimate culture or the “sweetness of the place”.

The smart and novelty materialities can be positioned in the current rural global debate as they are artifacts that can appear adaptively and fluidly in the transformation processes of the global south and north. The global nature of novelty and smart materials acquires multiple nuances in

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local materials. Smart and novelty villages would be elastic and malleable realities with a scalar dimension, which suggest renew social practices that aim to meet new social needs, which are formalized in place and have infinite but differentiated nuances in particular and individual experimental processes (Deleuze, 1994; Massey, 2005). A paradigmatic case is the rural walled villages in southern China and Hong Kong, traditionally defensive constructions that are now multi-ethnic refugees (Ng, 2023). The emblematic traditional ruralities are sites of representation or places with crisis of representation, new sites of others, where life, time and discourse of the others are written.

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# Call papers for Vol. 1， Issue 2

**1. Organizational Culture**

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