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Circular Economy Models in Agriculture in Vietnam

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Abstract: While the term "circular economy" is relatively new in Vietnam, the principles of this economic model have long been embedded in traditional agricultural practices. Recently, these economic models have experienced significant growth. This research involves a comprehensive review of circular agriculture research and an analysis of various models within Vietnam at different levels. The study categorizes circular economy models in the agricultural sector in Vietnam into four basic groups: reduction model, waste recycling model, ecological chain model, and zero waste design model. Through an exploration of these models, the study identifies eight main features of circular economy models in Vietnam's agriculture, such as a substantial surge, utilization of agricultural by-products, waste, and leftovers, prevalence in rural areas, focus on small-scale production models, leadership by big companies, and a shift from merely seeking cost savings to a more market-oriented approach. The study also proposes principles for transitioning to an agricultural circular economy from a linear economy and developing new agricultural circular economy practices in Vietnam.

Keywords: Circular economy, circular agriculture, sustainable agricultural development.

Subject classification: Economics.

1. Introduction

Agriculture is a crucial sector in any global economy, providing employment for a substantial portion of the population and ensuring overall food security. According to the U.S. Agency for International Development (USAID), sustainable agriculture involves practices that responsibly manage and efficiently utilize renewable natural resources, offering sustenance, income, and livelihoods for both present and future generations (Eswaran et al., 1993).

With the projected global population surpassing 9.8 billion by 2050 (FAO, 2022), there is an urgent need to meet the rising demand for food. The United Nations Economic Commission anticipates a tripling of the world economy by 2050 (United Nations

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Economic Commission for Europe, 2021), placing considerable strain on resource utilization, especially in agricultural production, which is a major contributor to climate change, responsible for one-third of greenhouse gas emissions.

Conversely, climate change is rapidly impacting agricultural production, leading to reduced crop yields, challenges in adapting crops to changing conditions, increased prevalence of pests and diseases, and diminished crop nutrient levels (FAO, 2022). This highlights significant challenges to sustainable development in agriculture.

In recent years, agriculture in Vietnam has played a pivotal role in economic development, serving as an economic backbone and providing job security, especially during crises. However, it faces substantial challenges due to increasingly limited natural resources and the growing impact of climate change. According to a report from the Organization for Economic Co-operation and Development (OECD, 2015), Vietnam's per capita agricultural land is only 0.12 hectares, just one-sixth of the global average. Additionally, Vietnam has effectively utilized its land, with a low number of abandoned or unused areas.

Furthermore, Vietnam's available arable land is primarily of low quality, with more fertile alluvial soils in regions like the Red River Delta and Mekong Delta facing issues such as salinization and aluminium contamination. The damage caused by climate change to agriculture could potentially reduce Vietnam's GDP by 2.4% (Rivoal & Nguyen Thanh Thuy, 2022). Excessive use of fertilizers and pesticides in agricultural production has led to soil and water pollution and degradation, posing a significant challenge.

Therefore, transitioning to a more resource-efficient development model is imperative. Globally, there is a shift from a linear economy to a circular economy, aimed at achieving sustainable development goals and addressing climate change. The circular economy focuses on creating a closed-loop system where materials and resources are reused efficiently at every stage, as per the Law on Environmental Protection of 2020.

Before the term "circular economy" gained recognition, many traditional agricultural models in Vietnam exhibited circular economy characteristics. Models like Garden - Pond - Barn (Vườn - Ao - Chuồng, known as VAC model), Garden - Pond - Barn - Forest (Vườn - Ao - Chuồng - Rừng), Garden – Pond – Barn - Biogas (Vườn - Ao - Chuồng - Biogas) were effective in sustainable waste management, renewable energy production, pollution reduction, and greenhouse gas emission reduction.

Advancements in science and technology, particularly in biotechnology and digital applications, have led to the rapid development of circular economy models in Vietnam's agricultural sector. Studying these models, incorporating circular economy principles, not only clarifies the unique characteristics of agricultural development in Vietnam, but also provides insights for transitioning agricultural models toward the circular economy. This is especially significant given Vietnam's strong commitment to achieving net-zero emissions by 2050 and aligning development with sustainable development goals.

This study, conducted through an extensive examination of circular agriculture research and an in-depth analysis of various models within Vietnam across different levels, delineates the classifications of circular economy models in the agricultural sector of

Vietnam. It also emphasizes their unique attributes, putting forward principles for the evolution and enhancement of the circular agriculture model in Vietnam.

2. Circular Economy in Agriculture

2.1. The Definition of Circular Economy in Agriculture

The literature reveals that the circular economy in agriculture has been acknowledged under various terms, including circular bioeconomy (Carus & Dammer, 2018; Gontard et al., 2018), rural eco-economy (Kitchen & Marsden, 2009; Kristensen et al., 2016), Agroecology (Altieri, 2015), and Agro-industrial Ecology (Fernandez-Mena et al., 2016).

Circular bioeconomy represents a fusion of bioeconomy and circular economy principles, emphasizing resource sharing, reuse, and recycling. Resources are employed hierarchically and organically, with an emphasis on leveraging organic waste streams to enhance resource value chain efficiency through organic recycling and nutrient cycles (Carus & Dammer, 2018). In this context, circular economy is distinct from bioeconomy, which primarily revolves around the production and utilization of renewable biological resources, often in a linear manner, lacking inherent circularity (Haaranen, 2015). Therefore, this novel concept of circular bioeconomy can be seen as a form of economic intelligence within the agricultural domain.

Rural ecological economy, as defined by Kitchen & Marsden (2009), is an economy intrinsically linked to its ecosystem, where productive activities intertwine with mutual benefits while being embedded within a specific society with distinct characteristics. This concept combines traditional agriculture with three fundamental aspects: first, it requires organic and value chain development; second, it integrates land resources with nature conservation and environmental protection; and third, it emphasizes resource mobilization that incorporates energy efficiency, technology inheritance, and application.

Agroecology, first coined by Russian agronomist Basil Bensin in the 1930s, involves applying ecological principles to enhance the efficiency of resources and minimize emissions in agricultural production activities (Wezel et al., 2020). It’s a specific economic model that leverages ecological principles for sustainable food systems design and management.

Public and agricultural ecology, as defined by Fernandez-Mena et al. (2016), involves deploying ecological principles in agriculture to optimize resource use by analyzing nutrient flows in the agri-food chain and designing efficient recycling loops.

The term “circular economy in agriculture” is employed in various studies, each offering a distinct perspective. According to Ward (2017), it refers to commodity agricultural production that minimizes the use of external inputs. This approach involves sealing nutrient loops during the production process, minimizing negative environmental impacts, and managing agricultural and food waste effectively. Toop et al. (2017) describe circular economy in agriculture as the application of advanced technology and production practices in agriculture, focusing on utilizing waste and by-products to achieve economic and environmental sustainability goals. Ruiz et al. (2019) argue that circular economy in agriculture revolves around prioritizing the efficient use of natural resources, emphasizing obtaining greater incremental value and conserving resources within the production system for as long as possible. Efficiency in circular agriculture models involves optimizing production processes to minimize natural resource usage and eliminate waste (Jurgilevich et al., 2016; Velasco-Muñoz et al., 2021). Circular economy in agriculture is also associated with the production of agricultural goods with minimal reliance on external inputs, focusing on closing nutrient loops and reducing adverse environmental impacts (Oldfield et al., 2016). According to EIP-AGRI (2015), "circular economy in agriculture" is about preserving and enhancing natural capital through the balance of renewable resource flows, the optimization of natural resources by rotating products, finished products, and materials, enhancing resource efficiency through waste reduction, and promoting interactions among people to encourage optimal resource use and waste avoidance.

Ward (2017) characterizes circular agriculture as a form of commodity agricultural production with minimal reliance on external inputs. This approach involves closing nutrient loops, minimizing negative environmental impacts, and managing agricultural waste.

From the above concepts, this study proposes that circular economy in agriculture refers to a closed-loop agricultural production process. It involves transforming waste, waste products, and by-products from one stage into inputs for other production processes, achieved through the application of ecological, technical, and biotechnological principles. This approach effectively optimizes natural resource usage, reduces emissions to the environment, safeguards ecosystems, and enhances human health.

2.2. Main Features of Circular Economy in Agriculture

Circular economy is a resource-efficient economy based on three fundamental principles: zero-waste and pollution design, keeping materials and products in use for as long as possible, and regenerating natural ecosystems (Ellen MacArthur Foundation, 2019). In the context of agriculture, this economic philosophy exhibits certain defining features:

Firstly, it champions efficiency by adhering to zero waste and pollution design. Agricultural economic models are devised to optimize the utilization of natural resources by continuously circulating and employing all raw materials, by-products, and waste products. This promotes the preservation and enhancement of natural capital by carefully managing renewable resource flows and closing nutrient loops (Haaranen, 2015). Specific models that exemplify this principle include the use of biofertilizers in production, harnessing renewable energy sources, and adopting ecosystem-based approaches, such as symbiosis in agriculture. Hence, the essence of circular agriculture lies in implementing production operations with a focus on waste reduction and pollution prevention.

Secondly, it strives to maximize the usage of natural resources by promoting the reuse of by-products, waste materials, and resources. Enhancing resource efficiency is a cornerstone of circular agriculture models. Circular agriculture is dedicated to optimizing the efficient utilization of natural resources. Following the use of agricultural products, their by-products are reintegrated into the agricultural process in the form of biomass. The raw materials of the production process are made more efficient by elevating biological processes, recycling biomass, nutrients, and water. Characteristics of circular agriculture aimed at resource efficiency include combining mixed agriculture (integrating cultivation and animal husbandry) with organic agriculture, agro-forestry practices combined with water recycling and wastewater reuse. These approaches are geared towards efficient resource utilization, reducing the need for inputs, and mitigating greenhouse gas emissions.

The third principle centers on regenerating natural ecosystems through the preservation and enhancement of resources and the balanced management of renewable resource flows. In agriculture, the economic model views waste as a valuable resource (Sharma, 2018). This perspective interprets recycling to reduce economic and environmental costs in agricultural production activities, mirroring natural ecosystem processes. As indicated by Helgason et al. (2021), recycling water sources and reusing wastewater can enhance irrigation capacity, minimize pollution, and replenish aquifers. Therefore, when managed effectively, wastewater becomes a valuable resource that bolsters food security, nutrition, and livelihoods. The recycling of nutrients, biomass, and water within manufacturing operations enhances resource efficiency, curbing waste and pollution (FAO, 2018).

In summary, the traits of the circular economy in agriculture are commonly exhibited through practices such as the use of biofertilizers, the diversification of value chains in agricultural production, the adoption of symbiotic agricultural practices, the efficient utilization of by-products and waste materials, strategic water management and circulation, land use and management, and waste recycling in agriculture, along with the incorporation of renewable energy sources.

3. Circular Economy Model in Sustainable Agricultural Development in Vietnam

While the term "circular economy" is relatively recent in Vietnam, the concept of circular economic practices has long been ingrained in traditional farming methods. In the present era, with advancements in science and technology, Vietnam's circular agriculture models are becoming increasingly apparent at various levels and scales, ranging from partial circular approaches to comprehensive circular systems.

3.1. Reduction Models

By applying economic principles to optimize production costs, several noteworthy models have emerged, including the production of organic fertilizers from agricultural waste, biomass production, biochar derived from agricultural by-products, and circular aquaculture.

The model for producing organic fertilizers from agricultural waste has gained widespread adoption across the country. By utilizing by-products from crop cultivation (such as rice straw, corn, legumes), household waste, and livestock waste, the composting process, aided by microbiological preparations, transforms these waste materials into organic fertilizers. These organic fertilizers enhance soil quality, remediate nutrient-deficient soil, and restore soil fertility, thereby improving crop yields. This model not only helps farmers reduce their expenses on commercial organic fertilizers but also aligns with the strategy of promoting low-carbon agriculture, mitigating greenhouse gas emissions, and safeguarding the environment. An illustrative example of this model can be found in Triệu Phong district, Quảng Trị province, where the shift from burning rice straw in the fields to composting, combined with microbiological preparations and the principles of sustainable agriculture, has yielded valuable products, including rice, organic vegetables, and livestock with substantial economic value.

In addition to organic fertilizer production, by-products and agricultural waste materials have found applications in biomass development. This model harnesses various agricultural and forestry waste resources like stems, branches, leaves, wood chips, sawdust, rice husks, straw, bagasse, bamboo, and cork. These materials undergo primary processing to create biomass fuel pellets. These pellets have versatile applications, from household use to small-scale agricultural production and even export. The process of utilizing biomass pellets also generates biochar, a type of high-carbon charcoal with natural porosity. Biochar serves as an organic fertilizer that enhances water and nutrient retention in the soil, protects soil-dwelling microorganisms, and mitigates the adverse effects of weather and soil erosion. Various biomass pellet technologies are being deployed in Vietnam, capitalizing on an abundant biomass resource base of approximately 118 million tons per year, which includes 40 million tons of rice straw, 8 million tons of rice husk, 6 million tons of bagasse, and over 50 million tons of other waste materials (Đỗ Năng Vịnh et al, 2022). The production of biomass and biochar presents a promising model in Vietnam.

According to Vũ Công Tâm (2021), the Recirculating Aquaculture System (RAS) model was developed in the late 1950s and subsequently advanced through microbiological research applied to aquaculture. This system features an enclosed culture setup with interconnected components, including inlet water treatment tanks, shrimp tanks, and water circulation filtration systems. RAS enables a stable cultivation environment, reduces water usage, minimizes wastewater discharge, and ensures water quality remains uncompromised. It promotes biosecurity, does not release pollutants, and aligns with environmentally friendly practices. Economically, RAS offers high shrimp productivity, reduces the required farming area, and can be implemented across diverse locations. In Vietnam, the application of RAS in shrimp hatcheries and the cultivation of whiteleg shrimp in the Mekong Delta has had significant positive effects. It has effectively controlled environmental factors, conserved water resources, improved larval survival rates, and demonstrated substantial economic benefits, establishing itself as a sustainable aquaculture solution.

3.2. Waste Recycling Models

The practice of utilizing domestic waste as animal feed is a common model in many regions, with a notable example being the cultivation of worms and black soldier flies for animal husbandry.

According to Lê Thị Xuân Thùy & Lê Hoài Nam (2020), worms, also known as cinnamon worms, belong to the group of fecal worms and are typically found in environments rich in decomposing organic matter. Unlike some soil-dwelling worm species, they have larger bodies and are not as adept at direct soil reclamation. Cinnamon worms are among the worm breeds that have been domesticated and introduced into small to medium-scale industrial farming, primarily as pet food. They are a preferred and popular food source for animals like ducks, chickens, geese, ornamental birds, and fish. Cinnamon worms possess the advantageous ability to break down organic matter. One ton of cinnamon worms can effectively decompose up to 80 tons of organic waste. Therefore, worm farming serves as a method for treating domestic organic waste. Worm manure also contains highly reactive microbiological support, acting as a biological catalyst rich in amino acids. Consequently, worm fertilizer not only stimulates crop growth but also enhances soil quality, helping to prevent root diseases. Thus, the use of worms not only aids in managing agricultural waste and addressing environmental pollution issues, but also creates organic fertilizer sources for plants and serves as a nutritious food source for livestock. Representative models of worm farming are implemented in significant farms located in Củ Chi (Hồ Chí Minh City), Hòa Vang (Đà Nẵng city), Phú Cát (Bình Định province), and Bình Phước province.

In a parallel manner to worm farming, the model of black soldier fly farming is widely employed in waste management within animal husbandry. This approach helps control house flies and transforms organic waste into valuable products such as organic fertilizer. As described by Nguyễn Dương Khanh et al. (2017), black soldier flies are insects commonly found in outdoor environments near livestock or areas with decomposing organic matter, including animal waste. Before the pupation stage, black soldier flies have a nutritional composition containing 43-51% protein, 15-18% fat, 2.8-6.2% calcium, and 1-1.2% phosphorus. Consequently, they are a rich source of nutrients suitable for animals such as pigs, chickens, ducks, and serve as an exceptional live food option for specialty animals like shrimp, crabs, fish, and frogs. In Vietnam, black soldier flies are successfully utilized as animal feed in various localities, including Bình Phước, Bà Rịa - Vũng Tàu, and Cần Thơ.

3.3. Ecological Chain Transformation and Connection Model

The model of ecological chain transformation and connection is rooted in the application of circular economy principles, emphasizing the efficient circulation of nutrient flows. Noteworthy models within this framework include Garden - Pond - Barn and its variant versions, and “rice - shrimp” and “rice - fish” models.

The Garden – Pond - Barn model gained popularity in Vietnam during the 1980s and is considered one of the simplest circular agriculture models. It integrates farming, aquaculture, and livestock activities. In the Garden – Pond - Barn model, farming and animal husbandry work together in a natural way, creating a sustainable agricultural ecosystem. This model is adaptable to the specific production conditions of different regions, leading to variations like Garden - Pond – Barn - Forest, Garden - Pond – Barn – Biogas. Research demonstrates that the

Garden - Pond - Barn model and its variant versions are effective solutions for improving waste management practices, optimizing the use of agricultural by-products, enhancing soil fertility, and reducing emissions, thereby mitigating greenhouse gas effects that contribute to climate change (Nguyễn Ngọc Sơn et al., 2010; Nguyễn Xuân Hồng, 2020). Today, the Garden – Pond - Barn model and its variant versions are widely adopted throughout the country, incorporating advancements in production and business organization, as well as the application of science and technology. While it has found success in many businesses and corporations, it remains a popular model at the levels of households and cooperatives.

The “rice - shrimp” and “rice - fish” models represent unique crop rotation practices applied since the early 2000s in the provinces of the Mekong Delta, and have more recently expanded to various regions across the country. In these models, when cultivating shrimp or fish in rice fields, the manure from these aquatic species and leftover feed serve as natural fertilizers for the rice crops. Conversely, after the rice harvest, shrimp and fish are introduced into the fields, and the remaining rice stubble and grains become a source of food for these aquatic species. As per Nguyễn Công Thành (2018), this special farming system offers numerous mutual benefits, including the efficient use of organic matter remaining after a shrimp farming season to enrich the nutritional content of rice plants. Livestock raised in the rice fields thrive on a diet that includes artificial and natural food sources from the ecosystem, benefiting from the decomposition of rice roots. The rice - shrimp and rice - fish farming system create an ecological balance and a safe environment with mutual advantages for both crops and livestock. It also restricts pests for both rice and livestock through the practice of virtuous crop rotation, thereby creating a unique system of mutual benefit. Additionally, it enhances the ability to break down and remove toxic elements due to alternating between salty and freshwater regimes and the presence of plant flora. This system reduces production costs by minimizing the need for fertilizers due to the presence of residual organic sources that enhance plant growth and by decreasing the use of pesticides, thanks to reduced pest populations through crop rotation. It also curtails environmental pollution, ultimately resulting in clean, organic products that benefit human health, provide valuable export commodities, increase incomes for farmers and businesses involved in the production-to-consumption chain.

3.4. Zero Waste Design Models

At a more advanced level, surpassing the models aimed at reducing, recycling, and establishing ecological connections, the application of circular economy principles extends to the industrial-scale agricultural production carried out by corporations. Notable examples include the biosecurity livestock model, known as 4Fs model (Farm-Food-Feed-Fertilizer) by Quế Lâm, production model by the T&T159, “green circle” model by the Vietnam Dairy Corporation (Vinamilk), and the circular model by the TH True Milk Group. These models are designed holistically based on the principle of zero waste in agricultural production. They operate under the premise that the output of one production process serves as input for another, facilitated by the application of advanced science and technology.

In the 4Fs model and the T&T159's model, production cycles involve several key components:

Farming activities are conducted by the enterprise and may involve collaborations with the local community, ensuring strict quality control processes to produce organic feeds.

Animal feed production integrates traditional agricultural practices with advanced biotechnology and quality probiotics. By utilizing waste products from cultivation, such as rice bran, corn, soybeans, and plant material, the feed production process minimizes waste.

In animal husbandry activities, enterprises establish bio-fed pig farms that adhere to organic standards. These barns feature improved natural ventilation, biologically padded surfaces, and automated feeding and drinking systems. They also implement environmentally friendly management technology that prevents odors and wastewater issues. Biosecurity is maintained through microbiological culture technology and probiotics added to feed and water, effectively preventing livestock diseases.

Fertilizer production activities focus on organic fertilizer and biological product production, serving both enterprise needs and the market for clean and organic agricultural production.

The TH True-Milk Group's model applies the principles of circular economy to enhance water use efficiency, waste by-product management, waste treatment, and energy reuse. Water conservation is achieved through control technology, automated irrigation, and wastewater treatment geared towards maximizing reuse. The recovery and reuse of corn silage at the feed center are integral to their sustainable practices. To manage cow manure, the enterprise invests in technology to separate water from manure. Fresh manure, post-separation, is composted into organic fertilizer, improving soil structure, increasing moisture retention, and providing nutrients for crops. Energy efficiency is realized through the use of solar power and bagasse geothermal energy, reducing reliance on national electricity, minimizing environmental impact, and limiting CO_2 emissions.

In the Vinamilk model, the principles of circular economy are executed through specific activities such as sustainable land management, advanced agricultural practices, green energy utilization, and waste-to-resource management. A key feature is the conversion of waste into resources. At Vinamilk farms, livestock waste is efficiently managed and treated with modern technology, including a biogas system. This waste is separated into solid fertilizer or liquid treatment, which is then used to fertilize pastures and cultivate crops, improving soil quality. Additionally, biogas is employed to generate methane gas for cleaning farm equipment and pasteurizing calf milk. Vinamilk farms are also adopting solar energy systems to reduce fuel consumption, lower electricity costs, and contribute to CO_2 reduction in the environment.

4. Characteristics of Circular Economy Models in Agriculture in Vietnam

In the realm of agriculture, the principles of a circular economy become distinctly evident in the form of biological cycles aimed at optimizing raw material sources and closing nutrient loops. In Vietnam, these circular characteristics are deeply rooted in traditional agricultural practices. Our findings, based on a comprehensive analysis of studies conducted up to 2022 combined with surveys of typical models in the provinces of Hà Nam, Bình Phước and Vĩnh Phúc, reveal that the rapid advancement of science, technology, and agricultural techniques has accentuated the circular attributes within Vietnam's agriculture. These characteristics manifest themselves through growth, tradition, the extent of application, model scalability, and community engagement in production.

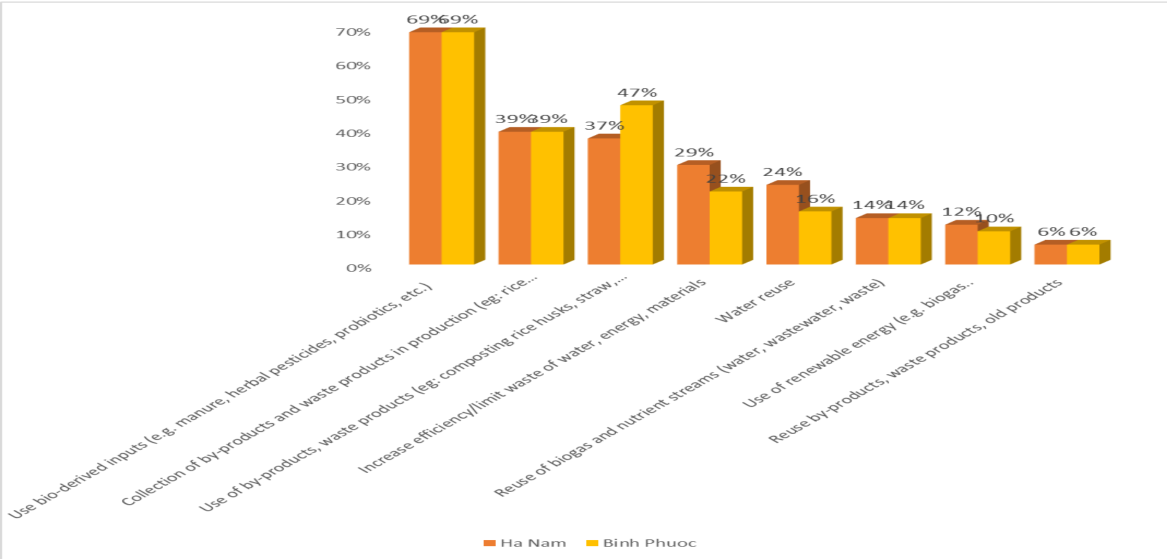
Firstly, circular agriculture models in Vietnam are experiencing a substantial surge. Evolving from traditional agricultural methods, circular agriculture models intertwined with scientific and technological applications are on the rise. This surge is indicative of the growing interest in such models. Forums focusing on clean agriculture, organic agriculture, chemical-free agriculture, and circular agriculture have garnered attention from thousands of enthusiasts. Furthermore, the areas dedicated to organic and ecological agricultural production are expanding. According to statistics from the Ministry of Agriculture and Rural Development, the organic farming area in Vietnam surged from 53,350 hectares in 2016 to approximately 237,693 hectares in 2019. A total of 46 out of the 63 provinces and cities have initiated and embraced the organic production movement. There are 17,168 farmers involved in organic production, and 97 enterprises have ventured into organic production.

Secondly, the origins of circular agriculture models in Vietnam can be traced back to traditional agricultural production techniques, intimately linked with the utilization of agricultural by-products, waste, and leftovers. This characteristic is notably exemplified by the VAC models and their variations. These production models are associated with livelihood diversification in rural Vietnam, allowing farmers to harness agricultural by-products and waste to generate various agricultural products on a small scale. Consequently, the sheer number of laborers and farmers engaged in circular agriculture in Vietnam is substantial. The abundant human resources in Vietnam's agricultural production sector provide a significant advantage when it comes to implementing circular agriculture.

Thirdly, the circular agriculture models in Vietnam primarily exhibit elements of a circular economy, often leaning toward semi-circular practices. These models encompass circular stages in various agricultural production activities, such as employing raw manure for crop cultivation, composting straw and rice husks to produce compost, reusing waste to generate biogas, and raising worms and black soldier flies.

Fourthly, the manifestations of circular agriculture in Vietnam remain prevalent in rural areas, with a concentration on small-scale production models adopted by households, cooperatives, and collectives. These models commonly involve waste management and reuse in agriculture, exemplified by the Garden – Pond - Barn models, symbiotic models, and reciprocal effects in production processes. Surveys conducted in Hà Nam and Bình Phước reveal that the majority of agricultural production cooperatives in these provinces exhibit circular agriculture practices within specific segments of the production process, especially concerning the repurposing of agricultural waste. Among the 102 circular agriculture models examined, a significant 71% were production models at the cooperative level.

Figure 1. Features of circular agriculture models in Hà Nam and Bình Phước



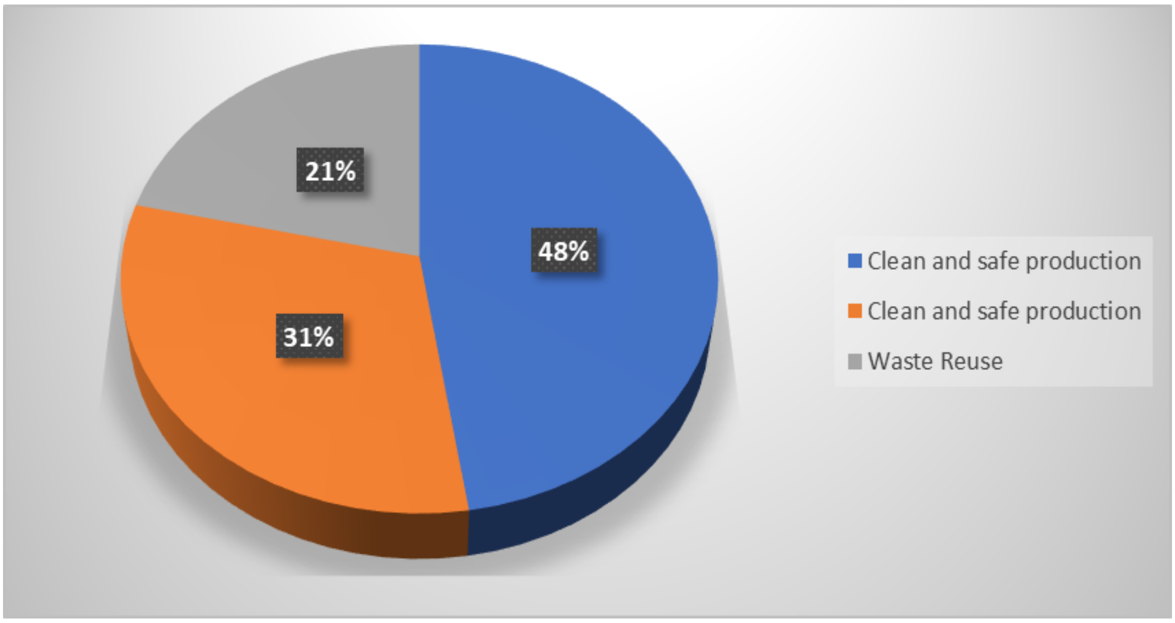
Source: Survey in Hà Nam and Bình Phước in 2021

Fifthly, concerning circular agricultural models, especially on a smaller scale, they predominantly employ the fundamental principles of circular agriculture. These principles encompass the utilization of biologically-sourced inputs like raw manure and herbal pesticides, along with the collection and repurposing of waste by-products in the production process. A survey conducted on 102 agricultural models from households and cooperatives in Hà Nam and Bình Phước revealed that these practices are quite prevalent. Approximately 69% of these models acknowledged the use of biologically-sourced inputs, 42% engaged in the utilization of agricultural by-products and waste materials, and 40% partook in the collection of agricultural by-products and remnants. Conversely, more advanced technological requirements in agricultural production, such as water source recycling, biomass reutilization, nutrient flow closure, the adoption of renewable energy, and the recycling of by-products and waste materials, were only embraced by a relatively smaller proportion, falling below 20%.

Sixthly, high-level agricultural models have recently emerged and are advancing rapidly. These circular models primarily find their home within enterprises equipped with economic, scientific, and technological capabilities. A few notable examples include the circular models of TH True Milk, Vinamilk, Quế Lâm Company, and T&T159 Company. In these models, the essence of the circular economy is comprehensively demonstrated through the application of cutting-edge science and high-tech techniques. They harness all waste by-products and agricultural waste, effectively reuse water sources, manage wastewater, and harness bioenergy. Notably, companies like TH True Milk and Vinamilk exemplify these practices.

Seventhly, enterprises wielding substantial economic prowess play a leading role in the advancement and refinement of circular agriculture in Vietnam. This leadership is exemplified through the interconnection between enterprises involved in circular agricultural production, technology transfer, and the supply of agricultural materials relevant to circular agriculture. Indeed, this interplay extends to households and cooperatives providing raw materials for animal feed growing areas associated with TH True Milk and Quế Lâm Company, and the repurposing of by-products and waste materials at T&T159. Of special significance is the supply of organic animal feed, organic manure, and circular breeding techniques by Quế Lâm and T&T159, as well as the guidance provided by the Chairman of Quế Lâm Company for the Organic Circular Agriculture Association.

Figure 2. Main principles of use in circular agriculture models in Hà Nam and Bình Phước



Source: Survey in Hà Nam and Bình Phước in 2021

Eighthly, within the realm of circular agriculture models, the underlying philosophy has shifted from merely seeking cost savings to a more market-oriented approach that caters to the demands of consumers while promoting improved public health. An examination of agricultural models in Hà Nam and Bình Phước has unveiled that the majority of these models originally sprang from the utilization of agricultural by-products to reduce production costs. Nevertheless, at present, these models are inclined to recognize their strength in delivering clean, high-quality products to consumers. This shift in perspective is becoming the cornerstone for the expansion of production scales. Alongside the growing trend of selecting safe agricultural products and a transformation in mindset towards the application of the principles of the circular economy, it is fostering the development of the circular economy in the agricultural sector of Vietnam.

5. Recommendations on the transition principles to a circular economy model in agriculture

Promoting a circular economy within the agricultural sector involves establishing an economic model where agricultural production adheres to a closed-loop cycle. This model ensures that waste, by-products, and waste products from one stage become inputs for subsequent production processes. This is achieved by employing ecological, engineering, and biotechnological principles, resulting in the effective optimization of natural resources, reduced environmental emissions, ecosystem preservation, and enhanced human well-being. The development of this economic model can either evolve from the transformation of a linear economic model or can be built entirely anew, providing two distinct pathways for its development.

To foster the growth of economic models in agriculture, several principles must be upheld:

Firstly, waste must be recognized as a valuable resource in agricultural production. Circular agriculture models necessitate a thorough reassessment of available resources for agricultural production, maximizing their utilization, including waste.

Secondly, an emphasis on resource efficiency and cost savings is crucial. It underscores the importance of natural resources and ecosystems by promoting their economical and efficient use through optimization. This includes the reuse of by-products, waste, and waste products in agriculture, as well as the utilization of natural conditions to optimize land and water resources. Simultaneously, it encourages symbiosis and reciprocity within agricultural production.

Thirdly, a zero-waste design should guide agricultural model development. Models must be designed holistically and in a zero-waste manner, which optimizes inputs and closes nutrient loops, thereby enhancing model efficiency.

Fourthly, products must be safe and meet market demands. Products resulting from circular agriculture should adhere to food safety standards, exhibit increasing quality, ensure food security, and satisfy market needs in terms of quality and production costs.

To transfer from linear agriculture to circular agriculture models, the following stepwise approach should be employed, aligning with the principles of the circular agriculture mode:

Step 1: Conduct a resource analysis of the model based on the production and value chains, identifying potential strengths, and re-evaluating waste, particularly agricultural waste, as a resource. Develop plans to enhance resource utilization and reuse while minimizing environmental impacts.

Step 2: Based on the resource evaluation and plans for increased resource efficiency, progressively replace production methods with ecological agricultural solutions to reduce environmental harm.

Step 3: Gradually reconfigure the agricultural system to operate in accordance with ecological principles. Begin by focusing on adjustments based on ecological principles, especially in stages that have adverse environmental effects.

Step 4: Re-establish connections between consumers and producers through the creation of suitable food networks. Gradually shift consumer, producer, and stakeholder habits.

Step 5: Develop a new production system grounded in ecological principles, utilizing appropriate technology and involving the community. Continue to refine the model with new innovations and improvements aimed at resource regeneration and sustainable development.

6. Conclusion

In Vietnam, agricultural production serves as the bedrock of national development and remains an economic cornerstone, particularly during crises. However, the developmental journey over the years has unveiled significant challenges for agriculture, including resource scarcity and environmental degradation. Concurrently, rapid urbanization and the growing demand for safe, high-quality agricultural products necessitate new production methods that support sustainable agriculture. Drawing upon a comprehensive review of circular agriculture research and a survey of circular economy models across different strata, this study delineates various groups of circular economy models within Vietnam's agricultural sector and outlines eight defining characteristics of contemporary circular economy models. The study underscores that Vietnam possesses several advantageous factors for the cultivation of circular agriculture models. Nonetheless, the development and transition toward these economic models necessitate alignment with specific conditions, optimizing available resources, and actively engaging relevant stakeholders. Consequently, the advancement of new agricultural economic models can flourish sustainably, making a meaningful contribution to the sustainable development of Vietnam's agriculture.

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