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RESEARCH ARTICLE

Current status and potential of circular agricultural economy for sustainable development in the Mekong Delta, Vietnam

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Abstract

The study evaluates the circular economy's present state and its potential to advance sustainable agricultural development in Vietnam's Mekong Delta. The study has reviewed data, inherited, compared and synthesized the cycle of agricultural models, thereby making suitable recommendations for land use models. The results show that the current models can apply the cycle of models, ensuring efficiency in economic, social and environmentally sustainable development, including items and by-products of the most popular agricultural farming models that people use to generate things like rice, beef, wood, lotus seeds and fruit trees. The by-products of production and harvesting, such as straw, rice straw, rice husk, bones, fish skin, fruit tree sawdust, bagasse etc., are still plentiful but have not yet been fully utilized. Using circular economy in agricultural models can help improve economic and social efficiency and support and effectively exploit resources and human resources. Thereby orienting the cyclic model development, building product linkage chains, efficiently using resources, which can increase models' efficiency and simultaneously protecting the environment sustainability.

Keywords

circular economy; circular products; land use planning

Introduction

According to a study, the green revolution has propelled modern agriculture, mainly dependent on machinery, chemical pesticides and fertilizers (1). It has reduced food quality while posing a severe risk to genetic diversity and environmental quality. Nevertheless, modern agriculture has managed to feed the world's growing population. The Circular Economy is "a recovering system in which resource input and waste, emission and energy leaks are curtailed by slowing, closing, and reducing material and energy loops" (2). A circular economy is a type of economy where product development, manufacturing and service delivery goals. Cyclical systems use reuse procedures, including sharing, repair, refurbishing, remanufacturing and recycling, to close resource loops in the economy. It lessens the resources required to create waste and inputs as well as emissions and environmental degradation.

By prolonging the useful life of products, technology and infrastructure, the circular economy seeks to enhance the productivity of these resources, whether a by-product or a resource recovered from an

operation. All the trash produced by consumer manufacturing operations should be considered raw material for subsequent consumer production processes. Contrasting this approach with the widely used linear economic model (2). Resources only travel in one way in the linear economic model, from resource extraction and production to disposal after consumption. Compared to the linear economy, the circular economy helps to reduce the number of resources to be used. In addition, the amount of waste generated contributes to resource conservation and reduces the impact of environmental pollution (3). However, some of the assumptions used in the circular economy model may be too simplistic and impractical. The definition models ignore the complexity of the existing economic system and its trade-offs in the new economic model. The social dimensions of sustainability are generally discussed in most research articles about the circular economy. Many cases will require additional strategies, such as acquiring new equipment and consuming more energy efficiently. By systematically reviewing the studies that have been done, a team of researchers from the universities of Cambridge and TU Delft (2) showed that there are at least eight types of links between sustainability and the circular economy. Furthermore, the innovative research component at the core of sustainable development based on the circular economy's components must be given special attention (4) to waste resources and create considerable waste.

Circular economy and sustainability

The European Union unveiled its "Close the Loop" action plan to support the circular economy in 2015, which aims to provide future natural resources through natural resources. Their efficiency includes reducing resource use, reusing waste materials and replacing scarce resources as inputs with readily available and renewable resources (5).

Organic waste (such as manure and sludge) must be recovered and put back on the land where the biomass is created to solve the global phosphorus shortage. The recovery of nutrients in a form that can be transported over great distances is accomplished using several approaches in the Netherlands, where there is a significant volume of excess manure. Initially, the mineral struvite, which contains phosphorus, is extracted from the sludge.

According to the studies, the efficient and long-term reuse of resources is a crucial component of the circular economy (6, 7). As a result, using biological (renewable) materials as industrial inputs is an essential part of the circular economy. The limited use of resources opens up various opportunities that could spur competitiveness and pressure on land use. The quantity and quality of soil and how it is managed all affect the potential for increased use of biological resources. Due to the competition between natural resources, fuel, food and fodder production in agriculture, the cycling of minerals and nutrients may be further hampered. Shifting uses may also result in the degradation of natural habitats.

In addition, the European Commission (5) set a goal of zero actual land occupation by 2050. An essential contribution to achieving this goal is regenerating brownfields instead of developing green ones. In cities, beneficial land usage must be maintained by careful planning and developing creative solutions where land might be crucial. The Urban Land Management Strategy Project advocates a broader view of city land. Ingenious spatial planning uses the characteristics of natural soils and groundwater systems to mitigate issues, including soil movement, soil degradation, water storage and fluctuations in groundwater levels.

To achieve its goal of a 50% reduction in the use of non-renewable primary resources (metals, minerals and fossil fuels) by 2030, the Dutch government launched a circular economy program in 2016 (8). Utilizing resources in the current supply chain efficiently can lower resource requirements, replace non-sustainable and endangered fossil fuels with renewable resources that can be produced sustainably, create new production techniques, create new products and adjust to new spatial planning guidelines. Furthermore, it encourages alterations in consumer conduct to maximize the depreciation, transfer and utilization of resources and goods.

Land use planning plays a vital role in socio-economic development, such as balancing the supply of land, optimizing the structure, detailed design and the overall layout of the land. However, in Vietnam, economic activities are still mainly based on the traditional approach of linear economics. Resources only flow in one way in a linear economic model from resource extraction and production to disposal following consumption. It leads to significant resource waste and waste (9). The goal of the circular economy is to maximize the productivity of resources by extending the usable life of infrastructure, machinery and products. Treating all trash from one production process as raw materials for other consumer production activities is essential. Safeguarding the environment, sustainable development and natural resources can be substituted with the circular economy paradigm.

Under Prime Minister's Decision No. 417/QD-TT, which established the Master Action Programme to carry out Government Resolution No. 120/NQ-CP (10). About adapting to climate change through sustainable development, the Mekong Delta is currently working on creating a circular economy through sustainable land use planning. However, in recent years, climate change's limitations, challenges, negative impacts and rising sea levels, such as saltwater intrusion, prolonged hot weather and high tides, have led to flooding in the rainy season. In addition, fluctuating weather conditions significantly affect food security (11, 12).

The study aims to assess the circular economy's current status and potential for sustainable agriculture development in the Mekong Delta, Vietnam, which minimizes the difficulties, makes the most of the necessary measures for a future solid sustainable development and further enhances the value.

Methodology

Along with the advanced research and findings on agricultural circular economy in various regions from journal publications, the study gathers references from various platforms, including the Department of Agricultural and Rural Development of various provinces in the Mekong Delta, Vietnam and the Ministry of Agricultural and Rural Development.

The search criteria of the study include the definition, application, advantages/disadvantages and recommendations for sustainable application and development of agricultural circular economics.

The inclusion criteria of the papers are to recognize and recommend the direction for the application of agricultural economic models for the region in the future for sustainable development.

The study is mainly on sustainable agricultural development and recommendations since the study excluded the application and models from industrial and other unrelated to agricultural production.

The search keywords included agricultural product/ by-product, circular economy, sustainable development and the Mekong Delta.

Current status of agricultural land use in the Mekong Delta

According to a study, based on land adaptability to land use types, the farm production situation of regions in the Mekong Delta differs markedly (12), such as :

In the upstream area: The rice cultivation area is about 170703 ha, suitable for 2 and 3 rice crops. The fruit tree model (Cay An Trai-CAT) has an area of about 2450 ha, an appropriate choice for structural transformation to adapt to climate change. Annual livestock production in the region significantly contributes due to the application of linkages in the farming model with crops to deal with agricultural by-products effectively.

In the center of the delta, planting rice in an area of 171980 ha is the area with the most suitable natural conditions for rice cultivation. The CAT contributes only a small part of the cultivated area but is increasing yearly. Livestock and aquaculture in the region are being developed and given more attention to increase livelihoods.

In the coastal and island ecological sub-regions, the rice cultivation area only accounts for 172907 ha and fruit trees have an area of about 16000 ha, accounting for a small proportion of the region. On the other hand, the saltwater and brackish aquaculture industries in the flood situation developed by climate change help improve people's living standards.

Table 1 shows the current status of agricultural crop structure in the Mekong Delta with many diverse models such as mono, double and triple rice crops, rice shrimp, rice-fish, sugarcane, upland crops, lotus, fruit trees and livestock farming etc. Rice is the primary crop, occupying 3963.7 ha (54.5% of the country) and the average yield is 6.1 tons/ha (Triple and double rice models are the primary models). It was active most of the months. The Mekong Delta has promoted its advantage as the top rice production in the country by contributing more than 90% of Vietnam's rice exports, affirming Vietnam's role and position as the world's top rice exporter (29). However, each locality has different farming patterns, mainly due to natural factors. Besides, the market requires various products and the output is increasing. Therefore, farming models must be developed off-season to develop product diversity.

Table 2 shows the classification of products and by-products of agricultural farming models in the Mekong Delta. The main products, such as rice, meat, wood, lotus seed and fruit, are widely concentrated in production. Besides, many by-products in the production and harvesting process have yet to be effective consumption methods, such as straw, rice husk, shell, fish bone-skin, sawdust, bagasse, leaf-stem-leaf and leaves. In the Mekong Delta, rice and shrimp have been grown in cycles for several years (13). Rice is grown during the rainy season when the water is less salinized. When the water salinity is too high to sustain rice cultivation during the dry season, shrimp are farmed extensively and semi-intensively. The main products of this model are mainly rice and shrimp,

Table 1. Current status of primary agricultural production models in the Mekong Delta

Month Model	1	2	3	4	5	6	7	8	9	10	11	12
Mone rice crop							■	■	■	■	■	■
Double rice crops					■	■	■		■	■	■	■
Triple rice crops	■	■	■		■	■	■		■	■	■	■
Shrimp-Rice	■	■	■	■	■							
Rice-Fish	■	■	■	■	■							
Sugarcane	■			■	■	■	■				■	■
Upland	■	■	■	■	■	■	■	■	■	■	■	■
Lotus			■	■	■	■	■	■	■	■	■	
Fruit trees	■	■	■	■	■	■	■	■	■	■		
Breed	■	■	■	■	■	■	■	■	■	■	■	

(**Source**:nongnghiep.vn)

Table 2. Classification of crop products of agricultural farming models in the Mekong Delta

Crops	Main product	Main By-products	Main Input
Paddy rice	Rice seeds	Straw, straw, rice husk	Water, fertilizers, pesticides
Shrimp	Shrimp meat	Shrimp shell, head	Water, food, medicine
Fish	Fish	Fish bones, fish skin	Water, food, medicine
Forest	Wood	Sawdust	Water, fertilizers, pesticides
Sugarcane	Sugar	Bagasse, sugarcane leaves	Water, fertilizer
Lotus	Lotus seed, lotus root, lotus root	Lotus leaf, lotus stem, lotus flower	Water, mud
Mangosteen	Mangosteen fruit	Stems, leaves	Water, fertilizers, pesticides
Banana	Banana fruit	Stems, leaves	Water, fertilizers, pesticides
Coconut	Coconut fruit	Coconut peat, leaves, coconut body, root,	Water, fertilizer

(**Source**: compilation)

while the by-products of rice are straw, husk, and bran. However, the by-products from shrimp account for a considerable proportion, from 48.5 to 56 % of shrimp weight, depending on the species. It is an abundant source of aquatic by-products, but if appropriately handled or reused, it helps the surrounding environment. Waste and by-products from seafood contain many organic substances, soluble proteins and carbohydrates. In addition, the shells and appendages of shrimp can also increase the amount of waste and oversupply nutrients to neighbouring waters, increasing the organisms' need for oxygen and thereby reducing the concentration of oxygen level in the water (29).

Meanwhile, high input factors such as fertilizers and pesticides (plant protection) affect the profit and efficiency of the model (14). Therefore, it is necessary to have solutions to classify and apply circular economy, such as reusing or developing new products from by-products. In addition, it significantly develops models based on land use planning to take advantage of local strengths, thereby improving the model's efficiencyin the Mekong Delta.

According to a study, rice straws, coffee husks and other agricultural by-products are examples of recycled waste from crop output (15). Among the waste created in 2010 were 61.9 million tons of rice straw, 5.6 million tons of rice husks, 4.8 million tons of maize products and 0.3 million tons of coffee husks. Between 2013 and 2015, waste generated 67600000 tons of rice straw, 11 million tons of rice husks, 4.4 million tons of maize products and 0.7 million tons of coffee husks. In 2020, the total volume of agro-forestry-fishery by-products in our country was over 156.8 million tons, according to the Government Electronic Newspaper (16). Of these, 88.9 million tons were harvested from crops during the processing of agricultural products in the crop industry, accounting for 56.7% of the total; 61.4 million tons were from the livestock industry, representing 39.1% of the total; 5.5 million tons were from the forestry sector, accounting for 3.5%) and approximately 1 million tons were from the fisheries sector (10.6%), 8.6 million tons of rice husk, 3.5 million tons of bagasse, 1.4 million tons of maize cob, 1.3 million tons of cassava tubers and another 2 million tons of miscellaneous materials. Just 56.3% of rice straw applications include making raw feed for grazing cattle, filler for livestock, biological cushions for livestock, cattle mulch and straw mushrooms. A considerable amount (42.8 million tons) is made up of after-harvest crop wastes from rice straw; maize stalks (10 million tones); vegetables and fruits (3.6 million tons); cassava stalks (3.1 million tons); fake peaches (3.1 million tons) and miscellaneous crop residues (6.1 million tons). 8.6 million tons of rice husks, 3.5 million tones of bagasse, 1.4 million tons of corn cobs, 1.3 million tons of cassava husks and an additional 2 million tons are by-products of the processing of agricultural products used in the horticultural industry. In the Mekong Delta, Kien Giang is the province with the most significant agricultural by-products in the region, with 5.7 million tons per year, followed by An Giang with 5.2 million tons. Only 52.2% of crop by-products—such as peanut shells, corn stalks, rice straws, cassava stalks, soybean husks, and firewood—are gathered and put to use. About 56.3% of individuals utilize rice straws for various purposes, such as creating raw feed for grazing cattle, filling animal needs, providing a biological cushion for animals, creating straw mushrooms, mulching plant roots, lining fruits etc.

The circular economy has been used in production for a very long time. The output of products applying the circular economy is being widely developed. However, not all by-product sources have been optimally used. The continued development of circular economic models helps to limit the use of chemical products; farmers restrict the use of chemical fertilizers, pesticides and growth drugs in cultivation and animal husbandry, limiting adverse impacts on the environment and affecting human health (Table 3). According to a study (17), the Mekong Delta provinces are suitable for growing mushroom straw in the field (1 crop/year), growing mushrooms on a trellis and under-covered columns (12 crops/year). The mushroom residue is used to feed earthworms and compost for other crops. In case no solution is applied, straw can be harvested. Besides, stated that straw and rice husks are renewable energy sources with massive potential in our country (18). Rice husk alone can contribute up to 112 x $10^{\wedge 6}$ GJ, equivalent to 2.67 Mtoe. Rice straw has a

Table 3. By-products and applications of cyclic research in agricultural production in the Mekong Delta

By-products	Cyclic products
Rice husk, straw from rice	Rice husk is researched as activated carbon Straw is used as fodder for cattle, Used to grow mushrooms; after growing, mushrooms can be used as bio-compost for plants
Shrimp shell, shrimp head Fishbone	Researched as feed for livestock, feed for aquatic animals, Make fertilizer for plants
Sawdust	Made into charcoal or fertilizer, Used to make paper, Used to combine as a pressing device
Bagasse, sugarcane leaves	Sugarcane leaves are used as compost and animal feed Bagasse is used to make recyclables, compostable foam boxes, decorative items
Corn cores, corn stalks	Used as animal feed Make bio-compost fertilizer
Pineapple leaves, pineapple peel	Used as a bio-compost Researched as a bio-textile
Banana tree trunk	Used as animal feed Used to compost for soil bio Used to make recycled products such as paper, textiles

(**Source:** compilation)

theoretical energy potential of 447.88 x 10^6 GJ, equivalent to 10.7 Mtoe. The total potential theoretical energy from rice by-products is about 13.34 Mtoe. Several products are processed from pineapple by-products (19), the processing waste from the pineapple industry, such as peel, core, pomace and crown, is abundant in different bioactive chemicals. Most of the time, the by-products have higher concentrations of beneficial substances than the final product, which makes them more meaningful for nutrition and medicine. Pineapple wastes have been studied for their potential as an inexpensive substrate for the extraction of enzymes (bromelain, pectinase, xylanase and cellulase) and for synthesizing organic acids, phenolic antioxidants and dietary fiber. In addition, the high cellulose content of pineapple peels and debris can be used to make biodegradable packaging, bio adsorbent and cellulose nanocrystals. It can be used in the food, textile and polymer sectors (20). In the Mekong Delta, making pineapple leaves – A form of agricultural waste used in spinning and weaving fabrics not only overcomes environmental problems but also brings economic efficiency (21).

Ecological zones' primary and secondary resources and by-products are diverse and abundant. Therefore, there is potential for efficient exploitation of results or by-products for processing or processing into products that bring value and efficiency to the development of models.

Application Models of Circular Economy in the Mekong Delta

Garden-Pond-Cage-Biogas Model (VACB-Vuon-Ao-Chuong -Biogas)

To promote a circular economy in agricultural land use planning, such as the proposal to disarm the application of the "Garden-Pond-Cage" (VAC) model. The VAC concept in rural and connected agricultural areas. The continuity between cultivation and husbandry activities in gardens, ponds and stables at households has existed for hundreds of years. Under the VAC model, animal waste is used as agricultural fertilizer, assimilated by plants and as a food source for aquaculture and cattle. Water from the pond will be used to irrigate and care for plants.

Breeding stables model: raising pigs, chickens and dairy cows on a scale to help increase productivity and promote the breed's strength towards investment in science and technology to meet current consumer demand. The model of Pig-Fish has the highest fish yield and production; besides, it can reduce the environmental contamination due to pig raising (Table 4).

Table 4. The scale of livestock and poultry farming (Sources: The Government, 2020)

	The scale of liver stock	The regulated scales
1	Large-scale livestock farming	From 300 livestock units or more
2	Medium-scale livestock farming	From 30 to less than 300 livestock units
3	Small-scale livestock farming	From 10 to less than 30 livestock units
4	Farming households	Less than 10 livestock units

Garden model: vegetable garden, fruit orchard applied in provinces with fresh water sources, high productivity, high profit, low cost, meeting the consumption needs of domestic and international economic markets (Fig. 1).

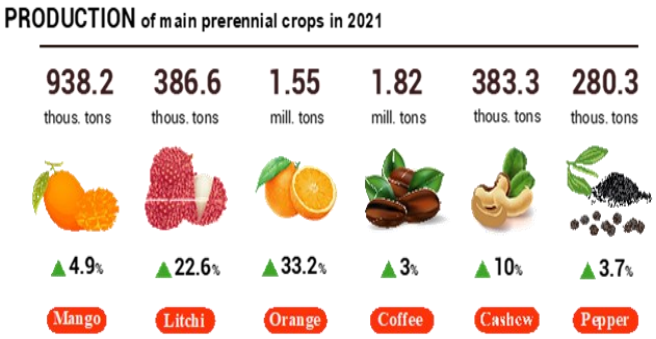


Figure 1: The primary perennial production of Vietnam in 2021

Garden-Pond-Cage - Biogas (VACB) model was born based on the traditional VAC model to solve shortcomings and bring more practical benefits (Fig. 2). With the new development model, agricultural production activities have changed markedly. The VACB model improves production efficiency and is environmentally friendly. They combined the construction of a biogas cellar with a garden pond barn (22). It is an effective solution to the problem of waste in livestock and by-products of small and medium-sized plants to increase economic efficiency and save household fuel.

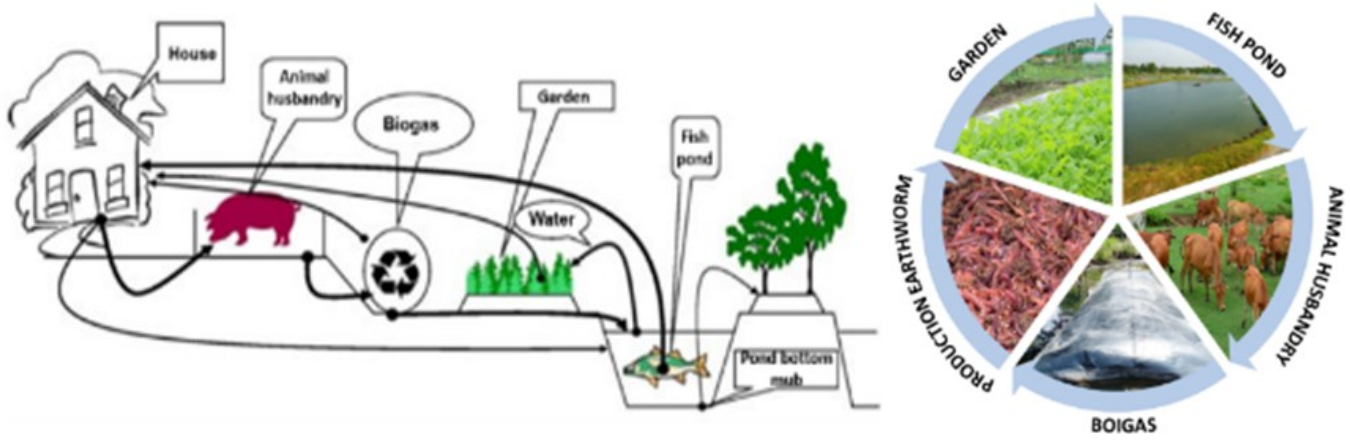


Figure 2: VAC and VACB models

Figure 3: Crops-aquaculture model

Crops-aquaculture model

Crops such as rice and aquatic products such as rice-fish, rice-shrimp, or rice-Integrated-shrimp models are widely applied in the Mekong Delta provinces. In this model, the wastes of fish or shrimp will be used as additional nutritional fertilizer for rice. Rice by-products will be used as food for fish and shrimp (Fig. 3). Create more economic resources parallel formal rice cultivation, reducing environmental pollution problems. The complexity of crop structure in rice production in the Mekong Delta has different characteristics in scale, sowing date, rice variety, farming system and seasonal structure in different fields and regions. Aquaculture is considered a breakthrough direction to promote strengths in each areaand multiply aquaculture models to bring high efficiency and stable economic sources.

The model is applied in most provinces in the Mekong Delta, divided into 3 groups: in the upper delta provinces, including An Giang, Dong Thap, Long An and part of Kien Giang, intensive or semi-intensive farming is applied, advanced technology to save water or raise freshwater prawn-rice intercropping. The provinces Can Tho, Hau Giang, Vinh Long and part of Tien Giang give priority to the development of giant freshwater shrimp - intercropping rice, giant freshwater shrimp - garden ditch; coastal provinces including Bac Lieu, Ca Mau, Tra Vinh, Soc Trang, bordering brackish, fresh water, giving priority to the development of giant freshwater prawn farming - crop rotation (23).

An alternate rice-shrimp farming strategy has been widely used and successful in the coastal regions of the Mekong Delta.The quantity of rice-fish integrated is 0.43-0.8 ton/ha/crop and prawn-rice integrated is 0.35-0.50 ton/ha/crop (Table 5).

Table 5. Production of various integrated freshwater farming systems

Farming systems	Yield(ton/ha/crop)
Rice-fish integrated	0.43-0.8
Pig-fish integrated	3.88-7.59
Fish-rice alternative	0.6-0.9
Prawn-rice alternative	0.75-0.8
Prawn-rice integrated	0.35-0.50

(Source: Wilder and Phuong, 2002)

Additionally, mangrove forestry and agriculture have been growing in the Mekong Delta, particularly in the Ca Mau Province in southern Vietnam. This technique aims to reduce poverty in coastal areas using shrimp farming to encourage reforestation and slow down the degradation of mangroves (24).

Model from coconut tree

The Mekong Delta's provinces are home to many coconut trees, particularly in Ben Tre, Tra Vinh, Tien Giang and Vinh Long (25). Coconut is a tree that brings high economic efficiency from the main product, such as coconut, to by-products, such as coconut body, coir, coconut shell and coconut chips. From the raw material of copra, many factories in the province have applied technology, modern machinery and equipment to squeeze coconut milk as raw materials for producing coconut milk or coconut oil. As a

result, it is widely used in food processing and serving the trade, tourism and service industries. For example, after using coconut milk to make coconut candy, the copra by-product is combined with other ingredients to create coconut flower cake products. In addition, it has many natural flavors and unique brand-shaping characteristics for high export value (26).

Coconut trees and coconut products are also used in other fields, basically meeting the circular economy model, such as the construction industry, manufacturing industry, cosmetics, recovery and recycling. Coconut products for the construction industry are diverse such as pillars, wooden beams, wooden planks, floor boards, partitions, soundproofing materials and wooden coconut houses. Products made from coconut wood and coconut shells are very diverse, from furniture and kitchen products to towels and paper that can replace products that can be substituted and produced from plastic materials and nylon bags (Fig. 4). According to a study, coconut shell pieces are used as a planting medium to help plants maintain moisture and avoid fungal growth (27). Coir or fibers from coconut shells are versatile and may be utilized in numerous applications. Chipboards, doormats, brushes, twine, biodegradable packaging materials and even mattresses and floor tiles are made from coir. Additionally, coconuts have been utilized to manufacture composites from coconut shells that have been used to make living wall plants, electric car battery boxes and trunk liners for cars. This material is lighter and performs better than synthetic fibers; it is also more robust and rigid.

The solution to forming a circular economic model in the coconut industry must synchronize awareness, resources and policies, especially linkage. Linking "4 houses" will accelerate the process of researching solutions for recycling, product reuse and creating new products while promoting sustainable development, gradually improving the role and position of the province's coconut industry in the direction of green growth.

The application of the circular economy to the production and exploitation of the people has taken advantage of all that coconut trees have to create economic sources, jobs and stable industries for social development.

In addition, according to a study, coconut trees in Ben Tre province can absorb a significant amount of CO_2 (75.24 tons of CO_2/ha and in the low-growing group of coconut varieties, 69.92 tons of CO_2/ha) (28). The older the coconut tree's ability to absorb CO_2, the greater its ability to absorb carbon, significantly mitigating the adverse effects of climate change and the anomaly of natural disasters.

Product model from rice by-products

According to are port, the Mekong Delta is a large rice producer in the country, so the amount of straw is also considerable, estimated at 38 million tons/year and has the highest rice straw density, about 944770 tons/km^2 (29) (Table 6). People often burn it in the field, causing the soil at the burning site to be hot, affecting the organisms in the soil. Some of the mechanical components of the soil are changed, causing the soil to degrade. As a result, nutrient sources are gradually lost and crop yields decrease.

A	Integrated coconut farming.
B	Fresh coconut water, the nucleus of coconut tree trunks used as food or drink.
C	Copra is processed into jams and candies.
D	Dried coconut meat processed into oil.
E	The trunk of a coconut tree makes houses, tables, and chairs.
F	Dipper and trunk coconut make furniture and handicrafts.
G	Coconut fiber is used for rope and horticulture for filler in fertilizers.
H	Small coconut trees are made into bonsai.

Fig. 4: Model from coconut tree

Table 6. Production of rice and straw in ecological regions of Vietnam

No	Region	Rice production (1,000 dry tons)	Amount of rice straw (1,000 dry tons)	Rice straw density (1,000 dry tons / km^2)
1	Red River Delta	6.698.0	10.273	487.80
2	Northern Midlands and Mountains	33,275.8	5.024	52.73
3	North Central and Central Coast	6,600.7	10.123	105.63
4	Highlands	1,162.8	1,783	32.64
5	South East	1.345.8	2.064	87.49
6	Mekong Delta	24.993.0	38.331	944.77
7	**Total**	**44,076.1**	**67,599**	**204.24**

(**Source:** The General Statistic Office, 2022)

After rice is harvested, rice straw is generally burned and considered waste (15). Up to 98.2% of farmers in the Mekong Delta burn rice straw after the winter-spring crop, 89.7% after the summer-autumn crop and 54.1% after the autumn-winter crop (30). The estimated rice straw production in the region is 18-19 million tons/year (31). Burning straw is a widespread practice to eliminate post-harvest debris because it is a cheap and quick approach to preparing the soil for the following crop. On the other hand, it immediately causes issues with air pollution and human health. Burning rubbish releases a variety of gases, including aerosols, atmospheric methane hydrocarbons (NMHCs), sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon dioxide (CO_2), carbon monoxide (CO), black carbon (BC), organic carbon (OC), CH_4, volatile organic compounds (VOCs) and ozone (O_3). As a result, global atmospheric chemistry and climate may be impacted (32). On an average, burning straw directly in the fields in the Mekong Delta will emit 2.97 million tons/year of CO_2, CO 34.7 - 113.2 thousand tons/year and 56 g of dust (fly and ash) (33). CH_4 emission from burning rice straw is about 1.0 - 3.9 thousand tons/year (34). CH_4 emissions from using rice straw as fodder are about 15000 g (10000–20000 g) CH_4 per ton of straw (33). Assuming that 50% of rice straw is burned in Vietnam, it will emit about 100 million tons of carbon dioxide annually (35). Farmers who do not utilize straw for animal feed and those who wish to shorten the time between rice crops are particularly fond of burning.

Several farmers collected and repurposed straw on their farms rather than burning it. Straw, for instance, can occasionally be used to cultivate mushrooms, grow vegetables and feed animals. Black coal is occasionally produced from coffee and husks for industrial and domestic usage. Animal feed is produced from corn by-products (fermented and fresh feed). In 2015, several publications proposed an alternate use for the straw to boost its selling price and the availability of machinery to gather and roll it. Unfortunately, there is no published official data or statistics on this. In the Mekong Delta, burning straw during the winter and spring continues to be the primary disposal technique.

To overcome the waste of economic resources and reduce environmental pollution, the model of reusing rice straw to grow mushrooms, make fertilizer, make charcoal and activated carbon from rice husks (Fig. 5).

Rice and rice husks are crushed to become mixed humus and sieved to remove impurities. After 48 h of incubation, they are transferred to a drying stage and pressed into charcoal (36).

In addition to taking straw to produce fertilizer, rice straw is also used as an input source for mushroom growing. In particular, they create jobs and generate income for farmers' families. Mushroom farming materials are available in agricultural wastes such as straw, rice straw, cotton waste, saw dust and corn cob. Most of the farmers can participate in mushroom cultivation. However, according to one report, mushroom growing techniques still have many things to improve (in terms of straw harvesting, sowing fungus, using pesticides, harvesting, preserving etc.), transportation, preliminary processing, processing) to advance to large-scale production of straw mushrooms and bring more added value (37).

Recycling models of agricultural by-products for soil improvement using rice straws and rice husks as bio-fertilizers instead of chemical fertilizers. Biochar from rice husks can improve soil fertility, stimulate plant growth and help improve soil nutrients. In addition, to limit environmental pollution when harvesting rice, the remaining rice products, such as rice grains and straw will be nutritious food for shrimp.

In addition, straw is also used to process microbial organic fertilizer. Organic fertilizer from rice straw will help limit and prevent yellow leaf disease. The physiological delay allows the rice to harden and develop balanced, concentrated tillering, reducing the rate of harmful pests and diseases. Besides, organic fertilizer from rice straw produces high results on crops such as corn, potatoes and vegetables (38). In addition to the post-harvest treatment of straw and straw making it into organic fertilizer is also of practical significance in protecting the environment and reducing traffic accidents caused by burning straws. It is a condition for building clean and sustainable agricultural production.

Model of sugarcane production and recycling of by-products

The Mekong Delta is an area with favorable climatic conditions for the development and growth of sugarcane. As of 2016, the area under sugarcane cultivation in the whole region is about 41890 ha, the average sugarcane

A	Growing rice.
B	Rice is the main product, and the by-products are bran and husk.
C	Rice stem, germ, and bran layers use animal diets.
D	Husk charcoal.
E	Rice bodies make rice straws, brooms, and others.
F	Straw is used in growing mushrooms
G	The straw is the compost as organic fertilizer.

Figure 5: Product model from rice by-products

output is 3.2 million tons and the sugar level is 9 CCS. The sugarcane growing area is mainly concentrated in Long An, Hau Giang, Soc Trang, Tra Vinh, Bac Lieu and Ca Mau. Hau Giang is the province with the most significant area and production of sugarcane (39).

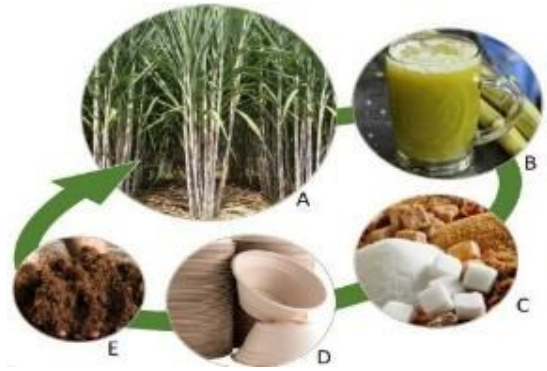
According to the Ministry of Industry and Trade (2016), the results of aggregate statistics of sugar mills across the country show that the amount of by-products after sugar processing is considerable, including 3 main types: bagasse and sugarcane bagasse. About 2.27-4.67 million tons (accounting for 25-30% of pressed sugar cane volume); molasses 347000-690400 tons (4-4.5%); Microbiological products account for 3-4% of packed sugarcane weight. Sugarcane was grown in several districts in the Mekong Delta, most concentrated in Phung Hiep district, Hau Giang province, in 2021, with an area of 4725 ha and an output of 478700 tons. After that, however, there is a tendency to switch to other crops (40).

In previous years, the by-products of sugar production were inefficient in utilization. For example, up to 80% of the bagasse after pressing is mainly used for boiler combustion and 20% for plywood, molasses is used to produce alcohol or to process animal feed (Fig.6). Unused ash and sludge are discarded, causing waste and environmental pollution. However, in the Mekong Delta, organic fertilizer composted from sugarcane residue is applied to improve Al toxicity and nutrition in the acid-sulfate soils (41).

Model of processing aquatic by-products

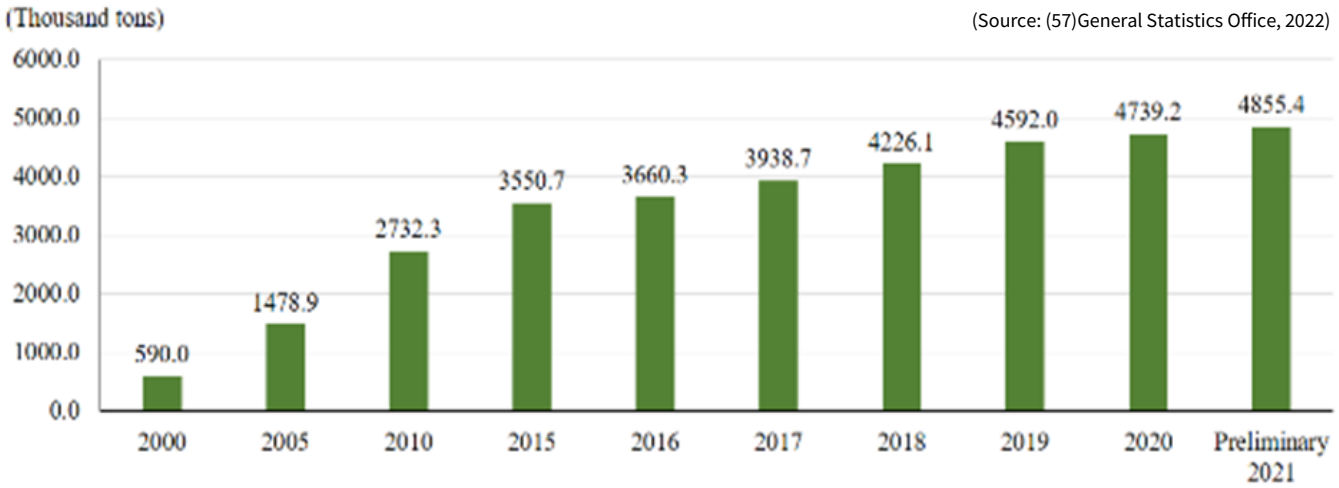
According to statistics from 2000-2021, seafood production has increased. This is mainly due to the increased production of critical products such as pangasius and vannamei shrimps (Fig. 7). Aquaculture helps people improve their lives in responding to climate change. Climate change causes floods, droughts and saltwater intrusion, which has changed the aquaculture industry and the location and area of aquaculture following climate change conditions (42). Processing by-products of the fishery industry brings high efficiency, but if the source of aquatic by-products is fully exploited, the efficiency can be increased many times. That is a significant source of profit, so the models of processing by-products of the seafood industry have been put into production.

Vietnam is one of the major exporters of shrimp worldwide. The Mekong Delta is one of the leading suppliers of this seafood source. At the same time,most exported shrimp are processed in the form of shelled, head accounting for 50-60% of the input, which, if discharged into the environment, causes heavy pollution. Therefore, research on shrimp products in the food industry, such as shrimp salt production, shrimp roe-eggs and animal feed production, is also proposed as a source of economic benefit.



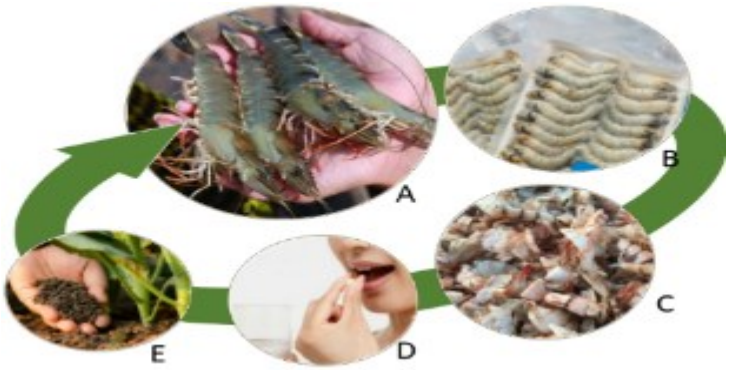
A	Sugarcane
B	Fresh Sugarcane juice is squeezed.
C	Sugar of cane and molasses.
D	These eco-friendly forks, knives, and spoons are made with residual sugarcane fiber (bagasse).
E	Residual sugarcane is used as organic fertilizer.

Figure 6: Model of sugarcane production and recycling of by-products



(Source: (57)General Statistics Office, 2022)

Figure 7: Aquaculture production in the period 2000-2021



A	Shrimp from the farming pond
B	Shrimp meat is processed and preserved.
C	Shrimp shells for animal feed.
D	Shrimp shells to make glucosamine sulfate or collagen drugs.
E	The rest, as the sludge of wastewater and by-products, becomes fertilizer.

Figure 8: Shrimp by-product processing

Shrimp by-products are organic products that serve cultivation very well. Most importantly, it is possible to process waste from farmed shrimp, such as shrimp manure and shrimp shells, into fertilizer for plants to ensure environmental sanitation and bring economic efficiency to the people (Fig. 8). In 2020, shrimp by-products will reach about 291375 - 374625 tons. Due to the limited technology of aquatic and seafood treatment, only about 33% is used to produce products such as fertilizers and animal feed. About 7% is used to develop high-value strains—the high-added-value such as food and medicine.

Meanwhile, shrimp by-products have many nutrients such as protein, chitin, minerals, fat etc. If the nutrients are extracted optimally and their activities are preserved, many new products will be produced and applied to many industries. Realizing the potential of by-product treatment in the processing industry chain, many companies have researched and developed specializing in by-product processing. As a result, achieve recovery efficiency from 50% to a minimum of 80% serving the pharmaceutical, food and agricultural industries (43).

The pond bottom sludge and sewage sludge are used to grow vegetables (44). In addition, it will be recovered and processed by biotechnology through black soldier flies to produce cocoons and larvae. Larval waste makes protein powder and oil to process animal feed, chitin and organic fertilizer (45). When completed, this model promises to bring economic and environmental efficiency by reusing and recycling waste streams.

Only 30% of the pangasius' weight in the body was used in 2019, while the remaining 70% in the head, skin and bones were by-products. In 2019, Vietnam exported 1.3 million tons of pangasius. An average of 5-8 tons of fish skin are produced by each pangasius facility, much of which is discarded. Yet collagen and 69% protein make up to 50% of the dry matter of pangasius skin (46). While the global collagen market demand is high, many studies on producing collagen and gelatin from fish skin aim to reduce the environmental pollution they release. Additionally, the investigated approach yields extraction efficiencies of up to 84.81%, preventing input material waste and contributing to an increase in the value of pangasius in general and the goods made from it in particular (43).

Model of products from wood

According to the General Statistics Office, during the period (2014-2020),The development of the wood industry in Vietnam and the Mekong Delta region has prospered. Provinces with large timber production include Ca Mau, Long An, Dong Thap and Tien Giang (Fig. 9).

Sawdust by-products of trees bring high value when exploited as burning pellets, bio-fertilizers, barn pads or pressed wood, bringing high economic resources. Wood pellets are renewable materials from sawdust and wood chips (47). This product is expected to replace fossil fuels to provide energy for domestic activities and industrial production. Wood pellets have the advantages of easy

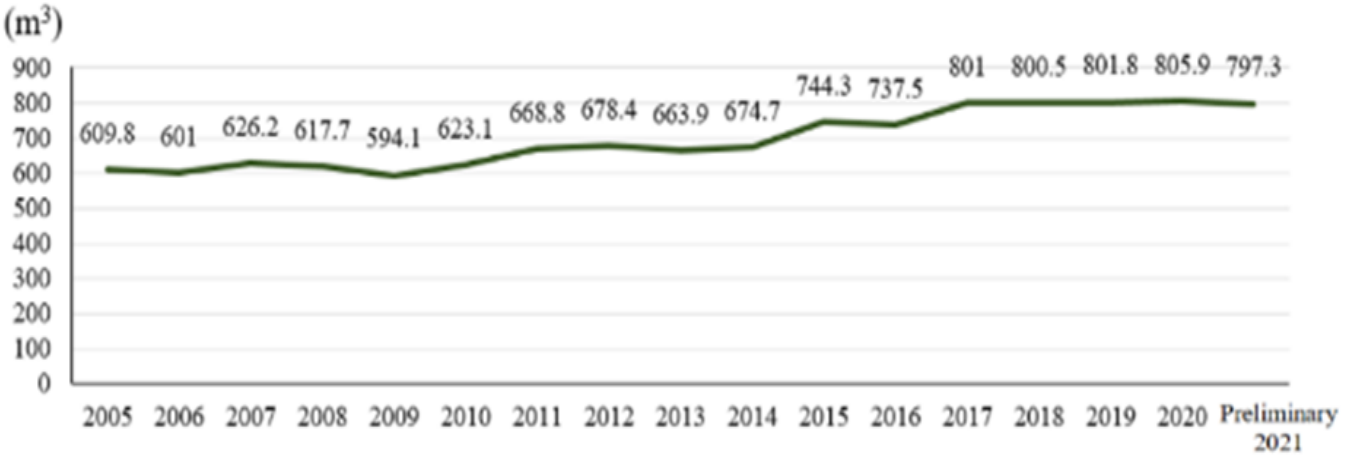


Figure 9: Timber production in the Mekong Delta in the period 2005-2021 (Source: GSO)

transportation, high energy efficiency, low cost and environmental friendliness. In addition, wood chips are also used to produce plywood, also known as chipboard or Okal board. After being collected, wood chips will be crushed and mixed with binders and other ingredients. Large planks will be created by pressing under high temperature and pressure conditions (48). Pressed wood chips are widely used in interior decoration, producing shelves, tables and chairs.

Model of production of corn by-products

Maize is one of the crops that can replace rice production in the Mekong Delta in the context of increasing climate change, leading to dry weather, lack of water to irrigate fields and low yields of rice cultivation. The solution to switch to upland crops such as corn and green beans to serve livestock development and many other purposes helps farmers increase income in the context of climate change.

Corn is easy to grow and has a higher economic value than other food crops such as rice, potatoes and cassava. This strength makes corn plants gradually become famous and popular among people. It strongly impacts each producer's psychology that the crop must bring the most benefits and the lowest risks. The average yield of maize is 10-12 tons of corn kernels/ha. In some households, it is 14.2 tons/ha. After deducting costs, each ha of corn earns a profit of 24 million VND, nearly 3 times higher than rice (49). High economic efficiency also helps people's lives to be more stable.

In addition, corn cob is also used to grind to make activated carbon. Accordingly, after being collected, the cob is crushed and mixed with some ingredients to form briquettes. The cob is crushed and then put into the press to turn it into cob firewood (Fig. 10).

The by-product model from the banana tree

The Banana tree is a crop suitable for Vietnam's humid tropical monsoon climate. Bananas are easy to grow and less susceptible to pests and diseases, so many farmers do business with them. The selected banana varieties are mainly pink pepper and western, with good quality, large chambers and beautiful fruit for high efficiency. However, especially at the time of Tet, the demand to buy bananas to burn incense increases. Hence, the price of bananas is higher than on regular days, from 20000 to 25000 VND/bag, profiting the average farmer 20 million VND/bag (50).

A	Corn can be intercropped.
B	Corn processed into foods or built into flour.
C	Corn silk to make tea.
D	Corn silk makes tea
E	Cornstalks are used to fill a forage gap or bedding
F	The rest is used as fertilizer.

Figure 10: Production model of corn by-products

A	Banana tree
B	Banana
C	Making cakes and jams from bananas.
D	Leaf banana use wrapping as a food preservation method.
E	Young banana stems are used as food for humans.
F	Banana stems that are making feed.
G	Banana tree bark for weaving.
H	The remaining banana trees are compost fertilizers.

Figure 11: The by-product model from the banana tree

Using banana stems as a green source of raw materials to create products to replace disposable plastic utensils (straws, masks, medical protective gear) dramatically protects the living environment (Fig. 11). The fruit and leaves of the banana tree are still harvested as traditionally and the stem, through the processing process, will obtain silk fibers used for knitting handicrafts. In squeezing and preliminarily processing banana fiber, biological fermentation will receive banana juice, yielding an organic fertilizer. This fertilizer contains many nutrients, enzymes and minerals used to irrigate flowers and plants (such as orchids and roses) (51), helping reduce pressure on using other chemical fertilizers. Plants can easily absorb this fertilizer through the leaves, which is beneficial for plants that cannot absorb some nutrients through the roots. The foliar application allows for correcting mid-season nutrient deficiencies and provides additional nutrients to the soil. The banana residue generated during processing will be dried, packaged and sold as a substrate for growing mushrooms, orchids and sprouts due to its ability to retain moisture very well compared to sawdust, store nutrients and have high-resolution density. Medium water retention helps the plant not to be waterlogged. The paper factory supplies the outer skin of the banana stem and dried banana tuber (52).

Model by-products from durian

Durian belongs to the group of fruit trees, suitable for growing in areas that are not flooded, not affected by salinity and for soils that are not contaminated with alum or mildly contaminated. Moreover, durian is one of the agricultural products with high and stable economic efficiency less affected by the irrigation system (53).

Durian is a trendy fruit, but few people consider using durian skin - the part that accounts for more than half of the fruit's weight. A team of researchers developed the technology to make antibacterial bandages from durian peels at Singapore's Nanyang Technological University (NTU) by extracting cellulose from the fruit's thick, green skin. The ice made from durian peel is beneficial for the environment and health. Unlike existing patches, the new dressings contain hydrogels, which can protect the wound and retain moisture (54).

In addition, durian skin is researched and produced into activated carbon, preparing flavor for the food industry or in textile and dyeing waste treatment, bringing economic efficiency, low cost and environmental protection (55).

Solutions for developing models in land use planning

The following land use planning solutions are required to establish the circular economic models for agriculture:

Limit the use of chemicals that can affect the quality of recirculating products.

Limit complex or non-biodegradable materials such as plastic bags, plastic bottles etc. use biodegradable products from recycled agricultural/industrial by-products and by-products.

Utilize biological resources (wood, crops or fibers) to generate energy (biofuels) and goods (food, paper, bags and bio-based products).

Ensure credit policies and support loans for households and businesses to meet production investment needs. They were stabilizing people's livelihoods by providing vocational training and diversifying occupations and income for people from exploiting agricultural/industrial by-products and by-products.

Changing cognitive thinking towards being environmentally friendly, regularly updating news, applying scientific and technical advances to production and minimizing waste of limited resources.

Mekong Delta's planning proposal is based on the land's potential to adapt to the circumstances of each locality. Therefore, it should select a suitable circular model for planning land use based on local benefits.

They were built, organized and developed production and development linkages to ensure linkages to solve outputs for circular agricultural/industrial products.

The above requirements should be considered adaptation requirements for developing promising land-use planning models.

Conclusion

The circular economy plays a significant role in land use planning. Although the circular economy has been and is being developed in the Mekong Delta, the current land use models have not been used effectively to exploit agricultural/industrial by-products. The results of the synthesis of sources in the region include products and derivatives of the leading agricultural farming models widely produced by people, such as rice, meat, wood, lotus seeds and fruit trees. The by-products in the production and harvesting process are still a lot but have not been exploited, such as straw, rice straw, rice husk, bones, fish skin, fruit tree sawdust, bagasse etc. Therefore, there is a need for solutions to classify, apply circular economy and reuse or develop new products from by-products. They can increase the region's overall economic efficiency by utilizing and capitalizing on the area's advantages.

It is essential to have ways for classifying, utilizing weekly economics and significantly building land-use planning models to locate and exploit each location. Furthermore, in land use planning and resource exploitation, it is necessary to have orientations and solutions for sustainable land use, improving economic efficiency and environmental protection through by-products, responding to climate conditions and ensuring the sustainable and reasonable development of natural resources.

Authors' contributions

Vo Quang Minh, VQM carried out the studies, participated in the outline, and drafted the manuscript.

VQM participated in the design of the study and performed the statistical analysis.

Pham Thanh Vu, **PTV** participated in the design of the study and performed the statistical analysis.

Nguyen Minh Thuy, **NMT** conceived of the study and participated in its design and coordination.

Huynh Thi Thu Huong, **HTH** carried out the experiments.

Pham Cam Dang, **PCD** participated in the alignment.

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Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

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