CIRCULAR ECONOMY APPROACH IN AGRICULTURAL WASTES MANAGEMENT: A CASE STUDY IN MINH CHAU COMMUNE, BA VI, HA NOI

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ABSTRACT

The agricultural wastes including crop residues and livestock manures contains high contents of organic matter and nutrients still discharged into environment. This research proposed the circular economy approach in waste reutilization as its interaction between crop and livestock systems. The waste audit technique was applied to evaluate feeding and discharge during the life cycle of cow. The results showed a diverse component of agricultural production with king grass, banana, and maize. The main livestock production included cows, pigs; and poultries. The total waste from livestock generated about 114.2 tons of waste (manure) per day. Manures were used for biogas (35%), fertilizer directly for plant (61.06%), earthworm feedstuff (3.06%), and fish (0.01%). The king grass, banana and maize were used as main feeding stuffs (92% of the total amount) for cow. King grass yields 200-250 tons/ha representing highest amount of nitrogen source roughly 8.09 tons/day (84.5%) in feeding intake by cow. Minh Chau commune shows a potential for applying a closing loop of waste-resources within the crop-livestock production.

TIẾP CẬN KINH TẾ TUẦN HOÀN TRONG QUẢN LÝ CHẤT THẢI NÔNG NGHIỆP: TRƯỜNG HỢP NGHIÊN CỨU TẠI XÃ MINH CHÂU, BA VÌ, HÀ NỘI

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TỪ KHÓA

Kinh tế tuần hoàn
Phát triển bền vững
Không phát thải
Môi trường bền vững
Tái sử dụng chất thải

TÓM TẮT

Chất thải nông nghiệp gồm phụ phẩm trồng trọt và phân thải chăn nuôi chứa hàm lượng cao chất hữu cơ và dinh dưỡng vẫn được thải bỏ ra môi trường. Nghiên cứu này áp dụng tiếp cận kinh tế tuần hoàn trong tái sử dụng chất thải của hệ thống trồng trọt và chăn nuôi. Kỹ thuật kiểm toán chất thải áp dụng cho qui trình chăn nuôi bò từ đầu vào và đầu ra trong cả quy trình chăn nuôi. Kết quả cho thấy hoạt động trồng trọt khá đa dạng với các loại cây có năng suất cao như cỏ voi, chuối và ngô. Chăn nuôi chủ yếu tập trung vào phát triển đàn bò, lợn và gia cầm. Hoạt động chăn nuôi đóng góp tới 114,2 tấn chất thải (phân) mỗi ngày. Phân thải từ gia súc chủ yếu được sử dụng làm khí sinh học (35% tổng lượng phân), bón trực tiếp cho cây trồng (61,06%), thức ăn cho trùn quế (3,06%) và cho cá (0,01%). Thức ăn thô như cỏ voi, chuối và ngô được sử dụng làm nguồn cung chính với 92% tổng lượng. Cỏ voi có năng suất 200-250 tấn/ha là nguồn cung cấp nitơ cao nhất, khoảng 8,09 tấn/ngày (84,5%). Xã Minh Châu cho thấy một tiềm năng cho việc áp dụng vòng tuần hoàn kín đối với tương tác chất thải – tài nguyên trong hệ thống sản xuất trồng trọt – chăn nuôi.

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1. Introduction

Livestock sector and crops are important components of agriculture and contributes significantly to country's economy. However, the number of cattle and poultry that continues increasing every year has posed big problem for waste collection and disposal activities [1], [2]. In contrast, agricultural waste has shown its beneficial uses as an energy source, chemical recycling agent, and chemical adsorbent [3], [4]. In recent years, a number of animal waste treatment models aimed at recovering resources from elimination process have been invested and obtained initial results, application of recirculation economy, agriculture zero waste. The concept of circular economy bases on a closing loop production model, minimizing the amount of waste discharged from the output of one process as input to the other, bringing about economic and environmental benefits.

Circular economy and the Sustainable Development Goals (SDGs) have a close relationship in many aspects. Circular economy practices directly contribute to achieve 21 targets of SDGs and indirectly to an additional 28 targets [5]. It was reported that targets in SDG6 (Clean water and sanitation), SDG7 (affordable and clean energy), SDG8 (Decent work and economic growth), SDG12 (Responsible consumption and production), and SDG15 (Life on land) have the strongest relationships with the circular economy practices to be achieved by 2030 [5], [6]. The design philosophy behind circular economy concept is to consider all materials involved in industrial and commercial processes to be nutrients, in which two main categories are the actors: (1) technical and (2) biological. Thus, technical and biological process could contribute as main components of circular economy paradigm [7], [8]. The application of circular economy has been initiated an undergone different stages such as matured, progressive, and initiated CE-driven societies. Recently, Hidalgo et al. [9] proposed the use of a waste management procedure based on the technical development and practical implementation of a “Multi-Waste Plant” concept to reduce the costs related to waste treatment processes, thus optimizing its management, from the ecological viewpoint, as well as from the money related perspective. Antoniou et al. [10] revealed that coupling anaerobic digestion with gasification for enhanced energy and material recovery contributed to circular economy options of mixed agricultural wastes management. Masullo [11] indicated using anaerobic digestion followed by composting enriched with earthworms to produce bio-methane and humus. In China, Xu et al. [12] demonstrated that the net present value (NPV) of the project was 8.85 million dollar, and the internal rate of return (IRR) was 36% and the environmental benefits of the reduction of greenhouse gas emission was 1.54 million dollars/year. Vietnam has paid great attention on circular economy as initiated CE-driven society [13].

Minh Chau commune is a unique commune located within the inning land of the Red river. The economic development is strongly based on livestock and crop production. The amount of waste from animal husbandry is estimated at 114.2 tons per day. A large number of animal husbandry owners have actively controlled waste through reutilizing manure, urine, and water through biogas system or sources of plants. However, many households have not yet controlled waste discharge and discharged directly into the environment, flowing into the Red River. It is necessary to control the amount of waste from animal husbandry activities and water environment protection as many parts of the country experiencing similar situations. In the context of circular economy, feces and water can be used as sources for nutrient. Therefore, this research is to investigate the reused potential of livestock waste for plants as an involvement of closing loop to reduce wastes to environment.

2. Research methodology

2.1. Study site and approach

Minh Chau commune was selected as study site because it has special geographical characteristic. It is located on the accumulated land within the Red river without surrounding connection with others (Figure 1). Minh Chau is located about 5 km from the center of Ba Vi district, with a population of 6,517 people. Crop cultivation and animal husbandry are mainly contributed to household income. In this research, the circular economy approach was emphasized on the waste recycle as outputs from livestock production were reused as input for crops and plant cultivation. The recycles were considered in terms of carbon, nitrogen and phosphorus recovery toward a closing loop for agricultural-livestock systems.

Figure 1. *Location of Minh Chau commune*

2.2 Data collection

2.2.1 Secondary data collection

Overall assessment of situation animal husbandry and cultivation: articles from scientific journals, data published in recent statistical yearbook; the most up-to-date reports on natural characteristics, socio-economic development situation of Minh Chau commune and relevant information were collected from the People's Committee of Minh Chau commune.

2.2.2 Primary data collection

Structure questionnaire interview

Questionnaires were used to collect primary data about production situation, husbandry process, forms of waste management and treatment by farms. The households have quite similar characteristics in terms of culture, experience and natural and social conditions, so in this study, information-gathering interviews were conducted with 60 households raising cows.

Waste audit method

Waste audit was conducted in 3 aspects: 1) Nutrition management (type of food, protein content, dietary fiber), water, energy and other components; 2) Waste management through forms of management such as use as fertilizer, worm farming, food for fish, direct application to crops, other activities and release to the environment; 3) Waste discharge. The waste audit techniques were applied to the cow raising processes of which different growing stages were measured [7].

2.2.3 Data analysis

Secondary data on cropland use was summarized and analyzed. Primary data were statistically analyzed as mean, standard deviation.

3. Results and discussions

3.1 Crop-livestock system in Minh Chau commune

3.1.1 Crop land use

The total cultivated area was fixed as 283.44 ha, however, cultivation performances of crops were estimated at 1.5 times. Annually, there were 8 types of crop types including maize (22 ha), soy beans (5 ha), black bean (6 ha), green bean (4 ha), vegetables (40 ha), chilli (5.5 ha), egg plant (8 ha), banana (75 ha), fruit (20 ha), king grass (239.66 ha). Figure 2 showed the percentages of crops of which king grass, banana and vegetables are dominant with more than 83.4% of the total crops area. If calculating direct food for cows, maize and king grass contribute about 24.99 million VND and 69.4 million VND per hectare. In term of income contribution, banana and fruit play highest contribution with 125-128 million VND per hectare. On average, farmers could obtain about 85.3 million VND per hectare.

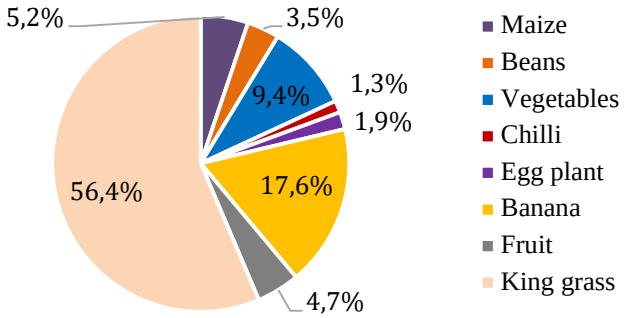

Figure 2. *Distribution of crops in Minh Chau commune*

3.1.2 Livestock production

According to the People committee of Minh Chau, the strategies for livestock production have been addressed on high productivity cows and dairy cows. As of June 2020, there were a total of 4,228 cows, of which there were 2,652 breeding cows, 356 male calves, 1,220 dairy cows, and 556 dairy cows. On average, each cow delivers about 18 kg of milk per day. The total number of pigs was 7,290 heads, of which there were 1,046 sowing pigs and 6,232 pigs for meat. Poultry has 21,977 and 2,345 dogs (Table 1).

Table 1. *Number of livestock as of June 2020*

Type of livestock	Total number	Percentage (%)
Cows	4.228	
Breeding cows	2.652	62.7
Male calves	356	8.40
Dairy cows	1.220	28.9
Pigs	7.290	
Sows	1.046	14
Pork	6.232	85
Poultry	21.977	
Dog	2.345	

It was reported that there were 452 households raising cows with the scale of households and farms ranging from 3-27 heads/household. The barn structures composed of solid and semi-solid

accounts for 96.7%; other households use simple cages with soil floor and straw roof. The average barn area was about 78.05 m^2. In particular, households with large breeding facilities were mainly dairy farmers; each cow has an average area of 8.6 m^2/cow, beef cattle account for about 7.1 m^2/head. Recently, the animal husbandry activities have shift to raising cattle for meat or dairy farming. The average cow raising period was from 18 months to 20 months. Forage consists of king grass, banana stalks, throne stems collected from field whereas commercial feeds include corn bran and milk-fortified pellets.

3.2 Waste audit of cow breeding process

The cow raising process was divided into 4 stages with a total period of 20 months. At different stages, farmers feed the cows on different amount of foods based on nutrient demand. The calve period of 6 months was the stage of calving that has been completely weaned and fed with grass and bran. The amount of food given to them will vary and increase with their growth. Over the next 6 months, cows were supplemented with more concentrate to increase their nutrient intake. The period of cattle being 18 months old was the time when they were separated from the breeding cows for fattening. At this stage, cows were supplemented with both concentrate and roughage to increase cattle biomass. After the fattening process, when the market demand and reasonable prices will be slaughtered (Figure 3).

The solid waste, waste water and emissions were issues that arise during the entire production process at farms. On average, an adult beef cow generates about 16.5 kg of manure/day, the amount of wastewater including water to wash the shed and urine was about 190 liters/day [7]. Emissions were also a concern in cow farming which contribute as major sources of CH_4 and causes an unpleasant odor for people. Although CH_4 was collected as biogas for heating and cooking, the mixture of collected gases contain large proportion of hydrogen sulfur (H_2S) causing negative effect on livestock and environment.

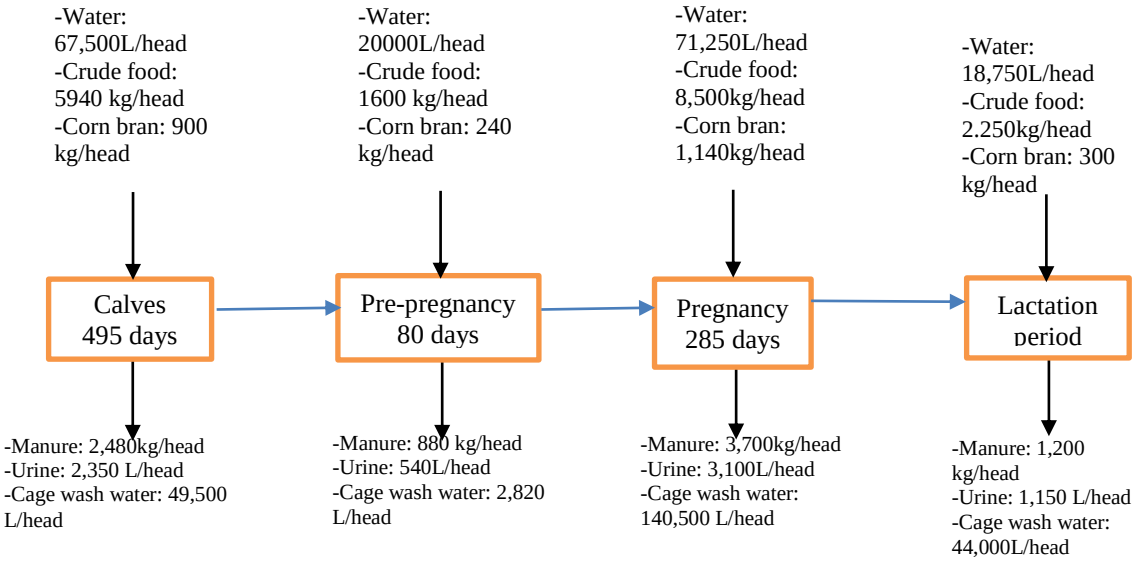

Figure 3. *Process flow diagram of beef cattle*

3.3 Waste collection and discharge from animal husbandry

Figure 4 shows the main waste collection from livestock activities. According to the survey data, manures from livestock were used for biogas (35% of the total manure volume), as fertilizer for plant (61.06%), as feedstuff for earthworm (3.06%), and for fish (0.01%). Households initiated the biogas digesters with an average volume of 10-15 m^3 corresponding to 0.3 m^3/head. However, it was observed that biogas digesters experience overload due to high volume of water

use with manure feeding into the biogas system. The hydraulic retention time was shortened then incomplete treatment of wastewater being discharged directly into the environment. Most farmers do not use raw manure directly for plants but use wastewater from biogas. Most households have not yet treated the livestock wastes due to lacking of treatment facilities, however, farmers with giant grass cultivation and raising earthworm pay more attention on utilization of manure.

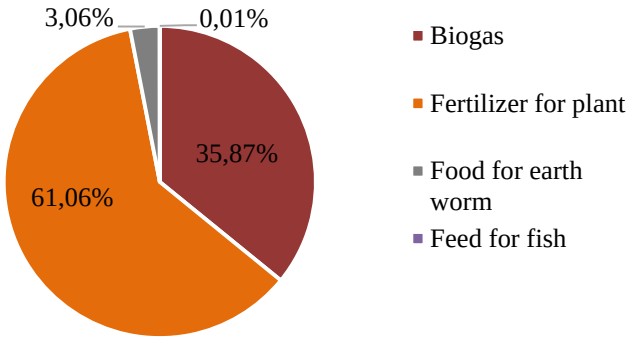

Figure 4. *Situation of waste collection in Minh Chau commune*

3.3.1 Nitrogen release from cow

Total nitrogen from cattle raising process in Minh Chau commune was shown in Table 2. The amount of nitrogen entering the breeding system was calculated from roughage, corn bran and water, estimated to 3,496 tons/year. The amount of nitrogen discharged from cow farming was 865.92 tons/year. The waste disposal rate into the environment based on input was 7.79%. The nitrogen circulation system in the cow raising process was very important to minimize the impact on the environment. Farmers use fertilizer directly for planting grasses and crops, worms and biogas production. This amount was mainly discharged from the biogas system.

Table 2. *Estimation of Nitrogen release from cow production*

No.	Type of waste	Emission (tons/day)	Amount of Nitrogen	Amount of Nitrogen	
				tons/day	tons/year
1	Manure	67.55	2.96%	2.00	729.79
2	Urine	47.84	1.99 g/L	0.10	34.75
3	Cage wash water	845.52	328.5 mg/L	0.29	101.38
	Total			**2.39**	**865.92**

3.3.2 Phosphorus release from cow

Table 3. *Estimation of Phosphorus release from cow production*

No.	Type of waste	Emission (1 day)	Amount of Phosphorus	Amount of Phosphorus	
				Tons/day	Tons/year
1	Manure	67.55	0.36%	0.243	88.76
2	Urine	47.84	0.23 g/L	0.011	4.02
3	Cage wash water	845.52	28 mg/L	0.024	8.64
	Total			0.274	101.42

The amount of phosphorus entering the system was calculated according to the sources of the nitrogen stream. The total amount of Phosphorus entering the system was 114.84 tons/year. Cattle raising produces 101.42 tons of phosphorus/year (Table 3). Phosphorus was an essential nutrient for plants. However, when released into the environment in high concentrations, the plant cannot absorb all, Phosphorus will accumulate in the soil, when washed away into the water sources causing eutrophication in water, causing imbalance in the system. The results show that

phosphorus flow in the waste circulation system representing in grasses, crops and worms. The amount of waste released into the environment was mainly from the source after the biogas digester, corresponding to 24.25 tons/year.

3.4 Proposed nutrient recovery

Figure 5 demonstrates a possible paradigm of circular economy in Minh Chau commune with two typical components livestock – plants via nutrient cycles. Livestock, such as cows, release large amount of solid waste and water containing high nutrients (nitrogen and phosphorus) becoming input as nutrient uptake for crops, fruits and king grass. A circular economy seeks to retain the added value of products for as long as possible by productively reusing resources when a product has reached the end of its life [14]. In this research, added value was observed during the application of earth worm for manure valorization. The output products contain biomass of earthworms and fertilizer. A field survey shows that earth worm farming could gain a benefit of 35-40 million VND per month by selling earth worm while fertilizer can be used for vegetables within the commune [15]. At the current stage, the amount of manure used for earthworm cultivation occupied only 3.06% of the total manure in the commune, thus, a nutrient recovery should be considered for circulation of waste while monetary benefits will be obtained (Figure 4).

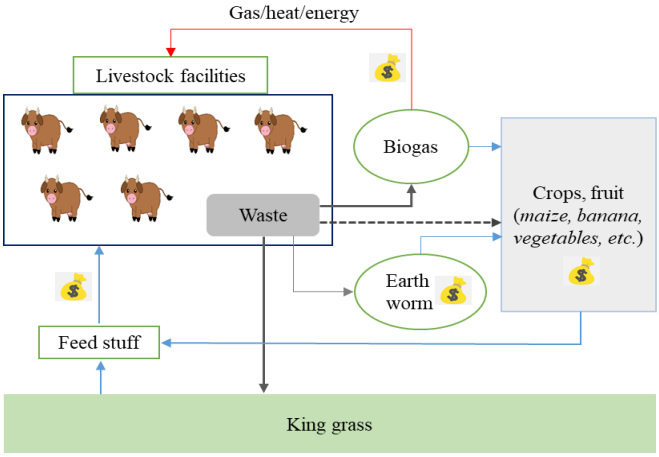

Figure 5. *Livestock waste recovery as nutrient flow*

Table 4. *Nutrient as Nitrogen and Phosphorus recovery as feeding stuffs*

Feedings	Total consumption (tons/day)	Estimated Nitrogen (%w/w)	Nitrogen equivalent (tons/day)	Estimated Phosphorus (%w/w)	Phosphorus equivalent (tons/day)
King grass	89.90	9.0%	8.09	0.07%	0.063
Banana	21.71	0.6%	0.13	0.03%	0.007
Maize	18.54	1.7%	0.32	0.40%	0.074
Maize (with corn)	4.43	8.0%	0.35	0.70%	0.031
Maize bran	9.09	3.4%	0.31	1.10%	0.100
Commercial bran	2.36	16.0%	0.38	0.90%	0.021
Total	**146.03**		**9.58**		**0.296**

Table 4 shows the feeding components and amount for the total number of cows in Minh Chau commune. Beside commercial feeds, raw feeding stuffs such as king grass, banana and maize were used as main supply with 92% of the total amount. King grass represents the highest amount for nitrogen source, roughly 8.09 tons/day (84.5%). This result indicates that nitrogen from waste uptake by king grass can be recycled via grass biomass. Phosphorus

recovery presents small amount compare to that of nitrogen, however, the plants play a role as 60% phosphorus supply.

4. Conclusion

Minh Chau commune has a total area of 563.33 ha, of which agricultural land accounts for 283 ha (50.2%). The development strategies were strongly focused on high productivity plant cultivation and livestock production. The annual crops include maize (22 ha), soy beans (5 ha), black bean (6 ha), green bean (4 ha), vegetables (40 ha), chilli (5.5 ha), egg plant (8 ha), banana (75 ha), fruit (20 ha), king grass (239.66 ha) of which king grass, banana and vegetables were dominant with more than 83.4% of the total crops area. There were a total of 4,228 cows, including 2,652 breeding cows, 356 male calves, 1,220 dairy cows and 556 dairy cows. The livestock production contributed to 114.2 tons/day. Manures used for plants accounted for 61.06% of the total amount and earthworm (3.06%). King grass, banana and maize accounted for 92% of the total amount of feed stuff for cows. The circular economy approach has shown a potential to reduce waste discharge into environment while generate more values for farmers.

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