

DEVELOPING CIRCULAR ECONOMY IN AGRICULTURE – A DRIVER FOR SUSTAINABLE MULTIDIMENSIONAL POVERTY REDUCTION IN SON LA PROVINCE

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ABSTRACT

This research focuses on analyzing the mutual relationship between the development of circular economy in agriculture and the goal of sustainable multidimensional poverty reduction in Son La province. The study employs several methods: document collection, processing, analysis, and synthesis; fieldwork; and expert consultation. The results indicate that the initial formation and application of circular economy models not only optimize resources but also serve as a direct lever to improve income and living conditions for the residents of Son La province. Based on the practical implementation in Son La, the research proposes a comprehensive system of solutions, including: Digitalizing the circular loop (smart agriculture); Building circular economy clusters (to break fragmentation); Leveraging green credit and index-based insurance; and Enhancing the “Son La Circular Brand”. Furthermore, Son La province needs to refine its policy mechanisms to promote a circular economy tailored to the province's specific characteristics, accelerate the application of science and technology, and increase community awareness and participation. This provides an important scientific basis for building a sustainable poverty reduction roadmap for ethnic minority communities in Son La in the new period.

Keywords: Circular economy, sustainable agriculture, multidimensional poverty, Son La province, mountainous livelihoods.

1. INTRODUCTION

In the context of climate change and resource depletion becoming global challenges, there is an urgent demand for transforming production methods. Therefore, the transition from a linear economy model to a circular economy (CE) is not only an inevitable trend but also a core strategy for sustainable development. In Vietnam, agriculture serves as the backbone of the economy, and the application of circular principles in this sector is opening new directions, especially for Northern mountainous provinces.

Son La - a national agricultural phenomenon in recent years has affirmed its position as the largest production hub for agricultural products and fruit trees in Northern Vietnam. However, the rapid development of the agricultural sector has also brought environmental consequences stemming from agricultural by-products and the pressure on land resource exploitation. Furthermore, although the poverty rate has decreased significantly, maintaining these results and improving the quality of life for ethnic minorities in a mountainous province with a high minority population and fragmented topography remains a complex challenge. Poverty in Son La today is not limited to income deficiency but also encompasses the lack of basic social services and a safe living environment known as multidimensional poverty.

The application of circular economy in agriculture (CEA) through the reuse of by-products as input materials, reducing production costs, creating added value, and protecting the ecosystem is the key to resolving the conflict between socio-economic development and environmental conservation. This is not just a technical solution but also a powerful driver for sustainable multidimensional poverty reduction, helping to optimize agricultural value chains and improve multidimensional deficiency indicators. This article focuses on analyzing this mutual relationship in Son La to propose specific policy mechanisms and strategic orientations, aiming to transform circular models into effective tools that contribute to the province's sustainable poverty reduction roadmap in the new era.

2. LITERATURE REVIEW

2.1. Circular economy in agriculture

Circular economy: The concept of CE was first introduced in the book “*Economics of Natural Resources and the Environment*” by Pearce and Turner (1990). CE refers to a new economic model based on the fundamental principle that “everything is an input for something else”, which stands in stark contrast to the perspective of the traditional linear economy [1].

The Ellen MacArthur Foundation (2015) established three core principles of a circular economy: (1) Design out waste and pollution right from the design stage; (2) Keep products and materials in use through reuse, repair, refurbishment, and recycling; (3) Regenerate natural systems and restore natural resources [2].

In Vietnam, CE is officially defined in the Law on Environmental Protection: A circular economy is an economic model in which design, production, consumption, and service activities aim to reduce the extraction of raw materials, extend product lifecycles, limit waste generation, and minimize adverse environmental impacts [3].

Circular Economy in Agriculture: Khanh Nguyen (2023) defined CEA as the application of scientific and technological advances, along with the recycling of waste and by-products during production, to create safe, high-quality products while reducing waste and environmental pollution. This also helps raise public awareness regarding the reuse of by-products and environmental protection, thereby generating high-quality, safe, and eco-friendly products, aiming toward green agriculture. CEA is a form of ecological agriculture [4].

Thus, CEA is understood as a closed-loop production process through the application of scientific-technical progress, biotechnology, and physicochemical technology in recycling waste and by-products as input materials for the production and processing of agricultural, forestry, and fishery products. Through this process, not only are safe, high-quality products created, but environmental waste is also minimized. Simultaneously, it contributes to enhancing people's awareness of reusing by-products and residues in agricultural production in conjunction with environmental protection.

Basic Principles of CEA: (1) Principle of Source Reduction: Minimizing waste at the point of origin. (2) Principle of Material Circulation: Ensuring materials flow in a continuous loop. (3) Principle of Direct Reuse: Utilizing resources or products again without significant processing. (4) Principle of Biological Recycling: Converting organic waste back into the ecosystem. (5) Principle of Proper Sorting and Treatment: Classifying waste for appropriate processing methods. (6) Principle of Ecological Safety: Ensuring all activities are harmless to the natural environment. (7) Principle of Socio-Economic Efficiency: Balancing economic gains with social benefits. (8) Principle of Systems Approach: Viewing agriculture as an integrated, holistic system.

Although the theoretical system of CE has progressed significantly from resource management thinking to specific legal frameworks, a notable limitation is that current

approaches remain overly focused on environmental engineering. There is a lack of theoretical frameworks that directly link these conceptual definitions with social welfare goals. Existing studies have yet to clarify the mechanisms through which circular principles can be transformed into direct economic values to address multidimensional deprivations for vulnerable populations in mountainous areas.

2.2. Multidimensional poverty

Methodologically, the measurement of multidimensional poverty has undergone a significant evolution. From the household analyses to the latest global Multidimensional Poverty Index (MPI) framework by Alkire et al. (2022) [6], scientists have provided tools to deconstruct deprivation clusters, enabling a deeper understanding of the nature of non-income poverty. In a modern context, a World Bank report (2023) [6] indicates that digital poverty in fragmented mountainous regions is becoming a new barrier to development. To address this, UNEP (2024) [7] affirms that the circular economy is an effective tool for enhancing the resilience of highland communities.

In Vietnam, poverty reduction and improving living standards are consistent themes in sustainable development research, especially in the northern mountainous region. Methodologically, Le et al. (2014) laid the foundation for multidimensional poverty analysis through household living standards surveys, transforming the model from a one-dimensional to a multi-dimensional mindset [8]. Recently, the Ministry of Labour, Invalids and Social Affairs (Molisa) (2021) issued multidimensional poverty standards, providing a legal and practical basis for applying new deprivation criteria [9].

Focusing on the practical reality of Son La province, the research system of Tran (2019) [10] has established a rich database of empirical and theoretical evidence, ranging from proposing solutions to enhance living standards in her doctoral dissertation. Accompanying this research direction, Duong (2021) [11] provided analyses of local social indicators, clarifying the fluctuations in the living standards of Son La's residents over the past decade.

Existing research on multidimensional poverty, while methodologically sound in measurement, remains largely static and focused on describing the current status of deprivation. The most significant theoretical gap is the absence of dynamic analysis to demonstrate the systemic impacts of new economic models on changing non-income indicators over time. Specifically, current literature has not adequately prioritized quantifying the improvement in quality of life when barriers such as digital poverty and fragmented terrain are addressed by localized economic solutions.

2.3. The relationship between circular economy in agriculture and poverty reduction

According to the study by Schröder et al. (2019), circular economy practices (such as agricultural waste management) contribute directly to achieving SDG 1 (No Poverty), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible consumption and production). The authors indicate that CE empowers vulnerable groups (such as highland residents) to become more self-reliant regarding resources [12].

Thailand possesses many mountainous and rural areas with characteristics similar to the Northern region of Vietnam. According to the Ministry of Foreign Affairs of Thailand (2021), they have successfully improved livelihoods through the BCG model (Bio-Circular-Green) - a three-legged stool strategy that has helped Thailand achieve breakthroughs in rural development. The research analyzed how to leverage highland biodiversity to create high-value products (e.g., herbal cosmetics, zero-waste ecotourism). This helps highland residents not only escape income poverty but also improve their quality of life in terms of environment and education [13].

In Vietnam, scholar Vo et al. (2021), in a study on circular economy development in agriculture in Vietnam, analyzed circular models such as V-A-C (Garden-Pond-Livestock) and the recycling of coffee husks and straw into organic fertilizer. Experimental results showed that reducing the cost of chemical fertilizers and animal feed helped households save on input costs [14].

Nguyen's (2019) study provided international experiences and policy implications relevant to Vietnam's practice. The study emphasized that the application of the circular economy not only helps protect the environment but also creates new economic value through optimizing the value chain and reusing by-products, especially in key sectors such as agriculture [15].

International models provide evidence of CE benefits, a limitation exists as these studies often overlook the specific sloping topography and socio-cultural barriers of ethnic minorities in Vietnam. Most literature still views CE as an environmental adaptation solution rather than a multi-objective poverty reduction driver. This creates a disconnect in policy orientation, where circular solutions have not been effectively integrated into national target programs for sustainable poverty reduction in unique locales like Son La.

Although independent studies on the circular economy and multidimensional poverty have achieved certain milestones, decoding the dual linkage between circular agriculture and sustainable poverty reduction in a specific locale like Son La remains a significant gap in the existing literature. This study positions itself at the intersection of these two fields, filling the gap in interdisciplinary integration that is often fragmented between environmental engineering and socio-economics. Rather than merely describing the current status or analyzing macro-level models, this paper pioneers the establishment of an empirical reciprocal mechanism at the household level, transforming agricultural by-products from environmental burdens into strategic economic resources to directly address multidimensional deprivation indicators for ethnic minority communities. Consequently, the research contributes to strengthening the theoretical framework of green resource management in sloping terrains while shifting the poverty reduction paradigm from external support to fostering sustainable internal strength based on localized value loops.

3. METHODOLOGY

Document collection. The authors conducted an extensive collection and review of diverse document sources, including: official State documents related to the Circular Economy (CE) [16]-[17]; regional planning schemes [18]; development projects; summary reports; and statistical yearbooks of Son La province. Additionally, scientific literature and research works concerning CE in general and its specific application in Son La were thoroughly examined.

Data processing, analysis, comparison, and synthesis. The collected documents and data were processed and systematized using a logical and scientific approach. The authors performed detailed analysis, comparison, and cross-referencing of information and statistics to derive objective and accurate assessments regarding the research objectives.

Expert and stakeholder consultation. To ensure objectivity, scientific rigor, and comprehensiveness, the authors consulted with experts in the fields of economics, environment, and agriculture. Consultations were also held with managers from relevant departments and agencies in Son La province. Most importantly, the authors conducted interviews and discussions with local residents, particularly those directly involved in circular agriculture models.

Fieldwork (site surveys). Field surveys were conducted across several districts in Son La province specifically Mai Son, Moc Chau, Van Ho, and Yen Chau where CE models have

been implemented or show significant potential for development. This provided the authors with practical, first-hand insights into the local implementation of CE, allowing for a rigorous comparison with the data gathered from secondary sources. The technical specifications of the survey process are established as follows:

Sample size and study area: The study conducted a survey with a total sample size of 100 agricultural households. The survey area focused on 10 representative communes in Son La Province (including Co Noi, Hat Lot, Muong Bon, Chieng Mung, Chieng Mai, Chieng Ban, Na Bo, Chieng Luong, Chieng Sung, and Phieng Cam). These areas exhibit distinct topographical differentiation (lowland and highland regions) and represent the specific circular agricultural models of the province.

Sampling method: The study utilized the purposive sampling method. The subjects selected for the survey met two core criteria: (1) Being households categorized in the multidimensional poverty group as of 2016; (2) Having directly applied at least one circular economy model in agricultural production (such as improved VACB, recycling of coffee and corn by-products, or biosecure livestock farming).

Survey tools and procedures:

Structured survey questionnaires: Used to collect quantitative data on economic indicators (total input costs, revenue, profit, ROI) and the deprivation levels across 6 multidimensional poverty indicator groups before and after implementing the CE.

In-depth interviews and group discussions: The research team conducted direct interviews with heads of households and consulted experts from relevant departments and agencies to record qualitative information regarding technical barriers, policies, and the local people's mindset toward technology adoption.

Field observation: Directly recorded and evaluated environmental hygiene indicators around the houses as well as the operational processes of circular loops within the households.

Conclusion on Methodology. The flexible combination of the aforementioned research methods provided the authors with a multidimensional, in-depth, and holistic perspective. This foundation enables the formulation of highly persuasive analyses, evaluations, and proposed solutions.

4. RESULTS AND DISCUSSION

4.1. Current status of circular economy in agriculture implementation in Son La

Son La is a mountainous province with a vast territory and a large population (1.4 million people in 2025), the majority of whom reside in rural areas and engage in agriculture (76%). The province's topography and climate are diverse and complex, divided into three distinct sub-regions, offering immense potential for the development of agriculture, forestry, and tourism. Son La is currently accelerating its economic development, particularly in the agricultural sector, and has emerged as the second-largest fruit hub in the country. Currently, several typical cooperation models between processing enterprises and smallholder farmers within the circular agriculture value chain have been established:

Son La Agricultural Cooperative: A pioneer in promoting international cooperation and applying science and technology to CE research and implementation. The cooperative partners with other enterprises and farmers to maximize the use of agricultural by-products, implementing organic circular models. They manage 900 beef cattle and 300 breeding cattle. All livestock waste is treated using microbiological processes; additionally, they collaborate with local firms to purchase coffee husks and cassava skins for vermiculture (earthworm farming) to produce organic fertilizer. On average, each hectare of vermiculture yields 500

tons of organic fertilizer per month. In 2024, the cooperative's revenue reached 32 billion VND, creating stable jobs for nearly 30 local workers.

Son La Sugar Joint Stock Company: This company actively applies technical and technological solutions to save costs and enhance production value by utilizing all by-products from sugar processing to produce fertilizer and fuel for biomass power generation.

Minh Tien group joint stock company (coffee waste treatment): Annually, this company generates tens of thousands of tons of coffee husks. To address this, they have applied a CE model to produce Cascara tea, bio-packaging, biodegradable bags, eco-friendly cutlery, namigo biological products, and microbial organic fertilizer ensuring that zero waste is achieved from the coffee cherry.

Son La Agricultural Development JSC: Currently the leading edible mushroom producer in the province. The primary substrate used is crushed and treated corncobs a common waste product in Son La due to intensive corn cultivation over the last 20 years. Previously, corncobs were mostly burned for drying agricultural products. This model employs 47 workers with monthly salaries ranging from 8,000,000 to 10,000,000 VND.

Automated waste treatment in Moc Chau: This model helps dairy farms in Moc Chau efficiently process waste, protect the environment, and generate income from selling pressed dry manure. This also enhances the quality of agritourism, attracting visitors to experience clean and sustainable farming.

Integrated circular models at the household level: Integrated production (Cattle-Vermiculture-Grass/Corn-Livestock/Poultry-Fish); Cultivation on waste (using bagasse, corncobs, and organic waste as substrates for mushrooms); Circular production between fruit orchards and livestock (Mai Son, Moc Chau); Biomass corn cultivation linked with livestock (Mai Son, Yen Chau, Song Ma); Biogas production (Mai Son, Song Ma, Van Ho); Water recycling in starch and coffee processing; 4F Bio-safety Farming (Farm-Food-Feed-Fertilizer); Notably, the improved “Garden-Pond-Cage-Biogas” (VACB) model in highland villages represents a primitive yet highly effective manifestation of CE in poverty reduction.

The success of CE models in Son La is not merely the result of individual efforts but is strongly driven by the leadership of anchor enterprises like Son La Sugar and Minh Tien Group. These are the strategic links that complete the Circular Agricultural Value Chain by closely connecting factories with fields. In this ecosystem, while enterprises provide technological solutions and large-scale markets for by-products, smallholder farmers are the entities directly operating and benefiting from the surplus value of this resource loop.

To further clarify the spillover effects from these corporate models down to each village, and to demonstrate how CE has become a lifeline helping people overcome multidimensional poverty barriers, we will analyze empirical data collected from 100 farming households across 10 representative communes. These satellites are directly transforming, proving the close synergy between enterprises and farmers in the goal of sustainable development in the Northwest highlands.

4.2. Impact of circular economy in agriculture on multidimensional poverty in Son La

4.2.1. Positive outcomes achieved

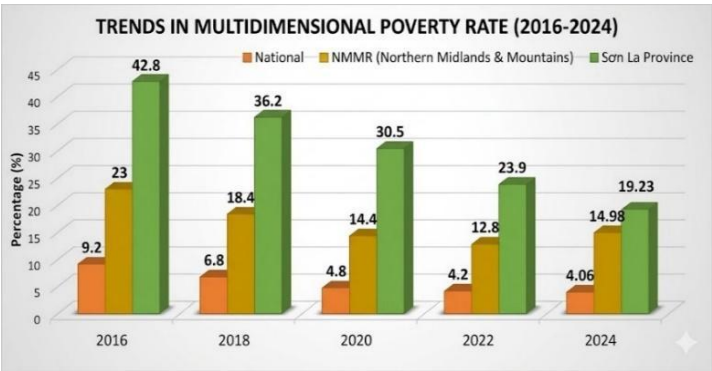


Figure 1. Multidimensional poverty rates for the 2016-2024 period (%).

Source: Compiled by the authors based on General Statistics Office (GSO) data.

The data illustrates a significant and positive trend in multidimensional poverty reduction across all analyzed subjects during the 2016-2024 period. The most prominent highlight is Son La province, which achieved the most impressive decrease plummeting from 42.8% (2016) to just 19.23% (2024) effectively halving its poverty rate in less than a decade.

However, despite this remarkable progress, Son La's 19.23% poverty rate in 2024 remains substantially higher than the average for the Northern Midlands and Mountainous Region (14.98%) and the national average (4.06%). This underscores the province's extraordinary efforts while simultaneously highlighting a significant developmental gap that requires continued narrowing.

A crucial contributor to these poverty reduction results in Son La is the strategic application of CEA models. The improvements in income and living conditions for households adopting CEA were analyzed through a survey of 100 agricultural households across 10 representative communes in Mai Son district (Mai Son has successfully established high-income specialised fruit-growing areas and serves as a quintessential model for circular economy implementation in Son La province). Notably, at the start of the study period in 2016, all of these households were classified within the multidimensional poor group

Table 1. Economic Efficiency Indicators per Production Cycle.

Criteria	Traditional Model (A)	CEA Model (B)	Difference (B-A)	% Change
1. Total Input Costs	100,000,000	100,000,000	0	0.00
-Consumables (Fertilizer, etc.)	50,000,000	10,000,000	-40,000,000	-80.00
-Environmental Treatment	10,000,000	2,000,000	-8,000,000	-80.0
-Infrastructure/ Technology	10,000,000	40,000,000	30,000,000	300.00
- Seeds & Techniques	30,000,000	48,000,000	18,000,000	60.00
2. Total Revenue	140,000,000	190,000,000	50,000,000	35.71
- Main Product Revenue	139,000,000	145,000,000	6,000,000	4.32
- By-product Revenue	1,000,000	45,000,000	44,000,000	4400.00

3. Net Profit	40,000,000	90,000,000	50,000,000	125.00
4. ROI (%)	40.00	90.00	50.00	125.00
5. Monthly Avg Income (k VND)	2,575	4,275	1,7	66.02

Source: Surveyed and synthesized by the author group

The data in Table 1 serves as practical evidence that the CE is the key to sustainably solving the multidimensional poverty puzzle. The core lies in the optimization of capital flow: instead of spending 60% of total costs on chemical inputs and environmental treatment (such as coffee husks, bagasse, and livestock waste) as in traditional methods, the CE model has slashed these expenses by 80%. These savings are then strategically reinvested into technology and high-quality seeds.

Consequently, Net Profit skyrocketed by 125%, directly addressing the deprivation in the Income dimension. More importantly, the average income increase from 2,575 to 4,275 thousand VND/month (a 66.02% rise) creates a financial buffer for households. This allows them to bridge other deprivation gaps across the six groups of multidimensional poverty indicators: from purchasing health insurance (Health) and paying tuition fees (Education) to upgrading clean water systems and hygienic latrines (Sanitation). In particular, a fourfold increase in technology investment costs helps residents gain rapid access to smart devices and the internet, removing barriers in the Information dimension. Thus, CE not only helps farmers escape poverty in terms of figures but also comprehensively upgrades their quality of life and economic self-reliance.

In the surveyed area, households participating in cooperatives have shifted toward organic production, ensuring process transparency through surveillance cameras, electronic logs, and QR codes for traceability. As a result, dragon fruit from the Ngoc Hoang Cooperative has been successfully exported to demanding markets such as Japan, Singapore, and the USA. Compared to traditional corn cultivation, the residents' income has increased 15 to 20 times.

Table 2. Changes in Basic Social Service Deficiency for CEA Households.

Indicator	Before CEA	After CEA	Improvement	% Change
1. Employment (Rate)	55	95	40	72.73
2. Health (Insurance Rate)	30	90	60	200.00
3. Education (Correct-age Enrollment)	45	100	55	122.22
4. Housing (Permanent Houses)	40	89	49	122.50
5. Water & Sanitation (Clean Water)	30	90	60	200.00
6. Information (Internet/Device usage)	5	85	80	1600.00

Source: Surveyed and synthesized by the author group

The survey results in Table 2 depict an impressive transformation of farming households following their transition to the CEA model. Most notably, there was an explosion in the Information dimension, with a record-breaking growth of 1,600%. From an initial state of near-zero information access (only 5%), the increased income from agricultural by-products has enabled 85% of households to bridge the digital divide, acquiring smart devices and internet access to adopt modern farming techniques.

Furthermore, indicators for Health and Clean Water & Sanitation both saw a 200% increase, demonstrating that once the income challenge is addressed, residents immediately

prioritize healthcare through health insurance and improved living environments. Notably, reaching the 100% threshold for correct-age school enrollment serves as a profound humanitarian testament, affirming that CEA creates not only economic value but also a solid foundation for investing in future generations. Overall, the synchronized improvement across all six indicator groups provides compelling evidence that CE has empowered farmers in Son La to move beyond income poverty toward comprehensive and sustainable poverty reduction.

Table 3. Living Conditions and Environmental Protection Indicators.

Indicator	Unit	Before CEA	After CEA
1. Recycling Rate of By-products	%	0	80
2. Domestic Chores/Wood-gathering time	Hours/day	3 - 4	0.5 - 1
3. Clean Energy Usage (Biogas)	% Households	0	35
4. Organic Fertilizer Produced	Tons/year	0	150
5. Environmental Hygiene Score	Scale (1-5)	1	4.5

Source: Surveyed and synthesized by the author group

The defining characteristic of CEA is waste recycling; therefore, environmental living conditions at the household level undergo a distinct transformation. While Tables 1 and 2 focus on quantitative economic and social service values, Table 3 serves as the missing piece that completes the picture, proving the sustainability of the CEA model for farm life.

The most impressive change lies in labor liberation. Previously, residents spent 3–4 hours per day gathering wood and performing housework; now, thanks to clean energy (Biogas), this figure has dropped to under 1 hour. This surplus time is a precious resource, allowing residents to participate in community activities, enhance their knowledge, or care for their children's education non-material factors that directly contribute to reducing multidimensional poverty.

Furthermore, recycling 80% of by-products to produce 150 tons of organic fertilizer per year is vital for sloping land cultivation in Son La, helping to preserve soil fertility and reduce dependency on chemicals. The environmental hygiene index around the house increased from 1 to 4.5 points, completely transforming the rural landscape from heavy pollution to a fresh living environment. Overall, CEA has demonstrated its ability to directly improve quality of life, helping people enjoy a cleaner, healthier, and more humane living environment.

Table 4. Summary of CEA Efficiency and Multidimensional Poverty Reduction.

Commune	The current status of the household (which was a multidimensionally poor household in 2016) after implementing CEA.			Net Profit (M VND /hh/yr)	ROI (%)	Poverty Reduction (%/yr)	Info Access (%)	Recycling (%)	Note
	Escaped	Near-poor	Poor						
Co Noi	10	0	0	112	101	5.6	100	95	Low-lying, central area
Hat Lot	8	2	0	103	96	5.3	100	92	
Muong Bon	3	7	0	84	89	4.9	95	85	Low-lying, near the center
Chieng Mung	9	1	0	99	93	5.1	90	95	

Chieng Mai	5	4	1	89	88	4.6	85	81	Low-lying, far from the center
Chieng Ban	6	2	1	91	87	4.5	83	80	
Na Bo	4	4	2	77	85	3.9	75	68	
Chieng Luong	5	4	1	90	86	4.1	80	69	High-lying, far from the center
Chieng Sung	6	3	1	98	92	4.5	79	75	
Phieng Cam	4	3	3	58	79	3.7	63	60	
Total	60	30	9						
Average				90	90	4.62	85	80	

Source: Surveyed and synthesized by the author group

The aggregated data from the 10 surveyed communes provides a comprehensive insight into the systemic impact of CEA on multidimensional poverty reduction. The results show an impressive rate: 60 out of 99 households (over 60%) have officially escaped poverty, with an average multidimensional poverty reduction rate of 4.62% per year. An average net profit of 90 million VND/household/year and an ROI of 90% serve as compelling evidence of the model's superior economic efficiency.

However, the data also reflects a clear differentiation based on geographical characteristics and infrastructure. In lowland and central communes such as Co Noi and Hat Lot, the model achieves maximum performance with an ROI exceeding 100% and 100% information access, demonstrating excellent synergy between CEA and favorable market conditions. Conversely, in highland and remote communes like Phieng Cam or Na Bo, while indicators are more modest due to topographical barriers, the waste recycling rate remains stable at 60-68%. This affirms that CE is not a privilege of favorable regions but a flexible adaptive solution that narrows the wealth gap and enhances digital literacy for residents in remote areas. Overall, CEA in Son La is a multi-objective strategy: simultaneously increasing income, improving quality of life and sustainably protecting sloping land resources.

The synthesized figures from the 10 surveyed communes in Table 4 reveal a strong economic breakthrough, with an average net profit reaching 52 million VND/household/year. The impressive ROI indicators, ranging from 120% to 155%, confirm that reusing agricultural by-products has helped residents optimize investment costs much more effectively than traditional farming methods. A high waste recycling rate (averaging 78%) not only addresses environmental challenges but also acts as a direct driver, reducing the average multidimensional poverty rate by 4.5% per year. Specifically, the Information dimension recorded a marked improvement, with 85% of households having internet access, illustrating the close link between stable income and enhanced digital literacy. Despite slight ROI disparities between border-highland and lowland communes due to topographical hurdles, the circular economy model generally proves its excellent adaptability. These results are valuable evidence that the circular economy is a dual solution to achieve both income growth and the sustainable fulfillment of social deficiency dimensions locally.

4.2.2. Limitations, issues and causes

(1) *The poverty rate in Son La remains high, with a significant number of poor households.*

Table 5. Multidimensional Poverty Review Results in 2024.

No.	Province	Multidimensional poverty rate (%)	Total number of poor and near-poor households (Households)	Poverty rate (%)	Poor households (Households)
1	Ha Giang	36.35	69,740	25.93	49,760
2	Cao Bang	35.29	45,762	20.04	25,995
3	Dien Bien	33.24	47,361	21.29	30,327
4	Lai Chau	28.79	31,014	19.46	20,961
5	Bac Kan	28.72	23,801	19.46	16,123
6	Lao Cai	21.18	38,469	11.24	20,411
7	Son La	19.23	57,645	10.89	32,652

Source: Compiled by the authors based on General Statistics Office (GSO) data

Son La ranks 7th out of 63 provinces and cities nationwide in terms of its multidimensional poverty rate (19.23%), which is 4.7 times higher than the national average. The province continues to struggle with a large volume of poor and near-poor households, ranking 6th out of 63 localities (Data and statistics in this study were updated prior to the administrative merger of provinces and cities in Vietnam in July 2025). Notably, the number of poor and near-poor households in Thuan Chau district is massive (10,924 households) ranking 3rd in the country (behind only Yen Minh district in Ha Giang and Ky Son district in Nghe An), accounting for 18.95% of the total poor households in Son La province.

(2) High rates of re-poverty and new poverty unsustainable poverty reduction.

A major concern is that while Son La's poverty rate has decreased annually. The results are not yet sustainable, and the risk of re-poverty remains high. In 2024 alone, the province recorded 177 re-poverty households (0.5% of the total poor) and 1496 new poor households (4.6% of the total poor).

Looking at the situation objectively and fairly while CEA models in Son La are currently a star of hope, significant barriers remain for them to truly become a sustainable wealth-generating engine for the local people.

(3) Core limitations leading to moderate income and unsustainable poverty reduction in CEA models

The value-added bottleneck (Moderate income)

Although residents have learned to turn waste into money, these earnings remain at a cost-saving level rather than achieving a wealth-creation breakthrough due to several factors:

High Proportion of Raw Products: Farmers primarily sell raw or minimally processed agricultural products. Although agricultural by-products (such as coffee husks and corn cobs) are recycled into fertilizer, their value-added remains low. There is a critical lack of deep processing plants to transform these by-products into higher-value goods, such as cosmetics from coffee grounds or high-end animal feed.

Fragmented Household Scale: The majority of models in Son La (specifically in Phieng Cam and Na Bo) operate on a small, individual scale. The lack of connection into large-scale cooperatives keeps operating costs per product unit high and weakens bargaining power when negotiating prices with large purchasing enterprises.

The Sustainability puzzle and re-poverty risk

Sustainable poverty reduction occurs when households can withstand external shocks. Currently, the CEA model faces difficulties in this regard:

Market Volatility Dependence: While CEA creates a closed-loop system at the farm level, the output remains dependent on global agricultural prices. If coffee or longan prices drop, the entire circular cycle no matter how efficient severely impacts net income.

High Initial Investment Costs: As seen in Table 1, investment in infrastructure (Biogas digesters, shredding machinery) has increased fourfold. For poor households, this is a significant burden. Without access to green credit, they risk falling into a debt spiral if a harvest fails.

Regional constraints specific to Son La

Son La possesses natural and infrastructural bottlenecks that directly affect sustainability:

Fragmented Topography: Logistics and transportation costs in highland communes like Phieng Cam are immense, often consuming a large portion of the residents' net profit.

Climate Change: Son La frequently suffers from frost and drought. CEA relies on natural biomass; if crops perish due to extreme weather, the circular chain is immediately broken.

Technical Proficiency: CEA requires specialized knowledge in microbiology, composting, and equipment operation. When residents have not mastered these techniques, the quality of self-produced organic fertilizer is inconsistent, leading to unstable crop yields.

Lack of a supporting Ecosystem

Currently, the CE model in Son La is more spontaneous at the household level rather than being part of a regional connection. There is a missing link in the “Farmer-Scientist-Enterprise” nexus. Furthermore, support policies for product certification (Organic, VietGAP) for circular models are slow, meaning clean products are often sold at the same price as conventional ones.

4.3. Solutions for sustainable multidimensional poverty reduction through the development of circular economy in agriculture in Son La

4.3.1. Digitizing the circular loop (smart agriculture)

Instead of relying solely on manual composting, technology must be integrated to optimize value: **Management App Development:** Develop user-friendly mobile applications (tailored to the local 85% information accessibility rate) to help farmers monitor composting processes, receive disease forecasts, and establish direct links with buyers.

Traceability: Implement QR codes for CEA products. Consumers are willing to pay 2-3 times more when they can verify that their longans or coffee were grown using organic fertilizers recycled from the plant's own by-products.

4.3.2. Building circular linkage clusters (breaking fragmentation)

Move away from fragmented household production toward a Commune-level Circularity model:

Establishing Specialized Cooperatives: These cooperatives will act as hubs to collect by-products (such as coffee husks and corn cobs) from hundreds of households to process into fertilizer pellets or industrial animal feed.

On-site Deep Processing: Shift from selling raw produce to investing in medium-scale local freeze-drying and essential oil extraction systems. This significantly increases product value-added and creates jobs directly within the villages.

4.3.3. Leveraging green credit and index-based insurance

To address the challenge of high initial investment costs:

Specific Preferential Loan Packages for CEA: Propose that banks in Son La offer low-interest credit lines dedicated to constructing biogas digesters or purchasing circular processing machinery.

Weather Index-based Agricultural Insurance: Provide a safety net for farmers, encouraging them to invest without the fear of losing everything due to natural disasters or the unique hoarfrost of the Northwest highlands.

4.3.4. Elevating the Son La circular brand

Transform CEA from a mere production technique into a cultural and tourism brand:

Circular Agritourism: Turn model circular farms into experiential destinations. Visitors to Son La will come not only for the plum blossoms but also to experience a zero-waste ecosystem. This serves as a highly sustainable secondary source of income for the local people.

5. CONCLUSION

5.1. General conclusion and policy recommendations

The developing CEA is not merely a production method but serves as a strategic lever and a universal key to achieving sustainable multidimensional poverty reduction in Son La Province a region characterized by fragmented and harsh geographical conditions. Quantitative analysis from the survey of 100 farming households across 10 communes demonstrates a significant breakthrough when resource loops are applied: household net profit surged by 125%, reaching an average ROI of 90%, and directly contributing to an average multidimensional poverty reduction rate of 4.62% per year. Alongside economic growth, deprivations in basic social services have been mitigated; notably, 85% of households gained access to the Internet and smart devices, driven by increased income from recycling agricultural by-products.

To establish the circular economy as a widespread driver, the Son La provincial government needs to enhance and synchronize specific support policies. Emphasis should be placed on Digitizing circular loops through smart agriculture platforms and establishing Circular Economy Clusters to overcome fragmentation and foster tight linkages between processing enterprises and farmers. Furthermore, the Province should utilize green credit levers and weather-index insurance packages to minimize initial investment risks for farmers, aiming to elevate the “Son La Circular Brand” in association with experiential tourism.

These practical results provide a vital scientific basis for replicating and expanding research in other Northern mountainous provinces with similar sloping terrains and crop structures, such as Lao Cai, Lai Chau and Dien Bien.

5.2. Limitations and further research directions

While this study elucidates the profound reciprocal relationship between circular economy development and multidimensional poverty reduction, several inherent limitations must be objectively acknowledged:

First, regarding data objectivity: The current quantitative findings rely heavily on self-reported survey data from households. This inevitably introduces potential random errors stemming from subjective bias or recall limitations regarding production costs and revenues throughout the production cycle.

Second, regarding sample size and generalizability: A core limitation lies in the spatial

scope, which is currently focused on 10 communes within Mai Son district, Son La province, with a sample size of 100 households. Although these areas are highly representative of specific circular agricultural models, the sample size remains modest relative to the vast and diverse landscape of Son La province. Consequently, the representativeness and the ability to generalize the research findings to other ecological zones or diverse socio-economic contexts within the region remain limited.

Based on these limitations, future research will focus on the following objectives: (i) Expanding scale and scope: Conducting cross-provincial surveys in neighboring areas of the Northern Midlands and Mountains to enhance representativeness and strengthen the generalizability of the theoretical model on a broader scale. (ii) Integrating technology in monitoring: Incorporating objective measurement methods and modern monitoring tools (such as electronic farming logs, traceability software, and remote sensing). This aims to verify and evaluate the accuracy of economic data and the long-term sustainability of circular loops in the multidimensional poverty reduction pathway more precisely.

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APPENDIX

Some images illustrating the development of the circular economy in agriculture in Son La province

		
Tea made from coffee husks, items made from coffee husks (Minh Tien Group Joint Stock Company, Son La City)		The biogas tank is covered with HDPE tarpaulin. (Minh Thuy Farm)
		
Wastewater treatment system area (Son La Sugar Company)	Model for raising earthworms at (Son La Agricultural Cooperative)	Interview with the director of Son La agricultural cooperative
		
Growing mushrooms using corn cobs at (Son La Agricultural Development Joint Stock Company)	Automated waste treatment line (Nong Truong town, Moc Chau)	Bagasse is used as a raw material for power generators (Son La Sugar Company).
		
Processing coffee husks to make fertilizer	Straw bales as stored feed for cattle	Producing organic fertilizer from cow manure