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Assessing the Economic Effectiveness of Community-Based Climate Adaptation Using an Evaluation Framework

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Abstract

This study develops and pilots an evaluation framework for assessing the economic, social, environmental effectiveness and climate change adaptation capacity of community-based models in the Northwest region of Vietnam, a region highly vulnerable to climate risks and characterized by indigenous agricultural practices. The framework includes 22 indicators across four dimensions, with a standardized scoring system enabling objective comparison and model selection. A pilot assessment was conducted on an in-field rice straw composting model in Lai Chau province. The model scored 76.5 out of 100, rated as "fairly high", reflecting strong environmental (95.5%) and social (85.7%) effectiveness, moderate adaptability to climate change (71.7%), and modest economic efficiency (46.7%). The model reduces greenhouse gas emissions by 1.5 - 2 tons CO_2/ha/year, enhances soil fertility, and cuts input costs. It is technically simple, low-cost, and well-suited to ethnic minority communities with limited capital and technical capacity. However, it lacks flexibility under extreme climate events and has limited access to green finance, restricting its scalability. The study recommends integrating the model into national target programs (e.g., new rural development, ecological agriculture), establishing micro-finance support (under 2 million VND/household/season), and improving its flexibility through seasonal and site-specific adaptations. This research contributes a scientific basis for selecting, evaluating, and scaling community-based climate adaptation models in mountainous and vulnerable areas, supporting Vietnam's climate commitments and green development strategies.

Keywords

Community-Based Adaptation, Climate Change, Northwest Vietnam, Evaluation Framework, Low-Carbon Agriculture

1. Introduction

Climate change poses increasing challenges to sustainable development, especially in vulnerable areas such as highlands, rural, and mountainous regions. Globally, Community-Based Adaptation (CBA) models have been developed since the 2000s, aiming to enhance local communities' capacity to respond to climate risks by leveraging indigenous knowledge, strengthening resilience, and linking adaptation to sustainable livelihoods (Reid et al., 2009).

Typical CBA models have been implemented in South Asia, Africa, and Southeast Asia in various forms such as community-based resource management, climate-resilient crop transformation, or community-based early warning systems (Ensor & Berger, 2009; Christoplos, 2010). In Bangladesh, the "Local Adaptation Plans of Action" (LAPA) model has integrated climate change into commune-level development planning (UNDP, 2011). In Kenya, community initiatives have improved adaptive capacity through early warning systems and micro-finance schemes for farmers (Jones et al., 2010).

The effectiveness of international CBA models is often assessed using a combination of qualitative and quantitative methods, employing economic, social, and environmental performance indicators. Recent studies emphasize the importance of Multi-Criteria Analysis (MCA), Cost-Benefit Analysis (CBA), and resilience assessment frameworks (Reid et al., 2019). Shammin et al. (2022) studied a standard model of Community-Based Adaptation (CBA) through three case studies from Philippines, Thailand, and Ethiopia as examples of CBA practices beyond South Asia, integrating indigenous and community knowledge. Increasingly, international research focuses on evaluating the performance of CBA models, especially using economic indicators and social equity aspects. Josephson et al. (2024) reviewed current cost-benefit estimation practices, highlighting issues such as inaccuracy, lack of micro-level data, and inequitable distribution of benefits across communities. In flood-related studies, Cano Pecharromán and Hahn (2023) found significant differences between high- and low-income communities in cost savings achieved through community-based flood defense systems.

Traditional CBA models like the LAPA program in Bangladesh or community-managed disaster funds in Kenya have successfully integrated indigenous knowledge and promoted sustainable resilience. Particularly, the combination of MCA with cost-benefit evaluation has become a popular method for quantifying the economic and social effectiveness of community-based adaptation models (Arfanuzzaman et al., 2021).

In Vietnam, the concept of community-based climate change adaptation began gaining attention in the 2010s through programs such as "Supporting Coastal Communities in Responding to Climate Change", jointly implemented by UNDP and CCFSC. Several pilot models have been carried out in the Central Region and Mekong Delta, including mangrove afforestation, improved farming techniques to cope with salinity intrusion, and integrated livelihood models (GIZ, 2014; Care, 2015). Recent research has mainly focused on analyzing the socio-economic im-

pacts of climate change at national or regional scales, with limited attention to evaluating specific community-level models. Lap (2023) analyzed the economic losses due to floods in the Ngàn Sâu River Basin (Ha Tinh), estimating losses between USD 380 - 526 million depending on the climate scenario, thereby providing a foundation for evaluating the costs required for adaptation planning. The GEMMES Vietnam project (2023-2026) is also developing a multi-dimensional analysis framework to assess economic, social, and energy transition impacts in support of policy planning for Vietnam's green economy transformation.

OECD (2025) forecasts that adaptation costs in Vietnam could reach USD 55 - 90 billion by 2030, stressing the need for community communication to raise awareness and prepare individuals and societies to deal with climate change. LVI (Livelihood Vulnerability Index) assessments in Ho Chi Minh City, linking sensitivity, adaptive capacity, and social networks of riverside households, have revealed significant variations in vulnerability among wards, highlighting the importance of micro-level community assessments. Tuan et al. (2017) assessed climate change adaptive capacity of communities in Vinh Long province using document synthesis, longitudinal social surveys, and multi-criteria analysis across four dimensions: human, physical, financial, and social capital. Hao et al. (2016) developed a 31-indicator household-level adaptive capacity assessment framework in Hoa Vang district, covering human, economic, livelihood, social, infrastructure access, and governance components. Results indicated that awareness, skills, and experience in adapting to climate change were still low among households. Access to infrastructure, livelihoods, and governance were the most influential factors shaping household-level adaptive capacity.

Despite a growing number of studies on climate change adaptation in Vietnam, research in the Northern mountainous region, especially the Northwest, remains fragmented, mainly focusing on climate risk assessments or proposing individual technical solutions such as crop conversion, improved varieties, or new cultivation techniques (Truong et al., 2022). Many works have merely described climate change impacts on livelihoods without fully developing integrated community-based adaptation models that consider socio-economic dimensions. In the Northern mountainous region, including the Northwest, studies on community-based adaptation models are still limited and mostly technical in nature. Therefore, this study plays an important role in filling the academic gap by developing a comprehensive quantitative framework to evaluate the effectiveness of CBA models in the Northwest.

Rather than limiting itself to surveys or status descriptions, the study pilots the real-world evaluation of a specific model of organic composting from rice straw in the field and quantifies economic, social, environmental, and climate adaptation aspects. The integration of quantitative methods with indigenous knowledge, contextualized to mountainous local conditions, helps establish a scientific foundation for selecting and scaling successful adaptation models in vulnerable regions like the Northwest, an area previously underrepresented in research efforts such as

those by Tuan et al. (2017), Lap (2023), or GEMMES Vietnam Consortium (2023).

The Northwest region is a highland area severely affected by drought, flash floods, extreme temperatures, and climate change. Traditional agriculture here relies heavily on indigenous knowledge. This area is characterized by a high proportion of ethnic minorities, low adaptive capacity, and low average income, making it an appropriate context to test CBA models with integrated socio-economic assessments. The region possesses rich indigenous knowledge (in farming, flood warning, water management, etc.), yet lacks quantitative studies on model effectiveness. This research aims to fill that gap and provide a scientific basis for scaling successful models in similar regions.

Developing a set of criteria to evaluate the economic effectiveness of community-based climate change adaptation models is a novel approach that is still lacking in current Vietnamese research. The study integrates quantitative methods (AHP, MCA, CBA) with indigenous knowledge to quantify and select optimal models. It focuses on the Northwest, a vulnerable but under-researched area, contributing to narrowing the research gap and supporting local-level adaptation policy planning.

The objective of this study is to develop and apply a set of criteria for evaluating the economic effectiveness of community-based climate change adaptation models in the Northwest region. It seeks to identify models that are appropriate to local conditions through qualitative and quantitative analysis, integrating indigenous knowledge and modern science. The study's findings will provide a scientific basis for scaling effective models and proposing practical adaptation policies at the grassroots level.

2. Materials and Methods

2.1. Description of Study Site

The Northwest region of Vietnam, comprising five provinces of Lai Chau, Dien Bien, Lao Cai, Son La, and Phu Tho, is characterized by complex terrain, with the majority of its area covered by forest land. The population consists mainly of ethnic minorities who depend on agricultural and forestry-based livelihoods (**Figure 1**). Climate change is having a significant impact on this region, with an increase in extreme weather events such as heavy rainfall, flash floods, droughts, and prolonged cold spells. In particular, abnormal weather patterns influenced by El Niño and La Niña phenomena are increasingly threatening local livelihoods. In this context, community-based climate change adaptation (CBA) models play an important role in ensuring livelihood security and promoting sustainable development. Although some models have been implemented, the scientific basis for selecting and scaling up these models remains limited. Therefore, conducting this study is both necessary and highly practical for climate change response and for achieving sustainable development goals.

2.2. Dield Surveys and Interviews Methods

The household survey was conducted across five provinces in the Northwest region

of Vietnam: Lai Chau, Dien Bien, Son La, Lao Cai, and Phu Tho. In each province, 100 households were randomly selected using stratified sampling to ensure representation across different ethnic groups, socio-economic backgrounds, and agro-ecological zones. This resulted in a total sample size of 600 households.

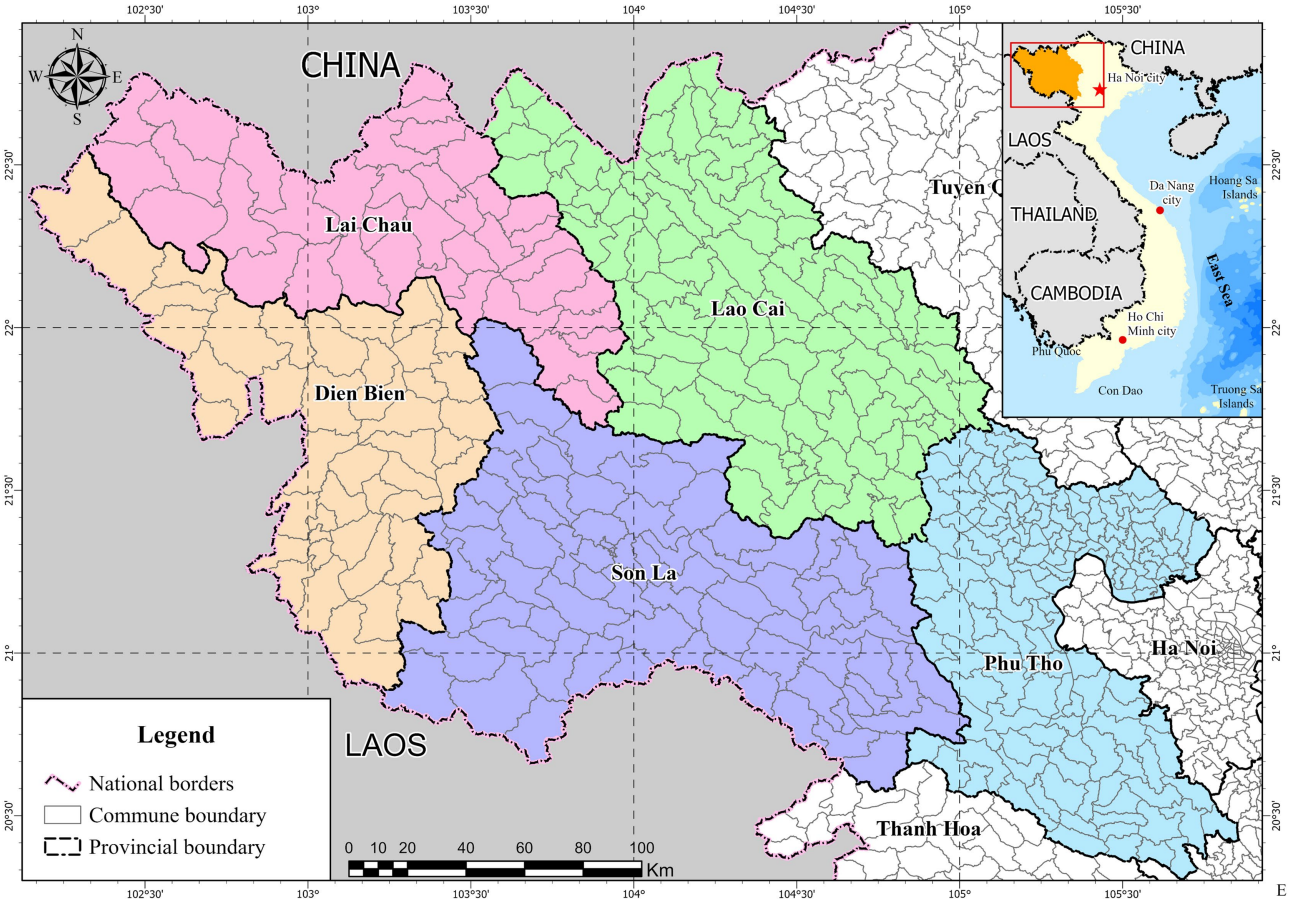

Figure 1. Description of study site.

We aimed to ensure regional representativeness by including both highland and midland provinces, areas with differing levels of climate vulnerability, infrastructure, and model implementation. The combination of these diverse provinces enhances the robustness and generalizability of the findings for the broader Northwest region. This stratified sampling approach was complemented by expert consultation and local government coordination to ensure balanced geographical and demographic coverage.

The questionnaire consisted of 53 items, of which 27 questions focused on evaluating the effectiveness of the models. This approach enabled the collection of both quantitative and qualitative data related to natural conditions, socio-economic context, infrastructure, financial resources, local knowledge, climate responsiveness, product quality, and model scalability.

The questions were categorized into four groups of criteria: economic efficiency, social impact, environmental outcomes, and climate change adaptability. The col-

lected data were processed and analyzed using descriptive statistical methods and visual charts to assess the suitability and effectiveness of the models in each locality. In addition, the study incorporated in-depth interviews and focus group discussions to clarify existing barriers and opportunities, as well as to propose evaluation criteria tailored to regional specificities. The results revealed significant differences among provinces in terms of model implementation conditions and the availability of resources.

The survey of 600 households across five Northwestern provinces of Vietnam (Lai Chau, Dien Bien, Son La, Lao Cai, and Phu Tho) revealed that the initial implementation of community-based Climate Change Adaptation (CCA) models has generated certain positive impacts, though considerable differences exist among localities. Over 65% of households in Son La, Lai Chau, and Lao Cai considered the models appropriate for local geographical and natural conditions, while this figure dropped to around 40% - 45% in Lao Cai and Phu Tho.

In terms of economic effectiveness, approximately 58% of respondents rated the models as having moderate economic benefits; 24% found the impacts unclear, and only 18% rated them highly. In Lao Cai and Lai Chau, 62% and 59% of households, respectively, reported income increases due to the models, while only 33% of households in Phu Tho experienced the same. The availability of essential infrastructure, input materials, and technical methods also varied: 55% of households in Lai Chau reported having adequate conditions to implement the models, compared to less than 40% in Lao Cai and Dien Bien.

On the social front, 51% of households said the models created additional employment, especially in Dien Bien and Son La, where this rate exceeded 60%. However, access to credit remained limited: only 34% of households stated they were able to obtain loans for model implementation. Support from local authorities or international organizations was noted by 52% of respondents in Dien Bien and 58% in Lai Chau, while only 11% in Lao Cai reported receiving such assistance.

Regarding environmental impact, over 70% of households indicated that the models helped reduce electricity/fuel use and promoted waste reuse, especially in Lao Cai, where 85% of households considered the models environmentally friendly. In contrast, only 12% of households in Phu Tho believed the models effectively conserved energy.

The climate adaptability of the models was still limited in some areas. In Phu Tho, more than 60% of households felt the models were inadequate to cope with natural disasters such as floods, droughts, or frost. Conversely, 78% of households in Lao Cai and Lai Chau appreciated the models' capacity to adjust cropping seasons and varieties in response to climate variability.

A notable success was the integration of indigenous knowledge into the models: in Lao Cai, over 90% of households acknowledged the use of traditional knowledge, compared to only about 35% - 40% in Phu Tho and Lao Cai. However, market access remained a challenge: only 46% of households reported stable product consumption, while nearly 30% responded with "hard to assess" or "other".

Overall, the survey results indicate that CCA models have been initially embraced by local communities and show certain positive effects. However, further adjustments are needed, particularly in technical design, investment capital, evaluation criteria, and alignment with the specific characteristics of each locality.

2.3. Development of Evaluation Criteria

The development of a set of evaluation criteria for community-based climate change adaptation (CBA) models is carried out based on an interdisciplinary integration approach, drawing from both domestic and international theories and practical experiences. The criteria are designed to comprehensively reflect the effectiveness of the models across four key dimensions: climate change adaptation capacity, economic effectiveness, social effectiveness, and environmental effectiveness (Table 1).

Table 1. Proposed initial set of criteria for evaluating climate change adaptation capacity.

No	Criterion	Indicator Code	Evaluation Indicator
1	Climate Change Adaptation Capacity	CT1	Geographical location
		CT2	Sustainability
		CT3	Model effectiveness
		CT4	Development of new energy and reduction of greenhouse gas emissions
		CT5	Local disaster response capacity
		CT6	Flexibility in adjusting inputs or raw materials to adapt to climate change
2	Economic Effectiveness	CT7	Investment cost
		CT8	Capital recovery and profitability
		CT9	Average household income after applying the adaptation model
		CT10	Availability of investment capital for the model
		CT11	Availability of technical capacity to implement the adaptation model
3	Social Effectiveness	CT12	Job creation for local labor
		CT13	Model compatibility with local education level and policy institutions
		CT14	Potential for scaling the model to other areas with similar conditions
		CT15	Participation of women and vulnerable groups in the model
		CT16	Simplicity and usability of techniques, including use of indigenous knowledge
		CT17	Availability of financial support for local people to apply the model

Continued

4	Environmental Effectiveness	CT18	Waste management capacity
		CT19	Waste reuse and recycling capability
		CT20	Ability to save and efficiently use existing energy resources
		CT21	Model compatibility with sustainable use of natural resources and local environmental improvement
		CT22	Flexibility of the model to adapt to current ecosystem changes (e.g., emergence of new pests, changes in crop/livestock varieties, etc.)

First, the criteria are grounded in a synthesis of interdisciplinary information related to climate change, as well as the socio-economic and environmental conditions of the Northwest region of Vietnam. Key references such as the IPCC report, UNFCCC guidelines on vulnerability assessment, and national studies form the foundation for identifying core indicators such as disaster risk reduction capacity, resource efficiency, sustainability, and community resilience (IPCC, 2021; UNFCCC, 2005).

Second, the process of developing the criteria combines both qualitative and quantitative methods. This research conducted surveys with 600 households across five provinces in the Northwest, using structured questionnaires, in-depth interviews, and data analysis via SPSS software to ensure representativeness and objectivity. In parallel, expert workshops were held to review, filter, and supplement the criteria to suit local realities.

To determine the weights of each evaluation dimension, a brief explanation is provided to clarify that the Analytic Hierarchy Process (AHP) was applied in combination with Multi-Criteria Analysis (MCA). The process involved a pairwise comparison matrix based on expert judgments from 12 specialists in climate change adaptation, agricultural economics, and rural development. Each expert was asked to rate the relative importance of the four criteria groups: climate change adaptability, economic effectiveness, social effectiveness, and environmental effectiveness.

The resulting consistency ratio was within the acceptable threshold ($CR < 0.1$), ensuring the validity of the comparison matrix. The derived weights were:

- Climate Change Adaptation Capacity: 60%.
- Economic Effectiveness: 15%.
- Social Effectiveness: 14%.
- Environmental Effectiveness: 11%.

This weight allocation reflects the dominant role of adaptive capacity in high-risk mountainous regions, where resilience to extreme climate events is prioritized over short-term economic gains (Saaty, 2008; Arfanuzzaman et al., 2021).

Three main steps were undertaken: 1) Analyzing the climate change context and assessing vulnerability; 2) Identifying the priority level of CBA actions based on criteria such as mitigation effectiveness, sustainability, and scalability; and 3) De-

veloping, reviewing, and piloting the set of criteria through field evaluation of exemplary models. The final refined set of criteria is applicable on a broad scale, serving as a decision-support tool for selecting and scaling up effective adaptation models in high-risk areas like the Northwest region.

The scoring system is designed to convert both qualitative and quantitative indicators into numerical values, allowing for objective comparison and selection of Climate Change Adaptation (CCA) models. The standardized maximum score is 100, distributed based on the importance of each criterion. Among these, the criterion group assessing climate change adaptation capacity accounts for 60 points, comprising six indicators (10 points each). The sustainable development group includes three sub-criteria: economic (15 points, 5 indicators), social (14 points, 6 indicators), and environmental (11 points, 5 indicators). Some indicators are allocated higher scores due to their prominent roles. Although the theoretical maximum score is 100, in practice, each model attains different scores due to variations in spatial conditions, structural design, and applicability. The evaluation results are categorized into levels: very low, low, medium, fairly high, and high.

3. Results and Discussion

3.1. Pilot Evaluation of the Model Using the Proposed Criteria

As part of the study on developing an evaluation framework for community-based Climate Change Adaptation (CCA) models, the research team selected the in-field composting model using rice straw for a pilot evaluation (**Table 2**). The trial was conducted in Binh Lu and Ban Bo communes and Sin Suoi Ho and Phong Tho communes, Lai Chau province, an area representative of the Northwest region's geographical, climatic, and agricultural characteristics. This region is notably impacted by climate change, with extreme weather, degraded sloped land, and high poverty rates.

The selection of this model was based on several key reasons. *First*, it is simple and easy to adopt, makes use of locally available rice straw, and requires neither advanced techniques nor specialized equipment, making it well-suited to the education level and production conditions of mountainous communities. *Second*, the model offers clear environmental benefits by reducing post-harvest rice straw burning, a major source of greenhouse gas emissions, while improving soil quality, fertility, and moisture retention in rice fields. *Third*, the model is scalable within the community due to its low cost, ease of implementation among household groups, and its compatibility with agricultural extension programs or new rural development goals.

Based on these factors, the research team applied a 22-indicator evaluation framework, divided into four groups: 1) climate change adaptation capacity, 2) economic effectiveness, 3) social effectiveness, and 4) environmental effectiveness. The indicators were quantified using a scoring system that converts qualitative assessments into numerical values, thereby providing an objective basis for comparing and selecting appropriate models. The maximum score for each model is 100, with the climate adaptation capacity group carrying the highest weight (60 points), re-

flecting its central role in the context of increasingly complex climate change challenges.

Table 2. Evaluation scores of indicators for the in-field composting model using rice straw.

Indicator Code	Evaluation Indicator	Score	Explanation
CT1	Geographical location	8	Binh Lu and Ban Bo communes and Sin Suoi Ho and Phong Tho communes, Lai Chau province are less affected by climate change annually.
CT2	Sustainability	10	The composting model using rice straw does not require high capital and is easy to replicate in multiple crop seasons.
CT3	Model effectiveness	8	Improves soil quality and water retention capacity, saves 20% - 30% of decomposition costs. Rice yields increase by 5% - 10%, reducing 40% - 50% of chemical fertilizer use.
CT4	Development of new energy and reduction of greenhouse gas emissions	10	Helps reduce greenhouse gas emissions from burning rice straw. Each hectare of rice applying this method can reduce emissions by approximately 1.5 - 2 tons CO_2/year.
CT5	Local disaster response capacity	5	The model has limited capacity to cope with natural disasters.
CT6	Flexibility in adjusting inputs or raw materials to adapt to climate change	2	The model lacks flexibility in adjusting inputs or raw materials in response to climate change.
CT7	Investment cost	3	Low investment cost.
CT8	Capital recovery and profitability	2	Households save on average 1.2 million VND/ha in N-P-K fertilizer costs.
CT9	Average household income after applying the adaptation model	2	Moderate increase in average income.
CT10	Availability of investment capital for the model	0	Self-implemented by local people without financial support.
CT11	Availability of technical capacity to implement the adaptation model	3	Makes use of readily available rice straw.
CT12	Job creation for local labor	3	Has potential for replication due to available materials and low cost.
CT13	Model compatibility with local education level and policy institutions	3	Suited to local education levels and governance conditions.
CT14	Potential for scaling the model to other areas with similar conditions	2	Simple and easy to implement, adaptable to various rural areas. Low cost and accessible to farmers.
CT15	Participation of women and vulnerable groups in the model	2	Technical training held in the fields by extension officers allowed access for women, elderly, and ethnic minorities.

Continued

CT16	Simplicity and usability of techniques, including use of indigenous knowledge	2	Simple, easy to apply model.
CT17	Availability of financial support for local people to apply the model	0.5	Self-funded by farmers.
CT18	Waste management capacity	3	Enables proactive waste management.
CT19	Waste reuse and recycling capability	2	No waste generated.
CT20	Ability to save and efficiently use existing energy resources	2	Long-term benefit by utilizing existing rice straw.
CT21	Model compatibility with sustainable use of natural resources and local environmental improvement	2	Very high compatibility.
CT22	Flexibility of the model to adapt to current ecosystem changes (e.g., emergence of new pests, changes in crop/livestock varieties, etc.)	1	Lacks adaptability to ecosystem changes.
	Total Score	76.5	

At the survey sites in Binh Lu, Ban Bo, Nam Xe, and Muong So, the research team collected field data, conducted interviews with households participating in the model, gathered input from local technical staff, and held focus group discussions to assess each specific indicator. The scores for each criterion were then compiled and analyzed using the standardized evaluation framework, resulting in an overall assessment of the model's effectiveness, adaptability, and potential for replication.

Testing the evaluation framework on this specific model allowed the research team to validate the practicality and relevance of the criteria and scoring system. It also provided concrete evidence to refine and adjust the framework for evaluating and scaling other community-based CCA models across the Northwest region and other climate-vulnerable areas.

The on-site composting model using rice straw has been implemented in Binh Lu and Ban Bo communes and Sin Suoi Ho and Phong Tho communes, Lai Chau province. This is one of the agricultural models with promising potential for climate change adaptation in the Northwest region of Vietnam. Based on the proposed evaluation criteria, the model achieved a total score of 76.5 out of 100, corresponding to a "relatively high" level. This result indicates that the model meets most criteria related to climate change adaptability, environmental effectiveness, and social impact, although some limitations remain in terms of economic efficiency and adaptive flexibility.

The climate change adaptability group (maximum 60 points) was the core of the assessment, reflecting how well the model responds to local weather conditions, natural disasters, and climate variability. The model scored 43 out of 60 points (71.7%), with highlights including sustainability (10 points), greenhouse gas emission reduction (10 points), and soil improvement and fertilizer cost savings (8 points).

By avoiding open-field straw burning, the model helps reduce 1.5 - 2 tons of CO_2 per hectare per year, contributing to community-scale emission reduction. However, some indicators, such as input adjustment capacity (2 points) and disaster response (5 points), remain weak, showing that the model is relatively static and not yet adaptable to extreme weather events such as hailstorms, flash floods, or prolonged droughts. This highlights the need to improve straw treatment technologies and integrate more flexible elements into the model to better respond to increasing climate variability.

In terms of economic efficiency, the model scored only 7 out of 15 points (46.7%), reflecting that its main benefit lies in cost savings rather than generating new income. The initial investment cost is low (3 points), and average fertilizer savings reach about VND 1.2 million per hectare (2 points). However, the additional income generated is minimal (2 points). Notably, the model has no external funding support (0 points) and is implemented voluntarily by local farmers based on experience and guidance from agricultural extension officers. This reflects both the strength of self-reliance and a limitation in scalability due to the lack of initial capital and supportive financial mechanisms. To improve economic performance, the model should be integrated into green agriculture credit policies or national target programs.

From a social impact perspective, the model scored 12 out of 14 points (85.7%), indicating a strong fit with the characteristics of local communities, farming knowledge levels, and accessibility. Key indicators such as job creation potential (3 points), compatibility with local knowledge (3 points), scalability (2 points), and participation of women and vulnerable groups (2 points) received positive evaluations. The model is implemented directly in the fields with technical training sessions held by extension officers, allowing participation from various groups, including elderly people and ethnic minority women. Its simplicity, ease of implementation, and use of local knowledge are major strengths, enhancing the community's internal capacity to cope with climate change.

Regarding environmental effectiveness, the model scored 10.5 out of 11 points (95.5%), the highest among the four evaluation groups. It produces no waste and enables on-site reuse and cycling of organic matter, contributing to improved soil and water quality. Outstanding indicators include waste management (3 points), efficient use of available energy sources (2 points), and strong compatibility with the sustainable use of natural resources at the local level (2 points). Although financial support availability remains low (0.5 points), the environmental benefits of the model are significant and align well with the current direction toward ecological and circular agriculture. Table 3 summarizes the detailed scoring across four evaluation groups, clearly illustrating the strengths and weaknesses of the climate change adaptation model in terms of adaptability, economic efficiency, social impact, and environmental effectiveness.

However, when examining all 22 indicators in detail, several weaknesses of the model become apparent. Some indicators, such as the level of flexibility in response to ecosystem changes (Indicator 22 - 1 point) and the capacity to adjust

agricultural inputs (Indicator 6 - 2 points), indicate that the model still lacks the adaptability needed to cope with rapidly changing environmental conditions and modern agricultural production systems. In addition, key indicators such as the ability to mobilize funding, attract investment, or create sustainable livelihoods have not shown significant improvement. These shortcomings may hinder the model's scalability to other areas without appropriate policy support or technical interventions.

Table 3. Scoring allocation by evaluation criteria group for the climate change adaptation model.

Criteria Group	Maximum Score	Score Achieved	Percentage (%)
1) Climate Change Adaptation	60	43	71.7%
2) Economic Effectiveness	15	7	46.7%
3) Social Effectiveness	14	12	85.7%
4) Environmental Effectiveness	11	10.5	95.5%
Total	100	76.5	

In summary, the trial assessment results show that the on-site composting model using rice straw is a feasible and practical climate change adaptation solution for the Northern mountainous region. With a total score of 76.5 out of 100, the model is rated as "fairly high", making it suitable for scaling up in areas with similar conditions. However, to elevate the model from a community-level solution to a policy-level intervention, it is necessary to integrate financial support mechanisms, enhance its flexibility, and improve its compatibility with advanced cultivation technologies. Additionally, the model should be incorporated into eco-agriculture development programs, aligning with the goals of sustainable development and effective climate change adaptation in the current context.

While the model achieved a relatively high overall score (76.5/100), we acknowledge that this score alone does not fully guarantee successful upscaling. Therefore, the proposal to scale up the model is not based solely on its quantitative rating. It also considers several supporting factors:

1) The model's low-cost, low-tech nature makes it accessible to a wide range of ethnic minority farmers in other mountainous areas;

2) Its alignment with national programs on ecological agriculture and rural development enhances policy compatibility;

3) Positive community acceptance and participation, especially from women and vulnerable groups, demonstrate strong social feasibility;

4) The environmental benefits of reducing open-field burning and improving soil quality are consistent across diverse regions.

Taken together, these factors suggest that the model holds potential for replication, provided that appropriate technical support, flexible composting techniques, and

micro-finance mechanisms are incorporated into the scaling strategy.

3.2. Proposed Solutions

3.2.1. Proposed Solutions for Pilot Model Implementation

The pilot implementation of the in-field composting model using rice straw in Lai Chau province has shown considerable potential, but also revealed certain limitations under real-world conditions. To improve its effectiveness and scalability, a comprehensive approach involving technical, organizational, and financial measures is necessary.

Firstly, technical training on rice straw treatment using bio-products (such as Trichoderma, EM, etc.) should be strengthened. Simple, accessible instructional materials should be developed, potentially in local languages, to accommodate the educational level of communities in mountainous areas.

Secondly, the model should be integrated into commune-level agricultural extension programs and linked with organic agriculture and sustainable livelihood support initiatives.

Thirdly, small-scale financial support mechanisms (under 2 million VND/household/season) should be established, mobilized from local Environmental Protection Funds or the National Target Program on Poverty Reduction, to subsidize microbial agents and input materials during the initial phase.

Moreover, the model should be adapted for increased flexibility, such as adding simple shelters, choosing appropriate composting periods based on weather conditions, and testing dry composting or slurry fermentation processes suited to different cropping seasons.

Finally, the model should be linked to agricultural service cooperatives to form a circular value chain, promoting internal consumption of organic fertilizers and facilitating market access for eco-friendly agricultural products (IPCC, 2021).

3.2.2. Economic Effectiveness of the Pilot Model

The model's economic effectiveness is demonstrated by input cost savings and increased productivity, although outcomes vary across households. Field evaluation results indicate that applying the model to each hectare of rice can save 20% - 30% on fertilizer costs, equivalent to around 1.2 million VND/ha/season (Ministry of Natural Resources and Environment, 2020). Additionally, rice yields increased by 5% - 10%, corresponding to an added value of about 1.5 - 3.5 million VND/ha, depending on field conditions.

The total direct economic benefit ranges from 2.7 to 4.7 million VND/ha/season, while initial investment costs (for microbial products and basic tools) are relatively low, at only 400,000 - 600,000 VND. The preliminary benefit-cost ratio (B/C ratio) ranges from 4.5 to 11.75, a very high return, particularly in the context of smallholder farming in upland areas.

Furthermore, the model helps reduce farmers' dependence on chemical fertilizers, stabilizes production amid agricultural input price fluctuations, and contributes to long-term soil improvement, all of which offer indirect economic ben-

efits that are difficult to quantify immediately. The effective use of agricultural by-products also lowers rice straw disposal costs and environmental pollution, providing dual benefits both economically and ecologically (Smit & Wandel, 2006).

Although the pilot model demonstrates a high Benefit-Cost (B/C) ratio, ranging from 4.5 to 11.75, mainly due to its low investment requirements and savings in fertilizer costs, its overall economic score in the evaluation framework remains moderate (7 out of 15). This noticeable discrepancy stems from the design of the scoring criteria, which assigns greater weight to factors such as access to capital, income generation, and profitability, rather than focusing solely on cost savings.

In this case, while the model effectively reduces input costs and delivers high returns on a minimal investment, it generates limited new income and receives no external financial support. As a result, it scores low on indicators such as "capital availability" and "average household income". Moreover, the model's voluntary and self-financed nature reflects strong community initiative but also highlights limitations in scaling due to lack of access to credit or subsidies.

Therefore, the low economic score does not reflect the model's inefficiency, but rather the broader structural barriers to upscaling, as well as the evaluation framework's emphasis on long-term income stability. The scoring system remains unchanged, but this explanation has been added to ensure coherence between the qualitative assessment and the reported B/C ratio.

3.2.3. Policy Recommendations for Model Scaling

Based on the practical pilot results, it is recommended that the in-field composting model using rice straw be incorporated into ongoing programs and policies in the northern mountainous region. Specifically, the model should be included as a priority extension model under the Program for Supporting Production Development and Livelihood Diversification within the National Target Program on New Rural Development.

In parallel, the model should be integrated into the National Action Plan on Climate Change Adaptation for 2021-2030, recognizing it as a climate-smart agricultural solution that contributes to Vietnam's greenhouse gas emission reduction commitments made at COP26 (UNFCCC, 2005; IPCC, 2021).

Furthermore, policies for small-scale green agricultural credit should be introduced to support households during the initial adoption phase, especially in disadvantaged areas where access to capital and technical capacity is limited.

Establishing a certification mechanism and market support for model-derived products, especially environmentally friendly agricultural goods, will also be crucial to motivate communities to maintain and expand the model.

In summary, effective model replication requires close coordination among government agencies, agricultural extension services, and local authorities, along with proactive participation from the local community.

3.3. Discussion

The composting model using straw directly in the field achieved a total evaluation score of 76.5/100, classified as "fairly high", indicating its feasibility in the context of mountainous agriculture affected by climate change. The model received particularly high scores in the environmental effectiveness (95.5%) and social effectiveness (85.7%) categories, demonstrating its relevance to local conditions especially in terms of utilizing indigenous knowledge, generating rural employment, and reducing greenhouse gas emissions from open straw burning, a widespread issue in rural Vietnam (IPCC, 2021; GIZ, 2014).

However, the economic effectiveness remained modest (46.7%), as the model focuses more on input cost reduction than on generating new income. This aligns with the findings of Josephson et al. (2024), who noted that small-scale adaptation models often lack micro-level data and face challenges in ensuring equitable distribution of benefits across different social groups.

The study further reinforces international literature asserting that Community-Based Adaptation (CBA) models tend to deliver long-term indirect benefits rather than immediate financial returns. Reid et al. (2019) argue that in CBA assessments, environmental indicators and resilience should be prioritized alongside financial metrics. The current model, with its potential to enhance soil fertility and reduce CO_2 emissions (estimated at 1.5 - 2 tons/ha/year), aligns well with such an approach. Moreover, its simplicity, scalability, and low technical requirements make it comparable to the LAPA model in Bangladesh and grassroots initiatives in Kenya, both of which achieved success through strong community engagement and integration into local development plans (UNDP, 2011; Jones et al., 2010).

Compared to the previous study, which mainly assessed adaptive capacity without piloting specific models, this research advances further by quantifying impacts using a set of measurable criteria. This paves the way for cross-model comparison and more evidence-based policy planning. Additionally, the model promotes the reuse of agricultural by-products and reduces air pollution, echoing the benefits of circular ecological models recommended in GEMMES Vietnam Consortium (2023) and OECD (2025).

Nonetheless, the model's limitations in terms of flexibility (scoring only 1 point) and capital mobilization (scoring 0 points) reflect concerns raised by Cano Pecharromán and Hahn (2023) about the risk of inequality when vulnerable communities lack financial support mechanisms. Therefore, this study emphasizes that for CBA models to be scalable and sustainable, they must be embedded within supportive policy systems covering technical assistance, green credit access, and integration into national target programs.

4. Conclusion

The study successfully developed and piloted a set of evaluation criteria assessing the economic, social, environmental effectiveness and climate change adaptation capacity of community-based models in the Northwest region of Vietnam, a re-

gion particularly vulnerable to climate change and characterized by specific agro-ecosystems.

The pilot application of this evaluation framework to the on-site straw composting model in several communes of Lai Chau province showed that the model scored 76.5 out of 100, rated as "fairly high", reflecting its practical relevance and relatively comprehensive effectiveness under mountainous farming conditions.

In terms of results, the model proved well-suited to local livelihoods by utilizing available agricultural by-products, contributing to a reduction in greenhouse gas emissions (approximately 1.5 - 2 tons of CO_2 per hectare per year), improving soil quality, and lowering input costs for farmers. Its simplicity, ease of implementation, and low requirements for capital and advanced technical skills make it suitable for ethnic minority communities with limited access to technology and education. Moreover, the model saw active participation from women and vulnerable groups, thereby enhancing the community's internal capacity to respond to climate change.

However, the study also identified several important limitations. First, the model lacks flexibility under extreme climate conditions and does not yet have effective mechanisms to cope with ecosystem changes such as pest outbreaks or abnormal weather. Second, its direct economic impact remains modest, focusing mainly on cost-saving rather than creating substantial added value. Third, the absence of financial support or linkage with green finance policies limits the model's scalability, leaving expansion largely dependent on individual initiative and self-reliance. These are critical areas that require improvement if the model is to evolve from a community-level solution into a large-scale action program.

Based on practical results, the study proposes scaling up the model by integrating it into national target programs, such as new rural development, ecological agriculture promotion, and the national climate change adaptation action plan. Additionally, the model should be incorporated into grassroots agricultural extension systems, supported by microfinance mechanisms (e.g., under VND 2 million/household/season), and connected with circular value chains to increase economic benefits. Importantly, the model needs to be improved toward greater flexibility through the application of appropriate seasonal and locally adapted treatment technologies, thereby enhancing overall effectiveness and long-term sustainability. This provides a scientific foundation for developing Community-Based Adaptation (CBA) policies in the context of Vietnam's climate commitments and green agricultural development strategies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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