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ARTICLE

Prioritizing Climate Change Adaptation Strategies for Tea-Producing Households: A SWOT–AHP Approach

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ABSTRACT

Climate change poses significant threats to sustainable agricultural livelihoods, particularly in tea-growing regions such as Thai Nguyen, Vietnam. This study aims to identify and prioritize effective climate change adaptation strategies for tea-producing households. The integrated SWOT–AHP (Strengths, Weaknesses, Opportunities, and Threats – Analytic Hierarchy Process) approach enables a quantifiable and systematic evaluation of strategic elements, allowing for the determination of their relative importance and guiding the ranking of adaptation priorities. The research employed the integrated mixed-method approach, including semi-structured interviews with tea farmers and experts to explore their perceptions and local adaptation practices, and structured AHP interviews with experts to assign weights to SWOT factors, sub-factors, and proposed strategies. The results indicate that the top-ranked adaptation strategies, in descending order of importance, are: (1) promoting sustainable organic tea production and applying advanced technologies; (2) developing value-added processing, diversifying tea products, and experiential tourism; (3) enhancing community capacity and disaster response; and (4) establishing an insurance system and climate risk mitigation mechanisms. The study proposes several practical policy implications for local implementation, including providing technical and financial support for organic production and

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technology transfer, integrating climate adaptation into cooperative training, investing in value-added processing and tourism infrastructure, and piloting insurance schemes in high-risk areas. This integrated SWOT–AHP framework offers a practical and replicable tool for strategic adaptation planning, supporting sustainable development in tea-producing regions across northern Vietnam.

Keywords: Adaptation Strategy; Climate Change; Sustainable Agriculture; SWOT–AHP Method; Tea Production

1. Introduction

Climate change has emerged as a profound challenge for global agriculture, particularly for smallholder farmers whose livelihoods depend heavily on natural resources and environmental conditions. According to the Intergovernmental Panel on Climate Change, agricultural productivity in tropical regions could decline by 10%–25% by 2050 in the absence of effective adaptation strategies [1]. This threat is especially acute in developing countries, where agriculture not only serves as the backbone of rural economies but also as the primary source of income for a significant proportion of the population. Sustainable agricultural practices, including resource management, climate-resilient crop varieties, and water conservation techniques, are essential to mitigate these risks. Effective adaptation is not only vital for food security but also for preserving the ecological balance and ensuring the long-term socioeconomic stability of farming communities.

Vietnam, where approximately 61.9% of the population resides in rural areas, remains highly dependent on agriculture, forestry, and fisheries [2]. Together, these sectors contributed about 11.96% of the country's GDP in 2023 [3]. This dependence makes rural economies particularly vulnerable to the adverse impacts of climate change, including more frequent droughts, floods, and extreme weather events, all of which pose significant risks to agricultural productivity and rural livelihoods. As climate change intensifies, these vulnerabilities are projected to grow, further threatening food security and socio-economic stability. Within this national context, Thai Nguyen province occupies a strategic role as Vietnam's foremost tea-producing region. Tea cultivation has long been intertwined with local identity, serving not only as an economic mainstay but also as a source of cultural pride. In 2024, the total tea cultivation area in the province exceeded 21,119 hectares, with fresh tea bud production surpassing 273,721 tons [4]. Thai Nguyen tea has significantly contributed to the socio-economic development of the locality and has successfully established a reputable brand both domestically and internationally. According to provincial statistics, by 2024, the tea sector's economic value in Thai Nguyen surpassed VND 13,000 billion, marking an increase of over VND 1000 billion compared to 2022 [4]. Despite these achievements, tea production in Thai Nguyen remains highly vulnerable to climate variability. Shifting rainfall patterns, prolonged droughts, and rising pest and disease pressures have reduced both yield and quality. These challenges threaten not only the region's agricultural productivity but also the sustainable livelihoods of smallholder farmers, highlighting the urgent need for climate-resilient agricultural practices and adaptation strategies.

Previous studies have examined the effects of climate change on agricultural systems and proposed a range of adaptation strategies [5–7]. These studies highlight the critical role of maintaining optimal climate conditions and the need for sustainable farming practices. Analytical frameworks, such as SWOT analysis, have been used to systematically evaluate farmers' internal capacities and external pressures [8,9]. However, conventional SWOT analysis remains largely qualitative and subjective [10]. While SWOT provides useful insights into internal and external factors, it does not quantify their relative importance. Integrating SWOT with the Analytic Hierarchy Process (AHP) enables the quantification of strategic factors' importance, thereby facilitating the prioritization of adaptation options based on empirical evidence [11,12]. Recent research has examined both the climatic impacts on tea production and the adaptive responses of smallholder farmers. As evidenced by a study in Bangladesh, temperature extremes negatively affect yields, rainfall variability may be beneficial, and changes in CO_2 emissions are harmful, underscoring the need to maintain optimal climate conditions and promote sustainable farming practices [7]. In line with these findings, studies on smallholder tea producers in Nepal highlight how climate change perception, cooperative membership, and access to information significantly influence farmers' adaptation strategies [13]. Similarly, the Food and Agriculture Organization [14] highlighted the socioeconomic vulnerabilities of tea-producing countries to climate risks, underscoring the need for systematic support mechanisms to strengthen farmers' resilience. In India, research on tea plantation workers in Assam revealed that while climatic shifts are widely recognized, adaptive measures remain fragmented and largely reliant on traditional practices rather than structured planning [15].

Although international studies provide valuable insights into tea-farming adaptation, research on smallholder tea production in Vietnam remains limited. Most existing studies focus on general agricultural impacts rather than sector-specific adaptation strategies. The study by Tran et al. [16] is one of the few to use an interdisciplinary approach to assess the potential of climate-smart agriculture in tea production in the northern mountainous region of Vietnam. Their findings show that tea production systems not only have strong biological adaptive capacity but also high carbon sequestration potential, demonstrating a strong synergy between food security and greenhouse gas mitigation. However, studies on the application of climate-smart agriculture methods in the context of tea production in Vietnam are still lacking and need to be expanded to assess the potential of the tea sector in the future, especially as tea production increasingly faces climate change and environmental challenges. The study by Tran and Yanagida [17] demonstrated that the adoption of organic production methods can help mitigate the negative impacts of agrochemicals and increase the value of tea products. However, significant challenges remain, such as the profit disparity between certified and non-certified tea producers, as well as the lack of coordinated strategies to support farmers. This indicates that, while there is potential, the application of adaptation methods in tea production in Vietnam needs to be more systematically implemented. In addition, the research by Nguyen and Yabe [18] highlighted the importance of efficient irrigation as a key strategy to cope with water scarcity due to climate change in small tea farms in Vietnam. Factors such as awareness of water shortages, soil and water conservation practices, and access to extension services significantly influence irrigation efficiency, showing the importance of various adaptation measures in tea production. However, a major research gap currently exists in the lack of multi-criteria decision-making (MCDM) methods, such as SWOT–AHP, to analyze and prioritize climate change adaptation strategic factors in Vietnam. MCDM methods can help quantify strategic factors, thus helping to build sustainable and feasible adaptation strategies. The absence of such methods has limited the ability to translate adaptation plans into actionable practices, especially in smallholder tea production. Therefore, further research is needed to apply SWOT–AHP to develop specific adaptation strategies for the tea sector in Vietnam, enhancing resilience to climate change.

To address these critical gaps, this study integrates the SWOT framework with the AHP method to systematically identify, evaluate, and prioritize climate change adaptation strategies for tea-producing households in Thai Nguyen province. By quantifying the relative importance of internal strengths and weaknesses alongside external opportunities and threats, the study provides a structured and evidence-based approach for strategic adaptation planning. The main contributions of this research are threefold. First, it operationalizes the integration of SWOT and AHP methodologies within the context of rural climate change adaptation, offering a replicable analytical framework. Second, it generates empirical evidence on the adaptive capacities and strategic priorities of smallholder tea farmers facing climatic challenges. Third, it delivers actionable recommendations aimed at enhancing adaptation capacity, improving production and business efficiency, and promoting sustainable household and local economic development in northern Vietnam.

The remainder of this paper is organized as follows. Section 2 provides a comprehensive review of the relevant literature. Section 3 describes the data sources, research scope, and methodological framework, including the operationalization of the SWOT and AHP approaches adopted in this study. Section 4 presents the empirical results, followed by a critical discussion in Section 5. Finally, Section 6 concludes the paper with key policy implications and recommendations to assist local authorities in formulating and implementing effective climate change adaptation strategies for the tea sector.

2. Literature Review

Climate change has emerged as a profound global challenge, particularly for agriculture—a sector that depends heavily on climatic conditions and natural resources. Rising temperatures, altered precipitation patterns, and the increasing frequency and intensity of extreme weather events such as droughts, floods, and storms have adversely affected crop productivity and quality [19]. Additionally, physical risks like forest fires and flooding not only damage the environment but also induce economic instability, especially for households facing decisions such as housing insurance [20]. These disruptions have made the pursuit of food security and sustainable agricultural development an urgent imperative on a global scale.

Numerous studies have confirmed that climate change increases the likelihood of short-term crop failures and long-term declines in agricultural yields, even though some regions may temporarily benefit from shifting climatic patterns [21]. Agriculture is both a victim and a contributor to climate change: it is severely impacted by extreme weather events and is also a major emitter of greenhouse gases [22]. A case study on Taiwanese tea production revealed that carbon emissions primarily originate from the raw material input phase and energy consumption during the consumer use phase, underscoring the need to develop sustainable agricultural models through reduced use of chemical fertilizers, improved processing technologies, and optimization of consumption behaviors [22]. This suggests that climate adaptation solutions must be holistic, integrating production, value chain development, and market behavior.

Within this broader context, the tea industry emerges as a particularly climate-sensitive sector. As a perennial industrial crop with substantial economic, cultural, and social value, tea is directly affected by variations in temperature, rainfall, soil conditions, and the frequency of climate extremes [23]. Research conducted in Sri Lanka indicated that over a 15-year period, increases in temperature and rainfall led to a decline in tea yield, with projections under high-emission scenarios showing a potential 12% reduction in production by mid-century [24]. Regional disparities in vulnerability have also been observed, depending on microclimatic conditions, biological adaptive capacity, and local resource availability [16,25]. In Vietnam, tea production systems in the northern mountainous regions demonstrate considerable carbon storage potential and biological resilience, yet they face infrastructural limitations, fragmented production scales, and poor access to international markets [26].

A pressing concern is that climate change not only reduces tea yield and quality but also intensifies pest and disease outbreaks while altering ecological relationships between crops and pollinators. Research has shown that rising temperatures and rainfall variability can disrupt plant growth cycles, affecting productivity and ecological suitability, thereby threatening long-term food security [27]. A study in Bangladesh revealed asymmetric effects of temperature, rainfall, and CO_2 emissions on tea output, highlighting that both positive and negative shocks can result in production losses, which underscores the sector's vulnerability [7]. These findings reinforce the view that tea is not only a socio-economic staple in many countries but also a representative case for studying the intersection of climate change and agriculture.

In response, sustainable adaptation strategies have become essential for mitigating the adverse effects of climate change. Factors such as education, access to information, technical support services, and credit availability significantly influence farmers' capacity to adopt adaptation measures [6]. Green technologies, organic farming, efficient irrigation management, and integrated pest control are among the key strategies being explored. In addition to these conventional climate-smart practices, recent technological advances have expanded the scope of agricultural adaptation through data-driven and AI-supported decision-support systems. For instance, hybrid recommendation models for organic fertilizer management have been developed to optimize input use and promote sustainable practices among coffee farmers [28]. Similarly, deep learning–based hybrid weather prediction systems have achieved high accuracy in forecasting temperature and precipitation trends, offering valuable early-warning tools for agricultural planning and risk management [29]. These innovations illustrate the growing role of digital technologies and artificial intelligence in supporting climate-resilient farming, complementing field-based adaptation strategies such as those examined in this study. Evidence from Vietnam indicates that climate-smart tea production systems can generate higher net returns and household labor income compared to alternative crops while contributing to emissions reduction and increased carbon sequestration [16]. Moreover, strategies such as product diversification, adoption of eco-friendly packaging, and the development of centralized processing clusters are recommended to enhance value-added and competitiveness [26].

To identify and prioritize adaptation strategies, several studies have applied the SWOT and AHP frameworks. SWOT facilitates comprehensive identification of internal and external factors influencing agricultural systems, while AHP enables the quantification of strategic priorities, supporting decision-making under complexity [30,31]. A study in Ghana found climate change to be the greatest threat to agriculture, while favorable environmental conditions were a key strength. The integration of SWOT–AHP helped prioritize strategies in national agricultural development programs [32]. Similarly, in Iran, the combination of SWOT and other multi-criteria methods provided a robust framework for selecting development strategies for rain-fed agriculture [33]. These examples demonstrate the strong potential of the SWOT–AHP framework in formulating and ranking climate adaptation strategies.

In the tea sector, applying such an analytical framework is particularly relevant, as tea not only represents a climate-sensitive agricultural crop but also supports the livelihoods of millions of rural households. In Thai Nguyen, approximately 40% of rural households depend on tea production. However, the tea value chain remains limited by small-scale operations, a lack of standardization, and low international competitiveness [26]. Studies show that high purchase prices and external support are key drivers for farmers' transition to organic tea production [17]. Without these two factors, the adoption likelihood drops to nearly zero, emphasizing the need for well-designed policy interventions. Combining SWOT analysis to identify endogenous and exogenous influences with AHP to prioritize strategic options may prove instrumental in advancing the tea sector.

Nonetheless, a critical research gap remains: most studies to date have focused on assessing the impacts of climate change or suggesting fragmented adaptation strategies, without offering clear prioritization mechanisms—especially in key tea-producing regions such as Thai Nguyen. Although international research has demonstrated the effectiveness of SWOT–AHP in various agricultural contexts, its direct application in the tea sector under climate change remains limited. Moreover, there is a lack of studies that systematically integrate micro-level data, particularly household-level characteristics, with multi-criteria strategic frameworks to formulate practical and prioritized policy recommendations. Therefore, applying the SWOT–AHP framework to identify and prioritize sustainable adaptation strategies in major tea-producing areas not only represents a novel approach but also contributes practical value to policy planning and sustainable agricultural development.

3. Materials and Methods

3.1. Materials

This study employed both primary and secondary data to explore sustainable climate change adaptation strategies for tea-producing households in Thai Nguyen province, Vietnam.

Secondary data encompassed information on the impacts of climate change on the agricultural sector, issues related to agricultural and rural development in Vietnam, and the tea industry in Thai Nguyen Province. These data provided contextual insights into both national-level agricultural challenges and the specific conditions affecting local tea production. The information was sourced from the Thai Nguyen Statistical Yearbook, along with other official publications and reputable online sources from both Vietnam and international organizations.

Primary data were collected from tea-producing households and experts to gather information on climate change adaptation in tea production. The household sample comprised 30 tea-producing households from six key tea-growing communes in Thai Nguyen Province—Tan Cuong, Phuc Xuan, Phuc Trieu, La Bang, Tuc Tranh, and Trai Cai—with five households purposively selected from each commune. Selected households had at least five consecutive years of tea cultivation experience.

The household sample size (n = 30) was determined based on the principle of information saturation, which is commonly applied in qualitative research to indicate the point at which additional data collection no longer yields new insights or themes [34]. After conducting semi-structured interviews across six key tea-growing communes, similar themes repeatedly emerged among respondents — such as long-established tea cultivation traditions, limited access to investment capital and sustainable farming technologies, and increasing risks from extreme weather and market fluctuations—indicating that the data had reached saturation. Therefore, a total of 30 households was considered sufficient to capture the diversity of experiences and identify representative SWOT factors for the subsequent AHP analysis.

The expert panel consisted of 10 experts: two officials from the Department of Agriculture and Environment of Thai Nguyen Province (one responsible for agricultural management and one for environmental management), one manager from the Thai Nguyen Tea Association, one agricultural scientist specializing in crop production and sustainable agriculture from Thai Nguyen University of Agriculture and Forestry, and six agricultural extension officers based in the selected communes. All experts had a minimum of five years of relevant professional experience and extensive knowledge of tea production systems and climate change adaptation.

The number of experts (n = 10) was considered appropriate for the Analytic Hierarchy Process (AHP), which emphasizes the depth of expertise and consistency of judgments rather than large sample sizes. As originally proposed by Saaty [35], AHP relies on the experiential knowledge of specialists to structure complex decision problems. Vargas [36] further highlighted that AHP is most effective when conducted with small, well-qualified groups capable of reaching consensus through iterative comparison. Consistent with methodological recommendations and recent applications of the SWOT–AHP model [37–40], panels of approximately 5–15 experts are typically sufficient to ensure reliability and logical consistency in pairwise judgments. This range also reflects practical realities in the study area, including limited availability of qualified experts, geographic dispersion of tea-growing communes, and restricted research resources.

3.2. Methods

The study employed a two-stage qualitative–quantitative approach to identify and prioritize climate change adaptation strategies for tea-producing households through the integration of SWOT analysis and the Analytic Hierarchy Process (AHP). Following the classical AHP framework developed by Saaty [35], this study conceptualized the SWOT–AHP model as a hierarchical multi-criteria decision-making (MCDM) problem. The model quantitatively transforms expert judgments into priority weights through systematic pairwise comparisons and consistency validation. The overall SWOT–AHP procedure consisted of five main steps: (1) identification of SWOT factors, (2) development of a hierarchical structure, (3) pairwise comparisons, (4) consistency and weight calculation, and (5) strategy ranking and interpretation.

Primary data were collected in April 2025 through two stages of interviews in Thai Nguyen Province. The first stage involved semi-structured interviews with tea-producing households and experts to identify and validate SWOT factors, and the second stage consisted of structured AHP interviews with the same group of experts to perform pairwise comparisons. This two-phase design ensured both practical insights from farmers and technical validation from experts.

Step 1 – Identification of SWOT factors: The identification of SWOT factors was guided by both an extensive literature review and empirical fieldwork. Relevant studies and information on agricultural adaptation and tea production were reviewed to establish an initial framework of potential factors influencing the adaptive capacity of tea-producing households. Semi-structured interviews were conducted with tea-producing households and experts to explore, verify, and refine the key strengths, weaknesses, opportunities, and threats associated with tea cultivation under changing climatic conditions. The interviews focused on farmers' production practices, resource constraints, exposure to climate risks, and expert assessments of institutional and market factors. Qualitative responses from both groups were analyzed thematically to identify representative and non-overlapping factors within each SWOT category. The preliminary list of factors derived from the literature and interviews was subsequently reviewed and validated by the expert panel to ensure logical consistency, completeness, and contextual relevance before proceeding to the AHP prioritization stage.

Step 2 – Development of the hierarchical structure: A four-level hierarchy was constructed, comprising (1) the overall goal, (2) four SWOT groups, (3) sub-factors within each group, and (4) four predefined adaptation strategies. The initial set of adaptation strategies was developed by synthesizing findings from the literature review and qualitative data obtained from semi-structured interviews with tea farmers and experts. These preliminary strategies were refined through expert discussions to ensure that they reflected both practical realities and theoretical foundations. The final list of strategies was then validated by the expert panel and incorporated into the AHP model for prioritization. This hierarchical framework integrates both qualitative and quantitative dimensions of the decision-making process. Each level is logically connected to the next, enabling the computation of global priorities by systematically aggregating local weights across successive hierarchical levels.

Step 3 – Pairwise comparisons (AHP): Structured AHP interviews were carried out exclusively with experts to evaluate the relative importance of (1) SWOT groups, (2) sub-factors within each group, and (3) the predefined adaptation strategies. Saaty's nine-point relative importance scale (**Table 1**) was applied, where values range from 1 (equally importance) to 9 (extremely more important), with their reciprocals representing the inverse relationships [35].

Pairwise comparison matrices were constructed to capture expert judgments, satisfying the reciprocal property $a_{ji} = 1/a_{ij}$ and $a_{ii} = 1$. Each expert completed the full set of matrices, and their responses were aggregated using the weighted arithmetic mean method to obtain the final consensus matrix. This approach preserves the proportional influence of each expert and ensures transparency in the aggregation process. The mathematical representation of the AHP decision model can be expressed as:

$$W(S_i) = \sum\nolimits_{j=1}^{n} (w_j \cdot v_{ij}), \quad i = 1, 2, 3, \ldots, m \tag{1}$$

Where:

$W(S_i)$ is the global priority weight of the i^{th} adaptation strategy,

v_{ij} is the local weight of strategy S_i with respect to the j^{th} criterion (or sub-factor),

w_j is the weight of the j^{th} criterion, and

m and n denote the total number of strategies and criteria, respectively.

Table 1. Saaty's scale of relative importance.

Scale	**Verbal Scale**	**Scale**	**Reciprocal**
1	Equally Important	-	-
3	Moderately more important	1/3	Moderately less important
5	Strongly More Important	1/5	Strongly less important
7	Very Strongly more important	1/7	Very strongly less important
9	Extremely more important	1/9	Extremely less important
2, 4, 6, 8	Intermediate score between two number	1/2, 1/4, 1/6, 1/8	Intermediate score between two number

Once all pairwise comparison matrices were established, the next step was to compute the relative weights and verify the logical consistency of expert judgments.

Step 4 – Consistency and weight calculation: Pairwise comparison matrices were developed based on expert responses. Local and global weights were calculated, and the consistency ratio (CR) was checked to ensure logical coherence of the judgments, with CR ≤ 0.1 considered acceptable. The CR was computed as:

$$CR = \frac{CI}{RI} \tag{2}$$

where the consistency index (CI) is given by:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

Here, λmax is the highest eigenvalue in the matrix, n is the number of groups and RI is the random index (**Table 2**). In this study, n = 4, hence RI = 0.90.

Table 2. Average random consistency index (R.I.).

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Each expert's matrix was first evaluated individually for CR ≤ 0.1. Only consistent matrices were aggregated to compute the final weights. The weighted arithmetic mean was again used to synthesize the experts' judgments at each hierarchical level. The validated local weights were then multiplied according to the hierarchical structure to obtain global weights for each subfactor and strategy, ensuring that the sum of all priorities equals one (ΣW = 1).

Step 5 – Strategy ranking and interpretation: Final global weights were aggregated to obtain the priority ranking of adaptation strategies using the formula:

$$W_{gbStrategies} = \sum_{i=1}^{n_j} \left(W_{subFStrategies_{ij}} \cdot W_{subF_{ij}} \cdot W_{factor_j} \right) \tag{4}$$

Where:

$W_{gbStrategies}$ is the global priority score of each adaptation strategy;

$W_{subFStrategies_{ij}}$ is the local priority of the strategy with respect to the i^{th} sub-factor within SWOT group *j*;

$W_{subF_{ij}}$ is the local weight of the i^{th} sub-factor within its corresponding SWOT group *j*;

W_{factor_j} is the weight of the j^{th} main SWOT group (Strengths, Weaknesses, Opportunities, Threats);

i denotes the sub-factors within each SWOT group; j denotes the four main SWOT groups (j = 1, 2, 3, 4);

j denotes the main SWOT groups.

n_j is the number of sub-factors within group j.

This formula corresponds to the standard AHP weighting principle for hierarchical aggregation, as presented in the AHP guideline, enabling quantitative comparison among the strategies. These results formed the basis for policy discussion and practical recommendations. All calculations were performed using Microsoft Excel, which facilitated the computation of normalized weights, CR values, and the ranking of adaptation strategies based on their global priority scores. To enhance transparency and accessibility, a flow diagram (**Figure 1**) was developed to summarize the integrated SWOT–AHP procedure applied in this study. The diagram visually presents the sequence of activities, from qualitative data collection to AHP-based quantitative analysis and final strategy prioritization.

4. Results

4.1. The Tea Industry in Thai Nguyen Province: Impacts of Climate Change and Adaptation Strategies

Thai Nguyen Province plays a crucial role in Vietnam's tea industry, being one of the most prominent tea-growing regions in the country. The tea sector in this province has long been an integral part of the rural economy, with approximately 40% of rural households relying on tea cultivation for their livelihoods [26]. In 2024, the total area for tea cultivation reached 21,119 hectares, with most of this land dedicated to commercial tea production [4]. Thai Nguyen is known for producing high-quality tea, primarily consumed domestically but also exported to international markets.

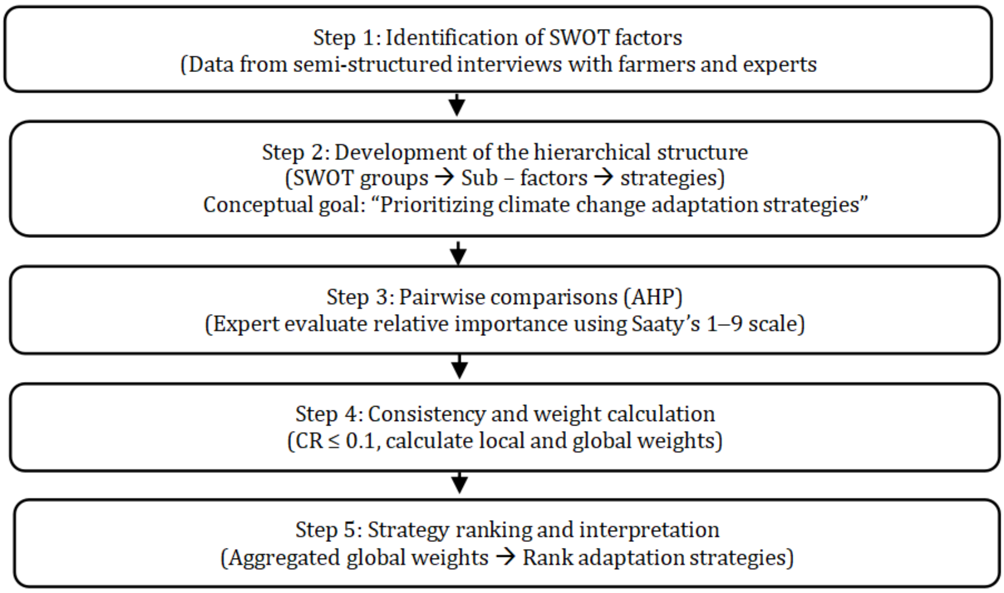

Figure 1. Flowchart of integrated SWOT–AHP procedure.

The tea industry in Thai Nguyen has experienced steady growth in recent years, despite facing several challenges. According to the Thai Nguyen Provincial Statistics Office [4], the tea cultivation area in 2024 saw a slight increase compared to previous years, reflecting the stable expansion of the sector. The tea yield in 2024 reached 12.961 tons per hectare, slightly up from 12.556 tons per hectare in 2023, contributing to a total fresh tea production of 273,721 tons, up from 264,426 tons the previous year, as reported in **Table 3**. The continuous growth in both area and yield indicates that the tea industry remains a vital part of the local economy.

Table 3. Tea production and export data of Thai Nguyen province (2020–2024).

Year	2020	2021	2022	2023	2024
Tea harvest area (ha)	19,812	20,564	20,889	21,060	21,119
Fresh tea output (tons)	244,432	250,732	260,857	264,426	273,721
Tea yield (tons/ha)	12.338	12.193	12.488	12.556	12.961
Tea export value (million USD)	1.9	2	2.4	1.6	0.9

Source: Thai Nguyen Statistics Office [4].

The tea sector involves over 91,000 households, 38 enterprises, 163 cooperatives, and 251 traditional craft villages [41]. Some areas, such as Tan Cuong, have production values exceeding VND 1 billion per hectare, reflecting tea's strategic role in poverty reduction and improving rural incomes.

In 2024, Thai Nguyen exported about 541.1 tons of various types of tea, generating 0.9 million USD in revenue, with an average price of 1.66 USD per kilogram [4]. However, this remains a small share due to the limited production scale and challenges in meeting international standards. As for branding, the "Tan Cuong" geographical indication has been protected in the European Union (EU) under the EU-Vietnam Free Trade Agreement (EVFTA), while the "Tra Thai Nguyen" collective trademark has been registered in six countries/territories: the United States, China, Russia, Japan, South Korea, and Taiwan [42].

Despite positive trends in production, the tea industry is becoming increasingly vulnerable to the impacts of climate change. Rising temperatures, changing rainfall patterns, and the increasing frequency of extreme weather events such as droughts, floods, and storms pose significant risks to tea production. Climate change has caused fluctuations in both yield and quality, affecting the financial stability of farmers and the competitiveness of Thai Nguyen tea in international markets. Smallholder farmers, who make up the majority of the region, are especially vulnerable to these challenges, as they often lack the resources to invest in climate-resilient technologies.

To address these issues, Thai Nguyen has implemented various strategies to improve tea quality and enhance sustainability in production. Over 80% of the province's tea-growing area meets safety standards, with 5900 hectares certified under Vietnamese Good Agricultural Practices (VietGAP) and 80 hectares dedicated to organic tea production [43]. These efforts reflect the local government's commitment to improving the quality and competitiveness of the tea industry.

However, despite significant efforts to improve production quality, the Thai Nguyen tea industry still faces several barriers to achieving sustainable development. Issues such as limited technological innovation, weak production linkages, and low access to international markets continue to hinder the sector's growth potential. In 2024, tea export value amounted to only USD 0.9 million, a sharp decline from USD 1.6 million in 2023, reflecting the challenges the industry faces in expanding its global market share [4].

In conclusion, although the Thai Nguyen tea industry has shown signs of growth and sustainable development, the challenges posed by climate change and other systemic factors present significant risks. Continued investment in technology, infrastructure, and expanding access to international markets are crucial to sustaining the industry's growth. Despite significant achievements, the Thai Nguyen tea industry is still facing challenges such as limited technological innovation, weak production linkages, and low access to international markets; therefore, increasing policy support, investment in processing technology, strengthening cooperatives, and developing brands are necessary to increase added value and competitiveness of products.

Thai Nguyen Province, a key tea-producing region in northern Vietnam, has experienced significant climate variability over recent decades. The average temperature in 2024, based on nationwide observations, reached 25 °C, about 1.3 °C higher than the multi-year average [44]. This rise, coupled with more frequent extreme weather events—such as droughts, frosts, and intense rainfall—has disrupted tea cultivation cycles. Tea plants, sensitive to both heat and water stress, have shown reduced yields and lower bud quality due to prolonged dry spells, unpredictable cold snaps, and erratic rainfall. Soil erosion and flash floods during monsoon seasons further exacerbate plant damage and input loss.

In the latter half of 2024, the key tea-growing regions in Thai Nguyen, such as Tan Cuong, Phuc Trieu, La Bang, and Trai Cai, experienced almost no rainfall, with water scarcity significantly affecting tea plants. The prolonged drought, high temperatures, and reduced soil moisture caused severe damage to tea cultivation. Tea plants, already vulnerable to both heat and water stress, failed to produce new shoots, severely limiting growth. As reported by Green Tan Cuong [45], some tea gardens were completely destroyed, and in others, yields were reduced by 30-40% compared to previous years. This drought, lasting from late autumn through spring, decimated the spring harvest, which is critical for both yield and quality. Tea buds failed to develop, leading to an average production loss of 50%–70% in some areas, the worst decline seen in over a decade. In addition to reduced yields, the quality of tea was also compromised, with smaller, drier buds and a reduction in essential compounds such as catechins and essential oils, leading to a loss of the characteristic aroma and flavor [45].

Furthermore, the impact of climate change on tea production has had a cascading effect on the economy and market of Thai Nguyen tea. Reports have highlighted that the persistent drought not only affected farmers but also caused supply shortages and fluctuations in market prices. With limited availability of raw materials, the production of premium teas such as Dinh Tea and Tuc Thiet Tea has been significantly constrained. This situation has disrupted both domestic and international tea markets, making it difficult for exporters and distributors to maintain stable operations. As a result, the reputation of Thai Nguyen tea—long valued for its high quality—now faces serious challenges due to climate-induced disruptions[46].

In response, local authorities and farmers have begun to implement various adaptation strategies. These include improving irrigation systems, restoring water sources, and adopting drought- and frost-resistant tea cultivars. Farmers have also been encouraged to adopt sustainable farming practices, such as organic fertilization and soil conservation, to mitigate the negative effects of climate change. Additionally, capacity-building programs have been introduced to train farmers in climate-smart agriculture techniques, particularly integrated pest management and efficient water use.

Despite these efforts, challenges persist, particularly with limited access to resilient seed varieties, insufficient infrastructure, and a lack of climate research tailored to the specific needs of tea agroecosystems[46]. As the region faces these ongoing challenges, local farmers have expressed the need for further governmental support to build water storage systems, such as dams and industrial wells, and to install irrigation systems with reliable electricity to ensure the continuity of tea production. The need for SWOT-AHP methods to prioritize adaptive interventions and enhance strategic planning capacity has also been emphasized to help the tea industry navigate these challenging circumstances effectively.

4.2. SWOT Factors Identification

To construct the SWOT matrix for the tea industry in Thai Nguyen Province, the study drew upon two complementary sources of information: academic research and empirical local evidence related to climate change impacts on tea production. Relevant studies and documents provided a conceptual foundation for identifying potential factors influencing the adaptive capacity of tea-producing households, while local reports and statistical data reflected the real-world conditions and emerging challenges of the provincial tea sector.

Building on this foundation, semi-structured interviews were conducted with tea-producing households and experts to refine and validate the key factors within each SWOT group. Tea farmers contributed insights into internal aspects such as strengths and weaknesses in their production practices, whereas experts provided external perspectives related to institutional support, policy implementation, and market dynamics under climate stress.

All qualitative information was thematically analyzed and synthesized to identify representative, non-overlapping factors across the four SWOT groups, as summarized in **Table 4**. The resulting matrix was subsequently reviewed and validated by the expert panel to ensure logical consistency, completeness, and contextual relevance for the AHP prioritization stage.

Based on the validated SWOT factors, four preliminary climate change adaptation strategies were synthesized from the literature review and qualitative findings, emphasizing the most influential strengths, weaknesses, opportunities, and threats. These strategies were then incorporated into the hierarchical framework for subsequent AHP evaluation.

Table 4. SWOT matrix.

Strengths (S)	**Weaknesses (W)**
(S_1) Long-standing tradition, advanced tea cultivation and processing techniques (S_2) Tea quality recognized by both domestic and international markets. (S_3) Closely linked production community (tea cooperatives, cooperative groups). (S_4) Integration of production and processing directly in the local area.	(W_1) Lack of investment capital to improve farming and processing technology. (W_2) High dependence on natural weather conditions. (W_3) Low level of application of sustainable agricultural techniques. (W_4) Lack of diversification of products and consumption channels.
Opportunities (O)	**Threats (T)**
(O_1) Rising demand for organic tea expands market opportunities. (O_2) Government and international project support for climate change adaptation. (O_3) Application of advanced agricultural technologies (O_4) Rising demand for agritourism and tea-related experiential tourism. (T_4) Risk of losing agricultural land to urbanization and industrialization.	(T_1) Climate change: rising temperatures, prolonged droughts, extreme storms and floods. (T_2) Fluctuating consumer markets (unstable tea prices, international competition). (T_3) Emerging pests and diseases due to climate change

Following the establishment of the hierarchical structure (**Figure 2**), the Analytic Hierarchy Process (AHP) was employed to quantify the relative importance of SWOT groups and sub-factors and to prioritize the proposed adaptation strategies according to their computed global weights.

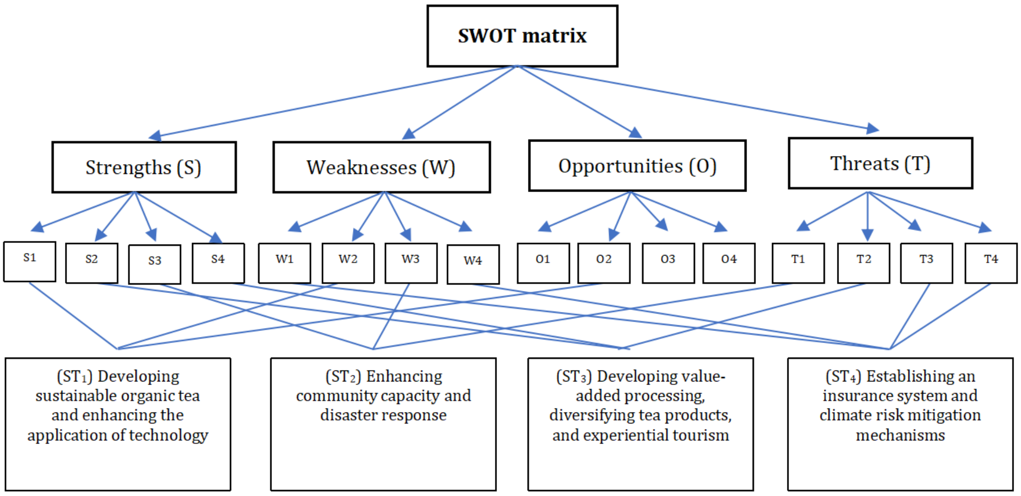

Figure 2. Hierarchical structure for evaluating strategies to enhance the sustainable climate change adaptation of tea-producing households in Thai Nguyen province.

4.3. Determination of Adaptation Strategy Priorities Using the AHP Method

The study conducted interviews with experts using a questionnaire, which required comparisons of pairs of indicators, using Saaty's scale [35]. First, the study conducted pairwise comparisons between SWOT groups (S, W, O, T), the results of which are shown in the **Table 5** below.

Table 5. Pairwise comparisons of SWOT factors.

SWOT Group	S	W	O	T	Importance Degrees of SWOT Groups (W_{factor})
Strengths (S)	1.00	4.20	3.00	3.80	0.5233
Weaknesses (W)	0.24	1.00	1.37	2.80	0.1972
Opportunities (O)	0.33	0.73	1.00	3.20	0.1926
Threats (T)	0.26	0.36	0.31	1.00	0.0870
CR = 0.065					

The results indicate that "Strengths" is considered the most influential factor in shaping climate adaptation strategies (weight = 0.5233), reflecting the importance of internal assets in household-level adaptation. This is followed by "Weaknesses" (0.1972) and "Opportunities" (0.1926), while "Threats" received the lowest priority (0.0870). The Consistency Ratio (CR) of 0.065 confirms the logical consistency of expert judgments, as it falls well below the accepted threshold of 0.1.

The pairwise comparisons of sub-factors within each SWOT group (Strengths: S1–S4, Weaknesses: W1–W4, Opportunities: O1–O4, and Threats: T1–T4) were conducted using the same procedure as described for the main SWOT groups. The local priority weights and corresponding Consistency Ratios (CR) were calculated and are presented in **Table 6**.

Table 6. Pairwise comparison of sub-factors in SWOT groups.

Factor	Sub-Factors	Local Priority	CR
Strengths (S)	S1	**0.4386**	0.0873
	S2	0.2922	
	S3	0.1656	
	S4	0.1035	

Table 6. *Cont.*

Factor	Sub-Factors	Local Priority	CR
Weaknesses (W)	W1	**0.5076**	0.0743
	W2	0.1293	
	W3	0.2248	
	W4	0.1383	
Opportunities (O)	O1	0.3258	0.056
	O2	0.2029	
	O3	**0.3775**	
	O4	0.0937	
Threats (T)	T1	0.3600	0.0606
	T2	**0.3699**	
	T3	0.1329	
	T4	0.1372	

Note: Local priority indicates the importance degrees of factors within the Group (W_{subF}).

From the data presented in **Table 6**, it can be seen that the sub-factors with the highest local priorities from the internal environmental factors are: Long-standing tradition, advanced tea cultivation and processing techniques (S_1- 0.4386) and lack of investment capital to improve farming and processing technology (W_1- 0.5076). Regarding the external environmental factors, the key sub-factors are the application of advanced agricultural technologies, such as IoT, efficient irrigation, and climate-resilient crops (O_3–0.3775), and fluctuating consumer markets (unstable tea prices and international competition) (T_2–0.3699). Furthermore, all pairwise comparisons of sub-factors exhibit acceptable consistency, with CR values below the 0.1 threshold, thereby confirming the reliability of expert judgments.

Next, the study conducted a pairwise comparison between the adaptation strategies in relation to each sub-factor of the SWOT groups. The following **Table 7** shows that the importance or priority level of the strategies (ST) for each sub-factor and the CR coefficient all have values less than 10%.

Table 7 illustrates the priority weights of four adaptation strategies (ST_1–ST_4) in relation to individual SWOT sub-factors. All consistency ratios (CRs) are below the accepted threshold of 0.10, indicating reliable expert judgments.

Table 7. Pairwise comparison of Strategies in relation to each sub – factor.

Factor	Sub-Factors	Adaptation Strategies ($W_{subFStrategies}$)				CR
		ST_1	ST_2	ST_3	ST_4	
Strengths (S)	S_1	0.48	0.20	0.22	0.10	0.067
	S_2	0.48	0.21	0.22	0.10	0.055
	S_3	0.47	0.19	0.24	0.10	0.063
	S_4	0.47	0.19	0.23	0.10	0.073
Weaknesses (W)	W_1	0.36	0.17	0.37	0.09	0.063
	W_2	0.50	0.26	0.16	0.08	0.075
	W_3	0.24	0.20	0.44	0.11	0.072
	W_4	0.31	0.17	0.43	0.09	0.070
Opportunities (O)	O_1	0.48	0.17	0.26	0.09	0.086
	O_2	0.30	0.44	0.17	0.10	0.086
	O_3	0.48	0.27	0.16	0.09	0.082
	O_4	0.31	0.17	0.42	0.09	0.080
Threats (T)	T_1	0.30	0.43	0.18	0.10	0.091
	T_2	0.47	0.18	0.25	0.10	0.091
	T_3	0.24	0.47	0.19	0.11	0.073
	T_4	0.46	0.18	0.26	0.10	0.085

Overall, ST_1 (sustainable organic tea development and technology application) received the highest weights across most sub-factors, especially under strengths (S_1–S_4), with values consistently around 0.47–0.48. This highlights expert consensus regarding the strategic relevance of leveraging technological innovation and organic practices to capitalize on existing strengths.

Under weaknesses, ST3 (value-added processing and diversification) emerged as a competitive alternative, notably for W_1 (0.37) and W_3–W_4 (≥0.43), suggesting its potential in addressing internal structural constraints.

For opportunities, ST_1 remains dominant under O_1 and O_3 (0.48), aligning with its technological focus, while ST_2 (community capacity and disaster response) is preferred for O_2 (0.44), reflecting alignment with institutional and social support systems.

In the threats dimension, ST_2 is prioritized under T_1 (0.43) and T_3 (0.47), indicating its suitability for immediate climate-related risks. ST_1 retains a leading role under T_2 (0.47), tied to stabilizing market uncertainties through quality and branding. ST_4 (insurance and climate risk mitigation) holds relatively lower weights across all sub-factors, indicating a supportive but non-primary role in the adaptation strategy mix.

The analysis reveals that ST_1 is the most consistently prioritized strategy, particularly for leveraging strengths and exploiting opportunities. ST_2 and ST_3 serve as complementary approaches, especially in managing vulnerabilities and external threats.

Following the pairwise comparisons and local priority estimations, the final step involves computing the global priority scores of the proposed adaptation strategies. These scores reflect the overall importance of each strategy, considering the hierarchical structure of the SWOT–AHP model. Specifically, the global priority vector of strategies ($W_{gbStrategies}$) is obtained by aggregating the weighted scores of each strategy across all SWOT sub-factors using the formula (4).

The results are presented in **Table 8**, indicating that strategy ST_1 (Developing sustainable organic tea and enhancing the application of technology) ranks highest (0.43260), followed by ST_3 (Developing value-added processing, product diversification, and experiential tourism) with 0.25136, and ST_2 (Enhancing community capacity and disaster response) at 0.22028. ST_4 (Establishing an insurance system and climate risk mitigation mechanisms) receives the lowest priority score (0.09576).

These findings emphasize the dominant role of technology and sustainable practices (ST_1) in climate adaptation for the tea sector, while also highlighting the strategic potential of market diversification and local capacity-building. Although ST_4 has relevance, it is perceived by experts as less immediately actionable or impactful compared to the other strategies.

Table 8. Global priorities of Adaptation strategies.

Adaptation Strategies	Global Priorities ($W_{gbStrategies}$)
ST_1	0.43260
ST_2	0.22028
ST_3	0.25136
ST_4	0.09576

5. Discussion

Building upon the results presented in the previous section, this discussion interprets the relative priorities identified through the SWOT–AHP analysis and connects them to existing literature. The integrated SWOT–AHP analysis shows that strategy ST_1—developing sustainable organic tea and enhancing the application of technology—holds the highest global priority (W = 0.43260), ranking well above the other strategies. This result is consistent with previous research that underscores the importance of sustainable farming practices and technological innovation in strengthening agricultural resilience to climate change [6,14]. The strong emphasis on ST_1 reflects local stakeholders' recognition that modernizing cultivation practices and promoting ecological farming are essential for both environmental sustainability and long-term productivity in the tea sector. Previous studies also confirm that the integration of climate-smart agricultural practices, including organic farming and technological applications, plays a vital role in mitigating the effects of extreme weather events — a challenge increasingly affecting tea production in provinces such as Thai Nguyen [18].

Following this, strategy ST_3 (Developing value-added processing, diversifying tea products, and experiential tourism) ranks second (W = 0.25136), suggesting a strong need for economic diversification and market-oriented transformation. This aligns with previous research emphasizing the importance of improving value chains and creating additional income streams to buffer against climate-induced risks [13,15]. Diversification within the tea sector, including the development of premium teas and value-added products, provides an opportunity for farmers to increase their resilience to market volatility and climate-induced production challenges. Creating new revenue streams through diversified products and experiential tourism linked to tea cultivation is increasingly recognized as a viable solution to strengthen the sector's adaptability.

In contrast, ST_2 (Enhancing community capacity and disaster response) and ST_4 (Building an insurance system and climate risk mitigation) received lower weights (0.22028 and 0.09576, respectively), highlighting potential limitations in institutional support systems and the complexity of implementing collective risk management mechanisms at the local level. Although previous studies have stressed the value of community-based adaptation [5], its lower ranking in this study may indicate challenges in mobilizing resources, sustaining long-term training programs, and aligning institutional frameworks with farmers' needs. The lower prioritization of these strategies underscores the necessity for stronger institutional frameworks and support systems to ensure that community-based adaptation efforts are well-supported and sustainable. These findings also suggest that, while local communities may acknowledge the need for disaster response and climate risk mitigation, the actual implementation of such measures remains complex due to issues such as insufficient funding and institutional coordination.

The findings further underscore the importance of economic diversification and technological innovation in ensuring the long-term resilience of the tea sector. Research consistently indicates that climate change impacts, including water scarcity and increased pest pressures, significantly disrupt tea farming systems, leading to reduced yields and increased production costs [18]. These changes are expected to continue as the climate crisis accelerates, making it imperative for farmers to adopt climate-resilient farming techniques and value-added production methods to maintain and improve productivity.

These results offer novel insights into the adaptation priorities of smallholder tea farmers in Vietnam—an area previously underexplored in empirical literature. Unlike earlier research, which often remained qualitative or lacked methodological integration, this study provides a quantitative hierarchy of strategies based on expert evaluations, thus enhancing the applicability of findings for policy formulation and local planning. The use of AHP reinforces the objectivity of the SWOT assessment and ensures transparent, evidence-based decision-making, bridging the methodological gaps of earlier studies [10]. Previous studies, such as Firoozzare et al. [33], have used similar frameworks to assess agricultural adaptation strategies, but this study extends the use of SWOT-AHP to a more context-specific scenario for the tea sector in Vietnam.

Ultimately, the findings underline the necessity for context-specific, innovation-driven, and economically viable adaptation strategies. Promoting organic and tech-based tea farming, coupled with product diversification, emerges as a clear path toward building climate resilience in Vietnam's tea sector. Adopting integrated strategies that combine organic farming with technological advancements, along with proactive market diversification, is essential for strengthening the long-term resilience of the tea sector. These findings emphasize the need for policy support, such as infrastructure improvement, financial incentives, and access to advanced farming technologies, to ensure that farmers can adapt to changing climatic conditions while maintaining sustainable production practices.

Despite these important findings, several methodological limitations should be acknowledged. The subjectivity inherent in expert judgments may have influenced the pairwise comparison results; however, this bias was minimized by selecting experienced experts, verifying logical consistency through the Consistency Ratio ($CR \leq 0.1$), and using the weighted arithmetic mean to synthesize their evaluations. This averaging approach, while practical and transparent, may not fully eliminate individual bias. In addition, the relatively small expert panel (n = 10) and household sample (n = 30) limit the statistical representativeness and spatial generalization of the findings beyond the study area. Nevertheless, these sample sizes are consistent with AHP methodological standards, which emphasize the depth and consistency of expert knowledge rather than large-sample inference. Future research could expand the spatial scope, include more diverse stakeholders, and integrate complementary techniques such as Delphi or fuzzy AHP to enhance robustness and external validity.

6. Conclusions

This study integrated the SWOT framework with the Analytic Hierarchy Process (AHP) to identify and prioritize climate change adaptation strategies for tea production in Thai Nguyen province. The findings reveal that the strategy "Developing sustainable organic tea and promoting technological applications" (ST_1) holds the highest priority (W = 0.43260), emphasizing the critical need to transition towards environmentally friendly and climate-resilient production models. This prioritization reflects the local stakeholders' recognition that adopting sustainable agricultural practices and innovative technologies is essential for enhancing climate resilience and ensuring long-term productivity in the tea sector. In addition, the results show that ST_3 ("Developing value-added processing, diversifying tea products and tea-based tourism") ranks second (W = 0.25136), highlighting the importance of economic diversification and the need to create new income streams for farmers to reduce climate-induced risks. Meanwhile, ST_2 ("Enhancing community capacity and disaster response") and ST_4 ("Establishing an insurance system and climate risk mitigation mechanisms") received lower priorities (W = 0.22028 and W = 0.09576, respectively), indicating the necessity for further strengthening institutional support systems and improving resource mobilization to effectively implement these strategies at the local level.

These findings were further contextualized by comparing them with existing studies. When compared with previous studies, the results of this research show a similar pattern: sustainable farming practices and technological innovation remain the most important adaptation strategies. However, this study also highlights a stronger emphasis on economic diversification (W = 0.25136)—particularly value-added processing and tea-based tourism—which was less recognized in earlier works. This suggests that the tea sector in Thai Nguyen is moving beyond production-focused adaptation toward a more market-oriented and resilient development model.

From a policy perspective, the results suggest that local authorities should:

- Prioritize technical support for organic tea production by providing targeted support to farmers in vulnerable regions through technology transfer programs, subsidized credits, and certification assistance. This will be crucial in increasing the adoption of climate-resilient agricultural practices and in meeting the urgent need for ecological farming practices as outlined in ST_1.
- Integrate climate adaptation training into the activities of cooperatives and farmer associations, particularly focusing on weather forecasting skills, emerging pest control, and seasonal risk management. This will directly support ST_2, which emphasizes building local capacity and disaster response mechanisms.
- Encourage investment in deep processing and tea-based tourism diversification, by providing preferential credit, improving infrastructure, and building local tea brands. This aligns with ST_3, which emphasizes diversifying income sources through value-added products and tourism to enhance economic resilience.
- Pilot agricultural insurance schemes for tea in high-risk areas, combined with local budget support to enhance farmers' access and participation. This will help mitigate the impacts of climate-related risks, especially in vulnerable tea-growing areas.

The coordinated implementation of these policy measures can significantly improve the adaptive capacity of tea producers and promote the sustainable development of the tea sector in Thai Nguyen amid increasing climate change. The involvement of multiple stakeholders, including local authorities, private-sector actors, and farmer cooperatives, will be crucial to ensure the success of these measures. A clear financial framework needs to be established to allocate resources effectively and support farmers in adapting to changing climate conditions.

The proposed SWOT–AHP framework demonstrates strong potential for real-time implementation. It can serve as a decision-support tool for local authorities and farmer cooperatives to periodically reassess adaptation priorities and allocate resources effectively. Given its quantitative transparency and ease of replication, the model can be integrated into annual agricultural planning processes at provincial or commune levels. In future research, this framework could be extended to other climate-sensitive crops or regions, incorporating time-series climatic and production data to strengthen its predictive capacity and inform national adaptation policies.

While the study provides robust evidence to guide local adaptation planning, it is not without limitations. The reliance on expert judgments and a relatively small sample size may constrain the generalizability of the findings beyond the study area. Future research should therefore expand the spatial coverage, include a broader range of stakeholders, and apply complementary methods such as Delphi or fuzzy AHP to further validate and refine the prioritization framework.

By leveraging innovative farming techniques, sustainable agricultural practices, and economic diversification, the tea sector in Thai Nguyen can significantly enhance its resilience to climate change. Increased governmental and institutional support will be essential to ensure that these strategies are implemented effectively and that the sector continues to thrive in the face of climate-related challenges.

Author Contributions

Conceptualization, X.L.H. and H.T.T.N.; methodology, H.T.T.N.; software, H.T.T.N.; validation, H.T.T.N.; formal analysis, H.T.T.N.; investigation, X.L.H. and H.T.T.N.; resources, X.L.H.; data curation, X.L.H.; writing—original draft preparation, X.L.H.; writing—review and editing, H.T.T.N. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Informed consent was obtained verbally from all subjects involved in the study.

Data Availability Statement

The datasets generated and analyzed during this study comprise anonymized results from expert and farmer interviews, SWOT matrices, pairwise comparison data, and computed priority weights derived from the Analytic Hierarchy Process (AHP). To ensure participant confidentiality, the raw interview data cannot be publicly shared. However, all aggregated and anonymized datasets that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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