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The social-ecological resilience indicators of organic rice production in Northeastern Thailand

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Abstract Uncertainties in agriculture have been posing serious threats to organic farmers, especially the marginal ones in developing countries such as Thailand. Building resilience appears the most workable strategy to help them cope with those threats since its definitions and operation fundamentally focus upon the capacity to adapt to all types of change to be better in consequences. In this study, the author used a participatory principle and qualitative data analysis as tools. Sixty-two experienced organic farmers from four provinces in Northeastern Thailand were purposively selected as the informants. They were asked individually regarding the resilience concepts in agro-ecological contexts and related theories to generate a specific set of indicators whose qualities can maintain and recover organic rice production against ongoing change. Consequently, guided by three processes of qualitative study and the nominal group technique (NGT) aimed at converting abstract ideas into practical features aligned with resilience theories in agro-ecosystems, the organic farmers developed 28 indexes known as social-ecological resilience indicators (SERIs). The SERIs capture important components related to diversity and resource accessibility, such as ownership of legal credit sources and types of organic certification, to enhance adaptive capacity. The SERIs can serve as both quantifiable evaluation and qualitative guidance because the informants' social, ecological, and cultural contexts are integrated. The SERIs are effective to provide empirical insights into practices and assets for building resilience. The SERIs are also vital to propose policies to encourage organic farmers to conduct adaptations and transformation during a period of change.

Keywords Resilience indicators · Social-ecological resilience · Organic rice · Northeastern Thailand

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Introduction

In Thailand, organic rice production has always been praised as a lighthouse of sustainable agriculture and food production system (Seubsman et al. 2013). According to the data collected since 2000, the country currently ranks as the 7th largest organic rice production area in Asia, with continuous expansion of the production area (Salaisook et al. 2020). This is evidenced by the fact that 3.1 million farming households engage in organic rice production in Thailand. The production area has also grown from 10,524 rai in 2000 to 1,403,000 rai in 2023, representing an approximate annual growth rate of 16% (Office of Agricultural Economics 2023). The prosperity of organic rice production is due to its outstanding quality in providing staple food and promoting agricultural development (Seubsman et al. 2013). Furthermore, compared to conventional agriculture, organic rice production contributes to a 12% increase in biodiversity and provides a greater abundance of favorable environmental conditions (Biggs et al. 2015). Moreover, the ways in which organic rice production is being conducted are not undergoing much disruption from recent technologies nor are they being dominated by conservative notions (Polthanee and Promkhambut 2014). Therefore, organic rice production enables organic farmers to adopt holistic strategies of management so that they can formulate solutions to better cope with any changes in social-ecological systems (Biggs et al. 2015).

Although organic rice production has many substantial advantages, it is still vulnerable to uncertainty, which is influenced by both domestic and global incidents (Kuntiyawichai and Wongsasri 2021). For instance, organic rice production has always been subject to a higher degree of yield variation due to the absence of synthetic substances that would protect it from crop failures (IFOAM 2013). At present, climate change is another barrier to production success (Chinvarasopak 2015). During 2019 and 2020, when drought occurred in Thailand, it was reported that the productivity of organic farmers in certain provinces, such as Sakon Nakorn, Kalasin, and Mukdahan, was adversely affected (Chuasuwan 2018). These provinces experienced severe drought conditions, resulting in a noticeable decline in on-season rice crops for most organic farmers. As a result, their debt burden with the Bank for Agriculture and Agricultural Cooperatives (BAAC) increased (Phansak et al. 2021). Notably, in the first quarter of 2020 alone, the projected damage caused by drought to rice production, including both organic and conventional varieties, amounted to approximately 17.63 billion Thai baht, making it the highest value of damage compared to other economic crops (Statista Research Department 2022). Even organic farmers, whose rice fields were in irrigated areas, were unable to avoid the consequences of the drought. Insufficient agricultural water had not allowed them to nourish their crops or to practice weed control, which led to a critical loss of productivity (Kuntiyawichai and Wongsasri 2021). In other words, organic rice production has played a significant role in the Thai economy and the livelihood of its people, primarily due to its productivity benefits and the enhanced biodiversity it brings to farmlands and surrounding areas. However, the success of organic rice production is contingent upon several factors, with water accessibility being particularly important (Pattanapant and Shivakoti 2009). A previous study indicates that the amount of water required to produce 1 kg of rice varies widely, ranging from 800 to 5000L, with an average of approximately 2500L, depending on climate conditions, hydrological frameworks, and soil types (Surendran et al. 2021). In recent years, increased competition for water resources due to accelerated urbanization and industrial development in Thailand has further restricted water availability in agriculture (Yossuk and Kawichai 2017). Given this scenario, the failure to address this constraint poses a significant challenge to achieving sustainable development (Heis 2015).

Admittedly in agriculture, no one solution fits the problems of organic farmers (Carpenter et al. 2015). The problems are dependent upon the system's social-ecological dimensions, which cannot be managed by command-and-control approaches (Biggs et al. 2015). A feasible solution to fix those problems is resilience concepts that can generate a solution, which is suited to address the ongoing disturbance (Kuntiyawichai and Wongsasri 2021). For instance, climate change has been a comprehensive challenge for northeastern farmers of Thailand. They were difficult to raise their crops because of extreme weather events. To escape from that, some farmers changed the farming system, reducing the surface area of rice to vegetables and medicinal plants without more investment apart from the usual production costs. This adaptation was designed to not only help them consume less water but also provide a weekly or monthly income to nourish the household until the hardship of drought gets through (Pak-Uthai and Faysse 2018). This incident shows how the northeastern farmers applied the resilience concept in enhancing their capacity to generate effective adaptation and positive alternatives against impromptu threats. However, a higher frequency of extreme weather events may need those other capacities, such as adaptive or transformative. Therefore, resilience is not a given state and is independent of values but strongly context dependent. Importantly, to achieve long-term resilience, political encouragement, and economic support are vital as well (Darnhofer 2021). Worries about structural changes may draw organic farmers' attention away from making potential adaptations and lifelong learning (Ashkenazy et al. 2018).

Although the ways of resilience being addressed have meanings and operations, most of them share a common interest in making adaptations, which can lead to creative consequences (Biggs et al. 2015). The case of the northeastern farmers above is an example (Pak-Uthai and Faysse 2018). Moreover, the preservation of sustainability is not a goal of resilience but represents the autonomy to arrange plans based on the availability of resources. Organic farmers, who are equipped with the capacity for resilience, tend to generate suitable location-specific solutions (Darnhofer 2021). Nonetheless, building resilience requires a series of well-executed plans to deal with the complicated relationships that exist between stakeholders and their entire social-ecological details (Béné 2013).

No unanimity on how to build resilience has existed due to three rationales (Tan 2021). First, resilience is ambiguous. Its operations require the immaculate connectedness of components that range from household to policy level (Duchek et al. 2020). Moreover, there is no consensus regarding the meaning of resilience across society when it comes to the objectives of responding to change. The resilience of agroecosystems is influenced by power dynamics. In terms of general resilience, it is often associated with increased access to resources and political power to mitigate various negative pressures (Cordoba et al. 2020). Therefore, it becomes essential to identify resilience from the perspective of stakeholders, considering who it is for and what purpose it serves (Darnhofer et al. 2011; Béné 2013). Second, resilience has been associated with adaptive capacities to cope with change. It is arduous to quantify those because they have cultural, technical, and political components that need to be considered. Moreover, within resilience, there is an interplay between the formal (e.g., membership of institutes and the availability of assets) and the informal dimensions (e.g., social relations and leadership) (Carpenter et al. 2001). Although these dimensions are essential to the process of building resilience in systems, it is difficult to measure the informal dimensions even though they provide opportunities to establish robustness and transformation in times of crisis (Le Campion et al. 2020). Finally, developing resilience indicators may be the most challenging task. The nature of resilience entails a dynamic process that evolves. Resilience indicators should be designed to reflect this dynamic nature and can capture changes and adapt to new challenges across temporal and spatial scales (Panpakdee and Limnirankul 2018).

One of the most feasible guidelines to build resilience that has been cited is developing the quantification tool of the specific-context indicators (Béné 2013). The indicators are a preliminary step to understanding the complex relationship that exists between humans and their environments (Duchek et al. 2020). These indicators are also fundamental in not only facilitating progress regarding the system's resilience but also monitoring its existence or absence for the benefit of deciding what to do next. Indeed, developing a universal measurement of resilience is productive, but it is more productive to develop a set of specific indicators that can focus on perceiving which of the components is the most imperative (Cabell and Oelofse 2012). In this way, the variables, such as income, social assets, and access to safety nets, can be observed and built as proxies to monitor resilience. Furthermore, those variables are in the sustainable livelihood approach (FAO 2019). Essential components for building resilience are various but at least must represent local ecological and socioeconomic conditions (Biggs et al. 2015). Importantly, the process of developing resilience indicators must be conducted by participatory principles. Participation helps capture the systems that can prepare for change that promotes sustainability. Consequently, the outcomes can lead to the introduction of a local understanding based on the systems' social-ecological attributes (Ashkenazy et al. 2018; Darnhofer 2021).

Although articles have indicated that developing resilience indicators are difficult, they have disclosed some pragmatical guidelines that can be used to overcome it (Panpakdee and Limnirankul 2018; Tan 2021). To narrow the research gap, this paper, nonetheless, only aims at developing the social-ecological resilience indicators of organic rice production in Northeastern Thailand. The Northeastern Region (Isan in Thai) of Thailand is the largest region of the country, located on the Khorat Plateau, bordered by the Mekong River (along Laos–Thailand border) to the north and east, by Cambodia to the southeast and the Sankamphaeng Range south of Nakhon Ratchasima (Baker and Phongpaichit 2014). Like other areas of the country, performing agriculture practices as a means of generating the main source of income has been predominant (NESDC 2019). Although a decline in rice consumption per capita has been found, rice production remains topmost for more than a millennium due to its importance in culture, economy, and politics (Rambo 2017). Although the Thai economy has experienced significant growth over the past decades, poverty and inequality continue to prevail, particularly in the Isan region. Despite being a major agricultural producer with 7.8 million people relying on farming for their livelihoods, local farmers face numerous challenges. Poor soil quality, inadequate irrigation systems, fluctuating crop prices, and the impacts of climate change pose significant obstacles to agriculture in the region (Ouyyanont 2017). Besides, most of them had a moderate education, having completed elementary school as their highest academic achievement. This has not only constrained them as experimenters in acquiring more knowledge through trial and error but has also limited their ability to adopt technologies (Rambo 2017). As a result, Isan farmers have an average annual income of only 62,751 baht, which is considerably lower compared to farmers in the central and southern regions, who earn an average of 329,579 and 210,397 baht per year, respectively (Kao Sod 2022). These findings underscore the importance of examining the natural environment and the historical context of Thailand, which are integral to this study.

Literature review

The concept of resilience in agricultural systems and its importance for adaptation

The concept of resilience originated from a seminal study by Holling (2001), which underscored the capacity of ecosystems to restore a stable state following a disturbance. Since then, the concept has evolved, embracing alternative states, and recognizing the intricate interconnections between ecological and social systems, as well as the dynamic nature of system change (Biggs et al. 2015). In response to the imperative for both persistence and flexibility in an ever-changing world, scholars introduced the notions of adaptability and transformability (Folke et al. 2010). Adaptability refers to the ability to learn and adjust in the face of change, while transformability pertains to the capacity to transition toward a new system configuration. Consequently, resilience is now perceived not as an inherent trait of systems but rather as a dynamic process (Carpenter et al. 2001). Besides, the resilience of systems can vary depending on their specific characteristics within a given context (Béné 2013). This understanding necessitates a fundamental shift in the mindset concerning farming systems, moving away from a focus on optimizing productivity within a relatively stable context and towards embracing continuous changes through the implementation of adaptive strategies (Darnhofer et al. 2011).

In the present day, the importance of resilience in agricultural systems cannot be overstated (Duchek et al. 2020). Resilience has emerged as a crucial attribute of farming systems, arising from the intricate interactions between farmers, environmental conditions, and broader contextual factors (Tan 2021). Darnhofer (2014) highlights three essential capacities for achieving resilience in agricultural systems: (1) buffer capability, which involves the temporary reallocation of resources to resist minor disturbances; (2) adaptation capability, encompassing the ability to design and execute effective adaptations within the existing system; and (3) transformative capability, denoting the capacity of individuals and/or systems to reorganize themselves from a state of dependency on previous patterns to embrace novel opportunities.

It is worth noting that not all types of agricultural systems can achieve resilience, except for organic agriculture (Le Campion et al. 2020). Organic agriculture, characterized by its holistic and sustainable practices, plays a pivotal role in building resilience by fostering biodiversity conservation and abstaining from the use of harmful chemicals that can have adverse effects on beneficial organisms (IFOAM 2013). Besides, the presence of rich biodiversity within organic farming systems enhances ecosystem resilience by promoting natural pest control, pollination services, and nutrient cycling (Kotamee and Pratthanawutthikun 2017). As a result, the reliance on external inputs is significantly minimized (Green Net 2020). Nevertheless, it is crucial to acknowledge that the benefits of organic agriculture in terms of resilience can vary depending on specific contexts and management practices. For instance, if the transition period to organic practices is less than 5 years, the contribution of organic agriculture to resilience is often limited. The limitation arises due to the insufficient enhancement of the soil's ability to absorb mineral nutrients through organic management practices, therefore hindering soil health (Chinvarasopak 2015).

Developing social-ecological resilience indicators

Developing social-ecological resilience indicators is a complex task as it involves assessing and monitoring key components that provide insights into the resilience of a given system. These components help us understand the system's ability to withstand disturbances, adapt to changes, and maintain its productive functions and structures across temporal and spatial scales (Plastina 2022).

In their comprehensive analysis of studies about the resilience of social-ecological systems, Folke et al. (2002) identified four fundamental properties crucial to the establishment of resilience for reaching the domain of "the capacity of people, communities, societies, and cultures to live and develop with ever-changing change." These properties entail: (1) learning to live with change and uncertainty, (2) nurturing diversity in various forms, (3) combining different types of knowledge and learning, and (4) creating opportunities for self-organization and cross-scale linkages. These four properties collectively encompass a set of processes that entail the implementation of practices and social mechanisms operating in conjunction, transcending both temporal and spatial dimensions, and thereby thwarting the loss of resilience (Brunner and Regamey 2016). Consequently, this qualification not only assumes a quantitative character but also provides qualitative guidance for the sustainable reduction of vulnerability via the facilitation of adaptation and transformation amidst dynamic periods of change.

Previous studies have outlined five general steps for building social-ecological resilience indicators (Bidwell 2011; Béné 2013; Panpakdee and Limnirankul 2018; Hutter and Bailey 2022). These steps are the following:

A) Identifying components. The first step is identifying the relevant components of a system. This involves identifying key dimensions such as economic, ecological, and political dimensions that are relevant to resilience. For example, in an organic rice system, ecological dimensions may include biodiversity, soil health, and water availability, while social dimensions may encompass farmer livelihoods and community cohesion.
B) Defining indicators. Once the dimensions are identified, specific indicators need to be defined to measure the state or condition of each dimension. These indicators should be measurable, reliable, and sensitive to changes. For instance, an indicator of biodiversity could be the species richness and habitat diversity, while an indicator of the social dimension could be the presence of social norms that reflect the society's ability to bond through social capital.
C) Collecting data. Data collection is the next step, and suitable methods such as surveys, field measurements, or existing datasets should be used to collect data for each indicator. It is important to ensure that the collected data is representative and covers an appropriate temporal and spatial scale. Both qualitative and quantitative data sources should be considered to capture the complexity of the system effectively.
D) Analyzing and interpreting data. The collected data should then be analyzed and interpreted to assess the current state of each indicator and understand the relationships and interactions between different indicators. Statistical analysis techniques and qualitative methods can be employed to gain insights into the vulnerabilities and strengths of the system's resilience.
E) Validating and refining indicators. Validation and refinement of indicators are crucial steps. Indicators should be validated by comparing them with existing resilience frameworks or related theories. Seeking feedback from stakeholders and experts is important to ensure that the indicators effectively capture the essential dimensions of resilience. If necessary, indicators should be refined to improve their relevance and accuracy.

Developing resilience indicators for social-ecological systems require reliable and relevant data to address their complexity. It is vital to simplify indicators while considering feedback loops to avoid an incomplete understanding of resilience. Additionally, it should be noted that resilience is context specific. Indicators developed for one system may not be directly applicable to another system, limiting their transferability and comparability.

Methods

Study Site

This study was conducted in four northeastern provinces of Thailand: Ubon Ratchathani, Yasothon, Amnat Charoen, and Sisaket. These provinces are neighboring each other and are in the lower portion of the region (NESDC 2019) (Fig. 1). They share similar agroecological contexts, characterized by sandy soils with moderate fertility and a tropical savanna climate that exhibits distinct wet and dry seasons. The average annual rainfall in these provinces is approximately 1469 mm/year (Baker and Phongpaichit 2014).

Currently, these four provinces are widely recognized as Thailand's leading organic rice-producing areas, with over 50% of their provincial areas predominantly covered with paddy fields (Chinvarasopak 2015). During the 2020–2021 period, they ranked among the top producers in the region, with an average in-season organic rice yield ranging from 356 to 563 kg per rai (National Statistical Office 2021). This success can be attributed to several factors. Firstly, the abundant water supply from the Mun River, which merges with the Mekong River, contributes to irrigation. Additionally, the presence of the Korat Plateau, formed by uplifted sediments and volcanic activity, has resulted in the accumulation of nutrient-rich materials in the soil (Panpluem and Yin 2021; Singtuen et al. 2021). Another positive factor contributing to the maintenance of soil fertility in the Korat Plateau is the presence of parent rocks, which significantly release essential nutrients such as nitrogen, phosphorus, and potassium crucial for plant growth (Singtuen et al. 2021). Moreover, the utilization of modern machinery and government subsidy programs has been vital in supporting organic farmers (Khunthongjan 2016). Additionally, organic rice production in these provinces is facilitated by organic farming network groups. These groups actively

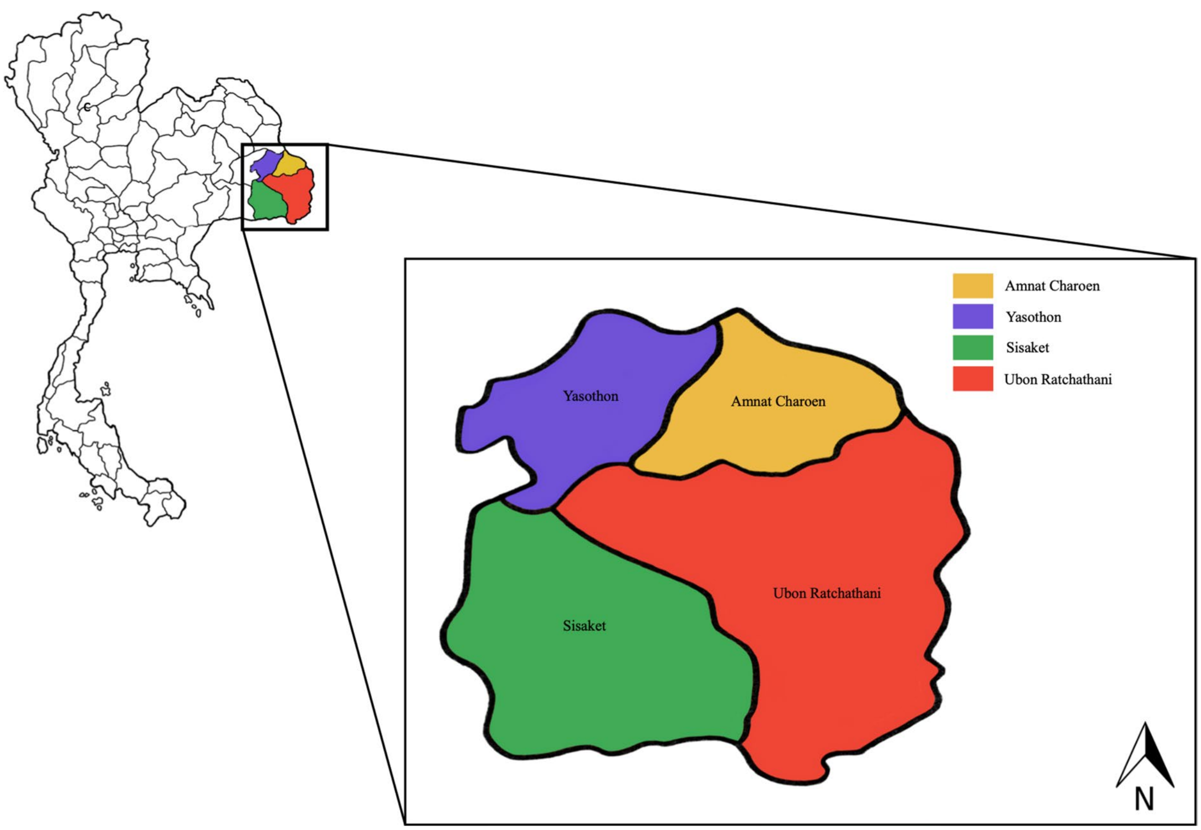

Fig. 1 Map of the study sites

work and view organic rice production as an economic instrument that promotes safe food security, self-dependence, and environmentally sustainable practices (National News Bureau of Thailand 2018; Loiypha 2022). As a result, they have gained national recognition for their outstanding performance (Arunrat and Pumijumnong 2015). Their collaboration enables them to negotiate fair prices with buyers, as well as forecast their income from rice sales, facilitating effective planning (Kotamee and Pratthanawutthikun 2017).

Sampling Procedure

Due to the limited number of organic farmers in northeastern Thailand, purposive sampling was conducted (Miles et al. 2014). The database of Organic Agriculture Certification Thailand was used to provide the empirical data, which resulted in a total of 62 organic farmers as informants (ACT 2020). Of them, fifty-five were males (88.71%) and seven were females (11.29%) (Table 1). The average ages and years of experience in organic rice production are 56.08 and 17.53 years, respectively. The sizes of farms also averaged 9 rai per household.

Since the study employed a qualitative research-based approach for data collection, the informants shared these common criteria: (1) they had been recognized as being adept at organic rice production, which has been proven by their use of on-farm resources and indigenous knowledge to improve their farm management (Tan 2021); (2) their products had been certified following organic standards set by the Ministry of Agriculture and Cooperatives for more than 12 years (ACT 2020); and (3) they had been working with other organic farmers, groups, and cooperatives to become more adept at exchanging information. These criteria are imperative for developing resilience indicators (Béné 2013).

Data Collection

The data collection was primarily divided into three processes, with individual interviews conducted at the farm level between August and November of 2022. Firstly, the informants were apprised of the comprehensive resilience concepts in the social-ecological systems to transform an abstract definition of resilience into a concrete perception for better understanding (Carpenter et al. 2001; Folke et al. 2002; Darnhofer 2014). The study's expected outcomes were also communicated. Secondly, individual semi-structured interviews were done. Every informant was asked about his or her agricultural background and other relevant data such as socioeconomic conditions, farming practices, and agricultural histories. These details were crucial for data collection purposes (Abuhamda et al. 2021). Thirdly, the informants were solicited to apply their experiences for designing "a satisfactory farm." In short, the satisfactory farm is an ideal vision of organic rice production with the capacity to maintain primitive operations even when it is being affected by changes (Panpakdee et al. 2021). The concept of a satisfactory farm should be visualized alongside its components, which possess attributes that can serve as measures to quantify and establish desirable qualities in effectively dealing with, absorbing, and adapting to disturbances, without undergoing fundamental changes, ultimately aiming to restore a state of normality (Darnhofer 2021). In this process, behavior-based indicators in agroecosystems were applied (Cabell and Oelofse 2012). These indicators encompass metrics that assess the creative behavior of individuals, communities, or organizations in achieving sustainability, resilience, and environmental stewardship against change within agroecosystems. Therefore, they specifically focus on the implementation and adoption of sustainable agricultural practices. Examples of such practices

Table 1 The number of informants involved in this study

Province	District	No. of sampling participants	% of total sampling participants
Ubon Ratchathani	Don Mod Daeng	12	19.35
Yasothon	Kut Chum	21	33.87
Amnat Charoen	Mueang Amnat Charoen	15	24.20
Sisaket	Rasi Salai	14	22.58
Totals		62	100.00

include the adoption of organic farming techniques to enhance soil health and promote wildlife habitats, as well as the application of biodiversity practices such as the creation of buffer zones. As a result, these indicators provide valuable insights to farmers and other stakeholders, illuminating the decision-making actions taken to address social-ecological changes and achieve resilience. Consequently, the indicators prove instrumental in formulating meaningful questions that enhance the responses of informants regarding adaptations. For instance, questions like "How have you adapted your practices in response to changes in climate patterns?", "Have you introduced new crops into organic rice production to align with uncertainties? If so, what factors influenced these decisions?", "What role have social networks or community-based organizations played in facilitating adaptive practices?", and "What support or resources do you need to further enhance your adaptive capacity?" were formulated. The third process was done iteratively until the empirical saturation of results had been achieved (Miles et al. 2014).

Data Analysis

The data analysis consists of two parts with mixed-methods research. Qualitatively, the first part focused on how to organize the unstructured data into themes of resilience. Subsequently, the application of a quantitative approach known as the nominal group technique (NGT) was employed to facilitate a structured brainstorming process, complemented by thorough discussions and prioritization utilizing a multi-voting. This methodological choice aimed to foster a collaborative environment wherein the informants were encouraged to validate and consolidate those themes of resilience into indicators that closely aligned with their collective consensus.

The interviews, during which detailed notes were taken, were transcribed to capture descriptive and reflective data. This approach proved to be effective in transcribing as it facilitated the conversion of the data into meaningful units through the three processes of qualitative data analysis: (1) data reduction; (2) data display; and (3) concluding (Miles et al. 2014). Based on the first two processes, the descriptive and reflective data were designated and placed into initial sets of codes to show the relationship between the criteria and the resilience concepts. This was carried out based on the definition of resilience in agroecological systems (Folke et al. 2002). After that, the sets of codes were examined to separate the ambivalent data, and then, they were analyzed and placed into classified codes with similar resilient concepts. The classified codes were categorized within the same groups. The groups of classified codes were then verified into themes of resilience. The trustworthiness of these processes was established using the constant comparative method. It involved iterative analysis of emerging codes, focusing on identifying patterns and common features that align with resilience theories in agroecosystems (Miles et al. 2014). Finally, they were crystallized and placed in relationship to the four vital properties of resilience. This type of classification is methodical and interacts across temporal and spatial scales (Folke et al. 2002).

Next, group discussions were conducted as a preparation for the NGT, wherein five to nine informants were recruited to participate based on the number of districts involved. To initiate this process, the informants were presented with a comprehensive flipchart displaying various themes of resilience, which served as a basis for assessing their relevance in the context of building resilience. Assuming the role of a facilitator, the researcher described each theme of resilience, providing detailed specifications to facilitate the subsequent NGT process (Abuhamda et al. 2021). The informants were actively encouraged to contribute their knowledge and empirical support to the themes, while the facilitator ensured that each informant had an equal opportunity to express the logic and relative importance of the themes. This stage typically lasted between 40 and 60 min per round.

Subsequently, voting and ranking procedures were conducted. Each theme of resilience was presented individually to the informants, who privately cast their votes to prioritize the themes. The informants were prompted with the pivotal question: "Which themes are pragmatically vital for building resilience in organic rice production in northeastern Thailand?" Each informant expressed their choices by writing the final list on the flipchart, meticulously placing a checkmark in the right-hand box beside the respective theme. The themes that received votes from 80 percent of the informants (approximately 50 individuals) were retained, representing a consensus among the informants that had been unanimously reached. Themes that fell below the 80% threshold were discarded from further consideration (James and Warren-Forward 2015). Consequently, a total of 28 themes of resilience were successfully verified and deemed suitable as social-ecological resilience indicators (SERIs) for the domain of organic rice production. It is important to note that these themes were selected as direct responses to the study's objective, as posed by the researcher (Randall 2006).

Results and discussions

As previously mentioned, a comprehensive compilation of twenty-eight social-ecological resilience indicators (SERIs), specifically tailored to the domain of organic rice production, has been identified. Within this extensive set, eight indicators were attributed to the first vital resilient property, while the second, third, and fourth properties encompassed eight, five, and seven SERIs, respectively (Table 1). These four categorization schemes align precisely with the framework established by Folke et al. (2002), who delineated the four fundamental properties of resilience. It is crucial to emphasize that all SERIs hold equivalent significance in their respective contributions to the fortification of resilience within the realm of organic rice production.

The following are the outcomes, which present the fundamentals of the four vital resilient properties that organic farmers should be aware of. Besides, they describe how these properties operate to build resilience (Table 2).

Learning to Live with Change and Uncertainty

This property is associated with the qualities of an individual, which need to be enhanced to increase the rate of adaptive efficiency against times of change. Therefore, most of the SERIs are seen as a set of imperative components for self-reliance (Ashkenazy et al. 2018).

The method of NGT indicated that "The Educational Accomplishment", is a requirement for building resilience. Education is associated with establishing creative practices, decision-making, and adapting to cope with all ongoing change (Darnhofer 2021). Apart from that, continuous informal learning, which is theoretically called "Lifelong Learning", is included in this list. Due to the iterative processes of organic rice production, this SERI must play a much larger role. This means that uncertainties and negative events are always expected. Not only is "Lifelong learning" imperative for formulating problem-solving skills, as formal education is but also business competitiveness can be lifted by acquiring more knowledge and understanding. During challenging periods, this is what is needed in organic rice production (Oshio et al. 2018).

However, to make those two SERIs more effective, they must be supported by "The Appropriateness of Age Range". Organic rice production requires work daily, in which physical requirements are compulsory (Chinvarasopak 2015). At a certain level, the ability to carry out such work is impacted when the organic farmers become elderly because their strength and cognitive senses may naturally deteriorate. Meanwhile, the importance of "Experience in Organic Rice Production" is simple for the following reasons: (1) Agricultural experiences are a valuable human capital (Muyambo et al. 2017); and (2) Types of knowledge, which can be used to conduct wise practices and adaptations, can be acquired from the lessons, which had been learned in the past (Tan 2021). In the worst-case scenario of organic rice production having failed, such an experience may suggest new non-agricultural professions. This statement has been affirmed by studies (Cabell and Oelofse 2012; Biggs et al. 2015), which show that gaining experience has the potential to allow organic farmers to develop an unaccustomed outlook and thereby become more innovative to ideas that they may not have already been familiar with. For instance, according to several case studies found in Thailand and overseas (Sharma and Sahoo 2021), certain organic rice farmers have successfully shifted their focus to agroforestry practices practitioners and generated alternative income for compensate the failure of organic rice production. They were able to pursue this avenue because they had integrated trees, perennial plants, and other environmentally friendly elements into their organic rice production operation.

Another SERI is concerned with fostering "The Equity of Household Members in Farm Management". In Thailand, typical pieces of training, which are categorized by gender, can be easily predicted. Males are assigned to training about heavy activities, such as tilling, while females are responsible for product processing (ACT 2020). Both genders have different socio-cultural roles. However, they should

Table 2 A List of social-ecological resilience indicators for organic rice production (SERIs)

SERIs	Definition of Importance	Indication
The 1st vital property of resilience: learning to live with change and uncertainty		
1.1 The educational accomplishments	The capacity to form awareness and configurations based on the farm's desires	The accomplishment of the degree of formal education
1.2 The appropriateness of age ranges	The physical strength to manage and follow the farm's plans with efficiency	The ages from adolescence to middle age are positive, more advanced age is seen as negative
1.3 Experience in organic rice production	The intellectual resources to decide what practices and strategies should be adopted	The number of professional years in organic rice production
1.4 Lifelong learning	The essence of leveling-up the ability to cope with constantly evolving agriculture	The number and degree of collective action, trust, and solidarity in society to gain information and knowledge
1.5 The equity of household members in farm management	The opportunity to acquire the household's conscious choice-making and to balance the trade-offs with them	The more number of household members involved in making decisions related to organic rice production
1.6 Organically oriented inception	The potential to nourish and sustain organic rice production during crises	Performing organic rice production based on health and environmental concerns, not based on the economic fascination
1.7 The ownership of agricultural lands	The independence to experiment and decide about the farm's uses, which are aimed at positive consequences	The percentage of land use holdings owned legally
1.8 The number of household descendants	The opportunity to have free dedicated labor, who may one day inherit the organic rice production	Number of household descendants, who can work in organic rice production
The 2nd vital property of resilience: Nurturing diversity for reorganization and renewal		
2.1 Biodiversity for protection and restoration	The alternative to adapt with a dynamic disturbance influenced by changes in socio-ecologic systems	The number and variety of planted crops, (i.e., food crops, herbs, firewood, construction timber, and natural insecticide crops) as well as a degree of local plant
2.2 The diversity of alternative income sources	The alternative to survive the Northeast's inadequate irrigation system and drought	The number of alternative income sources
2.3 The diversity of markets	The alternative allows farmers to acquire security, extend their business potential, and reach new consumers	The number and type of accessible markets (i.e., markets organized by farmers themselves or markets organized by institutions)
2.4 The diversity of organic certification	The alternative to acquiring security, extending business potential, and reaching new consumers	The number of owners with organic certifications
2.5 The diversity of agricultural water sources	The alternative to nourishing organic rice production throughout a year	The number and degree of usable water resources in agriculture
2.6 The diversity of legal credit sources	The alternative to owning the necessary resources with reasonable interest	The number of accessible legal credit sources
2.7 The diversity of nearby ecosystems	The alternative to adapting to a dynamic disturbance, which is influenced by changes in socio-ecologic systems; the alternative to receiving various types of natural services	The number and degree of benefits gained from the ecological services

Table 2 (continued)

SERIs	Definition of Importance	Indication
2.8 The diversity of essential tools	The alternative to managing organic rice production at needed times	The number and specific function of exclusively essential tools that serve in organic rice production
The 3rd vital property of resilience: Combining different types of knowledge and learning		
3.1 Knowledge of organic rice production	The capacity to manage organic rice production to meet organic standards	The degree and efficiency of the knowledge to manage organic rice production
3.2 Knowledge of constructing ecological systems	The capacity to acquire essential services and resources, including enhancing the robustness of organic rice production after disturbances	The degree and efficiency of the knowledge to construct ecosystems
3.3 The exploitation and nurturing of indigenous knowledge	The capacity to solve problems, which is suitable for the system's social-ecological contexts	The degree of applicable Indigenous knowledge, and the degree of transmission of that Indigenous knowledge
3.4 The adequate use of digital technologies	The capacity to access broader knowledge, resources, and marketing opportunities	The number of accessible technologies, and the number and degree of benefits offered by these technologies
3.5 Knowledge of agricultural water management	The capacity to nourish organic rice production throughout the year with the amount of available water	The number of techniques used for the management of the existing agricultural water resources
The 4th vital property of resilience: Creating opportunities for self-organization		
4.1 Accessibility to the services of the *Bank for Agriculture* and agricultural cooperatives	The foundation to own the necessary resources with reasonable interest	Membership in the *Bank for Agriculture* and Agricultural Cooperatives
4.2 The application of cultural traditions	The foundation to build social bonds, the benefits of which are helpful and provide psychological stability	The number of cultural traditions applied within the community
4.3 The availability of an exclusive organic rice mill in the community	The foundation to compete in business and to secure the stability of the rice supply	The presence of an exclusive organic rice mill in the community
4.4 Living in an organic community	The foundation to get help and exchange knowledge	The percentage of organic farmers in the community
4.5 The availability of local green markets	The foundation to reach loyal consumers and decrease transportation costs	The number of local green markets that offer premium prices
4.6 The capability of the group leader to establish networks with other organizations	The foundation to prosperously evolve organic rice production by setting a creative direction and moving forward with others	The number and extent of successful projects propelled by the group leader
4.7 The harmonization of policies on various scales	The foundation to propel and invest in organic rice production with the confidence to reach sustainability	The number and continuation of policies established to promote organic rice production and the degree of satisfaction that organic farmers have towards those policies

know each other's skills to supplement when the other is not available. This equity must be extended to the adolescents in the household. In Thailand's agricultural sector, child labor still plays a key role, especially in operating tractors, which are among the most versatile farm mechanization tools, for planting and land preparation, the need for hired labor is significantly reduced (Phetphum et al. 2021; Takeshima and Vos 2022). Therefore, including them in some of the decision-making processes not only increases the number of enthusiastic workers but also urges them to inherit the farm after their parents give up on agriculture (Chinvarasopak 2015). This is critical as domestic agriculture is being run by the elders. This would jeopardize the state of food security if agriculture will not be received by younger generations (FAO 2019).

Admittedly, organic farmers have their motivation to engage in the industry (Ashkenazy et al. 2018). The inception of organic rice farming should be initiated by "Organically Oriented Inception" to gain healthy food and a friendly environment (Le Campion et al. 2020). This is because the concepts of resilience are mostly based on self-reliance to do daily management (IFOAM 2013). Therefore, resilience is unlikely to take root in organic farmers, whose inception was activated by a financial orientation (Panpakdee and Limnirankul 2018). The previous statement reflects the same situation faced by organic farmers who lack legal rights to the lands they presently cultivate. This limitation may impede their ability to consistently engage in organic rice production and adapt to changing conditions (Murken and Gornott 2022). "The Ownership of Agricultural Lands" is vital since it is associated with the independence of land use patterns. For instance, they will not invest in long-term plans, such as growing trees to boost the moisture-absorbing quality of the soil if the land is not their property (Muyambo et al. 2017).

Finally, regarding Thailand's regulations, children under 15 years of age cannot be employed legitimately (UNDP 2020). However, in the agricultural contexts of the Northeast, "The Number of Household Descendants" is seen as advantageous in ways. They represent flexible laborers, who are available to do tasks without extravagant conditions (a daily payment with free energy drinks) like the hired labor. As a result, the reduction in payroll allows for investing in more creative needs (Phetphum et al. 2021).

Nurturing diversity for reorganization and renewal

This property focuses on collecting various types of diversity to enhance resilience, both at the household and community levels. These diverse elements are nurtured to maximize their advantages as insurance against change and crises, while also transforming them into innovative opportunities (Biggs et al. 2015). Conserving diversity should not only be limited to apparent resources, but it should also encompass social-ecological memory, such as the people's life histories (Plastina 2022). Their understanding of environmental changes is needed for reorganization and renewal. They act as bridges between the past and the future (Darnhofer 2021). In general, every SERI in this vital property is concerned with buffering capacity that can cushion change and increase assets. Organic farmers are seen as informal workers, who do not have social protections (ACT 2020). Having ownership of assets can reward them with finance and opportunities in times of need (Plastina 2022).

It is known that organic rice production needs more manual labor and that management is difficult especially today given that Thailand's Northeastern region has been facing the global warming threat. As a result, there has been severe drought, and it is expected that there will be a massive migration of local people seeking to enter other economic sectors (Arunrat and Pumijumnong 2015). Regarding this statement, three SERIs were raised. The first was "Biodiversity for Protection and Restoration" which is aimed at introducing plants and animals on the farm. The presence of this SERI not only proposes food security but also refers to opportunities to accomplish new alternative sources of income to cope with the consequences of global warming. Nevertheless, biodiversity should be constructively introduced to avoid negative feedback. For instance, if it is the intention of the farmer to grow a certain type of plant, next, to construct a state of symbiosis, a herd of animals that consumes that plant may start to feed on the plant on that farm (Muyambo et al. 2017).

The second was "The Diversity of Agricultural Water Sources". Northeastern Thailand, compared to other regions, is known as an arid region (Kuntiyawichai and Wongsasri 2021). Also, the Northeast has less support for water infrastructure even though it is the country's largest area with 33% of the total population (Manorom 2022). The dependence on rainwater and irrigation to achieve organic rice production has often been fruitless. Therefore, it is expected that self-built wells, nearby canals, and optional sources of agricultural water will be exploited by organic farmers. Not only does the existence of those water sources nurture organic rice production throughout its growing cycle, but also enriches the establishment of biodiversity (Heis 2015). The third was "The Diversity of Alternative Income Sources during Dry Season". This SERI can be considered the positive outcome of the first two SERIs. When biodiversity and agricultural water sources are organized, alternative sources of income will be fruitful, which can subsidize in case organic production is unproductive. Especially in the dry season, the region's available water often makes conditions unfavorable for growing organic rice and other cash crops, except for maize, which is only slightly profitable (Arunrat and Pumijumnong 2015).

Next to those three diversities, the lands that are used to grow organic rice are areas that should be surrounded by "The Diversity of Nearby Ecosystem", which plentifully consists of habitats with earthworms, bees, and beetles. This benefits two items to build resilience. Firstly, natural, and semi-natural areas are home to those specific living creatures, whose mechanisms can reduce pests (Le Campion et al. 2020). Secondly, the interactions between different species decrease the dependence on external fertility inputs because soil organisms are empowered to carry out their duties by adding organic matter and suppressing plant diseases. These qualities, which are in harmony with organic farmers' desires both agriculturally and economically, help the soil to acquire more nutrients without having to make any purchases (Darnhofer 2021).

"The Diversity of Organic Certifications" and "The Diversity of Markets" are common in one essence: they both provide organic farmers with alternative economic opportunities aimed at reducing their reliance on market transactions (FAO 2019). In fact, each country has its organic standards. For example, Japan has been importing food and organic products that meet the quality of the Japanese Agricultural Standard (JAS) (IFOAM 2013). Owning a variety of organic certifications enhances the opportunities for a farmer's yields to be sold at a premium price. This is because having a product labeled as "organic" makes consumers feel that they can trust those products manufactured following the regulations for environmentally friendly methods of organic agriculture (Chinvarasopak 2015). The importance of this was extended to the SERI called "The Diversity of Market Outlets". In general, having access to feasible market outlets is the desire of all organic farmers, especially Thailand's smallholder farmers, who are facing a decreased market orientation. Therefore, they have been looking for maximum orders to secure their livelihoods (Kotamee and Pratthanawutthikun 2017). In brief, these two types of diversity are critical and may be in higher demand now with the influence of the COVID-19 explosion. The pandemic has reminded organic farmers that relying on one market, even trustworthy outlets, did not make them immune to the impacts, such as lockdowns (Duchek et al. 2020).

Most organic farmers in the Northeast have limited resources due to the lack of funds at different stages of production; it has been arduous for them to cope with shocks, such as a scarcity of labor and climate-related pressures (Poungchompu and Chantanop 2016). Thus, "The Diversity of Legal Credit Sources" is crucial because it is useful for mitigating risks (e.g., buying tools and services to take care of day-to-day matters). Nonetheless, such credit sources must be legal to ensure that the return on the loan is probable. Besides, subsidized loans must focus on short-run credit. This program is more positive for an organic farmer's varying financial needs than the long-run scheme (FAO 2019).

Lastly, "The Diversity of Essential Tools" was raised. Organic farmers should possess specific types of equipment, such as tractors and cultivators that are distinct from those typically used in conventional agriculture (Panpakdee and Limnirankul 2018). Owning these tools, whether individually or collectively, is needed because their availability to be used in the right situations is associated with the success rate of farming operations. This was proven by IFOAM (2013), who revealed that if weed management and tillage are delayed, organic rice production becomes more vulnerable to yield losses.

Combining different types of knowledge and learning

This vital property focuses on integrating the types of indigenous knowledge and modern education, through both formal learning and informal learning (Folke et al. 2002). These types of knowledge provide the foundation for obtaining the best consequences for operations and for making adaptations to deal with the complexity of social-ecological systems (Biggs et al. 2015).

Based on the findings, every SERI focuses on agricultural knowledge and off-farm skills for management on a day-to-day basis (Table 1). Because organic rice production is their main career, it was unanimous that "Knowledge of Organic Rice Production" is imperative. Most of the organic farmers are fortunate because they were born into traditional rice farming families. However, they still had to earn proper training in organic rice production as the miscellaneous practices of the two rice systems are distinct (IFOAM 2013). For instance, rice seeds and manures used in organic rice production must only be produced by trustworthy sources that are organic. Consequently, regular seeds and manures are unwelcome (Green Net 2020). This not only exists to achieve proper management but also to qualify the organic organizations' certifications (Chinvarasopak 2015).

To better enhance the resilient state, organic farmers must be aware of the "Knowledge of Constructing Ecological Systems", especially on the surrounding lands used to grow organic rice. According to the informants' opinions, the construction of ecological systems is concerned with introducing as much agrobiodiversity as possible. However, it emphasizes on how to introduce specific plant and animal species to inhabit the rice fields, e.g., nurturing snails, crabs, large water bugs, and local fish (Yossuk and Kawichai 2017). This is an activity that can nurture biological reactions, the consequences of which are a reduction in outside production inputs, such as composts. Moreover, the presence of ecological systems enhances pollination for other plants near the farmland, thereby boosting organic rice yields. This is attributed to the favorable conditions created by the flourishing plant communities, which benefit organisms such as natural predators of pests and soil microorganisms. Consequently, these ecological interactions contribute to the continuous provision of essential nutrients to organic rice plants (Biggs et al. 2015).

In addition, "The Exploitation and Nurturing of Indigenous Knowledge" were cited. In short, indigenous knowledge was built by previous generations' insights which were ignited by a given society that had had a long history of interactions with their natural surroundings (Duchek et al. 2020). An example was raised by the informants showing how the serviceable importance of indigenous knowledge: after they had become aware of the drought, they changed the planting dates to shorten the growing season so that the risk of water scarcity could be reduced. This indicates how indigenous knowledge can offer location-specific strategies that are approved to follow. If building resilience is the goal, it is important that applying indigenous knowledge does not lose its significance (Muyambo et al. 2017).

"Knowledge of Agricultural Water Management" is another SERI required. Not only must organic farmers be aware of the simple method of gravity-pull to divert water from irrigations and/or natural sources so that they can provide moisture for organic rice plots, but it is expected that they must also be aware of other advanced techniques, such as flood-based farming systems and the Khok Nong Na model (Kuntiyawichai and Wongsasri 2021). These pieces of knowledge are imperative, especially for the Northeastern region, which has been Thailand's most arid area. Their potential ensures that even in times of drought, there is a satisfactory amount of on-farm water, which is called water security (Rambo 2017).

Finally, the fifth SERI is "The Adequate Use of Digital Technologies". Digital technologies have been playing a key role since they first were introduced (FAO 2019). Now, their importance is becoming even greater because, during the COVID-19 pandemic, organic farmers encountered restrictions in mobility and commerce (UNDP 2020). To live serenely in the world, organic farmers at present need to adopt the skills of using smartphones, the internet, and apps to benefit from their underlying usefulness. Adopting those technologies, e.g., using the internet to access databases when making decisions, helps them in overcoming disruptive pressures to become resilient (Yossuk and Kawichai 2017).

Creating opportunities for self-organization

This vital property of resilience focuses on self-organization at various cross-scales, where authority has been re-allocated upward, downward, and sideways away from central states. It is essential that the capacity of self-organization become crystallized so that solutions can be acquired in response to stresses (e.g., ongoing unsteady policies, trade wars, and climatic changes) (Manorom 2022). In this study, SERIs are comprehensive and range from individual to national levels. Their existence is helpful by allowing organic farmers to explore different ideas, advantages, and alternatives.

The first SERI is at the household level called "The Accessibility to the Services of the Bank for Agriculture and Agricultural Cooperatives". This bank is the government's financial institute, whose mission is to subsidize Thai farmers with rational interest rates (DOAE 2013). Without the nexus to the bank's services, it would be difficult to carry out the farm practices, which require making investments in inputs. Moreover, having a connection with this bank is useful for receiving knowledge and other types of help (Chuasuwan 2018). For instance, clients can be empowered to adopt agricultural innovations and networks to help them shift from marginal farmers to entrepreneurs. Such a service makes this bank outstanding and set them apart from other leasing sources (Yossuk and Kawichai 2017).

Next, four SERIs are at the local level. Firstly, promoting the use of indigenous knowledge, "The Application of Cultural Traditions," was cited. Whether ceremonies, or poems, cultural traditions are ways of life as their foundations involve language, norms, and customs. Indeed, cultural traditions seem irrelevant to strengthen self-organization; they have no tangible practices to propose (Biggs et al. 2015). However, traditions can boost that capacity in both direct and indirect ways. Indirectly, the processes of cultural traditions can establish people's connectedness that can shape their thoughts to become smarter and more confident (Duchek et al. 2020). When these are formed, people are more open to receiving favors. This viewpoint is substantial as a valid theory. When there are positive emotions between and/or among people, they are more eager to help others. As a result, they become bonded, which is called theoretically relational and eco-centric notions of self and personhood (Plastina 2022). Meanwhile, regarding the indirect, cultural traditions allow the participants enjoyment through virtual practices and environments, which can elevate their positive perceptions. When these perceptions are supplemented, they are better to cope with existential crises (Manorom 2022).

Secondly, "The Capability of the Group Leader to Establish Networks with Other Organizations" was cited as a crucial factor. In Thailand, most organic rice production is operated within farming groups rather than by individual family farms because it is more appropriate for sharing responsibilities and receiving external resources (DOAE 2013). Administering via groups is more functional since each group must have a leader, who is accountable and visionary to propel the group members. For example, the group leader should collaborate with potential networks that can drive the group to become more commercialized (Seubsman et al. 2013). The importance of leadership was approved by the informants, who indicated that having a good leader is significant as hundreds of members. Because in Thailand's context, the roles of leaders are often extended. They not only mitigate conflicts among members, but they also act as role models by leading their groups (Chinvarasopak 2015).

Thirdly and fourthly, there are "The Availability of an Exclusive Organic Rice Mill in the Community" and "The Availability of Local Green Markets", respectively. These SERIs are needed to alleviate the current pressures of commercial rice production based on agrochemicals (Green Net 2020). The importance of milling is universally known as a crucial step to fulfill the standards of organic agriculture: organic rice yields must be processed only by exclusive rice mills (IFOAM 2013). For economic and food security aspects, having an organic rice mill in the community also ensures the steadiness of the rice supply for both household consumption and for sale in needed times (Manorom 2022). Meanwhile, the fourth SERI is essential in terms of exploiting economic opportunities. Having local organic markets offer the chance to conquer business stability. Customers often feel more inclined to support a business if they know it is locally based (Kuntiyawichai and Wongsasri 2021). Moreover, the significance of this SERI is associated with self-dependence. Local marketplaces propose a low-barrier entry point for instituting prosperous businesses, which are liberated from selling in large-scale quantities. This is significant. Their nature lends itself to avoiding the conditions of selling massive volumes at low prices as proposed by large wholesale outlets (Panpluem and Yin 2021).

For the nexus at the national level, one SERI was found. "Harmonization of Policies at Various Scales" is concerned with earning favors from the country's policymakers. Organic rice production is a system that is concerned with the relationships between agriculture, politics, and economics (Darnhofer 2021). To acquire positive outcomes, comprehensive policies across levels are required to supervise the entire process of organic rice production. For instance, intricate policies about improving land degradation must be proposed by the government's local institutions. National organizations have been anticipated to propel high-complicated policies about green markets and tax incentives (Yossuk and Kawichai 2017).

Conclusions and recommendations

Given its stated purpose to help organic farmers develop explicit strategies to protect against changes in organic rice production, this study provides an exclusive set of social-ecological resilience indicators that are related to organic rice production in northeastern Thailand. These indicators are exclusive given that the nature of resilience is based on a system's spatial and temporal scales. In a system, any metrics to gauge resilience must be built by stakeholders to make it applicable and to ensure that the correct information about their social, economic, and cultural values is examined. The need for such a degree of participation to be used when formulating the indicators is not only necessary for the effective application, but it is also to evade the state of having too computationally intensive approaches. This is requisite. Resilience indicators have been continuously developed. However, few are truly pragmatic as the outcomes have not been modified to fit the users' needs. It is recommended to identify crucial indicators using a bottom-up approach, guided by the logic of resilience theories. This method ensures that the indicators are not only practical but also effective in addressing temporal and spatial dimensions. For instance, in this study, the inclusion of diverse components and their connections and interactions represented their abilities to respond and recover from changes in organic rice production. This aspect may be overlooked if the informants, who are system owners, are excluded from the process. Moreover, resilience indicators would not be represented as inexplicable indexes. Instead, they need to be explained by accessible information, coupled with quantitative and qualitative details. This characteristic of indicators facilitates the systematic inclusion of empirical information, practices, resources, and feedback. Such inclusion is crucial for effectively addressing changes and vulnerabilities promptly. For example, the findings of this study demonstrate the importance of nurturing diverse markets and agricultural water sources to enhance resilience. These measures provide organic farmers with the capacity to withstand economic shocks and climate change impacts, respectively. This should be coupled with specific sets of efficient assessment scales and trade-offs. Consequently, they can better comprehend the interconnectedness between the indicators and the objective of building resilience.

The process of developing indicators should be conducted by researchers who have comprehensive insights into resilience theories and possess related knowledge about the given system's contextual environments. This ensures that the tasks of collecting and analyzing data can effectively yield results. This is particularly crucial when employing the three processes of qualitative data analysis, as these processes heavily rely on researchers gathering data from informant feedback and organizing it into coherent themes and patterns. The significance of such a statement in the development of social-ecological resilience is exemplified in the following scenario. In this study, the researchers initially examined the utility of various credit sources, encompassing both legal and illegal options such as borrowing from friends or loan sharks, as adaptive measures during adverse circumstances. However, during the initial phase of qualitative data analysis, which involved data reduction, the researcher opted to exclude the consideration of illegal credit sources. Although both legal and illegal credit sources serve the purpose of providing financial assistance, they differ in key aspects when viewed through a resilience lens. For instance, borrowing money from friends may initially appear advantageous as borrowers can directly negotiate interest rates and payment terms. If borrowers encounter difficulties in repaying on time, it can damage the relationship between the parties involved. This damage has negative implications for building resilience, particularly in terms of self-dependence and cooperative networks at the community level. Therefore, the focus was on legal credit sources. They offer loans at lower interest rates and provide certain legal protections. This can lead to significant savings over the loan term and provide organic farmers with greater flexibility to meet their diverse financial needs. However, the determination of which data to retain or exclude during the data reduction process should be grounded in evidence, guided by research questions and specific cases, rather than solely relying on the researcher's judgment.

In comparison to similar studies focusing on social-ecological resilience indicators of organic rice production in other regions of Thailand, this study's core findings are not significantly different. The key factors essential for making organic rice production resilient, such as owning diverse forms of resources, possessing skills in water management, and establishing ecological systems, remain unchanged. This aligns with expectations, as these components are fundamental for building resilience. However, the role of establishing collaborative networks appears to be more significant in the northeastern region. Networks organize training programs, workshops, and seminars on current agricultural issues and policies. These activities empower organic farmers by providing continuous learning opportunities and facilitating the exchange of information and resources, thereby enabling them to improve their farming practices and resilience. Furthermore, networks often play a vital role in ensuring the economic viability and market sustainability of organic rice production. They connect organic farmers with markets, buyers, and various economic opportunities. Therefore, an effective approach to building resilience in this region involves encouraging organic farmers to foster effective networks at both local and national levels. This effort should encompass not only agricultural networks but also governmental, public, and academic networks.

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Data availability The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethical approval This study was examined and approved for ethical considerations by the Center for Ethics in Human Research, Khon Kaen University.

Conflict of interest The author declares no competing interests.

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