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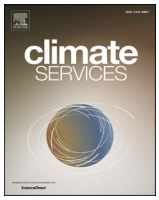

Original research article

Stakeholder engagement in agro-climate service planning

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ABSTRACT

The impacts of weather, climate variability and climate change on agricultural production underline the increasing importance of actionable agro-climatic services. Transitioning from supply-driven provision of climate and agricultural information to demand-driven agro-climate services (ACS) at scale cannot be accomplished in a top-down manner but requires the engagement of diverse stakeholders in all phases of ACS development and implementation. This requires methods and tools to handle the diversity and dynamics of interactions between relevant stakeholders, including during the pre-financing stage of the ACS. We propose a transparent method to identify and engage stakeholders in the ACS planning phase and demonstrate this method as part of the socio-economic development planning process in Dien Bien, Vietnam. We find that considering stakeholder attributes such as availability, experience, gender, expertise, benefits and costs for each stakeholder, interest, influence, relevance, and attitude, combined with insights about the socio-economic development planning processes, is crucial for the engagement of stakeholders. We also find that facilitating collaborative interaction between ACS stakeholders is pivotal in supporting the planning of demand-driven ACS. Our methodology for engaging stakeholders is transferrable to designing and planning other interventions in complex systems.

Practical implications

Transitioning from the supply-driven provision of climate and agricultural information to demand-driven agro-climate services (ACS) is a long-term process. The early stages of such a transition often feature uncertainty, scattered knowledge, conflicting views and the challenge of establishing dialogue among relevant stakeholders. Without coordination, such an "incubation" process can take a long time.

Integrating ACS into the government's policy and financial plan during the pre-financing stage of ACS is a prerequisite for implementation. At present, methods and tools for identifying and mobilizing relevant stakeholders during the pre-financing stage are lacking. We address this methodological gap by proposing a transparent method to engage stakeholders in ACS decision-making as part of socio-economic development planning. We demonstrate the method using the case of an ACS intervention in Dien Bien Province in Vietnam. Building on our experience, we draw key lessons and recommendations for policy-makers and practitioners.

For policy-makers

- Existing regimes often feature barriers to innovations that prevent new ideas from penetrating the socio-technical-political systems. Due to path dependencies, many systems are locked into unsustainable patterns that are difficult to overcome. Developing and upscaling sustainability innovations, such as agro-climate services, need windows of opportunity (e.g. supporting policy and finance) to overcome constraints so that innovations can be tried, tested and improved.
- Previous studies have indicated that failure to engage stakeholders in ACS scaling can lead to several risks: inability to meet farmers' diverse demands, lack of timely and seamless delivery, compromised actionability of services and reduced socio-economic impacts. Often, easily accessible farmers benefit from ACS, while marginalized groups are left behind.
- Co-creation from the early stages of planning enhances the chance of overcoming the common barriers in ACS last-mile delivery. However, stakeholders are not homogenous. They may have different views and motivations for engaging in ACS. Therefore, a challenge with the co-creation approach is handling the scattered knowledge, diversity, dynamics and conflicting views of stakeholders.

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- We suggest a strategy to deal with the scattered knowledge, diversity and dynamics of stakeholders by gaining insights into relevant stakeholder attributes (e.g. stakeholders' availability, experience, gender, expertise, interest, influence, relevance and attitude, as well as the cost-benefit profile of each stakeholder). The objective of gaining such insights is to help coordinate and enhance the engagement of relevant stakeholders and to balance potential conflicts between stakeholders in ACS knowledge generation and planning processes.
- In situations where reporting lines regarding climate services vary between non-government and government actors, valuable insights from non-government actors may remain untapped. To address this, governments should integrate relevant reports and experiences from non-government actors into their specialized reporting systems, such as the agricultural sector report.

For practitioners and NGOs

- Transitioning from supply-driven to user-driven climate information often involves substantial complexities and uncertainties. Decisions related to ACS scaling often lack clarity on the best course of action or on realistic outcome prospects. ACS scaling requires feedback and demand from and active participation of practitioners and NGOs during knowledge generation and from the early stages of ACS planning.
- ACS end-users are diverse (i.e. farmers with diverse farming systems, varying access to information and different languages). During socio-economic development planning, ACS end-users should be organized (i.e. into farmer groups) and coordinated (i.e. participation of diverse groups of farmers) to ensure that demands of the target population can be considered during ACS decision-making.
- Governments' oral and written reporting systems for specialized sectors are important channels for practitioners and NGOs to provide feedback and communicate essential aspects of ACS interventions.
- NGOs can be an essential catalyst in the promotion of ACS. NGOs and other local actors can play the role of knowledge brokers and support facilitating relationships among stakeholders.

Data availability

I have shared the link to my data in the manuscript and supplementary material

Introduction

Agriculture is facing multiple challenges, many of which are related to weather, climate variability and climate change, and to the resulting impacts on yields, pests and agricultural input use (Hansen et al., 2022; Luu et al., 2022a; WMO, 2015). Agro-climate services (ACS) have been suggested as one way to reduce farmers' vulnerability and safeguard their farm productivity and income (Hansen et al., 2022, 2019; Hansen and Sivakumar, 2006; Leal Filho and Jacob, 2020; Machingura et al., 2018; O'Grady et al., 2020). However, ACS delivery often faces a critical gap at the last mile, and considerable effort and capital may be needed to enable widespread access to ACS for actors from diverse socio-economic groups and with different intersectional needs (Ferdinand et al., 2021).

Generating evidence on ACS scaling impacts is crucial for decision-makers (e.g. government, businesses) to justify their financial investments in ACS. Previous studies have suggested that scientific evidence may have a high chance of being considered in decision-making if it fulfills certain criteria, including credibility (i.e. accuracy, plausibility and trustworthiness of information), legitimacy (i.e. "fairness" and "unbiasedness" of information and sources of information) and salience (i.e. relevant and timely information for decision-making) (Cash et al., 2003; Haigh et al., 2018; Wagner et al., 2023). However, generating ACS evidence on scaling and impacts at the last mile is characterized by high uncertainty and complexity (Hansen et al., 2019; Luu et al., 2022a; WMO, 2019). This uncertainty is due to a lack of proven scaling approaches, unreliable climate information and agricultural advice, data scarcity and biases concerning the economic, social and environmental impacts of ACS on society (Born et al., 2021; Lowry and Backus, 2021; Luu et al., 2022a; WMO, 2015). Additionally, valuing ACS impacts is complex since analysts must consider processes and interactions within local socio-technical–economic systems to forecast the scaling benefits (Born et al., 2021; Lowry and Backus, 2021; Luu et al., 2022a; WMO, 2015). Due to these challenges, monitoring and evaluating the societal benefits of ACS are regarded as one of the weakest components across the ACS value chain (WMO, 2019).

Concerning the integration of new evidence during ACS scaling, previous experiences have highlighted additional challenges. In development contexts, investments are often made through international development aid with the expectation that local resources will sustain and scale the introduced ACS approach (Ferdinand et al., 2021; Simelton and McCampbell, 2021; WMO, 2019). However, experience with integrating pilot projects into local planning and budgeting to support upscaling is very scarce. A mismatch often exists between pilot project design and the roll-out of ACS in real and complex socio-economic scaling landscapes (Woltering et al., 2019).

Challenges related to the complexities of and uncertainties about ACS delivery and ACS cost-benefit valuation provide barriers that may prevent decision-makers from investing in ACS (Luu et al., 2022a). A top-down approach is ineffective in designing and planning for actionable ACS, since it might risk mis-prioritizing resources that are already limited in development contexts (Daniels et al., 2020; Ferdinand et al., 2021; Lemos et al., 2012). Therefore, transitioning from the provision of conventional supply-driven climate and agriculture information to demand-driven agro-climate services (ACS) requires transdisciplinary approaches that are capable of engaging stakeholders in supporting decision-making related to defining, planning and implementing ACS (Daniels et al., 2020; Hansen et al., 2019). Such an approach must explicitly focus on engaging stakeholders to address the uncertainty, complexity, biases and data scarcity involved in knowledge generation and to support the integration of this knowledge into planning decisions.

Stakeholder engagement and decision analysis, when combined, promise to generate a powerful transdisciplinary approach to support complex decision-making processes.

Stakeholder analysis aims to identify and understand stakeholders' interests, goals, and influence in a given decision-making process (Reed et al., 2009; Yang et al., 2011). The importance of engaging stakeholders in all phases of climate information service development has been consistently acknowledged. However, while there have been some insightful studies on stakeholder engagement in co-creation (Barquet et al., 2022; Daniels et al., 2020; Font Barnet et al., 2021; Kalafatis et al., 2015; Rubio-Martin et al., 2023, 2021; Sperry and Jetter, 2019; Suhari et al., 2022), limited focus has been paid to engaging stakeholders during the pre-financing stage. Exceptions are studies by Sperry and Jetter (2019) and Rubio-Martin et al. (2021). The limited focus on the pre-financing stage highlights a considerable methodological gap since the dynamics of stakeholder engagement during the pre-financing stage can differ from those during the post-financing stage. For example, stakeholders who advocate for integrating ACS into local planning have their primary role in searching for evidence of ACS impacts and in trying to convince other stakeholders. Once the financial resources are approved, the role of implementation stakeholders, which can include some of the stakeholders from the pre-financing stage but also others, is to accompany the implementation of the ACS project and to document its impacts. Since the early stage of ACS development often features uncertainty, scattered knowledge and conflicting views (Luu et al., 2022a), it can be a complex process to mobilize stakeholders to engage in dialogues and discussions and to participate in the ACS planning

process. The outlined methodological gap calls for a specific procedure for supporting stakeholder engagement during the planning process. We therefore focus on the important yet often disregarded stakeholder dynamics and diversity throughout the pre-financing stage.

Luu et al. (2022a) recently applied Decision Analysis (DA) as a methodology to engage stakeholders in designing and forecasting ACS impacts to support investment decisions on complex systems under uncertainty. DA aims to create system understanding by integrating stakeholder knowledge with systems thinking (Luedeling and Shepherd, 2016). Traditional research has often focused on eliminating uncertainties of specific interactions within a system, not considering system dynamics and not evaluating alternative decision options (Shepherd et al., 2015). Such an approach can only provide a limited understanding of complex decision impacts and is restricted by the capacity to collect data for each specific system interaction. DA acknowledges that quantifying every interaction within a system is challenging and resource-intensive – and it may often be impossible. Therefore, within DA, uncertainties are acknowledged and accounted for by applying methods and tools to integrate them into the decision-making process (Luedeling and Shepherd, 2016). One of the key tools in DA to account for uncertainty is calibrating stakeholders through a process known as calibration training (Hubbard, 2014). A critical improvement of calibration training compared to other conventional stakeholder knowledge elicitation approaches is that stakeholders are trained to realize their own biases beforehand and often reduce these before their knowledge is elicited for data inputs (Hubbard, 2014).

DA is a way to engage stakeholders to generate system knowledge for supporting decision-making (Do et al., 2020; Fernandez et al., 2022; Lanzanova et al., 2019; Luedeling et al., 2015; Ruett et al., 2020). However, studies have rarely been explicit about how to select the stakeholders involved in DA. Furthermore, it is often unclear, how, by whom, and to what degree knowledge gathered throughout the complex planning processes is integrated into decision-making.

Acknowledging the potential benefits of stakeholder engagement in decision analysis to support complex decision-making, we propose a method to (1) integrate stakeholder analysis into DA and (2) explore the roles of stakeholders in ACS planning using their specific characteristics.

Background of the study

ACS pilot projects and their upscaling challenges

We use the case study of CARE in Vietnam (CVN) to showcase the application of DA and the steps of stakeholder analysis. CVN is funded by external sources and has implemented several ACS projects in Dien Bien since 2015 to reduce the vulnerability of rural communities to adverse climate change impacts (Luu et al., 2022a). When we began our study in July 2019, CVN was developing a plan to sustain and upscale ACS interventions, especially after 2022, when CVN's project was expected to end. This plan aimed to get the local government to support the upscaling processes. This was challenging, given the limited financial resources available to the provinces and the government's traditional approach to development interventions, which includes little stakeholder involvement. Despite these challenges, the need to provide reliable information to farmers appeared obvious, and CVN needed a strategy to guide the advocacy process.

An effective advocacy strategy has to serve multiple purposes, including guidance for the upscaling process and participation of various stakeholders relevant to the decision-making process. A further goal of the CVN strategy was to support the decision-making process through a business model justifying the upscaling of ACS. In a previous study, in partnership with stakeholders, Luu et al. (2022a) characterized and evaluated the costs and benefits of four alternative ACS investment options using a probabilistic approach. These investment options share some common interventions but are also distinct in terms of implementation. The common interventions include generating downscaled seasonal and weekly weather forecasts, training a technical working group to interpret the weather forecasts and translate them into agricultural advice, transferring these forecasts and advice to users as well as the monitoring and evaluation of their utilization. Investment options differ in terms of the optional establishment of weather stations, outreach measures (via paper, SMS, or loudspeaker), and consideration of gender issues in accessing and applying ACS information. Investment options were named based on their variations from the common interventions. These options are: Option 1) Weather station-SMS-Gender, Option 2) SMS-Gender, Option 3) SMS-Loudspeaker and Option 4) Paper-Loudspeaker. Results of the study suggested a high probability of a positive net benefit for investments in ACS across all intervention options (Luu et al., 2022a).

Investment decision-making in Dien Bien, Vietnam

Decision-making on investments in climate and agriculture in Dien Bien operates within the overall administrative structure and nested budget system commonly used in Vietnam (Fig. 1). The higher administrative levels include the budget of the subordinate levels. The Central Government and People's Committees at local levels prepare respective budget plans (Asian Development Bank, 2017; World Bank, 2015). One of Vietnam's most crucial guiding policies in development is the 5-year Socio-Economic Development Plan (SEDP). The implementation of SEDP is conditional on the approval of the budget by the National Assembly and the respective People's Councils (Asian Development Bank, 2017; Strauch et al., 2018; World Bank, 2015). Therefore, considering the complex administrative and nested budget system, any ACS scaling initiative would have to integrate the ACS plan and the respective budget into the Dien Bien Provincial SEDP.

Methods

In the context of this study, we explicitly focus on stakeholder engagement during the budgeting and planning phases. To this end, we integrated stakeholder identification and stakeholder analysis with decision analysis methodologies. While our focus was on stakeholder identification and analysis, Luu et al. (2022a) concentrated on co-identifying ACS decisions and solutions (i.e. characterization of ACS solutions and co-determination of stakeholders who will be involved in the potential implementation, monitoring, and evaluation processes) (step 1.1 - step 1.3 in Fig. 4). Luu et al. (2022a) also conducted an ex-ante analysis of ACS impacts using a decision analysis approach (step 1.4 to 1.7 in Fig. 2). Our research provided inputs (step 2.1 and step 2.2 Fig. 2) to Luu et al. (2022a) by supporting the identification of stakeholders and experts to work on specifying ACS solutions and to participate in the decision analysis. We benefited from the cost-benefit analysis undertaken by Luu et al. (2022a) and advanced it further by producing separate cost-benefit analyses for each stakeholder (step 2.3 Fig. 2). Additionally, we identified potential windows of opportunity for stakeholder participation in decision-making during ACS planning processes (step 2.4, step 3 and step 4 in Fig. 2).

Stakeholder identification

Building on various definitions (Bourne and Walker, 2008; Carroll and Buchholtz, 2009; Freeman, 1984; Luu et al., 2022a; Yang et al., 2011), we define a stakeholder (step 2.1 in Fig. 2) as any individual or group that has an interest in a decision, or who can affect a decision or is affected by a decision. At the time of composing this manuscript, our attention was drawn to a discussion, mainly on social media, regarding the racist or colonial connotations of the term "stakeholder" in the context of decolonization (Reed, 2022). While it seems that a more appropriate term may be needed (Reed and Rudman, 2023), we keep the term 'stakeholder' in the context of this study because there is currently no obviously preferrable alternative among the suggested options (i.e.

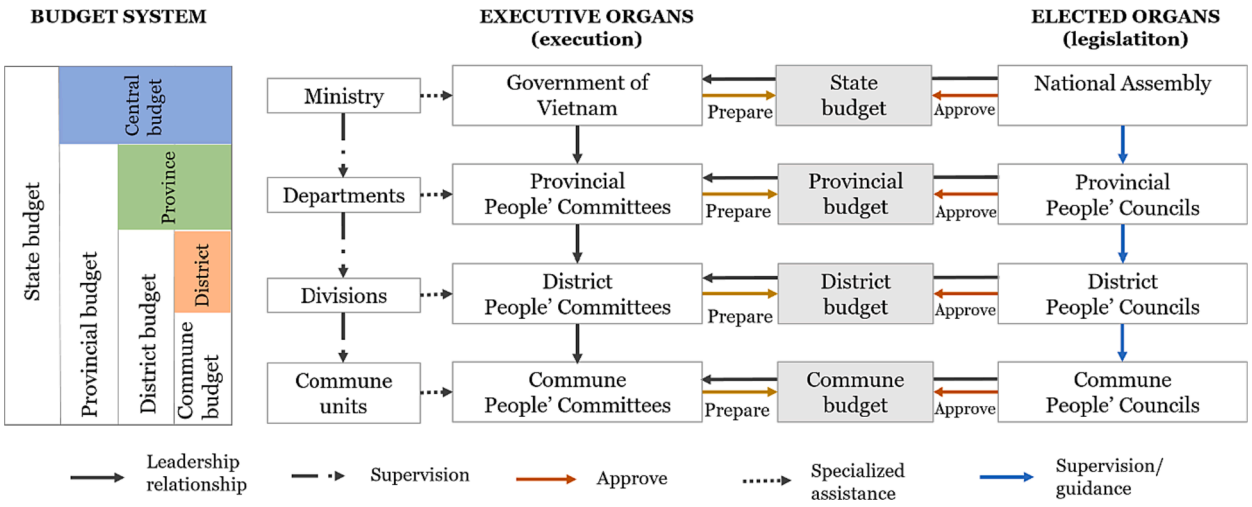

Fig. 1. Administrative structure and nested budget system in Vietnam. Adapted from Asian Development Bank (2017) and Strauch et al. (2018).

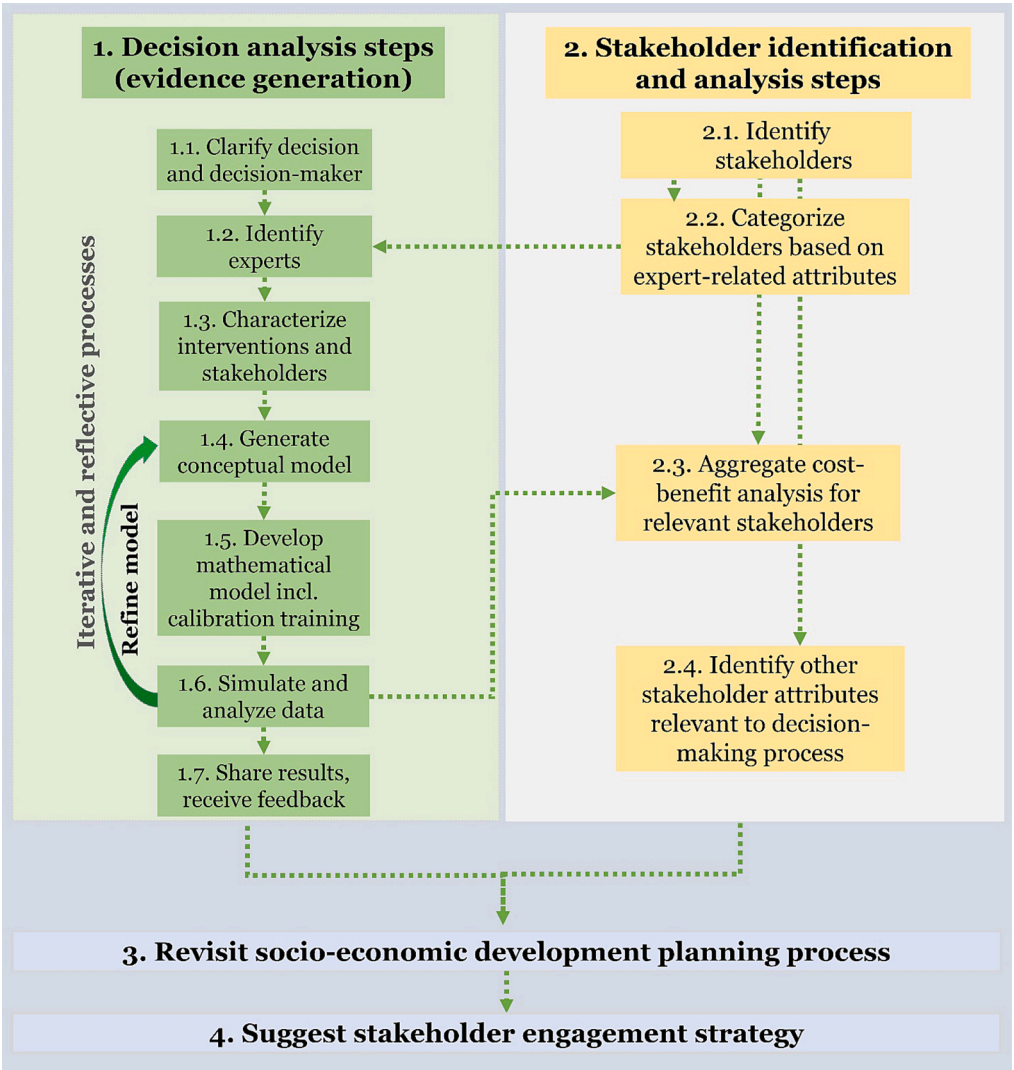

Fig. 2. Approach to engaging stakeholders in agro-climate service planning. The methodological steps of decision analysis in the context of ACS are based on Luu et al. (2022a).

partners, rightsholders, interested parties/affected parties, interest groups, relevant parties) (Reed, 2022) and rushing towards another term could have unintended negative consequences. Future studies should explore the etymology, the necessity for an alternative term and the potential impacts of these alternatives. We conducted a desk review to identify potential stakeholders for the design and implementation process of ACS projects. To this end, we reviewed several documents outlining the Vietnamese Government's organizational and decision-making structures to understand and capture the representation of different stakeholders in the process (Asian Development Bank, 2017; Strauch et al., 2018; World Bank, 2015). During this process, we also identified stakeholders across the information value chain of ACS, using CVN's project reports and other studies on ACS in Vietnam. To validate and refine our results, we organized a focus group discussion in Vietnam with six CARE employees who were involved in the management and implementation of ACS in Dien Bien. The group participants shared their knowledge about stakeholders relevant to CVN's efforts to implement ACS.

Due to time and resource limitations, we could not engage all identified stakeholders. Therefore, we identified a shorter list of key stakeholders in collaboration with a technical working group in charge of implementing CVN's climate service project. For the selection of key stakeholders, we considered a balanced representation of (i) stakeholders across the whole information value chain, (ii) stakeholders with experience in the provision and use of climate information and agricultural advice in Dien Bien, (iii) national stakeholders, who already had established a partnership with CVN, and (iv) actors not yet involved in a CVN project but with the potential to play a direct role in the upscaling of ACS in Dien Bien (e.g. departments working on animal husbandry, finance and socio-economic development planning). This set of key stakeholders served as a pool for identifying experts involved in the subsequent steps of the ACS planning process.

Stakeholder categorization and analysis

Expert identification among key stakeholders

We identified experts (step 2.2 in Fig. 2) from the pool of key stakeholders to characterize specific scaling options and assess the impacts of these options. For this purpose, we grouped stakeholders based on their time **availability** (i.e. the time that they could dedicate to attending meetings, participating in key informant interviews, and engaging in discussions related to agro-climate service planning) and **experience** (i.e. the accumulation of understanding and skills gained through involvement in ACS-related interventions) into core experts and resource persons. Together with seven members of CVN's technical working group, we evaluated the availability and expertise of each key stakeholder by scoring the stakeholders on a scale from 0 to 5 for these attributes. Experts initially provided individual scores, which were subsequently discussed. If a consensus was reached, the final score was recorded. Otherwise, scores were averaged. We characterized those with an availability score and an experience score greater than 2.5 as 'core experts' and those with availability lower than or equal to 2.5 and experience higher than 2.5 as 'resource persons'. We did not involve stakeholders with experience and availability scores below 2.5 as experts. However, they might still play a role during the planning process (see section 4.5). We considered the **gender** of stakeholders to support the constitution of a gender-balanced team of experts. Furthermore, we mapped out the **expertise** (i.e. knowledge and skills related to ACS) of stakeholders to identify experts with representative expertise across the value chain of ACS. We used the ggplot2 package (Wickham et al., 2022) in R (R Core Team, 2020) to visualize stakeholder attributes.

Cost-benefit profiles for relevant stakeholders

Luu et al. (2022a) used decision analysis to forecast the overall outcomes of different options to invest in agro-climate services. In this study, we argue that the benefits and costs of decisions might not be uniformly distributed across different stakeholders and that such an uneven distribution has the potential to create ambiguous incentives for stakeholders to engage in the ACS decision-making process. Therefore, in the present analysis, we explicitly analyzed the costs and benefits for each institutional stakeholder and for each decision option (step 2.3 in Fig. 2) and subsequently considered this specific **cost-benefit profile** as a relevant stakeholder attribute.

With the support of key experts (identified in step 2.2 in Fig. 2), we could assign potential costs and benefits to each stakeholder. While these were obvious for some stakeholders (e.g. rice and livestock farmers benefitting from the information provided), we experienced some challenges in defining costs and benefits for others. For example, for the Agricultural Service Centre and Women's Union involved in the implementation step of the intervention, we defined the benefits as the funding they receive for implementing the services. For the Provincial People's Committee (PPC), ACS implementation and upscaling would reduce their available funds, which we defined as their costs. Meanwhile, some other stakeholders, such as farmers and implementing stakeholders, will most likely benefit from ACS implementation. To gain an overview of all the investment costs and impacts, experts weighed all funds invested by the PPC against all benefits (i.e. benefits for all other stakeholders), to calculate the nominal cost-benefit for the PPC. Furthermore, while agricultural input suppliers do not incur any direct cost for implementing ACS, the farmers' potential reduction in fertilizer and pesticide use may reduce their revenues from agricultural input sales. We therefore considered the farmers' reduced expenses for fertilizer, pesticides and seeds as the "costs" to agricultural input suppliers.

Perceived interest, influence, relevance and attitude of stakeholders

Stakeholder attributes can change over time (Reed et al., 2009); therefore we conducted three focus group discussions (FGDs) with the expert team in 2019 and three in 2020 to map out the perceived attributes of stakeholders that are relevant in ACS planning (step 2.4 in Fig. 2). We categorized stakeholders according to four main attributes, including interest, influence, relevance of ACS to the stakeholders' mandates, and attitudes. **Interest** implies attention to or curiosity about ACS decisions. **Influence** refers to stakeholders' relative power over a decision (Smith, 2020). Here, we relate the influence attribute to stakeholders' authoritative power and knowledge relevant to the government's ACS decision-making system. **Relevance** relates to the alignment between the stakeholders' mandates or core business objectives and their potential roles in implementing the ACS solutions. **Attitude** represents ways of thinking or feeling about the possible ACS decisions and their potential impact. Due to limited resources, we could not assess the stakeholders' "soft" power, which may manifest, for instance, where a stakeholder may not have strong authoritative power but can use personal relations to influence the decisions of other actors. Together with the expert team, we gave a score to each stakeholder with a value ranging from 0 to 5 for interest, influence and relevance. We labeled the stakeholder's attitude as positive, negative or unknown (no information). We categorized stakeholders using a four-dimension matrix using the ggplot2 package (Wickham et al., 2022) in R (R Core Team, 2020).

Develop recommendations for stakeholder engagement

We conducted one meeting with the expert team in 2020 to revisit (step 3) the socio-economic development planning process (as described in section 2 on investment decision-making in Dien Bien). In this meeting, experts integrated stakeholder knowledge of ACS (outcome from step 1.1 to step 1.7), stakeholder attributes (outcome from step 2.1 to step 2.4) and insights into the ACS design and planning process to develop recommendations (step 4) on the stakeholder engagement strategy in Dien Bien's SEDP decision-making process (Fig. 2).

Results

Stakeholder identification

We identified 35 key stakeholders based on the outlined selection criteria. We categorized these stakeholders into different groups **(**Table 1**)**.

Expert identification

We classified stakeholders based on their expertise, availability, experience and gender **(**Fig. 3**)**. We identified 11 organizations and individuals as meeting the experience and availability criteria, which qualified them to serve as core expert stakeholders. We also determined 19 organizations and individuals as potential resource stakeholders due to their highly relevant experience but limited time availability. Five out of 35 key stakeholders did not join us since they were too busy or did not respond to our invitation. In total, 26 individuals (10 males and 16 females) ultimately joined our study as core experts (14 individuals) and resource persons (12 individuals).

Stakeholder expertise identified included the stakeholders' knowledge or skills in using climate information, translation of climate information into agricultural advice, budgeting, communication, fertilizer and pesticide use, weather forecasting, gender analysis and gender integration in development interventions, ACS intervention management, ACS implementation, socio-economic development planning and ACS policies. The explicit mapping of expertise helped us identify the overlap between stakeholders. Based on this information, we could identify "backup" experts for each field to attend workshops in case the first expert was unavailable.

Table 1
Most relevant stakeholders to be considered in knowledge generation and planning for ACS upscaling.

Type of organization/ group/ individual	Stakeholder and abbreviation
Local authorities of the State	• People's Councils (PC) at the provincial, district and communal levels
National administration	• Ministry of Natural Resources and Environment (MONRE) • Vietnam Meteorological and Hydrological Administration (VMHA) • Ministry of Agriculture and Rural Development (MARD) • Ministry of Planning and Investment (MPI) • Ministry of Finance (MOF)
Local administration	• Provincial People's Committee (PPC) • District's People's Committee (DPC) • Provincial Department of Planning and Investment (PDPI) • Provincial Department of Finance (PDOF) • Provincial Department of Agriculture and Rural Development (PDARD) • District Division of Agriculture and Rural Development (DDARD) • Project communes • Non-project communes • Project village leaders
Weather forecast provider	• Provincial Hydro-Meteorological Station (PHMS)
Political-social organization	• Women's Union
Public non-business service units	• District Agricultural Extension Center (DAEC) District Agricultural Service Centre (DASC) • – a potential new entity in the government system formed by merging DAEC and some other public service units
Private service providers	• SMS service providers • Agricultural input suppliers
Civil society organizations	• CARE International in Vietnam (CVN) • Dien Bien Center of Community Development (CCD)
VSLA groups	• Village Saving and Loan Association (VSLA) – direct beneficiaries in CVN's project villages
Conventional farmers (individuals)	• Other conventional farmers (non-VSLA) – farmers (women and men with different ethnicities and languages) residing in the same villages with VSLA. They do not engage directly in CVN projects, but they benefit from accessing ACS provided to CVN's project villages
Other individuals	• Other individuals within key organizations and groups

Cost-benefit analysis for ACS stakeholders

We calculated costs and benefits for individual stakeholders (Fig. 4**.**) likely to be directly affected by the implementation of ACS, using data collected by Luu et al. (2022b). In all four investment options, we found similar patterns, with a very high likelihood that the "winners" would be the Provincial People's Committee (98.3 %-99.9 %), rice farmers (99.9 %-100 %) and fish farmers (100 %). Service implementers would benefit in those investment scenarios where they have roles in implementation. These stakeholders are the Provincial Hydro-Meteorological Station, the Provincial Department of Agriculture and Rural Development, the District Agricultural Service Centre, SMS service providers, Women's Union/Local Non-Government Organization-LNGO, and village leaders.

We found that there is a small chance that animal husbandry farmers and the wider public will become "losers" (i.e. in cases when they experience wrong forecasts and advice) from ACS interventions (17.2 %-17.8 % and 4.8 %, respectively). Meanwhile, there is a very high probability that costs will outweigh benefits for seed (99.4 %-99.7 %), fertilizer (93.8 %-95.5 %) and pesticide suppliers (99.0 %). A summary of individual Net Present Value results for each stakeholder is available in the Supplementary Material 1.

Perceived interest, influence, relevance and attitude of stakeholders

Experts categorized all 35 stakeholders into four groups according to their level of interest and influence for 2019 and 2020. Experts also considered their attitude and the relevance of their mandate to the scaling of ACS **(**Fig. 5 **and** Fig. 6**)**. These considerations helped us formulate recommendations for the stakeholder engagement strategy.

Group one: In 2019, ten stakeholders were categorized as having high interest and strong influence. All these stakeholders were perceived as having positive attitudes about the scaling of ACS. Their mandates are highly relevant to the purpose and implementation of the potential interventions. In 2020, thanks to CVN's efforts in engaging with stakeholders, three stakeholders (the Vice Chairman of the PPC, the Vice Director of the Provincial Department of Agriculture and Rural Development and project village leaders) gained higher interest scores. This implies that they may become more likely to support ACS scaling activities. The influence score of the Vice Director of the Provincial Hydro-Meteorological Station also increased, as she became the Director of the same institution during the project. Experts suggested these stakeholders, particularly those who will benefit from implementing the ACS scaling (e.g. women's union, project village leaders, Dien Bien District Agricultural Extension Center), could be key allies in the planning process.

Nevertheless, among all stakeholders in group one, only the VHMA Chief of Office had very high influence and interest scores (i.e. scores of 4) in both years. Most of the other stakeholders did not have very high influence scores. Since opportunities to increase influence are limited, experts recommended a strategy to increase the interest of highly influential stakeholders with low-interest scores (from group 2).

Group two: In 2019, twelve stakeholders were categorized within group two (strong influence and low interest). In 2020, the Vice Director of the Provincial Department of Agriculture and Rural Development and Project village leaders moved to group one, thanks to the project's continued stakeholder engagement. At the same time, the Director of the Provincial Department of Agriculture and Rural Development, a vacant position in 2019 when we conducted our study, was newly appointed

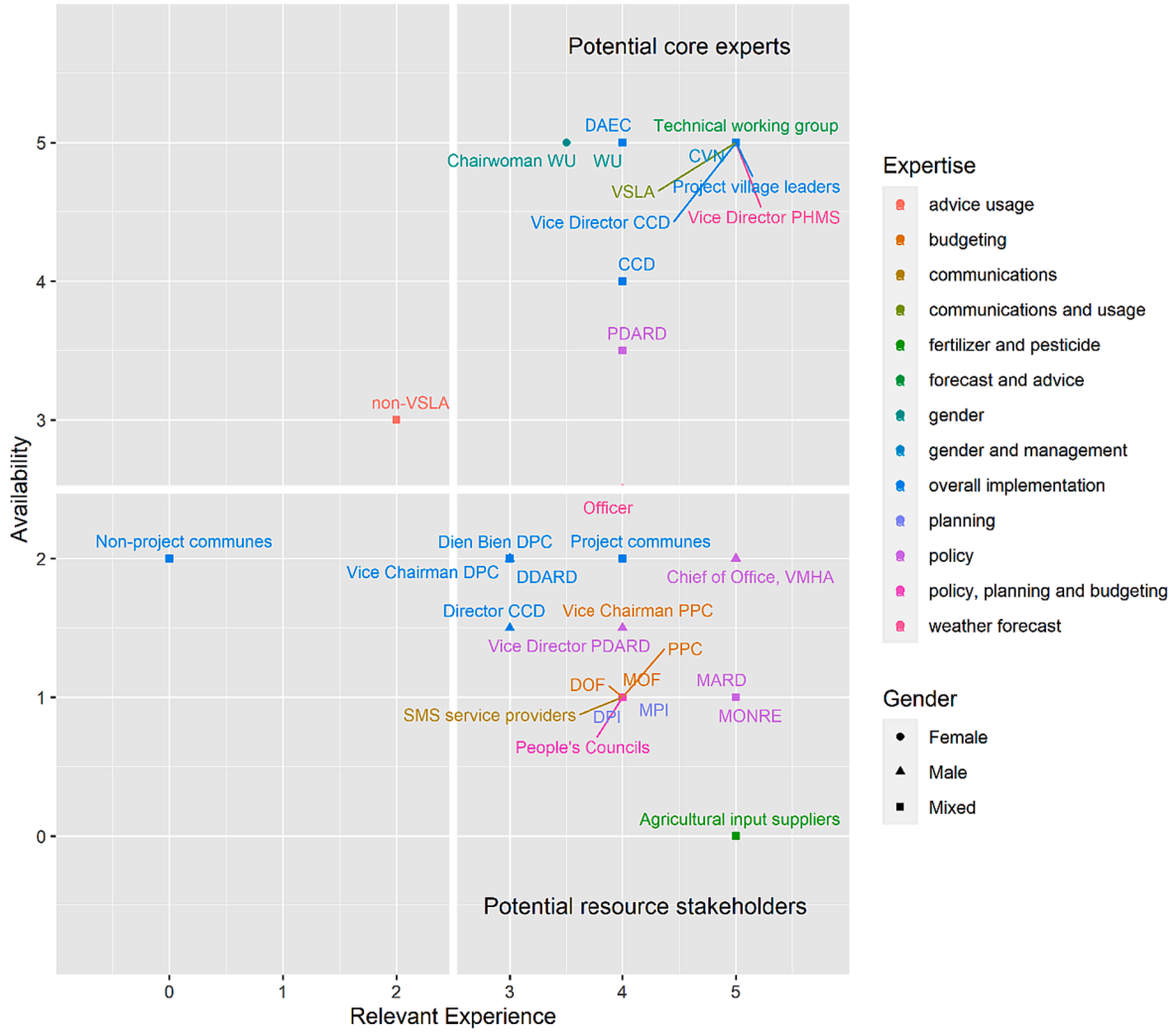

Fig. 3. Categorization of stakeholders to identify potential core experts and resource persons. Criteria for core experts (top right quadrant of the grid): availability score > 2.5 and experience score > 2.5. Criteria for resource persons (bottom right quadrant of the grid): availability score ≤ 2.5 and experience score > 2.5.

and joined group two (strong influence but little interest). Nine of the stakeholders in this group had very high influence potential and high relevance (i.e. influence and relevance scores at 4 to 5 in 2020). Among them, PPC was identified as one of the most important decision-makers for ACS scaling, since PPC is in charge of connecting the demand from the local level to support at the national level. Experts pointed out the importance of increasing the interest and support of influential stakeholders, keeping them informed and engaging them during the preparatory work and the actual planning processes.

In 2019, experts could not identify the attitudes of the Provincial Department of Planning and Investment, Provincial Department of Finance, Ministry of Planning and Investment, Ministry of Finance and non-project communes (group two), since they had not interacted with them before on ACS scaling. In 2020, thanks to the engagement of different stakeholders as part of this study, interactions could be initiated between the Provincial Department of Planning and Investment and the Provincial Department of Finance to introduce the scaling ideas. While these stakeholders did not object to any planned ACS intervention and signaled their willingness to review the scaling proposal as part of the planning and budgeting process, they were also cautious about signaling support for the interventions. Thus, in 2020, experts still ranked them as neutral in their attitude toward scaling decisions.

Group three: In 2019, five stakeholders were members of group three (high interest but low influence) and one stakeholder, the Vice Director of the Provincial Hydro-Meteorological Station, was positioned by the experts on the verge between groups three and four. Among these, the Vice Chairman of PPC and the Vice-Director of the Provincial Hydro-Meteorological Station moved from group three to group one in 2020, indicating an increase in influence. The Village Saving and Loan Associations (previously in group four) and the SMS company (experts did not have information about them in 2019) joined group three in 2020. These stakeholders, some of whom are likely to benefit from ACS (e.g. Village Saving and Loan Associations, SMS Company and Dien Bien Center of Community Development), are particularly relevant regarding upscaling of ACS. Stakeholder engagement efforts can help keep these stakeholders organized (e.g. Village Saving and Loan Associations) to amplify their voices or to keep them participating (e.g. CCD, SMS company) during the planning processes.

Group four: In 2019, group four (low interest and low influence) included four stakeholders. The Vice Director of the Provincial Hydro-Meteorological Station was placed on the verge between groups four and three. In 2020, this number decreased to four, with one senior government officer newly joining group four due to his changed position (i.e. he was in group 3 in 2019). Dien Bien Phu City Division of Agriculture and Rural Development was included as a new stakeholder since some part of Dien Bien District was moved to Dien Bien Phu City in early 2020. Two other stakeholders (i.e. Village Saving and Loan Association and Vice-Director of Provincial Hydro-Meteorological Station) moved

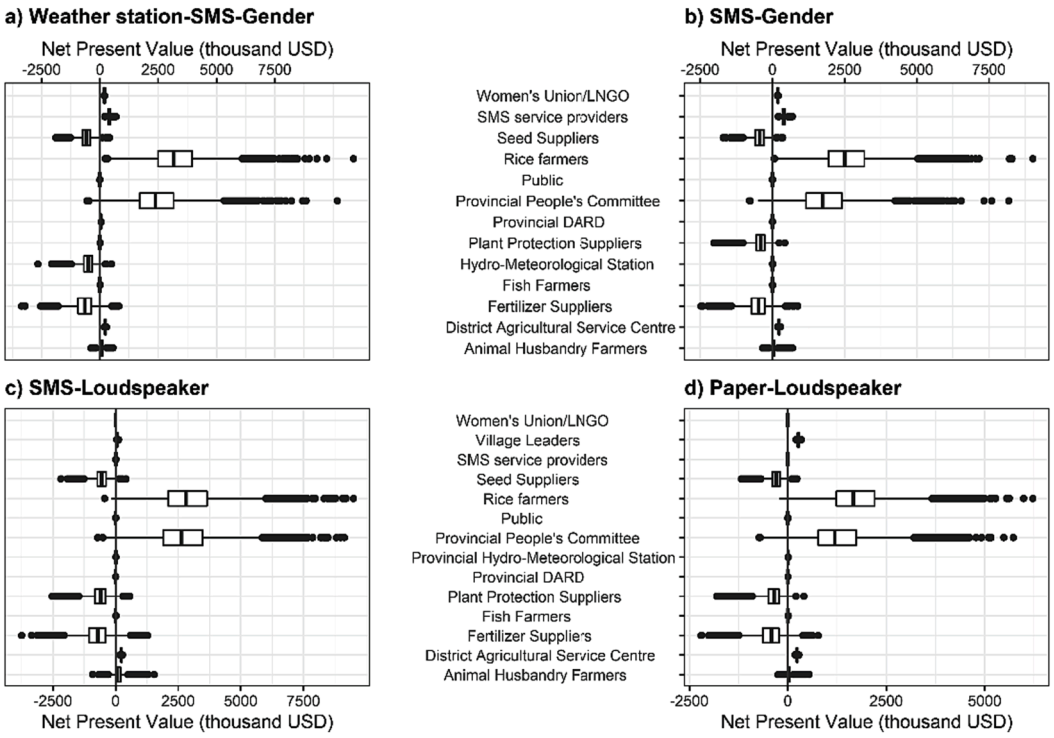

Fig. 4. Net Present Values of four agro-climate service (ACS) interventions in Dien Bien District, Vietnam, disaggregated for different stakeholders. Results were obtained through Monte Carlo simulation with 10,000 model runs for each investment scenario.

out of the group. Stakeholder engagement efforts have the potential to keep stakeholders informed and engaged in the process. For example, non-Village Saving and Loan Association farmers might have low interest due to their low awareness about the scaling initiative. However, they are potential beneficiaries and should be informed during preparation and planning. Dialogue is also needed where stakeholders have a negative attitude (e.g. agricultural input suppliers) about implementing ACS.

Possible considerations in engaging stakeholders

In this step, experts analyzed all relevant stakeholder attributes and answered the two following questions: (i) Does the stakeholder analysis suggest any substantial modifications in the SEDP decision-making process? and (ii) How do the attributes inform the potential coordination and roles of stakeholders in the decision-making process?

Does the stakeholder analysis suggest any substantial modifications in the SEDP decision-making process?

In principle, the involvement of stakeholders in the SEDP process did not lead to substantial modifications compared to the standard process (illustrated in Fig. 1). Besides, experts suggested that the composition of stakeholders involved in the SEDP planning remained unchanged. However, experts pointed out the importance of investing in preparatory actions given that many influential stakeholders (e.g. Provincial People's Committee, People's Council and all the relevant Ministry stakeholders) have low interest in ACS. Such preparatory actions aim to increase awareness and thus the interest of stakeholders with the power to support ACS scaling.

How do the stakeholder attributes inform the potential coordination and roles of stakeholders in the decision-making process?

Experts identified multiple opportunities for stakeholder involvement in ACS planning steps. In the following, we highlight results in the context of these different stages:

Involvement of stakeholders at the policy recognition stage. At present, development projects with external funding, such as CARE's project, usually go through the "administrative" but not the agricultural sector reporting system. We observed a low interest of influential stakeholders in ACS, partly because they were unaware of the insights of CVN's pilot project on agro-climate services. It is thus often difficult to bring up ACS topics in the policy discourse. While critical decision-making is expected to happen at the provincial level with PPC as the key stakeholder, efforts must be supported by specialized departments and governments at the village, commune, district and national levels, as well as by NGOs.

Supporting the recognition of evidence for the effectiveness of ACS, as well as potential limitations, can be considered the first step towards evidence-based decision-making. Experts point out that stakeholders should provide information and evidence mainly in the existing written and oral reporting systems since this is the only formal reporting line in the government system. This reporting process involves reflections from stakeholders, including Village Saving and Loan Associations and farmers with ACS experience, village leaders, project communes, the District Division of Agriculture and Rural Development, the Provincial Department of Agriculture and Rural Development, the District People's Committee, the Women's Union at provincial, district and commune levels, and NGOs (i.e. CARE in Vietnam and the Dien Bien Center of Community Development). These reports should include information about the application of ACS in Dien Bien and the impacts, opportunities and challenges. This process aims at increasing interest and support from the PPC, which holds a high influence (score of 4.5) and low interest (score of 2.5), as identified in 2020. In addition, the province needed support from upper levels, i.e. from national ministries with a high influence and low interest. MONRE and MARD are expected to signal support for the necessity and feasibility of the interventions given their high influence (score of 4 in 2020), and considering that ACS are well aligned with relevant policies within their thematic domains (e.g. the National Adaptation Plan). The Ministry of Planning and Investment and the Ministry of Finance are expected to advise on the appropriateness of funding acquisition and the potential funding sources according

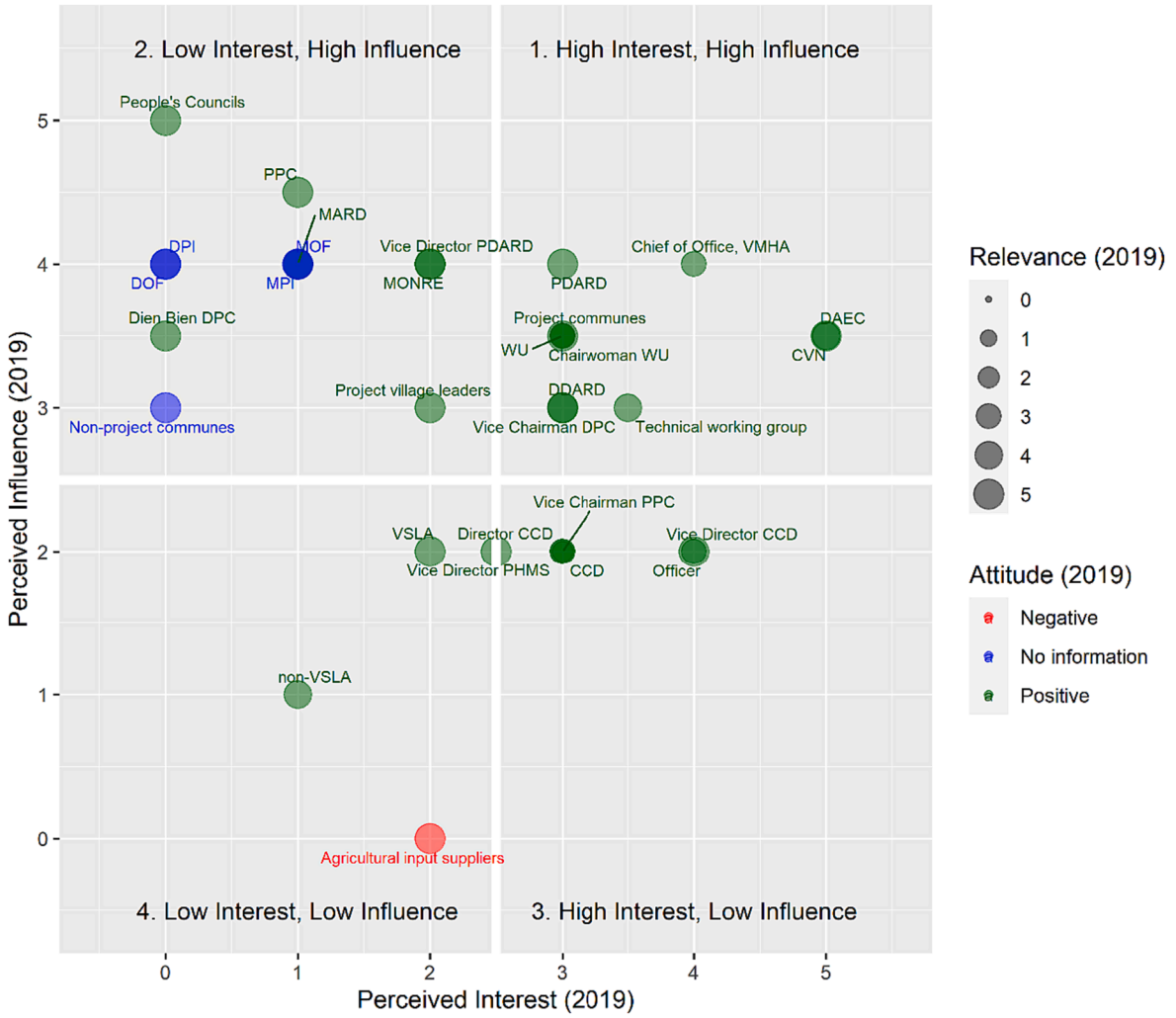

Fig. 5. Perceived interest, influence, relevance and attitude of stakeholders in the decision to scale agro-climate services in Dien Bien District, Vietnam. Results were captured through expert consultation in 2019.

to their relevant mandates (score of 5 in 2020). Considering the local requirement and the legal framework, the PPC could support the scaling plan and start setting the agenda. This support can be materialized in guiding the SEDP planning process, by indicating that it is possible to plan for ACS upscaling.

Involvement of stakeholders during the planning process. Based on the SEDP guidance, specialized departments and governments at the village, commune and district levels can integrate ACS in their SEDP planning. However, some communes did not have any experience (score of 0) using ACS before and thus had low interest (score of 0 in 2020). Therefore, scaling workshops in the project and non-project communes should be organized to record the needs and share experiences between project communes and non-project communes. In this way, the experience attribute of project communes (score of 4) is being used, aiming for increased interest from non-project communes. Furthermore, CARE had rich experience (score of 5) in ACS implementation and a high interest in ACS scaling (score of 5 in 2020). Thus, it is expected that CVN could provide technical support to the District Division of Agriculture and Rural Development to develop a detailed scaling proposal that makes use of CARE's experience and insights about the costs and benefits of the scaling solutions.

Coordinating and facilitating stakeholders. Acknowledging the complexity of the SEDP process (i.e. multi-stage, multi-actor, cross-sector and multi-level), experts also highlighted the importance of having a coordinating body for the whole process. The coordinating actor is supposed to gain an overview and support facilitating the stakeholders' roles in the horizontal (i.e. between departments at the same administrative level) and vertical (i.e. different administrative levels) dimensions of the SEDP planning process. Experts considered the Provincial Department of Agriculture and Rural Development the most appropriate stakeholder for this role due to the alignment of this task with the institution's mandate (score of 5 in 2020) and the department's high influence (score of 4 in 2020). Additionally, the Provincial Department of Agriculture and Rural Development is considered to have the least conflict of interest with other stakeholders in terms of finance and relevant mandate. Experts also suggested that CVN should support the Provincial Department of Agriculture and Rural Development in this process due to their rich experience (score of 5), strong interest (score of 5 in 2020) and relatively strong influence (score of 3.5 in 2020). Besides, CVN is perceived as having the lowest potential for conflicts of interest (i.e. funding for CARE is often from external sources and they do not have a potential financial conflict with other stakeholders in ACS scaling).

Collective organization of stakeholders. Village Saving and Loan Associations, the Dien Bien Center of Community Development and SMS service providers had strong interest (scores of 3, 4 and 5, respectively, in 2020) and low influence (scores of 2, 2 and 0, respectively, in 2020).

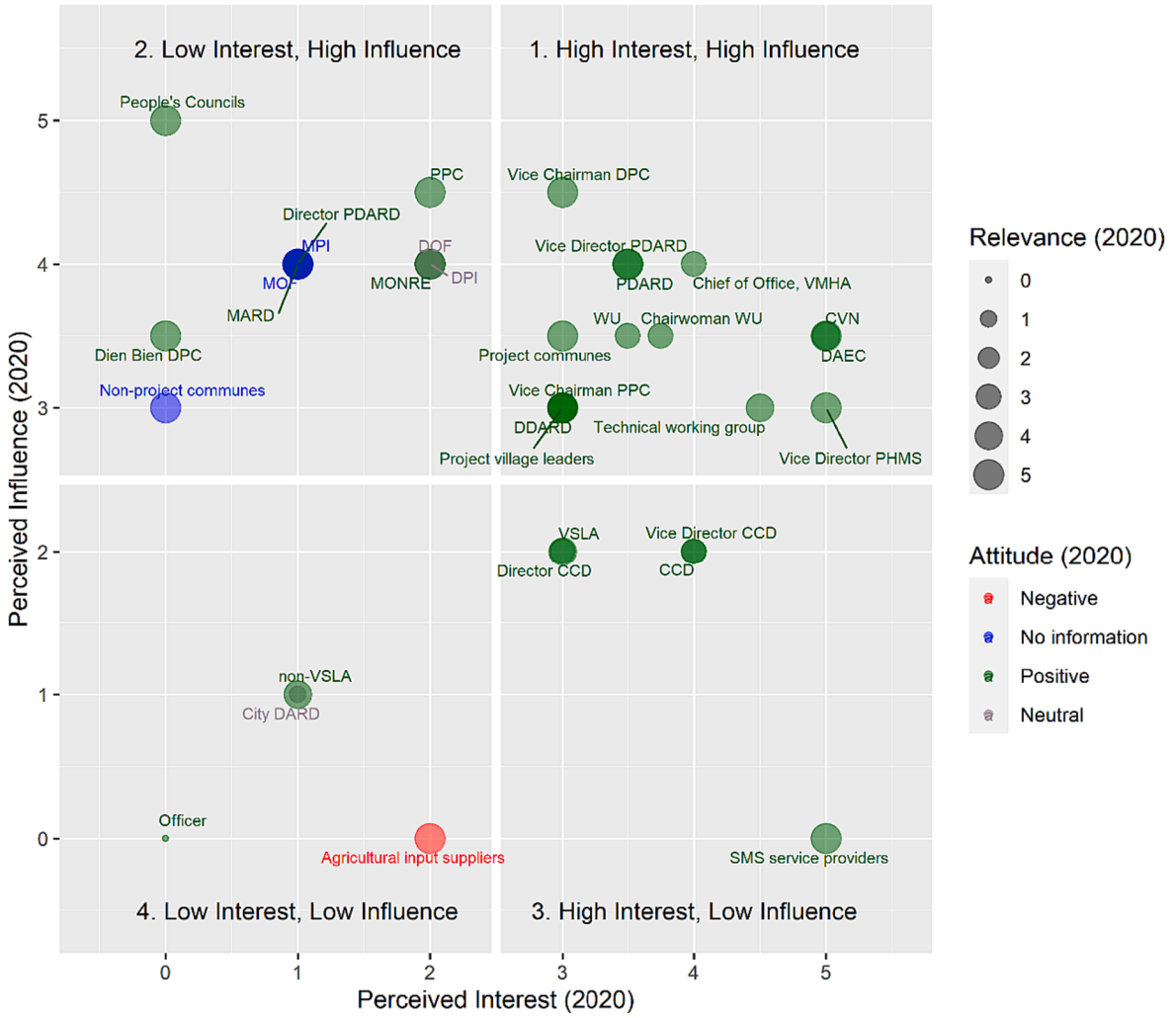

Fig. 6. Perceived interest, influence, relevance and attitude of stakeholders in the decision to scale agro-climate services in Dien Bien District, Vietnam. Results were captured through expert consultation in 2020.

However, according to the cost-benefit analysis, they are all potential beneficiaries of ACS scaling. Therefore, they can be allies in the process of driving ACS planning. Their low influence can be increased by pooling their voices. For example, the Dien Bien Center of Community Development could support organizing Village Saving and Loan Association farmers and help them collectively provide feedback, opinions and needs to the reporting systems and planning process.

Involvement of individual stakeholders. Even though experts were unable to describe in detail the possible participation of all individual stakeholders, they discussed the critical roles of a few stakeholders at some crucial steps in the SEDP. The Vice Chairman of the PPC and the District's People's Committee (high interest and high influence in 2020) must be involved at all critical decision-making moments in the SEDP (e.g. meetings to decide if ACS will be included in SEDP guidelines, meetings to defend the SEDP). The Vice-Director of the Provincial Department of Agriculture and Rural Development (high interest and high influence in 2020), the Chairwoman of the Women's Union (high interest and high influence in 2020) and the Vice-Director of the Provincial Hydro-Meteorological Station (high interest and high influence in 2020) are expected to support collecting evidence and incorporating such evidence into the reporting system of their respective organizations. The Vice-Director of the Provincial Hydro-Meteorological Station and the Chief of Office of the Vietnam Meteorological and Hydrological Administration (high interest and high influence in 2020) are expected to signal support for agro-climate service scaling during consultation and experience-sharing events at the national level. The Vice-Director and the Director of the Dien Bien Center of Community Development (high interest, low influence in 2020) are expected to support mobilizing and organizing farmers collectively during the reporting and planning processes.

Managing the stakeholders' different perspectives. Agricultural input suppliers were identified as the "losers" of ACS implementation since they might face a reduction in farm input sales. They are perceived as having a negative attitude towards ACS scaling. This suggests the necessity of managing the different perspectives of these stakeholders. One of the solutions proposed by the experts was to involve them in the SEDP process. Commune and District governments should invite them to the SEDP consultation meetings. In that way, these stakeholders can voice their concerns or proposals. Another suggestion during the potential implementation of ACS is to share agricultural advice with all these stakeholders. In the current situation, some agricultural advice requires agricultural inputs (i.e. drought-tolerant breeds, fertilizer or pesticides) that are unavailable in the local market. By receiving such information, agricultural input suppliers will be better informed about the users' demands in the new context.

We describe and visualize the detailed SEDP process with potential pathways to integrate ACS in the SEDP, and the roles of stakeholders in Supplementary Material 2.

Discussion

In the context of climate change, decision-makers are increasingly in need of effective measures to support and invest in transitioning the agricultural sector toward climate-informed agricultural planning and management (Ferdinand et al., 2021; WMO, 2019). A transdisciplinary and probabilistic approach has the potential to support the planning and budgeting processes (Daniels et al., 2020; Luu et al., 2022a).

Co-creation research usually does not include an explicit focus on the pre-financing stage (Barquet et al., 2022; Baulenas et al., 2023). Notable exceptions are studies by Daniels et al. (2020) and Rubio-Martin et al. (2021). However, earlier methodologies have some limitations, many of which stem from an imbalance between business case analysis and stakeholder analysis, as well as between the consideration of end-users and other stakeholders during the planning process. For instance, Daniels et al. (2020) provided valuable insights into stakeholder engagement in climate service co-creation, highlighting the need to consider funding sources and business cases. However, these considerations are not elaborated in great detail, leaving a gap in understanding how stakeholders can engage in analyzing the business case in uncertain and complex contexts. Taking a step further in co-creating business cases for climate service investment, Rubio-Martin et al. (2021) engaged users in co-creating the business model canvas for climate service investments. However, it seems that they used the terms 'stakeholders' and 'user segments' interchangeably, so that the precise definition of what constituted a stakeholder remained somewhat unclear.

In this study, we propose a comprehensive approach combining decision analysis with stakeholder engagement to generate system knowledge and incorporate it into decision-making processes. We contribute to the improvement of existing methods by offering comprehensive and transparent guidance for defining stakeholders, identifying experts and assessing relevant stakeholder attributes to explicitly suggest which roles they might play in ACS investment analysis and in planning.

We argue that defining stakeholders is fundamental and essential to supporting a participatory process. Despite some notable examples (Barquet et al., 2022; Baulenas et al., 2023), stakeholder selection is often done on an ad-hoc basis (Reed et al., 2009). This study emphasizes the importance of a transparent method to identify and strategically engage stakeholders (Barquet et al., 2022; Baulenas et al., 2023). We also argue that stakeholder engagement in the ACS design and planning process would greatly benefit from considering individual stakeholder characteristics. For example, a stakeholder interested in the scaling of ACS will most likely have a stronger motivation to share favorable information regarding ACS scaling initiatives than those not interested in ACS. While multiple attributes have been suggested to inform the stakeholder engagement strategy (Reed et al., 2009), the most commonly used in previous studies were interest and power or influence in the form of an influence/power interest matrix (Reed et al., 2009; Sperry and Jetter, 2019). We extended this approach by including nine attributes in determining stakeholder roles, from knowledge generation to influencing ACS decision-making. Attributes included in our study, such as relevant experience and availability, help to determine the overall strategy to engage stakeholders as core experts and resource persons. In our study, explicit consideration of gender revealed the gender disparity in the expert team. While it is not always possible to achieve a perfect representation of all stakeholders (Reed et al., 2009), such explicit analyses help to inform on the status quo and provide guidance for improvement.

We suggest moving away from internally-focused, narrow viewpoints in managing stakeholders (i.e. managing stakeholders to achieve specific goals set by some actors) and offering a way to explore opportunities for them to co-create research results by playing an active role in the planning process. Many common approaches for stakeholder analysis remain static in engaging stakeholders (Sperry and Jetter, 2019). Monitoring change in stakeholder roles helps to gain insights into the dynamics between different stakeholders, which can be used to adapt the engagement process over time (Fassin, 2011). In this study, examples of change include a new person taking on a leadership role (e.g. Director of the Provincial Department of Agriculture and Rural Development), changes in interest and influence due to the changing position (e.g. a government officer), or a change in the administrative structures resulting in the emergence of an additional stakeholder (e.g. City Division of Agriculture and Rural Development). Such changes suggest that if projects fail to include stakeholder dynamics in decision-making, they might risk failure of scaling processes and investments (Sperry and Jetter, 2019). Stakeholder engagement, therefore, requires continuous monitoring of stakeholder dynamics (Reed et al., 2009; Smith, 2020).

The DA approach supports decision-making by identifying decision options and providing evidence through analyzing decisions (Hubbard, 2014; Luedeling and Shepherd, 2016). In Vietnam's multi-stakeholder, multi-stage, cross-sectoral and multi-level collaboration system, such evidence may need to go through a complex planning process (Strauch et al., 2018; World Bank, 2015). We found that engaging multiple levels of stakeholders during ACS scaling and planning is necessary to influence decision-making. Stakeholders at individual, village, communal, district, provincial and national levels all need to be part of the process. Our findings agree with Gonzalez-Porras et al. (2021), who suggested that the contribution of stakeholders from different levels in a nested system helps further sustainability transitions. Moreover, Gonzalez-Porras et al. (2021) argue that collaborative relationships and interactions among stakeholders can be understood as change agencies accelerating sustainability transitions. This finding aligns with our result, implying that stakeholder coordination and collaboration are crucial in influencing multi-stage and multi-level decision-making processes.

Our transdisciplinary approach addresses the common barriers to rational organizational decision-making. These barriers include information gaps and imperfections, the complexity of the decision problem, human information-processing capacity, the time available for decision-making processes, and potential conflicts between the priorities of different stakeholders and decision-makers (Hatch, 1997). Our approach addresses the issue of imperfect, incomplete information and complexity by mobilizing stakeholder knowledge and secondary data to capture the current state of system understanding. While it may not be possible to obtain perfect information, the current state of system understanding is often sufficient to support decision-making (Luedeling and Shepherd, 2016). Regarding human information-processing capacity, we acknowledge that ACS systems and the impacts of potential ACS solutions are complex, which makes them difficult to communicate to time-constrained senior government decision-makers. We found that integrating evidence into the government's periodic oral and written reporting systems may effectively communicate information to senior decision-makers in an established format.

While asserting the comprehensiveness of our proposed approach, we acknowledge some limitations. We did not evaluate conflicts between the different priorities of stakeholders and decision-makers. ACS requires long-term investment and a focus on "soft" measures (i.e. awareness raising, information interpretation, communication, improved planning, and stakeholder collaboration) (Luu et al., 2022a). However, Vietnam's climate-related investment is biased towards large-scale infrastructure investment instead of softer measures (Lindegaard, 2013; Pannier et al., 2020). Therefore, there may be a conflict between prioritizing funding allocation for agro-climate services and other investments. We did not incorporate such prioritization conflicts into our model.

We explored the authoritative power of stakeholders as part of the government's guided SEDP process. We find this helpful for making concrete recommendations about each stakeholder's role in the decision-making process. However, social network analysis, which was outside the scope of this study, may also help clarify the dynamics, opportunities and challenges of stakeholder engagement. For instance,

social network analysis helps in understanding the patterns of information sharing among stakeholders, how one stakeholder can influence another in adopting a new idea, and what factors can disrupt information sharing within a cluster of stakeholders (Powell and Hopkins, 2015).

We did not manage to engage the potential "losers" of ACS in our study, limiting the insights we could gain regarding mechanisms to resolve stakeholder conflicts. While the CVN project established some exchanges, it did not involve an official partnership with the agricultural input suppliers. Due to time and resource constraints, we could not establish contacts and engage with these suppliers. Thus, we suggest future studies should focus on more systematic engagement with such stakeholders.

While we affirm the advantages of combining stakeholder engagement and decision analysis (as described in Fig. 2) to support decision-making in complex and uncertain multi-stakeholder contexts, we acknowledge that undertaking a full decision analysis to obtain cost-benefit analysis results may not always be feasible. Therefore, we also make recommendations to enhance the replicability of this methodology using Fixed and Flexible principles.

Fixed principles: Explicitly define what we mean by the term 'stakeholder'. Define and rank attributes that are relevant to ACS decision-making and the expectation of stakeholders' engagement. Identify specific entry points for investment opportunities. Analyze these attributes to inform an optimal engagement strategy. **Flexible principles:** While we explicitly focused on a socio-economic development plan, our approach can be applied to any plan relevant to investment decision-making. The specific attributes will depend on the objective that the stakeholder engagement aims to ensure and the feasibility of obtaining such information. For example, if the goal is investment in ACS, a cost-benefit analysis is crucial. However, in the absence of a cost-benefit analysis, one can rely on other sources of information for judgement including expert opinion, other relevant studies and databases. If obtaining cost-benefit information is entirely impossible, it can be considered as knowledge gap for future research. However, the outlined stakeholder engagement process could still be implemented, focusing exclusively on the other suggested attributes.

While we acknowledge some limitations, our approach to generating and translating system knowledge into decision-making supports the notion of stakeholder engagement as an effective approach to empowering marginal stakeholders to engage in and influence decision-making (Reed et al., 2009). We believe this approach will help increase the credibility, legitimacy and salience of evidence generated and promote a sense of shared ownership in decision-making processes.

Conclusions

Sustainability transitions are long-term processes. The pre-stage of transitions often features uncertainty, scattered knowledge, conflicts of different views (i.e. traditional and new perspectives), and the challenge of bringing stakeholders to the same table. Without coordination, such "incubation" processes can take a long time. Our study offers a transparent and systematic method to address critical challenges at this early process stage by engaging stakeholders in generating and translating system knowledge for decision-making. Using nine different attributes, combined with stakeholders' system knowledge and insights about the decision-making process, we could explicitly recommend where, when and how stakeholders can engage in the socio-economic development planning process in Dien Bien, Vietnam. This transparent approach offers the opportunity to increase the reproducibility of the methods and to support other complex decision-making processes.

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CRediT authorship contribution statement

Thi Thu Giang Luu: Writing – original draft, Visualization, Software, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Eike Luedeling:** Conceptualization, Funding acquisition, Methodology, Software, Supervision, Visualization, Writing – review & editing. **Cory Whitney:** Conceptualization, Methodology, Supervision, Visualization, Writing – review & editing. **Lisa Biber-Freudenberger:** Conceptualization, Methodology, Supervision, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have shared the link to my data in the manuscript and supplementary material

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Appendix A. Supplementary data

All input data for stakeholder mapping and analysis and supplementary materials are available at this public repository https://github.com/ThiThuGiangLuu/Stakeholder-Decision-Analysis-ACS/blob/master/Supplementary-material.html. Supplementary data to this article can be found online at https://doi.org/10.1016/j.cliser.2023.100432.

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