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Operationalizing Climate Change Adaptation Literacy through Framework Development and National Population Evidence from Taiwan

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Abstract

Climate change adaptation requires citizens to understand risks, navigate public institutions, and engage with feasible responses. We developed a climate change adaptation literacy framework comprising four domains and 16 subdimensions through literature synthesis, expert consultation, and pilot testing. A weighted national telephone survey assessed 2,527 adults in Taiwan in 2025. Only 11% correctly rejected a statement equating adaptation with emissions reduction, and 22% recognized the need to adjust policy for specific groups. Support for adaptation was high, while reported engagement with local resources and civic action was lower. Adjusted analyses showed higher conceptual and policy knowledge among respondents with more education. Younger adults had higher knowledge scores, and older groups reported more adaptive practice. These findings highlight priorities for clarifying concepts, differentiated protection, accessible local services, and practical participation. The framework provides a national baseline for evaluating communication and education on adaptation.

Introduction

In contemporary public-policy fields, literacy extends beyond possessing factual information. Health-literacy scholarship, for example, treats literacy as the capacity to access, understand, appraise, and apply information to support judgment and action in everyday life.[1,2] This broader meaning is relevant to climate change adaptation because citizens must interpret changing risks, understand available responses, and make use of institutions and resources under conditions that vary across places and social groups.

Climate literacy research provides a second foundation. Existing studies have examined scientific knowledge, awareness of climate change, attitudes, risk perception, and behavioral intentions, yet definitions and measurement approaches remain heterogeneous. A recent systematic review of quantitative climate-knowledge studies found that assessment practice prioritizes objective factual knowledge, with far less consistent attention to procedural or contextual knowledge.[3] Public understanding and engagement studies also show substantial variation across social and cultural settings, which limits the usefulness of a single universal pathway from awareness to action.[4,5]

Climate change adaptation literacy (CCAL) builds on this broader conception of literacy. It concerns whether people can recognize climate-related changes, interpret vulnerability and future risk, understand how adaptation is organized, and engage with feasible responses. These capabilities operate within a wider field of adaptive capacity. At the individual level, adaptation literacy includes the ability to interpret risk, identify options, and use relevant information and resources, all of which change over time. Broader adaptive capacity also depends on material assets, infrastructure, institutional quality, and social conditions that literacy itself does not capture.[6–14]

Recent work places climate change adaptation literacy within a wider set of capabilities. Simpson et al. organize the concept around climate-impact pathways, risk interpretation, adaptation competencies,

reflexive learning, and ethical or emotional engagement.[15] The framework examined here translates citizen adaptation literacy into questionnaire content addressing policy, implementation, local resources and everyday responses. These components allow assessment of how understanding and practical engagement vary across a national population.

Citizens encounter adaptation through household choices, community activities and public services. The framework focuses on individuals' ability to interpret risk and navigate these settings. Infrastructure, material resources and institutional quality provide the conditions within which those capabilities can be exercised.[6–14]

Behavioral evidence helps explain why knowledge alone provides an incomplete account of adaptation. A meta-analysis of 106 studies across 23 countries found that perceived self-efficacy, outcome efficacy, social norms and affect were more strongly associated with adaptation behavior than factual knowledge or previous experience.[16] Reviews of individual responses to climate-exacerbated hazards likewise show that adaptation behavior is shaped by social settings and by the distinction between privately beneficial actions and collective responses.[17] Broader behavioral research cautions against interventions that treat information provision as sufficient for climate action.[18]

Public participation gives adaptation literacy an institutional dimension. Reviews of participation in adaptation describe persistent uncertainty about what meaningful public engagement entails and how citizen involvement is incorporated into decision processes.[19,20] Classic participation scholarship also distinguishes the existence of participatory procedures from the distribution of influence within them.[21–23] For adaptation, this means that knowing how to participate and having accessible pathways for participation are both relevant to public capability.

The institutional dimension also makes adaptation literacy partly relational. A citizen may understand a risk and wish to respond, yet participation still depends on whether public institutions make information, decision processes, and local resources accessible. Participation scholarship has repeatedly shown that the formal existence of consultation does not guarantee meaningful influence.[19–24] For population assessment, policy literacy is therefore relevant because it captures whether people can recognize where adaptation responsibilities sit and how they might enter the governance process.

Adaptation knowledge is also situated. Local knowledge can reveal risk, vulnerability and feasible responses that standardized scientific information may overlook. Research on knowledge co-production therefore emphasizes context, pluralism, interaction and shared problem definition.[25,26] These ideas are particularly important where climate risks differ among communities or where adaptation measures depend on local experience.

Equity questions follow directly from this perspective. Vulnerability is unevenly distributed through access to resources, governance, social position, and historical conditions.[27–29] Adaptation can reduce these inequalities, but poorly designed interventions can also reproduce or intensify them.[30,31] Public

understanding of differentiated vulnerability and the need for context-sensitive adaptation is therefore part of the literacy needed to interpret adaptation policy.

Risk perception and communication provide another bridge between knowledge and action. Climate-risk judgments reflect experience, affect, values, norms and knowledge.[32,33] Communication research shows that climate information is interpreted through audience characteristics and social context, and adaptation communication becomes more useful when it connects future risk with locally meaningful choices.[34,35] The risk-perception literature also documents cases in which awareness of hazards coexists with limited preparedness, highlighting the role of trust, feasibility and other constraints.[36]

The temporal dimension of adaptation gives this literacy a distinctive educational purpose. Citizens face decisions about conditions that may differ from their experience: the capacity of drainage infrastructure, the suitability of housing, and the protection needed during heat waves. Understanding these decisions involves connecting present choices to future exposure and the circumstances of those affected. Experience can offer useful observations about local conditions, while scientific information can identify changes beyond those observations. Adaptation literacy brings these sources of understanding into decisions that remain open to revision as risks and available responses change. Adaptive-capacity and local-knowledge research provide a basis for this combination of situated understanding and continuing learning.[6,10,13,26]

Taiwan's national adaptation policy took shape in the aftermath of Typhoon Morakot in 2009. In June 2012, the Executive Yuan approved the National Climate Change Adaptation Policy Guidelines, establishing eight priority sectors: disasters, infrastructure, water, land use, coasts, energy and industry, agriculture and biodiversity, and health.[37] The Council for Economic Planning and Development, subsequently reorganized as the National Development Council, coordinated the first action plan for 2013–2017, approved in May 2014, to translate these strategies into sectoral action.[38] The second program covered 2018–2022 and was approved in September 2019 under the Greenhouse Gas Reduction and Management Act, strengthening integration into routine government work and annual reporting.[39] These successive programs provided the institutional foundation for the adaptation provisions adopted in 2023.

The Climate Change Response Act, promulgated in February 2023, added a dedicated adaptation chapter and established responsibilities for assessing future climate risk, supporting vulnerable groups, coordinating sectors and enabling participation.[40] The third National Climate Change Adaptation Action Plan (2023–2026), approved in October 2023, incorporates warming scenarios, nature-based solutions and coordination across ministries and levels of government.[41] This policy development makes citizens' understanding of adaptation, public responsibilities, and local participation increasingly relevant to implementation.

The institutional context also affects what a national assessment needs to measure. A citizen may recognize a climate hazard but be uncertain about which agency provides information, who is

responsible for a plan, or how to influence a public decision. These questions connect adaptation literacy to how government is organized. Taiwan's adaptation provisions make responsibilities and participation especially relevant to interpreting policy. Including institutional knowledge alongside concepts and everyday engagement therefore lets the assessment examine several points where citizens meet adaptation governance: interpreting a proposal, recognizing responsibilities, finding resources, and deciding how to participate. This approach connects the assessment to public policy implementation and to scholarship on meaningful participation.[19–24,40,41]

Despite the growing conceptual literature, operational evidence at the population level remains limited. Existing climate-literacy instruments often emphasize knowledge, whereas adaptation studies commonly examine risk perception, behavioral determinants, or particular household responses.[3,16–18,32,33] A different question arises at population scale: whether citizens possess a coherent set of capabilities for understanding adaptation, navigating its institutional setting, and engaging with feasible responses. A multidimensional assessment can reveal combinations that a single score would conceal, such as strong support alongside weak policy knowledge or practical engagement.

Population-level assessment is especially useful as adaptation policy moves into implementation. It can show whether public understanding keeps pace with new legal responsibilities, services, and participation mechanisms, and whether these capabilities develop similarly across social groups. Repeated assessment can then distinguish changes in conceptual understanding from changes in institutional literacy or practical engagement.[15,19,20,24,42]

Global evidence also shows that implemented adaptation remains uneven, often local and incremental, with limited evidence of risk-reduction outcomes. This implementation gap increases the value of measuring whether citizens can recognize adaptation responsibilities, locate relevant resources, and participate in emerging governance arrangements.[43]

This study defines climate change adaptation literacy (CCAL) as the integrated knowledge and capabilities through which citizens understand adaptation, interpret changing climate risks, navigate relevant policies and resources, and engage in responses appropriate to their circumstances. The construct comprises four complementary domains (Fig. 1; Table 1): basic understanding, policy literacy, implementation, and adaptation in everyday life. We informed the framework through a literature review, expert consultation, and pilot testing before applying it in a national adult survey. We examine its operationalization, the national profile across domains, patterns of support and reported engagement, and variation across demographic groups. The findings identify priorities for adaptation policy, communication, and education.

Table 1
Four domains and 16 subdimensions of the adaptation literacy framework.

Domain	Subdimensions
Basic understanding	Definition and goals; adaptation vs mitigation; adaptation vs disaster risk reduction; necessity and urgency; cost–benefit; international adaptation directions
Policy literacy	National adaptation law; national adaptation policy; planning adaptation action
Implementation	Risk assessment and management; role in implementation; civic action; cross-sectoral cooperation
Everyday adaptation	Local strategies and resources; adaptation in life planning; proactive adaptive capacity

Methods

Study design and framework development

The study used a staged framework-development and population-assessment design. Development began with a literature review on climate adaptation, climate literacy, vulnerability, adaptive capacity, risk, and public participation. The initial framework was then examined in a structured pre-field expert consultation involving specialists in climate-risk science, environmental systems engineering, and urban planning. The consultation led to changes in domain placement and wording, stronger treatment of future risk and vulnerable groups, and clearer attention to community capacity and the boundary between adaptation and disaster risk reduction.

The pre-field expert consultation was held on 10 July 2025. The discussion focused on whether the framework reflected the general public's understanding and capabilities, and whether the subdimensions were conceptually distinct. Recommendations led to several concrete changes: necessity was paired with urgency; adaptation versus disaster risk reduction was placed under basic understanding; vulnerability and future climate risk were made more explicit; local and community capacity received greater attention; and policy detail was differentiated between the public and civil-servant instruments. These revisions were completed before pilot testing.

The final architecture contained four domains and 16 subdimensions. Basic understanding covered definition and goals, adaptation versus mitigation, adaptation versus disaster risk reduction, necessity and urgency, long-term costs and benefits, and international adaptation directions. Policy literacy covered national law, national policy, and adaptation planning. Implementation addressed risk management, perceived role in implementation, civic action, and cross-sectoral cooperation. Everyday adaptation covered local strategies and resources, adaptation in life planning, and proactive adaptive capacity. The domains were designed to represent complementary components of citizens’ overall adaptation literacy. Individual adaptive capability is represented by assessing the ability to interpret risk,

locate resources, and act; material assets, infrastructure, and institutional capacity remain contextual conditions outside the individual literacy profile.[6–12]

We mapped questionnaire components to each subdimension before fieldwork to assess content coverage. Some diagnostic subdimensions were represented by a single item, while others used multi-item sets. The mapping links the framework to national results at the item and subdimension levels (Supplementary Table S1).

The domain structure connects these different encounters with adaptation. Basic understanding addresses the purpose of adaptation, the interpretation of vulnerability, and the relevance of future conditions. Policy literacy addresses the institutional responsibilities and planning principles through which adaptation is organized. Implementation concerns respondents' roles in risk management and public participation, as well as their support for cooperation. Everyday adaptation concerns engagement with local plans, the place of adaptation in daily choices, and the ability to obtain and communicate information. Each domain therefore has a practical reference point. The corresponding subdimensions specify the content to be assessed within it, making differences in concepts, institutions, and engagement visible in the population profile.

Item development and pilot testing

We mapped survey items to the predefined subdimensions and pilot-tested them by telephone with 114 adults between 27 August and 5 September 2025. Knowledge items were examined using difficulty and discrimination indices. We evaluated internal consistency for coherent multi-item attitudinal and behavioral sets using Cronbach's alpha and, for two-item measures, the Spearman–Brown approach.[44,45] Exploratory factor analysis was used as a pilot diagnostic for item clusters, with the Kaiser–Meyer–Olkin (KMO) statistic indicating sampling adequacy.[46]

Item difficulty was calculated as $P = (P_H + P_L)/2$, and discrimination as $D = P_H - P_L$, where P_H and P_L are the proportions correct in the upper- and lower-performing groups, respectively. Difficulty values below 0.25 were classified as extremely difficult, 0.25–0.39 as difficult, 0.40–0.70 as moderate, and 0.71–0.90 as easy. Discrimination below 0.19 indicated weak separation, with progressively stronger performance at 0.20–0.29, 0.30–0.39, and 0.40 or above. Item revision considered these diagnostics alongside the content's substantive importance.

The definition item was retained as a diagnostic of confusion between mitigation and adaptation. Only 9% of pilot respondents correctly rejected the statement equating adaptation with carbon-emissions reduction. Reliability and factor-analytic diagnostics were applied to coherent subdimensions within the multidimensional assessment.

In the pilot, reliability coefficients ranged from 0.42 to 0.86 across the ten multi-item subdimensions. Necessity and urgency (0.52) and adaptation planning (0.42) prompted wording revisions. Risk

assessment and management had a coefficient of 0.84 before one overlapping item was removed. KMO values were 0.64 for basic-understanding agreement items, 0.82 for implementation frequency items, and 0.79 for everyday-adaptation frequency items (Supplementary Tables S2 and S3). These pilot diagnostics informed questionnaire revision.

Pilot findings led to changes in both question specificity and direction. The initial vulnerability item stated that adaptation could reduce vulnerability and had a correct-response proportion of 0.88. Its replacement asked respondents to judge a statement about the relationship between social vulnerability and adaptation effectiveness. The initial international-context item emphasized locally appropriate measures and had a correct-response proportion of 0.91; the revised statement asked whether Taiwan could largely follow Western and Northern European plans. Policy questions similarly moved from endorsing support for older people to judging uniform policy application, and from recognizing a local-government role to identifying responsibility for national plans. These revisions changed what the questions demanded. The pilot proportions describe the original wording and are interpreted as development evidence, while the national findings describe responses to the revised questionnaire.

The pilot also showed why revising items required substantive judgment. The definition question had a correct-response proportion of 0.09, a difficulty index of 0.12, and a discrimination index of 0.09. The drought-resistant-crop question had corresponding values of 0.59, 0.57, and 0.40. The drainage question had values of 0.16, 0.24, and 0.33. Thus, difficult items differed in how clearly they separated higher- and lower-performing respondents. The definition item was retained because recognizing the purpose of adaptation was central to the framework. The drainage item was retained as a future-oriented classification task. These decisions established a questionnaire that included basic diagnostic questions alongside more applied questions.

National survey and sampling

The target population comprised adults aged 20 years or older residing across Taiwan’s 22 administrative jurisdictions, including offshore islands. Sample allocation followed the adult population distribution, with a minimum target of 30 respondents in jurisdictions whose proportional allocation would otherwise have produced smaller samples. Data were collected using computer-assisted telephone interviewing from 9 to 24 October 2025. The final analytical sample contained 2,527 respondents.

For demographic analysis, generation categories followed the survey's age classification in 2025: Generation Z, 20–28 years; Generation Y (Millennials), 29–44 years; Generation X, 45–60 years; Baby Boomers, 61–79 years; and the Silent generation, 80 years or older. These are the age-group labels used in this survey.

Monthly-income groups combined the original response categories as follows: codes 1–4, 5–6, 7–8, 9–11, and 12–23. Code 1 denotes no income, and code 98 denotes an unknown or refused response. Age

was derived from the reported birth year; an unknown or refused birth year was treated as missing. Regional classification grouped Keelung, Taipei, New Taipei, Taoyuan, Hsinchu County, Hsinchu City, and Yilan as North; Miaoli, Taichung, Changhua, Nantou, and Yunlin as Central; Chiayi County, Chiayi City, Tainan, Kaohsiung, and Pingtung as South; Hualien and Taitung as East; and Penghu, Kinmen, and Lienchiang as offshore islands.

We calibrated the completed sample to official population distributions for sex, age, and administrative jurisdiction using iterative proportional fitting (raking).[47] Iterations continued until successive weight changes were smaller than 0.0001 and goodness-of-fit checks indicated alignment with population margins. We used the resulting weights for population descriptions and subgroup comparisons.

The minimum allocation of 30 respondents allowed smaller jurisdictions to contribute observations to the national survey. Because this allocation differed from a purely proportional distribution, calibration weighting was important for interpreting national estimates. The weighted profile describes responses in relation to population margins, while observed counts describe the achieved sample. Table 2 presents both quantities so that population composition and the amount of information available within each category can be considered together. This distinction matters especially for smaller demographic groups and offshore jurisdictions. Their contribution to the national estimate depends on the weights, while their precision also depends on the number of respondents and variation in the measured responses.[47]

Of 62,948 telephone numbers dialed, 18,825 connected and 2,527 produced completed interviews. Completed interviews represented 4.01% of all dialed numbers, including unreachable, invalid, and non-residential numbers.

Ethics and participant consent

The survey was conducted under a formal commissioned project of Taiwan's Climate Change Administration, Ministry of Environment. Under government commissioning procedures, research content involving people must be reviewed for compliance with applicable research-ethics requirements before a contract is executed; the project proceeded to formal commissioning after this pre-contract review. The survey was anonymous and low risk, and no directly identifying personal information was collected. At the beginning of each telephone interview, the interviewer introduced the study as a climate change adaptation literacy survey conducted on behalf of the Climate Change Administration, explained that the interview would take approximately 10 minutes, and informed the respondent that participation was voluntary and could be discontinued at any time. The interview proceeded only after the respondent verbally agreed to participate.

Measures and scoring

The national questionnaire contained 34 substantive items: 11 knowledge items, 13 agreement items, and ten frequency items. Agreement responses ranged from strongly disagree to strongly agree. The frequency labels were never, occasionally, neutral, often, and always; the original Mandarin middle category translates as ordinary or neutral. Knowledge questions and answer keys are provided in Supplementary Table S1. The definition item asked whether adaptation means reducing carbon emissions, and the drainage item required a choice between adaptation and disaster prevention. Responses to these items therefore reflect recognition within their specific wording and options.

Knowledge items used binary or single-choice formats. Correct responses were scored 1; incorrect responses, ‘do not know’ responses, and refusals were scored 0. Attitudinal items used five-point agreement scales and behavioral items used five-point frequency scales. Reverse-worded items were recoded before analysis. Subdimension scores followed the predefined framework, with higher values indicating stronger performance within the corresponding dimension.

Response formats followed the task being assessed. Knowledge questions required identification of a concept or institutional responsibility; agreement scales assessed appraisals and planning; frequency scales assessed reported engagement. Scores were summarized within each subdimension using the corresponding response metric.

The national assessment reports a multidimensional profile across the four domains and 16 subdimensions. Psychometric analyses focused on coherent item sets that align with the framework's distinct content and response formats.[9,46]

Response formats were chosen to reflect the content of the assessment. The knowledge block asks respondents to identify a purpose, classify a measure, or judge an institutional statement against a keyed answer. The agreement block addresses the importance of adaptation, planning, investment, and cooperation. The frequency block describes engagement with information, local activities, and other people, and includes expressions of willingness and perceived capability. These formats expose different aspects of the national profile. Reporting them separately preserves information about what respondents recognize, what they endorse, and how they describe engagement. The four domains provide the assessment's substantive organization, while the response formats determine how each result is summarized.

The item mapping also identifies the coverage within each domain. Basic understanding includes seven knowledge questions and seven agreement questions. Policy literacy includes four knowledge questions and two agreement questions. Implementation includes six frequency questions and two agreement questions. Everyday adaptation includes four frequency questions and two agreement questions. Several subdimensions therefore draw on different response formats within the same substantive domain. For example, the adaptation–mitigation subdimension combines classification of drought-resistant crops with a reverse-worded statement about the relative importance of mitigation and adaptation. Presenting the knowledge and agreement components individually makes their meanings visible and supports

interpretation of the overall domain profile. Supplementary Table S1 links the question numbers to each subdimension.

Statistical analysis

Weighted descriptive statistics were calculated for all items and subdimensions. Correct-response proportions summarized knowledge items, with “do not know” and refusal responses scored as incorrect; weighted means and standard deviations summarized agreement and frequency measures. Three secondary analytic summaries were constructed for demographic comparisons. The conceptual/policy knowledge summary was the percentage of Q1–Q11 answered correctly. The normative-support summary averaged Q12 and Q16–Q24, with Q12 and Q16 reverse-coded as 6 minus the original response. These ten items address adaptation priority, urgency, long-term value, planning, cooperation, and everyday-life adaptation. Q13–Q15 address perceived climate impacts and were retained in the necessity-and-urgency subdimension. The reported-practice summary averaged Q25–Q34. Support and practice summaries required valid responses of 1–5 on every included item; codes 98 and 99 were excluded from these item sets. Knowledge responses coded 98 contributed zero to the 11-item denominator. Each model used respondents with complete covariate data.

We estimated weighted least-squares models separately for knowledge, normative support, and reported practice, with generation, sex, education, monthly-income group, and region entered as categorical predictors. We used the final survey weight for estimation. Heteroskedasticity-robust standard errors used the HC1 covariance estimator. We calculated covariate-adjusted marginal means by assigning each respondent to each category of the predictor of interest, retaining their other covariates, and averaging predicted values with survey weights within the outcome-specific complete-case sample. Normal-approximation 95% confidence intervals were calculated for marginal means and contrasts. Model sample sizes were 2,334 for knowledge, 2,098 for support, and 2,170 for reported practice. We repeated the knowledge analysis using ten items after excluding Q4, the drainage-system item. Analyses used Python 3.12.14, NumPy 2.3.5, and pandas 2.2.3.

For knowledge, an incorrect or “do not know/refuse” response remained in the denominator and contributed zero. For agreement and frequency summaries, “do not know/refuse” responses were excluded from the complete item set. The knowledge percentage combined 11 items with equal weight; support and practice were item means on their original five-point scales. The analysis treated the questionnaire domains as distinct measures in a profile. Agreement and frequency scores were interpreted within their response formats, and the comparison between support and practice describes their separate population patterns.

Internal consistency was assessed using unweighted item covariance matrices. KR-20 for the binary knowledge items is equivalent to Cronbach’s alpha in this calculation. Agreement and frequency summaries were evaluated using Cronbach’s alpha among respondents with complete responses to

each summary's items, before covariate exclusions. These analyses used 2,527, 2,258, and 2,338 respondents for knowledge, support, and practice, respectively.

The three demographic summaries provide a second view of this profile. The knowledge percentage gives each of the 11 questions equal weight in the overall correct-response proportion. The support and practice summaries retain the five-point coding of their respective item sets. Covariate adjustment then compares the population patterns associated with each demographic characteristic while accounting for the other characteristics included in the model. For example, the educational comparison accounts for generation, sex, income, and region. Presenting marginal means preserves the original units: percentage points for knowledge and scale points for support and practice. Confidence intervals indicate the precision of those adjusted estimates, and contrasts between groups are interpreted with their corresponding uncertainty. Figures 4 and 5 present these estimates alongside their intervals.

Declaration of generative AI and AI-assisted technologies

Generative AI tools assisted manuscript preparation, including language editing, structural review, consistency checking, assistance with analytic coding, and preparation of draft figures. The authors retained responsibility for the study framework, analytic decisions, verification of statistical results and references, interpretation of the findings, and the final manuscript. All reported results and visual content were reviewed by the authors, who take full responsibility for the accuracy and integrity of the work.

Results

National profile

The achieved sample contained 1,408 women and 1,119 men. Calibration weighting shifted the sex distribution to 51.3% women and 48.7% men and similarly adjusted age and county/city distributions to the target population. Table 2 reports observed respondent counts alongside weighted percentages. The national profile combined strong endorsement of adaptation with uneven conceptual and policy understanding and lower reported practical engagement (Figures 2 and 3; Table 3).

The weakest conceptual result concerned the meaning of adaptation. Only 11% of respondents correctly rejected the statement that climate adaptation means reducing carbon emissions. Understanding of vulnerability was also limited: 41% correctly recognized the relationship between social vulnerability and adaptation effectiveness. The resulting mean score for the definition-and-goals subdimension was 0.26 on a 0–1 scale.

Knowledge of the distinction between mitigation and adaptation was stronger. Sixty per cent correctly identified drought-resistant crops as an adaptation measure. The boundary between adaptation and disaster risk reduction was less clear. Only 27% correctly classified redesign of drainage infrastructure in

anticipation of future increases in rainfall as adaptation, and 55% correctly rejected the idea that past disaster experience alone would be sufficient for future climate impacts.

Other parts of basic understanding showed a different pattern. Respondents strongly endorsed the urgency and long-term value of adaptation. Mean scores were 4.08 for necessity and urgency and 4.14 for long-term cost–benefit considerations on five-point scales. Half of respondents correctly identified reducing climate risk as the principal international adaptation objective, and 56% recognized that adaptation plans developed in Western and Northern Europe require adjustment to Taiwan's local context.

Across the six basic-understanding subdimensions, definition and goals averaged 0.26, adaptation versus mitigation 0.60, adaptation versus disaster risk reduction 0.41, and international directions 0.53 on 0–1 scales. We assessed necessity and urgency and long-term cost–benefit separately on agreement scales and averaged 4.08 and 4.14, respectively.

The item results also distinguish two forms of concept recognition. Respondents were more successful in classifying a concrete measure, drought-resistant crops, than in rejecting a general statement equating adaptation with emissions reduction. The corresponding correct-response proportions were 60% and 11%. Future-oriented infrastructure presented another task: 27% selected adaptation for drainage redesign prompted by possible increases in rainfall. These questions require recognition at different levels of abstraction and use different response options. Together, they identify the content and wording through which adaptation is being understood in the population and indicate where further item-level investigation could be useful.

Policy knowledge and planning

Knowledge of national adaptation policy was uneven. 49% answered correctly on the item about legal responsibilities across government, businesses, and the public. The national-policy subdimension averaged 0.40. Only 22% correctly rejected the proposition that adaptation policy should be applied uniformly without adjustment for specific groups, and 24% correctly identified the relevant sectoral responsibility in the transport and communications item. By comparison, 74% correctly rejected the statement assigning responsibility for national adaptation policies and plans to local governments.

Adaptation planning averaged 4.25. Respondents generally endorsed investment in preparation, assessment of likely risks before planning, and cooperation across professional fields. Detailed institutional knowledge was less consistent: legal-framework knowledge averaged 0.49 and national-policy knowledge 0.40.

Institutional questions also showed substantial variation. The 74% result concerned who was responsible for national plans, while the 24% result required recognizing the transport and communications sector. The 22% result concerned whether policy should be adjusted for specific

population needs. These tasks address different parts of policy literacy: levels of government, sectoral organization, and the rationale for differentiated measures. Their distribution supplies a more specific account of public understanding than the national-policy mean of 0.40 alone. It also identifies content for public explanations of how adaptation decisions are organized and who may need additional protection.

Practical engagement

Risk assessment and management and perceived implementation role each averaged 2.85, and civic action averaged 2.42. Cross-sectoral cooperation, assessed through agreement statements, averaged 4.32. These implementation subdimensions therefore combined strong support for collaboration with lower reported personal engagement.

In everyday adaptation, support for incorporating adaptation into personal and household planning averaged 4.13. Reported engagement with local strategies and resources averaged 2.44, and proactive adaptive capacity averaged 2.58 (Figure 3).

Adjusted demographic patterns

The generational contrast remained after adjustment for sex, education, income and region. The adjusted mean knowledge score was 45.7% (95% CI 42.6–48.7) for Generation Z and 46.3% (44.1–48.5) for Generation Y, compared with 41.2% (39.7–42.6) among Baby Boomers and 34.6% (30.5–38.7) in the Silent generation. After adjustment, Baby Boomers scored 4.5 percentage points below Generation Z (95% CI −8.0 to −1.0), and the Silent generation scored 11.1 points lower (−16.3 to −5.8). Normative support showed little generational separation, with adjusted means ranging from 4.12 to 4.18 on the five-point scale. Figure 4 displays the adjusted generational profile across all three outcomes.

Reported practice followed a different age pattern. The adjusted mean was 2.42 (95% CI 2.29–2.55) for Generation Z, 2.56 (2.46–2.65) for Generation Y, 2.64 (2.57–2.71) for Generation X, 2.88 (2.80–2.97) for Baby Boomers, and 3.05 (2.68–3.42) for the Silent Generation. The adjusted difference between Baby Boomers and Generation Z was 0.47 points (95% CI 0.31–0.63), and the difference between the Silent Generation and Generation Z was 0.64 (0.24–1.03). The opposing gradients in formal knowledge and reported practice therefore persisted after simultaneous adjustment for the major demographic covariates.

Education remained the clearest independent correlate of conceptual and policy knowledge. Adjusted knowledge increased from 28.1% (95% CI 24.5–31.7) among respondents with primary education or less to 51.9% (49.2–54.7) among those with a master’s degree or higher, a difference of 23.8 percentage points (19.2–28.5). Normative support also rose across education levels, from 3.85 (3.70–4.00) to 4.21 (4.15–4.27). The corresponding adjusted difference in reported practice was smaller and statistically

imprecise (0.16, 95% CI −0.11 to 0.42), indicating that the educational gradient is concentrated more strongly in formal understanding than in practice.

The adjusted knowledge difference between the highest and lowest reported monthly-income groups was 3.5 percentage points (95% CI −0.7 to 7.7). The highest-income group reported higher practice, with an adjusted difference of 0.30 points (0.08–0.51). After education and the other demographic characteristics were included in the model, the remaining income pattern was therefore clearer for reported practice than for formal knowledge. Figure 5 shows the full education and income profiles, with Supplementary Table S4 retaining the numerical estimates.

Removing the drainage-system item produced a highly correlated knowledge summary (weighted r = 0.980). The largest change in an adjusted demographic marginal mean was 2.19 percentage points, and the main demographic patterns were retained (Supplementary Table S6).

In the national sample, internal consistency was 0.57 for the 11-item knowledge summary (KR-20), 0.77 for the ten-item support summary, and 0.90 for the ten-item reported-practice summary (Cronbach's alpha; Supplementary Table S5). These coefficients describe consistency within the analytic summaries; their dimensional structure remains to be assessed.

Discussion

The survey identifies a specific challenge for adaptation governance: strong public endorsement coexists with limited conceptual precision, incomplete policy knowledge, and lower reported engagement. Support was consistently high for urgency, long-term investment, planning, and cooperation, while only 11% correctly rejected the definition equating adaptation with emissions reduction, and local-resource and civic-action scores were comparatively low. A multidimensional assessment makes these components visible and shows how their demographic distributions differ. Behavioral research helps interpret this pattern by situating adaptation within perceived efficacy, social norms, affect, and feasible opportunities for action.[13,16–18] Climate-engagement studies likewise document differences between cognitive, affective, and behavioral dimensions.[4,5]

Taiwan's increasingly explicit adaptation responsibilities create a practical use for this profile. Agencies can connect the literacy component that needs attention to the public decision or service involved. Conceptual understanding matters when explaining what a measure is intended to achieve; institutional literacy matters when people seek assistance or enter planning processes; practical capability matters when they use resources and participate. Barriers research supports examining these tasks within their institutional setting.[14,42,48]

Concept clarification deserves a prominent place in public communication. Messages can explain adaptation by naming the hazard, identifying exposed people or assets, and showing how a response reduces risk. A heat-protection example can describe cooling spaces and support for exposed workers; a rainfall example can connect projected conditions with drainage and land-use decisions. Emissions

reduction can be explained alongside these measures through its contribution to limiting future warming. This approach connects terminology to mechanisms and locally meaningful choices, consistent with adaptation-literacy and communication research.[15,34,35]

Table 2. Characteristics of the public survey sample (n=2,527).

Characteristic	Category	Unweighted n	Weighted %
Sex	Women	1,408	51.3
	Men	1,119	48.7
Age	20–29	201	13.5
	30–39	203	16.0
	40–49	443	19.6
	50–59	607	17.6
	60–69	606	16.9
	≥70	439	15.2
	Do not know/refuse	28	1.1
Education	Primary or less	143	4.6
	Junior high	191	6.0
	High school	706	24.8
	Junior college	379	12.8
	University	845	39.3
	Master’s or higher	254	12.1
	Do not know/refuse	9	0.4
Reported monthly income (NT$)	<30,000	851	31.1
	30,000–<50,000	845	36.2
	50,000–<70,000	377	15.5
	70,000–<100,000	163	6.2
	≥100,000	116	4.8
	Do not know/refuse	175	6.1
Region	North	1,117	45.6
	Central	595	24.4
	South	657	26.5
	East	68	2.3
	Offshore islands	90	1.2

Unweighted n reports the observed respondent count. Weighted percentages use the final raking weight calibrated to sex, age, and county/city. Percentages may not sum to 100 because of rounding. Income categories summarize the original response intervals; the lowest group includes respondents reporting no income.

Table 3. Selected national adaptation-literacy results.

Domain	Indicator	Metric	National result
Basic understanding	Adaptation vs emissions reduction	Correct response	11%
	Vulnerability relevance	Correct response	41%
	Drought-resistant crops	Correct response	60%
	Future drainage redesign	Correct response	27%
	Past disasters alone insufficient	Correct response	55%
	Necessity and urgency	Mean, 1–5	4.08
	Long-term cost–benefit	Mean, 1–5	4.14
Policy literacy	Differentiated policy	Correct response	22%
	Adaptation planning	Mean, 1–5	4.25
Implementation	Risk management	Mean, 1–5	2.85
	Civic action	Mean, 1–5	2.42
	Cross-sectoral cooperation	Mean, 1–5	4.32
Everyday adaptation	Local strategies and resources	Mean, 1–5	2.44
	Everyday-life planning	Mean, 1–5	4.13
	Proactive adaptive capacity	Mean, 1–5	2.58

Public explanations should make the rationale for differentiated protection visible. Only 22% correctly rejected uniform adaptation policy without adjustment for specific groups, and vulnerability-related knowledge was also limited. Agencies can explain eligibility and resource allocation by highlighting exposure, sensitivity, and the ability to respond, using examples involving older residents, households with limited resources, or workers exposed to heat. This would help citizens evaluate targeted services and understand why measures differ among places and populations. Vulnerability and justice scholarship supports linking communication to the distribution of risks and benefits.[6,8,11,27–29] Attention to these distributions also helps identify interventions that could increase vulnerability elsewhere.[30,31]

Local governments can connect citizens with risk information, assistance, and participation. Familiarity with local strategies and resources averaged 2.44, indicating that accessible services are a priority. Each local program can specify who is responsible, who can use the service, how to obtain support, and when

citizens can influence a decision. A contact point, accessible offline information, and feedback on community proposals would make the institutional pathway easier to navigate. Participation research emphasizes access, influence, and responsiveness within such arrangements.[19–24]

Communication should be linked to opportunities to act. The civic-action mean of 2.42 identifies participation as a priority for program design. Community risk walks, discussions of local adaptation options, and participation in planning can give residents a clear task and a visible contribution. Scientific projections can be considered alongside residents' accounts of local conditions, following knowledge co-production principles.[25,26] Trust, perceived feasibility and social context should be assessed as part of program evaluation because risk information is interpreted through experience, affect and values.[32,33,36]

Communication materials can make these institutional distinctions concrete at the point of service. For example, a local heat-protection notice can identify the risk, explain eligibility for assistance, name the responsible service, and state how residents can get support. Public explanations of an infrastructure proposal can describe the future conditions considered and show where residents' observations enter the planning process. A consistent service structure would help agencies connect information with access: a named contact, a clear procedure, and feedback on what happens after a request or contribution. The survey identifies these as relevant areas for program design, given uneven institutional knowledge and lower reported local engagement. Participation scholarship further supports making procedures accessible and showing how contributions influence decisions.[19–24]

The adjusted education gradient was strongest in formal knowledge: respondents with a master's degree or higher scored approximately 24 percentage points above those with primary education or less. Adult education should therefore use plain language, visual examples, and short scenario tasks that connect a risk to a response and the responsible institution. Participants can explain a measure's purpose, choose an appropriate source of assistance, and justify protection for groups facing different risks. These tasks assess the ability to apply information, a central concern in broader literacy scholarship.[1,2] Multiple opportunities to learn through community services would improve access beyond formal classrooms.

The generational profile suggests complementary educational needs (Figure 4). Younger adults had more formal knowledge and reported less practice; older groups showed the opposite pattern. Programs for younger participants can define roles in community adaptation and provide opportunities to locate and use local resources. Sessions for older participants can connect familiar protective practices with climate projections and the institutional language of adaptation. Intergenerational activities could combine these strengths around a shared local problem. Research on local knowledge provides a basis for involving residents' experience in these activities.[10,13,26]

After adjustment, income was more clearly associated with reported practice than with knowledge, although the remaining difference was modest. Education and communication can therefore be paired

with assessment of practical access: whether participants can afford a measure, reach a service, or obtain support. Adaptive-capacity research identifies resources and institutional conditions as determinants of the responses available to people.[11,12,29] Local programs can examine these barriers when interpreting low participation and use the findings to improve service delivery.

Educational activities can connect the conceptual and applied questions that produced different results in this survey. Participants could classify a familiar measure and then explain the risk it addresses, whose vulnerability it reduces, and what future conditions matter to its design. Discussing drought-resistant crops can introduce the purpose of adaptation; a drainage example can introduce future rainfall and its overlap with disaster risk reduction. Asking learners to justify their choice would help educators identify the reasoning behind an answer. Such activities also allow several defensible responses when a measure serves more than one purpose. This gives adult education a way to engage with the survey's difficult items while linking terminology to recognizable decisions and circumstances.[1,2,15,34,35]

The four-domain framework connects policy objectives with observable learning and participation outcomes. Its knowledge questions identify conceptual and institutional difficulties, while agreement and frequency measures describe support and reported engagement. This extends assessment beyond the factual knowledge emphasized in climate-literacy reviews.[3,15] Coherent item sets can be evaluated through reliability and factor-analytic diagnostics, while the full profile retains the distinct content of its domains.[9,44–46]

Program evaluation can retain this distinction between learning and participation. An educational activity can assess whether participants explain a measure and identify an appropriate source of assistance. A service program can assess whether information is understood, whether people can complete an application, and whether those eligible obtain support. A community planning activity can document whose views were heard and how proposals were considered. Follow-up can then examine how learning persists, engagement continues, and access is distributed across groups. For implemented measures, evaluation can connect these intermediate changes with observed exposure and vulnerability. This sequence keeps the literacy assessment close to the decisions and services it is intended to inform while linking it to broader evidence on adaptation implementation and participation.[19–24,43]

The cross-sectional survey establishes associations and a national profile. It cannot identify causal pathways, separate age from cohort effects, or establish which proposed educational or communication intervention is most effective. Comparative intervention studies and repeated assessment are needed to evaluate the recommendations. The cohort labels describe survey age categories; they do not establish culturally distinct generational mechanisms.

Practice measures are self-reported and may be affected by recall, social desirability, and different interpretations of adaptation. They provide evidence of reported engagement and capability, but do not directly observe actions or risk-reduction outcomes. The survey also lacks direct measures of

experiential knowledge and institutional opportunities, leaving the mechanisms behind demographic patterns unresolved. Interviews and community observation could investigate these processes.[5,13,17,26]

Landline coverage and nonresponse may affect population estimates. Raking aligns observed sex, age, and jurisdiction margins, but bias from unmeasured characteristics may remain.[47,49] The 4.01% completion proportion includes invalid and unreachable numbers and is not a standardized response rate. Adjusted models use complete cases and may be affected by item nonresponse. Subgroup analyses involve multiple comparisons and are exploratory; precision is particularly limited for smaller groups. Robust model intervals treat respondents as independent observations and condition on the supplied calibration weights; uncertainty from weight estimation was not separately propagated.

The definition item used a binary response, and some knowledge statements required rejection of a proposition. Their correct-response proportions combine concept recognition with the ability to interpret the statement. The frequency block also included willingness and perceived capability, and its neutral middle category may be interpreted differently from the frequency endpoints. These features warrant cognitive interviewing and further measurement assessment before interpreting the summaries as validated behavioral scales.

Several subdimensions rely on single diagnostic items, and knowledge, agreement, and frequency scores have different measurement units. The drainage item also permits overlapping interpretations of adaptation and disaster risk reduction. Removing it retained the main adjusted demographic patterns, but wording refinement and further validation remain necessary. Application in other countries requires locally appropriate policy and resource items and assessment of conceptual equivalence.[9,15,19,42,48] The knowledge summary’s internal consistency was modest; its items cover heterogeneous concepts and policy responsibilities. Further assessment of dimensional structure and measurement equivalence is needed for all three summaries.

The national survey shows strong support for adaptation alongside gaps in conceptual understanding, policy literacy, and reported practical engagement. Formal education was closely associated with knowledge, and after demographic adjustment, age groups showed opposing knowledge and practice profiles. The four-domain framework retains these differences and provides a baseline for repeated population assessment.

For government, the findings prioritize clear explanations of adaptation and differentiated protection, accessible routes to local services, and practical opportunities for participation. Education can address conceptual gaps while drawing on different groups' existing strengths. Linking communication to services and evaluating understanding, participation, and completed actions would let public programs test how these priorities support adaptation.

Declarations

Data availability

The survey database is owned by and under the administrative responsibility of the Climate Change Administration, Ministry of Environment, Taiwan. The respondent-level dataset is not deposited in a public repository. Researchers seeking access may submit a formal written request through official correspondence to the Climate Change Administration. Decisions regarding access and permitted use are made by the Administration under its data-management procedures.

Code availability

No custom software was developed for this study. Reproducible analysis syntax for the final statistical models and figures is retained by the authors and can be made available subject to the data-governance conditions that apply to the respondent-level dataset.

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Author contributions

S.C.Y. led the research project, supervised its implementation, and wrote and revised the manuscript. S.W.L. conducted the questionnaire survey and preliminary analyses. S.Y.L. organized the expert committee. H.C.W. provided statistical advice. Y.Y.S. wrote and revised the manuscript.

Competing interests

The authors declare no competing financial or non-financial interests.

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Figures

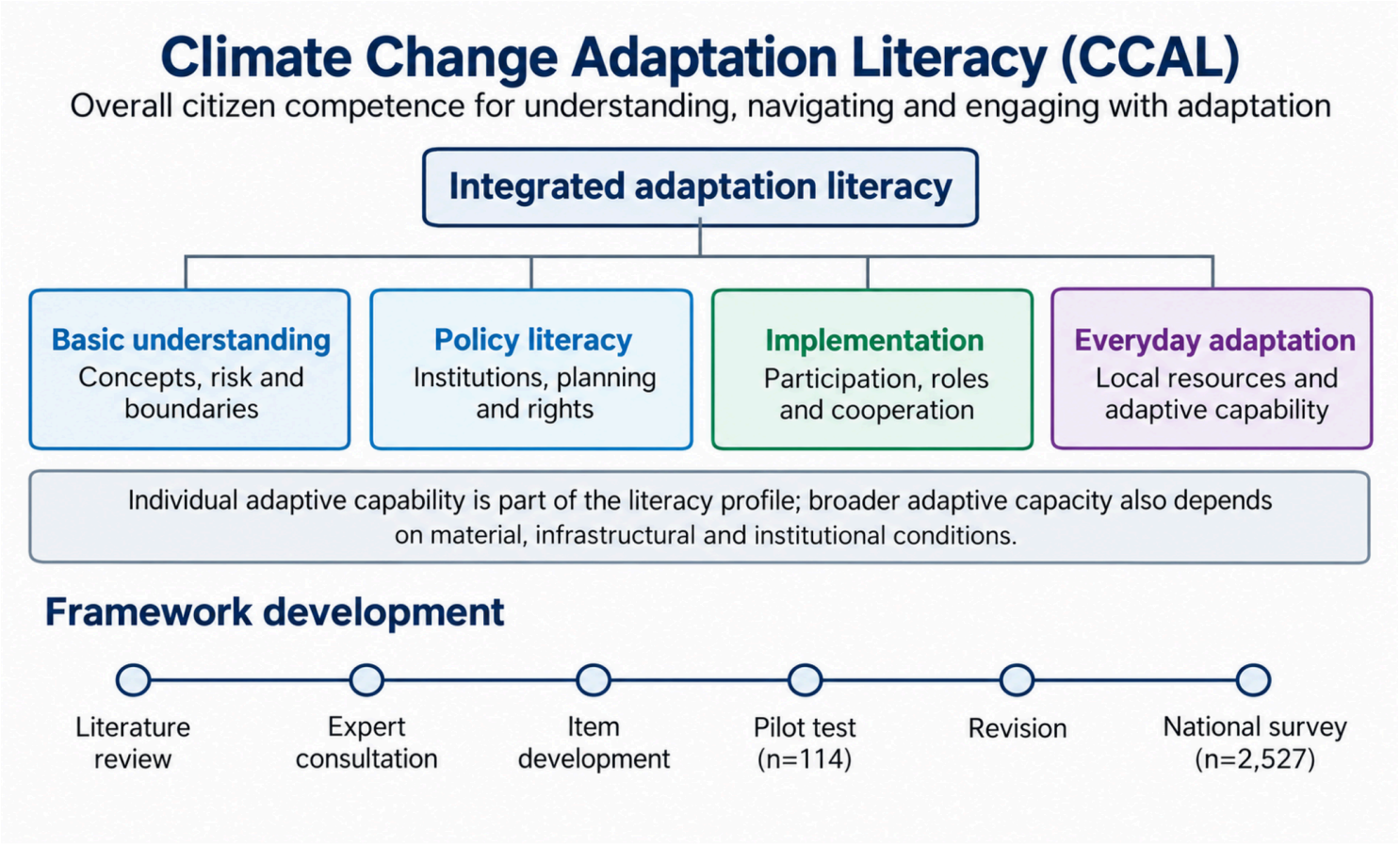


Figure 1

Conceptual architecture and development pathway of the climate change adaptation literacy (CCAL) framework. The four domains represent complementary components of citizens' adaptation literacy. Material, infrastructural, and institutional conditions shape the broader adaptive capacity within which these capabilities are exercised.

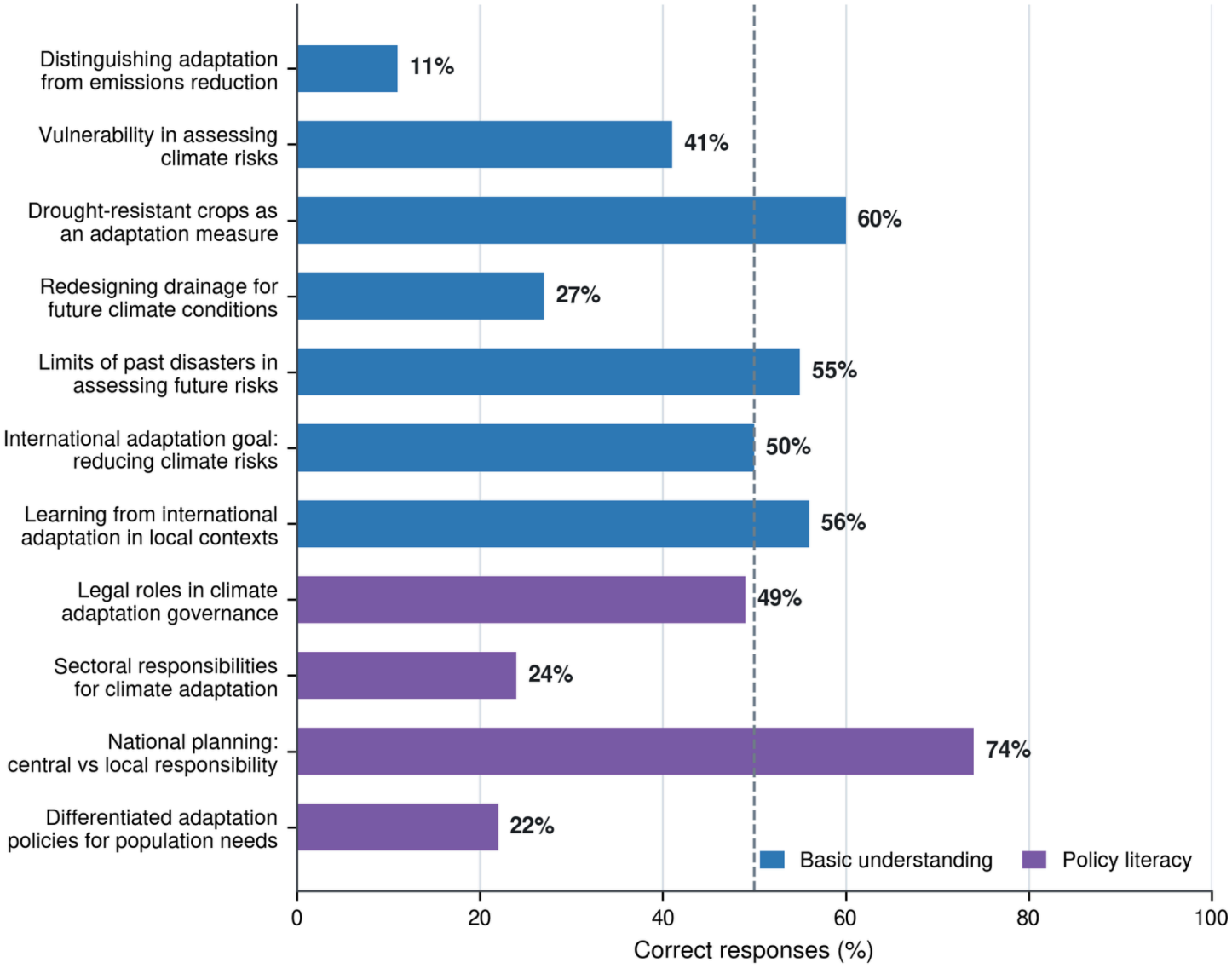


Figure 2

Correct-response rates for the 11 conceptual and policy knowledge items in the national survey. Blue bars show basic-understanding items, and purple bars show policy-literacy items. Percentages reflect correct responses, with incorrect, “do not know,” and refusal responses scored as zero.

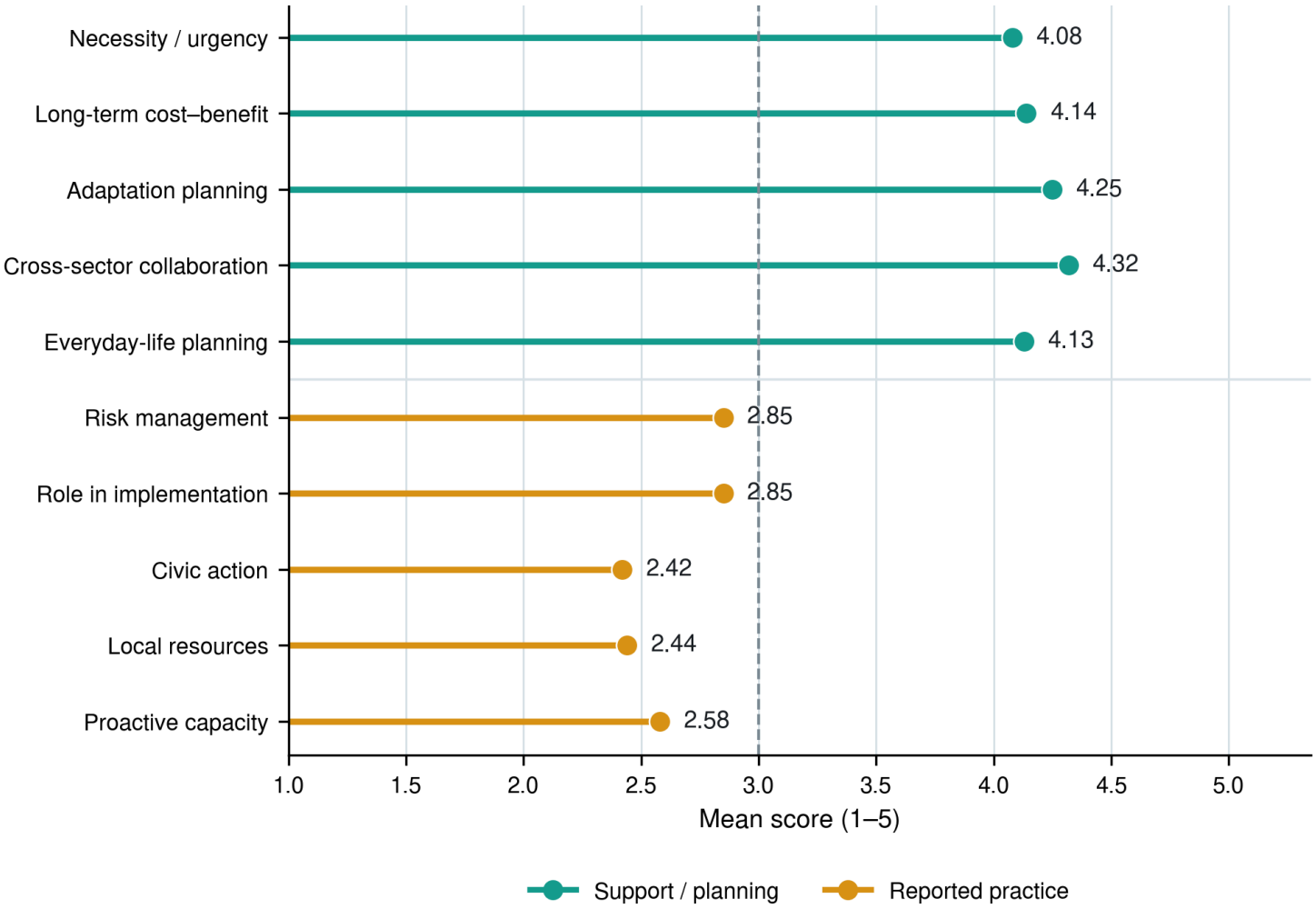


Figure 3

Mean scores for selected support, planning, and reported-practice subdimensions. Teal points show agreement measures, and ochre points show frequency measures. Both use five-point response codes, with different response anchors. The lines extend from the minimum coded value of one to the mean and do not represent confidence intervals.

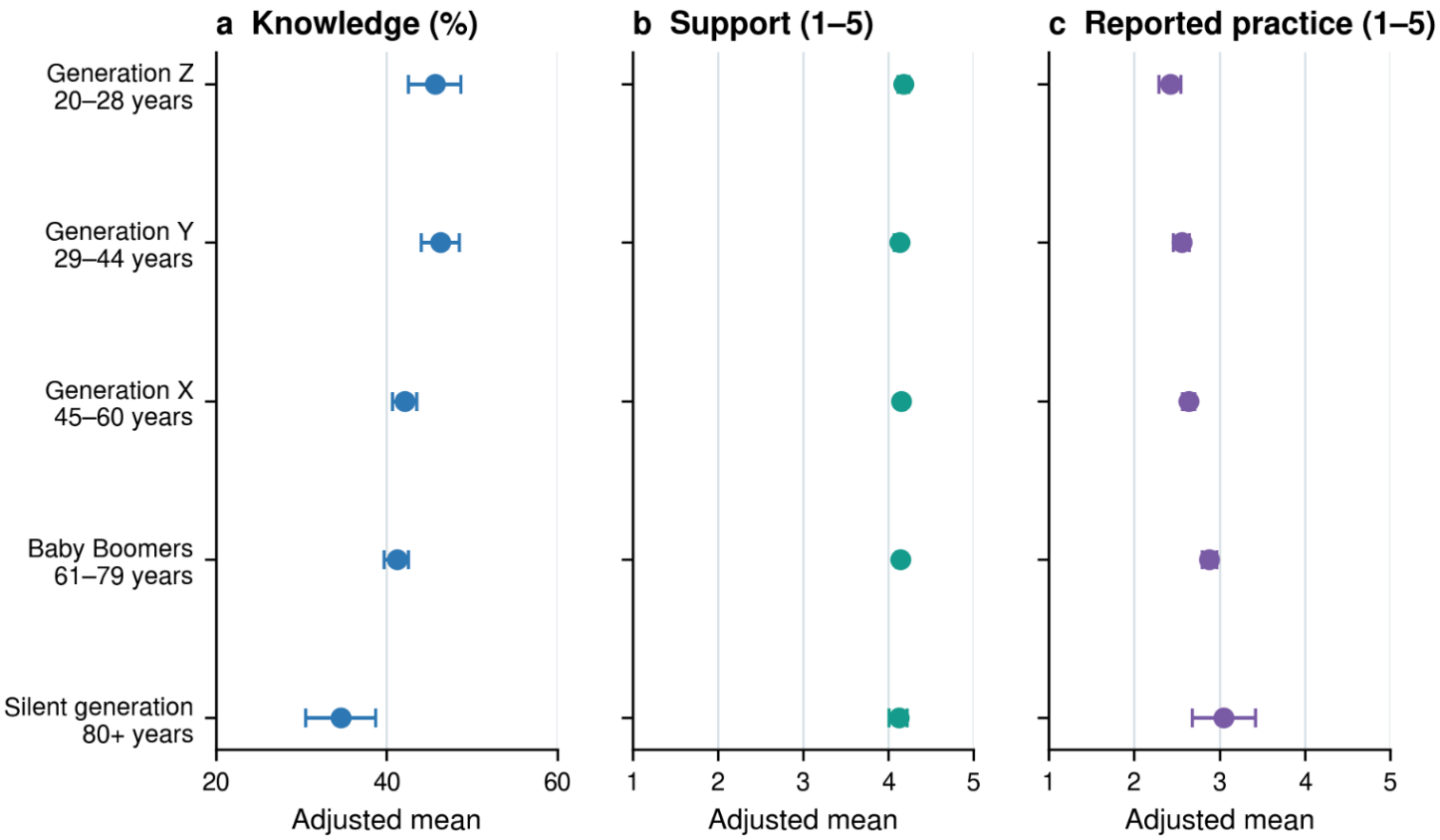


Figure 4

Covariate-adjusted generation profiles. Points show adjusted means and horizontal lines show 95% confidence intervals for knowledge, normative support and reported practice. Labels give survey age categories in 2025. Models adjust simultaneously for generation, sex, education, reported monthly income, and region; n=2,334, 2,098, and 2,170, respectively. Outcomes use separate scales.

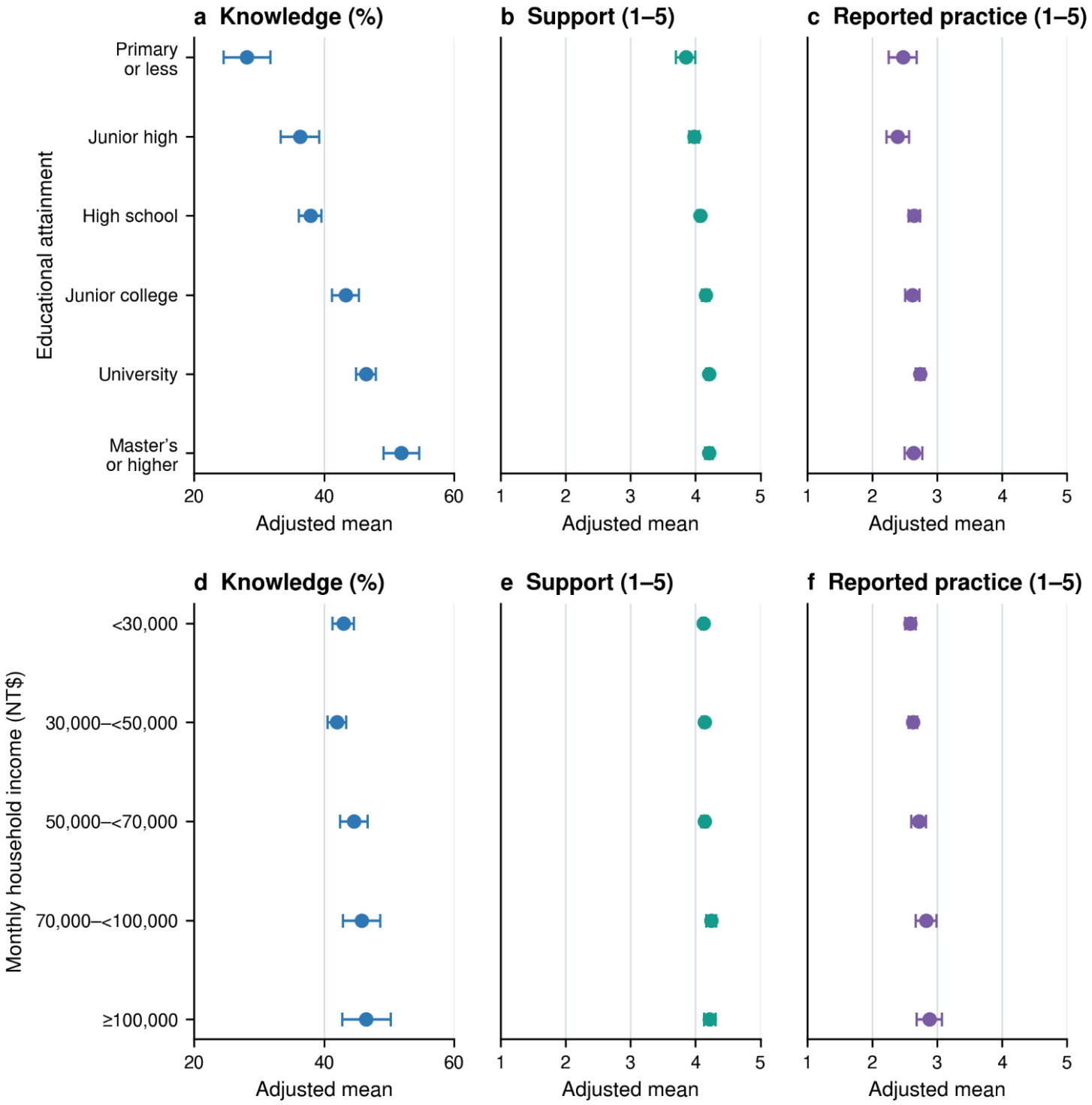


Figure 5

Covariate-adjusted education and monthly-income profiles. Panels a–c show educational attainment; panels d–f show reported monthly income in NT$. Points and horizontal lines show adjusted means and 95% confidence intervals. Models and outcome-specific sample sizes match Figure 4 and Supplementary Table S4. Outcomes use separate scales.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CCALTaiwanSupplementaryInformation.pdf