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Article

Digital Readiness and Disaster Resilience in Flood-Prone Communities of Pampanga, Philippines

Rizaline L. Santos[1,2,*]

1 Graduate School, Nueva Ecija University of Science and Technology, General Tinio Street, Cabanatuan City, Nueva Ecija 3100, Philippines; rizaysantos@gmail.com.

2 Provincial Science and Technology Office – Pampanga, Department of Science and Technology Region III, 2nd Floor, DOST Building, Capitol Compound, Brgy. Sto. Niño, City of San Fernando, Pampanga 2000, Philippines; rlsantos@ro3.dost.gov.ph.

* Correspondence: rizaysantos@gmail.com.

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ABSTRACT

Recurrent flooding in Pampanga requires disaster-risk communication that connects household practices with access, connectivity, local institutions, and the capacity to act on warnings. This cross-sectional secondary analysis used a final article-specific source workbook containing 694 populated Community Resilience and Transformability Survey records from 22 barangays in 10 municipalities and one city. To restrict the publication analysis to adults, we excluded 81 records in the combined 10–19 age category and 11 records with missing or invalid age codes, yielding 602 adult records. Descriptive statistics, internal-consistency estimates, missing-data analysis, and exploratory associations were calculated using transparent item-scoring and minimum-completion rules. We used brief project field notes only as contextual observations. The disaster-practice index averaged 2.52 of 3.00 ($n=482$; Cronbach's $\alpha=0.84$), indicating relatively frequent self-reported preparedness, prevention, response, and recovery practices. The digital-readiness composite averaged 1.05 of 2.00 ($n=311$). Institutional-support orientation was high (mean=2.47/3.00; $n=531$), whereas sustainability readiness was moderate (mean=1.99/3.00; $n=529$). Reported availability was highest for CCTV/security systems (75.3% of valid responses), water/waste technologies (74.6%), solar systems (67.6%), and early-warning alarms (61.1%); flood-monitoring sensors were reported by 21.8%. Adult respondents most often selected weak internet connectivity as a technology barrier (39.5%). Digital readiness had a small positive association with disaster-practice scores (Spearman $\rho=0.163$, $p=0.008$). The findings describe self-reported practices and perceived service availability rather than verified operational resilience. Hybrid warning systems, last-mile confirmation, accessible communication, localized monitoring, and livelihood-sensitive preparedness are needed. Non-probability recruitment and substantial item-level missingness require cautious interpretation.

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Digital readiness; disaster resilience practices; flood warning; Pampanga; community-based DRRM; missing data

1. Introduction

Flooding is a recurrent development and disaster-risk problem in Pampanga, Philippines. The province lies within the Pampanga River Basin, where monsoon and typhoon rainfall, river overflow, low-lying terrain, drainage constraints, land-use change, and local infrastructure conditions interact to produce repeated flood exposure (Nagumo & Sawano, 2016; Philippine Atmospheric, Geophysical and Astronomical Services Administration, n.d.; Iftikhar & Iqbal, 2024; Rebouh, Tout, Dinar, Benzid, & Zouak, 2024).

Community outcomes are not determined by physical protection alone. Residents must receive and understand warnings, mobilize household resources, move safely, protect livelihoods, access health and social services, and coordinate with barangay and municipal systems. This makes flood resilience a socio-technical issue involving hazard information, communication, social capacity, and governance (Cvetković, Milenković, Bašić, Lukić, & Renner, 2026; Cvetković, Milenković, Lukić, & Renner, 2026).

Evidence published in the International Journal of Disaster Risk Management (IJDRM) reinforces this systems perspective. Sukhwani et al. (2019) showed that flood early-warning systems are constrained when monitoring, communication, institutional coordination, and community response are not connected. Rico (2019) emphasized school-community collaboration as a practical route to resilient communities, while Goyal (2019) highlighted the role of disaster governance and legally supported institutions in community resilience (Cvetković et al., 2021). Reviews of innovative flood-risk management further show the value of sensors, communication technologies, participatory approaches, and cross-sector cooperation, while also cautioning that technology must be adapted to institutional and community contexts (Cvetković & Martinović, 2021).

Digital tools can accelerate warnings and coordination through social media, online government services, mobile communication, CCTV, localized sensors, and digital reporting (Hanspal & Behera, 2024; Jovičić, Gostimirović, & Milašinović, 2024; Mano, Kirshcenbaum, & Rapaport, 2019; Yamah & Folorunsho, 2026). At the same time, technology can widen inequalities where internet access, affordability, digital literacy, trust, message comprehension, or the ability to act are limited. Emerging artificial-intelligence and cyberspace capabilities may extend risk-management capacity, but they depend on reliable communications, governance, security, and human oversight (Beriša, Cvetković, & Pavić, 2024).

Philippine water-resources and hazard-information studies similarly stress the importance of basin processes, decision support, and translating scientific information into locally usable action (Lagmay et al., 2017; Tabios, 2018, 2020). International people-centered early-warning frameworks require risk knowledge, monitoring and forecasting, dissemination and communication, preparedness, and response capability to function as an integrated chain (United Nations Office for Disaster Risk Reduction & World Meteorological Organization, 2025; World Meteorological Organization, 2018).

The Community Resilience and Transformability Survey (CRTS) was administered in Pampanga in 2025 through the 3C-SHIELD initiative as an operational community-assessment, capacity-development, and local-planning activity. A July 31 implementation report frames the CRTS as a participatory data-democratization and governance tool (Romero, 2026). This article is a secondary academic analysis of the final article-specific workbook provided for this study. It does not evaluate the initiative's success or the performance of participating institutions.

The study addresses four questions: (1) What levels of self-reported preparedness, prevention, response, and recovery practices are represented in the available records? (2) What do the records indicate about personal technology use, perceived smart-DRRM service availability, barriers, sustainability readiness, and institutional-support orientation? (3) Are digital-readiness and disaster-practice scores associated with selected respondent characteristics? (4) What planning implications follow for hybrid, inclusive, and measurable flood-risk communication in Pampanga?

2. Methods

2.1. Research design

The study used a cross-sectional secondary-analysis design. The primary quantitative source was the consolidated CRTS workbook supplied for this article. The study reviewed brief project field notes to contextualize selected numerical patterns, but the available qualitative file did not include complete focus-group logs, participant rosters, verbatim transcripts, audio records, or a documented coding trail. The qualitative material was therefore treated as supplementary field-note context rather than as a fully auditable qualitative component. The study is not presented as a formal convergent or explanatory sequential mixed-methods design.

2.2. Study setting and site coverage

The final article-specific source workbook contained 694 populated records from 22 barangays in 10 municipalities and one city in Pampanga. A populated record was defined as a worksheet row containing both a barangay and a municipality/city identifier after excluding spreadsheet header and formatting rows. Operational scheduling files paired barangays characterized as relatively rural and urban within participating LGUs, and the workbook typically contained approximately 35 records per selected barangay, although actual counts varied. The retained files did not document a uniform flood-hazard-map threshold or a province-wide probability sampling frame; the article therefore describes participating sites and does not claim statistical representativeness for Pampanga as a whole.

The July 31 implementation report refers to more than 1,400 respondents in the broader CRTS rollout, whereas the consolidated workbook supplied for this article contains 694 populated records. No additional respondent-level files were available for the present analysis. Accordingly, we froze the 694-record workbook as the final article-specific source dataset, and we did not use the broader report total as this manuscript's study denominator. The distribution of source records and adult analytical records across the 22 participating barangays is shown by municipality/city (Table 1).

Table 1. Study sites and populated survey records in the consolidated workbook.

Municipality/city	Barangay or barangays	Source records by barangay (total)	Adult analytical records by barangay (total)
Bacolor	Cabanbangan; Tinajero	35; 35 (70)	32; 33 (65)
Candaba	Sto Rosario; Paralaya	38; 39 (77)	35; 37 (72)
Floridablanca	San Antonio; San Ramon	41; 38 (79)	25; 29 (54)
Guagua	Ascomo; Sto Nino	42; 31 (73)	38; 28 (66)
Lubao	Calangain; San Nicolas 1	37; 35 (72)	29; 30 (59)
Mabalacat City	Dau; Sapang Biabas; Marcos Village; Tabun	33; 15; 22; 17 (87)	31; 14; 22; 17 (84)
Macabebe	Dalayap	35 (35)	30 (30)
Mexico	Lagundi; San Jose Matulid	35; 35 (70)	28; 27 (55)
Minalin	Sta Rita	33 (33)	27 (27)
Porac	Mancatian; San Jose Milta	25; 26 (51)	24; 21 (45)
Santo Tomas	San Bartolome; San Matias	29; 18 (47)	29; 16 (45)
Total	22 barangays	694	602

Source: Author's audit of the Pampanga 2025 consolidated CRTS workbook. Source counts describe the final article-specific workbook; adult counts exclude the combined 10–19 category and invalid/missing age codes.

2.3. Participants, recruitment, and response rate

The CRTS used non-probability, quota-guided community recruitment organized around sector categories including youth, senior citizens, women, men, LGBTQ+ participants, persons with disabilities (PWDs), business-sector participants, Indigenous Peoples, local-government personnel, and higher-education representatives. The July 31 implementation report documents trained undergraduate and graduate student enumerators, a common field guide containing skip logic and consent procedures, supervisory spot checks and back-checking, and centralized Excel encoding. Recruitment and field coordination occurred through participating LGUs, barangays, and higher-education partners. The retained operational records did not preserve the number invited, refusals, or non-contacts; consequently, a conventional response rate cannot be calculated.

The data audit retained populated records without deleting responses solely because answer patterns were identical. Some worksheets lacked unique respondent codes, and identical response patterns could therefore represent different participants. The discrepancy between the 674 responses reported in the submitted version and the 694 populated rows in the supplied workbook was resolved by applying the documented populated-row rule. For the publication analysis, we excluded 81 records coded in the combined 10–19 age category and 11 records with missing or invalid age codes, yielding an adult analytical sample of 602. The article-specific data flow from the 694-record source workbook to the 602-record adult analytical sample, including exclusions and the complete four-index subset, is summarized below (Table 2).

Table 2. Article-specific data-flow audit.

Stage	n	Decision
Final article-specific source workbook	694	All populated rows with barangay and municipality/city identifiers
Excluded: combined age 10–19	81	Excluded because exact age and guardian-permission/assent linkage could not be verified consistently
Excluded: missing or invalid age code	11	Excluded because adult eligibility could not be established
Adult analytical sample	602	Eligible for adult-only publication analysis
Complete four-index cases	244	Not clustered because complete-case inclusion was strongly patterned by locality

The demographic composition of the adult analytical sample, based on valid category codes, is summarized by sector, age group, gender, and education (Table 3).

Table 3. Demographic composition of records with valid category codes.

Characteristic	Category	n	Valid %
Sector category	Senior citizens	128	21.3
	Women	113	18.8
	Men	90	15.0
	PWD	83	13.8
	Business sector	66	11.0
	LGBTQ+	59	9.8
	Youth sector (adult records only)	49	8.2
	Indigenous Peoples	11	1.8
	LGU official	1	0.2
Age group	20–24	63	10.5
	25–64	440	73.1
	65 and above	99	16.4
Gender	Female	295	49.3
	Male	240	40.1
	LGBTQ+	63	10.5
Education	Elementary	154	26.3
	Junior high school	197	33.6
	Senior high school	89	15.2
	College	129	22.0
	Graduate/professional	4	0.7
	No formal schooling	7	1.2
	Other	6	1.0

The table describes the adult analytical sample. Valid denominators differ because multi-coded, zero, blank, or out-of-range category entries were treated as missing: sector n=600, gender n=598, and education n=586. Age n=602 by design after the eligibility exclusions.

2.4. Instrument and measures

The CRTS instrument covered socio-demographic and geospatial information, flood experience, disaster-related practices, green or nature-based solutions, science and technology use, smart and sustainable community services, barriers to technology use, perceived stakeholder importance, causes of flooding, and community perspectives. Its introductory statement described voluntary participation, confidentiality, research and planning use, the right to stop, and the right to decline questions (3C-SHIELD DREAM CAPDEV Project, 2025).

The analytical measures, item bases, scoring rules, missing-item requirements, and interpretation ranges are summarized below (Table 4).

Table 4. Construction and interpretation of analytical measures.

Measure	Item basis	Scoring	Missing-item rule	Range and cut-offs
Preparedness practices	QC1–QC6 (6 items)	Often = 3; sometimes = 2; not done = 1; cannot say / blank = missing	≥5 of 6 valid	1.00–3.00; Low 1.00–1.66; Moderate 1.67–2.33; High 2.34–3.00
Prevention practices	QD1–QD5 (5 items)	Same recoding	≥4 of 5 valid	1.00–3.00; same equal-interval cut-offs

Measure	Item basis	Scoring	Missing-item rule	Range and cut-offs
Response practices	QE1–QE5 (5 items)	Same recoding	≥4 of 5 valid	1.00–3.00; same equal-interval cut-offs
Recovery practices	QF1–QF4 (4 items)	Same recoding	≥3 of 4 valid	1.00–3.00; same equal-interval cut-offs
Overall disaster-practice index	20 items across the four domains	Equal weighting of valid items	≥14 of 20 valid	1.00–3.00; same equal-interval cut-offs
Personal technology use	QI8	No use / no known user = 0; knows another user = 1; personal use = 2; cannot say / blank = missing	Single item	0.00–2.00
Smart-technology readiness	QJ1–QJ11	Absent / not needed = 0; absent but desired = 1; reported available = 2; cannot say / blank = missing	≥8 of 11 valid	0.00–2.00; Low 0.00–0.66; Moderate 0.67–1.33; High 1.34–2.00
Digital-readiness composite	Personal-use and smart-readiness scores	Equal weighting of the two components	Both components required	0.00–2.00; same equal-interval cut-offs
Sustainability readiness	QH1–QH6	Not appropriate = 1; should be implemented = 2; currently implemented = 3	≥4 of 6 valid	1.00–3.00; same equal-interval cut-offs
Institutional-support orientation	QM1–QM7	Cannot say = 1; not important = 2; important = 3	≥5 of 7 valid	1.00–3.00; same equal-interval cut-offs

All items were equally weighted within each scale. For the article-specific analysis, zero, blank, out-of-range, and 'cannot say' values were treated as missing unless the questionnaire defined the code as a substantive response. Domain scores required at least 70% valid items; the overall disaster-practice score required at least 14 of 20 items. The descriptive cut-offs are equal-interval categories and are not externally validated diagnostic thresholds.

The questionnaire items retained in each analytical measure, including their item codes, condensed content, and scoring, are presented below; item wording is translated and condensed from the Filipino CRTS instrument, which remains the authoritative source (Table 5).

Table 5. Item-level content of analytical measures.

Scale/domain	Item codes	Condensed item content	Scoring
Preparedness	QC1–QC6	Emergency supplies; protected documents; home reinforcement; preparedness meetings/training; weather-advisory monitoring; evacuation plan and routes	1 = often; 2 = sometimes; 3 = not done; 4 = cannot say; recoded 3, 2, 1; 4 = missing
Prevention	QD1–QD5	Proper waste disposal; tree/mangrove planting; avoiding unsafe construction locations; drainage/canal maintenance; community preparedness programs	Same recoding as preparedness

Scale/domain	Item codes	Condensed item content	Scoring
Response	QE1–QE5	Evacuating to a safer place; staying indoors and protecting family; following government advice; assisting vulnerable family members; coordinating with services/neighbors	Same recoding as preparedness
Recovery	QF1–QF4	Cleaning/repairing damaged property; seeking financial/temporary assistance; helping affected neighbors; rebuilding with stronger materials/design	Same recoding as preparedness
Personal technology use	QI8	Whether the participant personally uses, knows someone who uses, or does not use/know a user of technology for online selling, digital payments, or e-commerce	1 = 0; 2 = 1; 3 = 2; 4 = missing
Smart-technology readiness	QJ1–QJ11	CCTV/security; early-warning alarms; online government services; water/waste technology; traffic applications; digital fares/payments; GPS/road mapping; online booking/delivery; solar systems; recycling machines; flood-monitoring sensors	1 (absent / not needed) = 0; 2 (absent but desired) = 1; 3 (available) = 2; 4 = missing
Sustainability readiness	QH1–QH6	Trees/forest protection; mangroves; green spaces/rain gardens; river/wetland restoration; permeable pavement; rainwater harvesting	1 = not appropriate; 2 = should be implemented; 3 = currently implemented
Institutional-support orientation	QM1–QM7	Importance of LGU, national government, community, business, NGOs, universities/colleges, and scientists/researchers in addressing flooding	1 = cannot say; 2 = not important; 3 = important

2.5. Data management and missing data

Workbook sheets used different export structures. Header rows were removed, variable names were harmonized, and categorical responses were parsed from their leading response codes. For the present academic analysis, the operational cleaning rule described in the implementation report—under which blank cells were coded as zero—was not applied indiscriminately, because a blank could represent nonresponse, a structural skip, 'cannot say,' or an encoding omission. Available-case denominators and missing/unknown counts are therefore reported for every result. The 10–19 category corresponds to the World Health Organization age range for adolescence, but all records in that grouped category were excluded because exact age and participant-level guardian-permission/assent documentation could not be consistently linked (World Health Organization, n.d.).

The original respondent-level cluster analysis was removed. Under the transparent adult-only scoring rules, only 244 of 602 records had complete values for the disaster-practice, digital-readiness, sustainability, and institutional-support composites. Complete-case inclusion was strongly associated with municipality/city (χ^2=104.06, p<0.001; Cramér's V=0.416); Candaba contributed no complete four-index cases and Macabebe contributed only one. Because the original 321-case subset could not be reproduced from the supplied workbook and the reproducible complete-case subset was geographically patterned, clustering would have produced biased and unstable typologies. No respondent or community cluster labels are retained.

2.6. Statistical analysis

Frequencies, percentages, means, and standard deviations were calculated using available adult cases. Internal consistency was assessed with Cronbach's alpha among records with complete item responses for each multi-item scale; the corresponding reliability-analysis n is reported. Spearman rank correlations were used for exploratory associations involving ordinal predictors and index scores. A two-sided p value below 0.05 was used descriptively; because the analyses were exploratory and multiple comparisons were not adjusted, effect sizes and directions were emphasized over dichotomous significance claims. Analyses were conducted in Python using a reproducible data-processing specification.

2.7. Supplementary field-note context

The available qualitative summary contained brief facilitator notes covering the seven project dimensions of shelter and living space, mobility and access, income and livelihood, social services, social safety nets, community governance, and local-system integration. It did not identify the number, location, duration, language, or participant composition of each discussion and did not preserve verbatim quotations. The notes were therefore reviewed for recurring contextual observations only. No claims are made regarding frequency, saturation, theme prevalence, or sector-wide qualitative inference.

2.8. Ethical considerations, positionality, and safeguards

The original CRTS activity was implemented as an operational community-assessment, capacity-development, and planning initiative undertaken through the author's professional role. It was not initiated as a doctoral research project or prospectively submitted as an academic study to an institutional ethics review committee. Consequently, no committee name or ethics approval number exists, and the manuscript does not claim formal ethics approval.

Before survey or discussion administration, trained enumerators verbally explained the purpose of the activity, voluntary participation, confidentiality, intended research and planning use, the right to decline questions, and the right to stop. Prospective participants were given an opportunity to ask questions and then signed written informed-consent forms before participation. The signed forms remained with the original project records and were not entered into the analytical workbook; names and signatures were not included in the dataset used for this manuscript. The retained files did not contain a formal consent-record retention and destruction schedule, and this documentation gap is acknowledged.

PWDs, Indigenous Peoples, older adults, and other sectoral participants were covered by the verbal explanation and written-consent process. The operational files available for this secondary analysis did not systematically document participant-specific accessibility accommodations, the language used at each administration, or Indigenous community-level authorization. The manuscript therefore avoids identifiable subgroup quotations, suppresses potentially identifying cross-classifications, and acknowledges these documentation gaps as ethical and methodological limitations.

The questionnaire used a project-defined 10–19 age category to obtain adolescent representation; this age range is consistent with the World Health Organization definition of adolescence (World Health Organization, n.d.). Because the grouped category did not distinguish participants aged 18–19 from those younger than 18, and guardian permission and minor assent could not be verified consistently at participant level, all 81 records in that category were excluded. Eleven additional records with missing or invalid age codes were also excluded. The publication analysis therefore includes only 602 adult records.

The author initiated or coordinated the project as part of her professional responsibilities and held a leadership role within the implementing organization. This position facilitated project access but may have influenced recruitment, participant perceptions, and interpretation. To reduce the risk of favorable institutional framing, the manuscript does not evaluate project effectiveness, retains critical findings, distinguishes self-reported practice from verified capacity, reports missingness, and removes the original clustering when its complete-case sample proved geographically biased.

3. Results

3.1. Flood experience and sample coverage

Among 587 adult records with a valid flood-experience response, 214 (36.5%) reported occasional flooding and 166 (28.3%) reported frequent flooding; 204 (34.8%) reported no flooding and three (0.5%) did not know. These figures show substantial flood experience within the adult analytical sample while also confirming that not every participant described the household or neighborhood as flooded.

The principal practice and readiness measures, together with their valid sample sizes, descriptive statistics, reliability estimates, and interpretations, are summarized below (Table 6).

Table 6. Self-reported practice and readiness measures.

Measure	Valid n	Mean	SD	Cronbach's α	Reliability n	Interpretation
Preparedness practices	500	2.64	0.39	0.73	417	High
Prevention practices	416	2.38	0.49	0.64	290	High
Response practices	472	2.57	0.37	0.55	376	High
Recovery practices	477	2.41	0.47	0.62	372	High
Overall disaster-practice index	482	2.52	0.34	0.84	188	High
Personal technology use	460	0.83	0.73	—	—	Moderate
Smart-technology readiness	356	1.26	0.48	0.92	177	Moderate
Digital-readiness composite	311	1.05	0.48	—	—	Moderate
Sustainability readiness	529	1.99	0.49	0.70	448	Moderate
Institutional-support orientation	531	2.47	0.76	0.96	488	High

Cronbach's alpha is reported for multi-item scales using complete item responses, with the reliability-analysis n shown in the table. It is not applicable to the single-item personal-use measure or the two-component digital-readiness composite. Interpretations use the descriptive cut-offs in Table 4.

The overall disaster-practice index was high within the instrument's descriptive scoring framework (mean=2.52/3.00), but the wording 'high disaster resilience' is avoided. The measure captures reported behaviors and does not verify warning lead time, evacuation compliance, operational response capacity, flood losses, recovery duration, or livelihood restoration. Digital readiness was moderate (mean=1.05/2.00) and was based on 311 adult records because technology-related fields had substantial missingness (Table 6).

3.2. Reported smart and DRRM technology availability

Reported availability and missingness across the assessed smart and DRRM technologies are summarized for the adult analytical sample (Table 7).

Table 7. Reported technology availability and missingness in the adult analytical sample (N=602).

Technology	Valid n	Available n	Available %	Missing/unknown n	Missing/unknown %
CCTV/security systems	490	369	75.3	112	18.6
Water / waste management technology	433	323	74.6	169	28.1
Solar streetlights / energy systems	447	302	67.6	155	25.7
Early-warning alarms	432	264	61.1	170	28.2
Online government services	397	237	59.7	205	34.1
Traffic monitoring applications	361	120	33.2	241	40.0
Online booking / delivery	389	117	30.1	213	35.4
Road mapping / GPS navigation	339	87	25.7	263	43.7
Waste recycling machines	387	82	21.2	215	35.7
Flood-monitoring sensors	380	83	21.8	222	36.9
Digital fare/payment systems	359	47	13.1	243	40.4

Valid responses were 'reported available,' 'not available but desired,' or 'not available and not needed.' 'Cannot say,' blank, zero, multi-coded, and out-of-range responses were included in the missing/unknown column. The percentage reported as available uses the valid adult denominator for each item.

Technology visibility was uneven. A majority of valid adult respondents reported CCTV/security systems (75.3%), water or waste technologies (74.6%), solar systems (67.6%), early-warning alarms (61.1%), and online government services (59.7%). Flood-monitoring sensors were reported by 21.8%. Missing/unknown proportions ranged from 18.6% for CCTV to 43.7% for road mapping/GPS. The varying denominators are reported rather than silently replaced with a common denominator.

3.3. Barriers to technology use

The technology barriers selected by adult respondents are summarized below (Table 8).

Table 8. Technology barriers selected by adult respondents (N=602).

Barrier	Selected n	% of adult records
Weak internet connection	238	39.5
Low digital skills	148	24.6
High cost of technology/internet	138	22.9
Limited access to online markets	64	10.6
Other	4	0.7

Multiple responses were allowed, so percentages do not sum to 100%.

Weak connectivity was the most common reported barrier (39.5% of adult records), followed by low digital skills (24.6%) and cost (22.9%). These findings support a hybrid warning architecture rather than an online-only model: social media and web advisories should be complemented by SMS, sirens, radio, public-address systems, barangay messengers, and last-mile confirmation for vulnerable households.

3.4. Exploratory associations

Selected exploratory associations are summarized below (Table 9).

Table 9. Selected exploratory associations.

Association	Valid n	Effect estimate	p value	Interpretation
Digital readiness and disaster-practice score	267	Spearman ϱ=0.163	p=0.008	Small positive association
Digital readiness and education level	304	Spearman ϱ=0.212	p<0.001	Small positive association
Digital readiness and age group	311	Spearman ϱ=-0.009	p=0.872	No clear association
Digital readiness and flood experience	308	Spearman ϱ=-0.011	p=0.850	No clear association
Disaster practices and flood experience	470	Spearman ϱ=-0.097	p=0.036	Very small negative association

Analyses are exploratory, use available cases, and were not adjusted for multiple testing. Statistical significance does not imply practical importance or causation.

Digital readiness had a small positive association with reported disaster practices (ϱ=0.163, p=0.008) and with education level (ϱ=0.212, p<0.001). Age group and flood experience did not show clear associations with digital readiness. The very small negative association between flood experience and disaster-practice scores (ϱ=−0.097, p=0.036) should not be overinterpreted; it may reflect locality, missingness, household constraints, or differences in how repeated exposure shapes reporting.

3.5. Contextual observations from project field notes

The limited field notes were consistent with two cross-cutting observations. First, generally positive descriptions of concrete housing and accessible locations coexisted with reports that some PWD and older participants experienced discomfort, deterioration, or unsafe conditions during rain, and that transport cost or commuting difficulty could constrain mobility. Second, positive descriptions of assistance and governance coexisted with reports of no current harvest, intermittent assistance, missed puroks, and uneven service reach. These observations illustrate why favorable aggregate ratings cannot be interpreted as equal coverage for all households or sectors.

Because the notes were not verbatim transcripts and lacked a complete audit trail, this report presents no quotations, theme frequencies, municipality comparisons, or claims of qualitative saturation. This restriction avoids converting brief operational notes into a stronger qualitative evidence base than the records support.

4. Discussion

The adult-only analysis shows a clear distinction between relatively frequent self-reported disaster practices and more uneven digital readiness. Participants often reported preparedness, response, and recovery behaviors, yet personal technology use and smart-service readiness were moderate, and localized flood-monitoring sensors were uncommon. The findings support a socio-technical view of flood resilience: information must reach households through channels they can access, understand, trust, and act upon.

This pattern is consistent with Sukhwani et al. (2019), who emphasized that effective flood early-warning operation depends on connections among technical monitoring, communication, institutional arrangements, and community response. The current findings add a local equity dimension: even when alarms, CCTV, online services, or solar systems are visible, weak connectivity, limited digital skills, affordability, and gaps in last-mile coverage can break the warning-to-action chain.

The high institutional-support orientation suggests that respondents considered government, community actors, academe, scientists, and other partners important. This aligns with Goyal's (2019) emphasis on disaster governance and with Rico's (2019) account of school-community collaboration. For Pampanga, schools and higher-education institutions can support warning comprehension, drills, accessible message design, community mapping, and evaluation, but authorized DRRM institutions remain responsible for operational warning and evacuation decisions.

Cvetković et al. (2021) review of innovative flood-risk management highlights sensors, communication, cooperation, and emerging technologies as promising tools. The present results indicate where that promise is constrained: flood sensors were reported by only 21.8% of valid adult respondents, and missing or unknown responses were substantial. Investment decisions should therefore include maintenance, calibration, connectivity, data governance, trained operators, and community-facing protocols rather than treating device installation as the end point.

The small association between digital readiness and disaster-practice scores is also important. Digital access alone does not guarantee preparedness or protective action (Cvetković et al., 2020). Conversely, households may possess experience-based routines while having limited digital access. This supports differentiated communication: digitally enabled households can receive detailed online products, whereas low-connectivity households require redundant low-bandwidth and human-assisted channels.

Emerging artificial-intelligence and cyberspace capabilities may improve forecasting, information synthesis, and coordination, but they also introduce dependence on reliable telecommunications, cybersecurity, accountable governance, and human judgment (Beriša et al., 2024). In flood-prone barangays, advanced systems should therefore supplement rather than displace trusted local communication and manual verification.

The contextual notes help reconcile apparently favorable governance and support with reports of missed puroks and intermittent assistance. Aggregate positive perceptions can coexist with distributional gaps. The operational question is not only whether a service exists, but whether it reaches peripheral locations, PWDs, older adults, Indigenous households, low-income families, and livelihood-dependent groups in time.

4.1. Implementation priorities

The proposed implementation priorities are summarized below (Table 10).

Table 10. Proposed implementation matrix for flood-risk communication and resilience.

Action	Responsible institutions	Period	Indicative financing need	Measurable indicators
Hybrid warning protocol with online, SMS, siren, radio, public-address, and messenger channels	PDRRMO/MDRRMO, barangay DRRM committees, telecommunications partners	0–12 months	Low–moderate; local DRRM funds and partner support	% of warnings delivered through ≥3 channels; median time to purok confirmation
Localized water-level and rainfall monitoring with maintenance and data-sharing plans	PDRRMO/MDRRMO, DOST/PAGASA, LGUs, HEIs	1–3 years	Capital and recurring O&M; local DRRM funds and national S&T grants	Number and % of functioning sensors; data uptime; warning lead time

Action	Responsible institutions	Period	Indicative financing need	Measurable indicators
Accessible warning templates and comprehension checks for PWDs, older adults, and language groups	Barangays, PDAO, health units, IP representatives, HEIs	0–12 months	Low–moderate; training and content-development resources	% of messages in accessible formats; correct message comprehension rate
Purok-level last-mile confirmation and vulnerable-household follow-up	Barangay DRRM committees, social welfare and health workers	0–6 months	Staff/volunteer time, communications load, transport support	% of puroks confirming receipt; % of priority households contacted
Digital-literacy and misinformation-resilience activities linked to drills	LGUs, DICT/DOST, schools and HEIs	6–18 months	Moderate; training, connectivity, and learning materials	Training completion; drill participation; correct warning-action responses
Livelihood continuity and early asset-protection triggers	Municipal agriculture, social welfare, cooperatives, business groups	6–24 months	Moderate–high; contingency and recovery funds	Evacuation compliance; days of livelihood interruption; recovery-assistance coverage

Financing descriptions are indicative and require local costing, procurement review, and alignment with authorized DRRM and development plans.

5. Limitations

This study has substantial limitations. First, site selection and participant recruitment were non-probability and operational; invitation totals were not retained, so a response rate cannot be calculated and the findings cannot be generalized to all Pampanga communities. Second, the July 31 report describes a broader implementation total that is not represented in the 694-record workbook supplied for this article; the present analysis is limited to that article-specific source file. Third, excluding all 81 records in the 10–19 category also removed potentially eligible adults aged 18–19, and 11 records with invalid or missing age codes were excluded. The findings therefore do not represent adolescents or the youngest adults.

Fourth, the workbook contained inconsistent sheet structures, invalid or multi-coded entries, ‘cannot say’ responses, and substantial item-level missingness, especially in digital variables; missingness was strongly patterned by locality. Fifth, measures were self-reported and may be affected by recall, interpretation, institutional desirability, or social-desirability bias. The disaster-practice index does not verify actual warning receipt, evacuation behavior, response performance, flood losses, or recovery outcomes. Sixth, we removed the original cluster analysis because the reproducible complete-case sample was geographically biased. Seventh, the qualitative material consisted of brief field notes rather than complete transcripts and cannot support formal thematic saturation, sector comparisons, or verbatim quotation. Eighth, small subgroup sizes limit disaggregated analysis of Indigenous Peoples, PWDs, and other sectors without creating identification risk. Finally, the original operational activity included oral explanations and written consent but no prospective institutional ethics review; participant-specific accommodations, administration language, and a formal consent-record retention schedule were not systematically documented.

6. Conclusions

The adult records analyzed from participating Pampanga barangays show relatively frequent self-reported disaster-preparedness and resilience practices alongside moderate and uneven digital readiness. CCTV, water or waste technologies, solar systems, early-warning alarms, and online services were more visible than localized flood sensors, road-mapping tools, recycling machines, and digital-payment systems. Weak internet connectivity, limited digital skills, and cost remain important barriers.

These results do not establish "high community resilience" in an operational sense. They show reported practices and perceived technology availability within a non-probability project sample. Flood-risk communication should therefore combine technology with redundant low-bandwidth channels, accessible message design, purok-level confirmation, trained local personnel, livelihood-sensitive triggers, and measurable coverage indicators. Digital systems are most useful when they are maintained, trusted, understandable, and connected to the capacity of households and institutions to act.

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Conflicts of Interest: The author was employed by and held a leadership role within the organization that implemented the initiative from which the analyzed data originated. This represents a potential institutional and non-financial conflict of interest. The author declares no personal financial interest arising from publication. The manuscript does not evaluate project or organizational effectiveness, and it reports both favorable and critical findings.

Data Availability Statement: The respondent-level data are not publicly available because of confidentiality, community privacy, consent limitations, and institutional data-custodianship requirements. The 694-record workbook is the final article-specific source file; the publication analysis uses 602 adult records after age-based exclusions. De-identified aggregated tables, the scoring specification, and a data dictionary may be provided to the editor for verification, subject to organizational permission and data-protection requirements. We will not share signed consent forms because they contain personal identifiers.

Use of Generative AI Tools: Generative AI tools were used for editorial organization, language polishing, and document-formatting support. Statistical results were recalculated from the supplied workbook using a reproducible Python specification and were reviewed by the author. The author is responsible for verifying all data-processing decisions, ethical statements, citations, interpretations, and final text before submission.

List of Symbols: α: Cronbach's alpha; χ^2: chi-square statistic; ϱ: Spearman rank-correlation coefficient; p: probability value; n: valid number of observations; N: total analytical sample; SD: standard deviation; and V: Cramér's V.

Abbreviations: CRTS: Community Resilience and Transformability Survey; DICT: Department of Information and Communications Technology; DRRM: disaster risk reduction and management; HEI: higher-education institution; IP: Indigenous Peoples; LGU: local government unit; MDRRMO: Municipal Disaster Risk Reduction and Management Office; PAGASA: Philippine Atmospheric, Geophysical and Astronomical Services Administration; PDAO: Persons with Disability Affairs Office; PDRRMO: Provincial Disaster Risk Reduction and Management Office; PWD: persons with disabilities.

7. References

1. 3C-SHIELD DREAM CAPDEV Project. (2025). Community Resilience and Transformability Survey (CRTS) reference questionnaire [Unpublished project instrument].
2. Beriša, H., Cvetković, V., & Pavić, A. (2024). Implications of artificial intelligence and cyberspace on risk management capabilities. *International Journal of Disaster Risk Management, 6*(2), 279-295. doi:10.18485/IJDRM.2024.6.2.18
3. Cvetković, V. M., & Martinović, J. (2021). Innovative solutions for flood risk management. *International Journal of Disaster Risk Management, 2*(2), 71-100. doi:10.18485/ijdrm.2020.2.2.5
4. Cvetković, V. M., Milenković, D., Bašić, J., Lukić, T., & Renner, R. (2026). Predictive model of community disaster resilience across Serbia: A BRIC–DROP composite index and spatial patterns. *Safety, 12*(3), 59. doi:10.3390/safety12030059
5. Cvetković, V. M., Milenković, D., Lukić, T., & Renner, R. (2026). Theoretical evolution of measuring community resilience to natural and technological disasters: Past, present, and future – empirical insights from qualitative research in Serbia. *Open Geosciences, 18*(1), 20250968. doi:10.1515/geo-2025-0968
6. Cvetković, V. M., Nikolić, N., Radovanović Nenadić, U., Öcal, A., Noji, E. K., & Zečević, M. (2020). Preparedness and preventive behaviors for a pandemic disaster caused by COVID-19 in Serbia. *International Journal of Environmental Research and Public Health, 17*(11), 4124. doi:10.3390/ijerph17114124
7. Cvetković, V. M., Tanasić, J., Ocal, A., Kešetović, Ž., Nikolić, N., & Dragašević, A. (2021). Capacity development of local self-governments for disaster risk management. *International Journal of Environmental Research and Public Health, 18*(19), 10406. doi:10.3390/ijerph181910406
8. Goyal, N. (2019). Disaster governance and community resilience: The law and the role of SDMAs. *International Journal of Disaster Risk Management, 1*(2), 61-75. doi:10.18485/ijdrm.2019.1.2.5
9. Hanspal, M. S., & Behera, B. (2024). Role of emerging technology in disaster management in India: An overview. *International Journal of Disaster Risk Management, 6*(2), 133-148. doi:10.18485/ijdrm.2024.6.2.9
10. Iftikhar, A., & Iqbal, J. (2024). Changes in LULC and drainage network patterns the cause of urban flooding in Karachi City. *International Journal of Disaster Risk Management, 6*(1), 91-102. doi:10.18485/ijdrm.2024.6.1.6
11. Jovičić, R., Gostimirović, L., & Milašinović, S. (2024). Use of new technologies in the field of protection and rescue during disasters. *International Journal of Disaster Risk Management, 6*(1), 111-122. doi:10.18485/ijdrm.2024.6.1.8
12. Lagmay, A. M. F., Racoma, B. A., Aracan, K. A., Alconis-Ayco, J., & Saddi, I. L. (2017). Disseminating near-real-time hazards information and flood maps in the Philippines through Web-GIS. *Journal of Environmental Sciences, 59*, 13-23. doi:10.1016/j.jes.2017.03.014
13. Mano, R. M., Kirshcenbaum, A., & Rapaport, C. (2019). Earthquake preparedness: A Social Media Fit perspective to accessing and disseminating earthquake information. *International Journal*

of Disaster Risk Management, *1*(2), 19-31. doi:10.18485/ijdrm.2019.1.2.2

14. Nagumo, N., & Sawano, H. (2016). Land classification and flood characteristics of the Pampanga River Basin, Central Luzon, Philippines. *Journal of Geography (Chigaku Zasshi), 125*(5), 699-716. doi:10.5026/jgeography.125.699
15. Philippine Atmospheric, Geophysical and Astronomical Services Administration. (n.d.). *Flood forecasting and warning system for river basin*. Retrieved from https://origin.pagasa.dost.gov.ph/information/flood-forecasting-and-warning-system-river-basins
16. Rebouh, N., Tout, F., Dinar, H., Benzid, Y., & Zouak, Z. (2024). Integrating multi-source geospatial data and AHP for flood susceptibility mapping in Ain Smara, Constantine, Algeria. *International Journal of Disaster Risk Management*, *6*(2), 245-264. doi:10.18485/ijdrm.2024.6.2.16
17. Rico, G. C. S. (2019). School-community collaboration: Disaster preparedness towards building resilient communities. *International Journal of Disaster Risk Management, 1*(2), 45-61. doi:10.18485/ijdrm.2019.1.2.4
18. Romero, S. E. (2026). The Community Resilience and Transformability Survey (CRTS) as data democratization: Tool, strategy, and application in Pampanga [Submitted project report]. Future Earth Philippines.
19. Sukhwani, V., Gyamfi, B. A., Zhang, R., AlHinai, A. M., & Shaw, R. (2019). Understanding the barriers restraining effective operation of flood early warning systems. *International Journal of Disaster Risk Management*, *1*(2), 1-19. doi:10.18485/ijdrm.2019.1.2.1
20. Tabios, G. Q., III. (2018). Holistic approach to water resources development through generations. *Transactions of the National Academy of Science and Technology Philippines*, *40*(2). doi:10.57043/transnastphl.2018.1092
21. Tabios, G. Q., III. (2020). *Water resources systems of the Philippines: Modeling studies*. Cham, Switzerland: Springer. doi:10.1007/978-3-030-25401-8
22. United Nations Office for Disaster Risk Reduction, & World Meteorological Organization. (2025). *Global status of multi-hazard early warning systems 2025*. Geneva, Switzerland: Authors. Retrieved from https://www.undrr.org/reports/global-status-mhews-2025
23. World Health Organization. (n.d.). *Adolescent health*. Retrieved from https://www.who.int/health-topics/adolescent-health
24. World Meteorological Organization. (2018). *Multi-hazard early warning systems: A checklist*. Geneva, Switzerland: Author. Retrieved from https://community.wmo.int/sites/default/files/EWS_Checklist_0.pdf
25. Yamah, D., & Folorunsho, T. (2026). Leveraging social media and mobile technology for disaster communication in Nigeria. *International Journal of Disaster Risk Management*, *8*(1), 1-30. doi:10.66050/x77jr639