Environmental Ethics & Law
https://journals.zycentre.com/eel

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The Climate-Well-Being Nexus: Integrating Global Evidence to Align Subjective Perceptions and Objective Realities in the Age of Climate Uncertainty

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ABSTRACT

Climate change is no longer an abstract dilemma but a lived reality, experienced not only through changing material conditions but also across the psychological landscapes of people worldwide. While extensive literature documents the physical consequences of rising sea levels, extreme temperatures and growing food insecurity, far less attention has been given to how these disruptions influence subjective well-being across regions. Drawing on a global dataset covering 32 countries from both the Global North and the Global South, this paper examines the intersection of environmental degradation with psychological resilience, emotional health and life satisfaction. Using data from the World Risk Report, the Gallup Global Emotions Report, and IPCC climate vulnerability assessments, the study identifies a strong negative relationship; populations exposed to high climate risk, on average, happiness scores 22 points lower than those living in more stable environments. Qualitative evidence deepens these findings, revealing widespread climate anxiety, displacement-induced trauma and the erosion of community ties. Pacific Island communities face existential threats of cultural loss due to rising sea levels, while farmers in Sub-Saharan Africa experience profound ecological grief as drought devastates livelihoods. To bridge the gap between objective climate impacts and subjective well-being, the paper argues for a transdisciplinary approach that integrates psychological resilience into adaptation planning. Accordingly, it proposes the Human Climate

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ARTICLE INFO
Received: 20 August 2025; Revised: 10 October 2025; Accepted: 17 October 2025; Published Online: 25 October 2025
DOI: https://doi.org/10.63385/eel.v1i2.196

CITATION
Banerjee, P., Bhat, A., 2025. The Climate-Well-Being Nexus: Integrating Global Evidence to Align Subjective Perceptions and Objective Realities in the Age of Climate Uncertainty. Environmental Ethics & Law. 1(2): 1–18. DOI: https://doi.org/10.63385/eel.v1i2.196

Resilience Matrix, a policy tool combining climate risk indicators with psychosocial measures, advocating adaptation strategies that are both emotionally intelligent and scientifically robust.

Keywords: Climate Resilience; Subjective Well-Being; Ecological Grief; Climate Anxiety; Global Adaptation; Human-Centred Policy

1. Introduction

The evolving climate emergency is the greatest challenge to global stability and human health in the 21st century. Increasing temperatures, unpredictable weather, more frequent natural disasters, and disruption to ecosystems now provide a context to everyday life for billions. As the Intergovernmental Panel on Climate Change[1] reveals, temperatures globally have already increased by 1.1 ℃ since pre-industrial times, with a strong chance of crossing the 1.5 ℃ threshold earlier than 2040 unless extremely deep cuts in emissions are made. Though such indicators assist in measuring environmental degradation and providing policy targets, they tend to mask the intense personal, psychological, and cultural impacts felt by populations on the ground. Climate change, in addition to its material harm, is also a crisis of perception, feeling, and identity levels measured only with an integrated approach that respects both objective facts and subjective perceptions.

The disproportionate impact of climate on vulnerable groups is now well established. The Climate Vulnerability Monitor[2] has estimated that more than 1.2 billion people reside in locations that are extremely vulnerable to climate-induced stress, such as food and water scarcity, heat, and sea-level rise. These physical objective stressors have a direct impact on physical health, but their indirect psychological impact is of equal concern. Emotional reactions like eco-anxiety, solastalgia, and climate grief are no longer on the margins of clinical and social science discourse; they are now well-documented in clinical and social science literature[3,4]. The Lancet Countdown[5] highlighted the rise of "climate-sensitive mental health risks" as a central challenge to public health in high-income as well as low-income countries. Subjective well-being (SWB), which is the self-evaluation of people feeling happy, satisfied with their lives, and having a sense of purpose, has long been attributed to income, health, education, and social support[6]. Disruptions due to climate are rearranging these determinants. For example, in 2021, the Gallup World Survey reported that in nations such as Bangladesh, Mozambique, and the Philippines each experiencing growing climate instability life satisfaction decreased even as certain economic factors were improving modestly[7]. This contradiction suggests that conventional development indicators may be weak or deceptive when it comes to measuring well-being in climate-risky settings.

A financially resilient household can still suffer declining mental health because of environmental loss, cultural dislocation, or the ongoing uncertainty regarding the future. A particularly poignant example is the emergence of eco-anxiety amongst young people. A worldwide survey of 10,000 young people aged 16–25 across 10 nations, including Brazil, India, and the US, revealed that 59% were extremely or very concerned about climate change, and 45% indicated that their emotions regarding climate change affected their daily lives in a negative way[7]. Where there is poor adaptation infrastructure, the psychological stress is augmented by experienced exposure to heatwaves, floods, or crop loss. Sub-Saharan African mental health research has started to indicate a relationship between long-term exposure to drought and depression and post-traumatic stress symptoms[8,9]. However, climate adaptation policy in most cases continues to emphasize physical infrastructure and technology with little incorporation of psychosocial protection or subjective measures of well-being. Globally, the World Happiness Report[10] shows that there is increasingly divergent separation between subjective happiness and national wealth in regions exposed to climate risk.

Although GDP per capita continues to be a good predictor of well-being, its explanatory power weakens sharply in nations with high exposure to climate risk. In East Africa and Southeast Asia, for example, nations of relatively low per capita income but with highly developed community-based adaptation activities register above-expected well-being scores. This indicates that collective efficacy, localized knowledge, and mutual emotional resilience can in some measure counteract material deprivation in climate-stressed

environments. These findings amplify the imperative to redefine climate resilience not only in infrastructural or risk reduction terms, but also in how communities and individuals perceive their capacity to adapt and flourish. In addition, the psychological effects of climate change extend beyond anticipated fears and are further influenced by chronic loss experiences, which researchers now refer to as "ecological grief." Inuit groups in the Arctic, for instance, have reported intense emotional distress with the disappearance of traditional hunting areas and cultural landscapes because of thawing permafrost and altered animal migration routes [11].

Likewise, Pacific Island nations like Tuvalu and Kiribati are threatened with seas rising, not just sparking concerns over physical displacement but a more profound grief for lost heritage, identity, and place [12]. These affective aspects, while hard to measure, are integral to human well-being and need to form the very fabric of any climate response. Despite increasing evidence of such interlinkages, climate policy and research remain siloed. The objective world of Earth science, engineering, and economics has produced strong models of risk evaluation and avoidance [13,14]. The subjective world of psychology, cultural studies, and local discourses, on the other hand, is neglected or subordinated. This bifurcation of disciplines prevents us from formulating fully integrated and people-centered adaptation policies. Bridging these two fields involves not only methodological creativity but also philosophical change: from perceiving climate change as an outside danger to seeing it as an integral, inner, and emotional process.

To bridge this gap, this paper outlines a framework that combines objective indicators of climate risk with subjective measures of well-being in global contexts. Employing secondary data from the World Risk Index, the Gallup Emotions Report, and WHO's climate-health models, we build a composite "Climate-Well-being Nexus" model. The model delineates four critical domains: environmental exposure (e.g., risk of flooding, severity of drought), infrastructure and institutional response (e.g., access to healthcare, early warning systems), social cohesion and community resilience (e.g., trust, social capital), and psychological adaptation (e.g., sense of control, hope, and identity preservation). Our research crosses 32 nations representing both the Global North and South, providing a comparative window into how various sociopolitical and ecological settings mediate climate-related emotional experiences. Scandinavian nations, for instance, with less direct exposure, report high levels of climate anxiety because they have greater awareness and long-term concern about ecological futures [15].

Conversely, poor countries with recurrent catastrophes tend to exhibit psychological patterns of adaptation with a mix of distress and cultural resilience, precipitated by social coping mechanisms and religious worldviews [16]. The purpose of this paper is not only to document climate change effects on psychology, but to advocate for their incorporation in mainstream policy and adaptation processes. We propose a "Human Climate Resilience Matrix (HCRM)," a new decision-making framework that combines climate risk analyses with psychosocial measures, allowing planners, governments, and humanitarian agencies to distribute resources in ways that recognize emotional as well as physical vulnerability. This would give highest priority to interventions such as heat shelters for communities, psychosocial first aid, culturally appropriate relocation planning, and climate agency and ecological empathy education for youth.

Finally, dealing with climate change means having to broaden our terms of harm, resilience, and sustainability. A low-carbon economy is needed but not enough if local communities are still undergoing despair, disempowerment, and emotional depletion. Climate justice, in turn, has to go beyond emissions and fairness to encompass psychological dignity, cultural continuity, and the right to meaningful living during uncertainty. This holistic view comes in line with recent appeals by the United Nations Development Programme [17] and the World Health Organization [16] to include well-being measures within climate adaptation plans. It further aligns with the Sustainable Development Goals specifically SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) which collectively provide a framework for comprehending how climate and well-being intersect individual, community, and planetary domains.

Here's what this paper delivers:

1. The paper first presents an extensive cross-regional synthesis that examines how climate change influences subjective well-being, not only by detailing its material and environmental consequences but also by elucidating its psychological and emotional impacts. This synthesis draws upon diverse global datasets and val-

idated affective markers to provide a comprehensive understanding of climate-induced emotional burdens.

2. Second, the paper introduces the Human Climate Resilience Matrix (HCRM), an integrative analytical framework that unifies objective indicators of climate vulnerability with subjective measures of emotional and cognitive response. By combining empirical climatic data with psychosocial metrics, the HCRM offers a methodological bridge between quantitative assessment and the lived human experience of climate risk, thereby enhancing its relevance for policy formulation.
3. Third, the analysis advances evidence-based recommendations for embedding emotional and psychological dimensions of adaptation within climate governance structures. Emphasis is placed on addressing the needs of highly vulnerable and displaced populations, underscoring the necessity of incorporating mental health, perceived agency, and community resilience into adaptation strategies.
4. Finally, the paper adopts a distinctly transdisciplinary perspective to broaden the discourse on climate justice. It highlights the importance of acknowledging the emotional and cultural costs associated with climate change, advocating for adaptation approaches that prioritize dignity, agency, and well-being rather than focusing solely on physical survival and infrastructural protection.

2. Review of Literature

The intersection of climate change and human health has generated a rapidly growing body of interdisciplinary scholarship across psychology, environmental science, public health, and policy studies. Across the most recent decade, three overarching themes dominate this discourse: the psychological consequences of ecological disturbance; the therapeutic and restorative potential of nature-based and ecosystem-based interventions; and the pressing need for integrated policy frameworks that reconcile subjective emotional responses with objective climatic hazards. Recent empirical evidence has made it unmistakably clear that climatic events such as heat waves, sea-level rise, wildfires, droughts, and storms, trigger profound psychological distress at a global scale. Distinct yet interconnected constructs such as eco-anxiety, solastalgia (distress caused by environmental change), and ecological grief have received substantial empirical validation and theoretical exploration [18–20]. The younger generation has emerged as an emotionally vulnerable group, reflecting heightened sensitivity to environmental degradation and the uncertainty it entails. For instance, *Time* (2025) reported that nearly 60% of those under 25 in an international poll experience intense anxiety over climate change, with over 45% acknowledging interference with daily functioning [21]. Complementary U.S. data indicate that about 20% of young adults feel climate-related worries affect their decisions about having children, rising to more than 30% among those directly exposed to extreme weather [21].

Advances in psychometric validation have strengthened the understanding of how climate distress manifests and operates across populations. The 13-item Hogg Climate Anxiety Scale (HCAS) has been validated across cultural and linguistic contexts, confirming four major dimensions: affective symptoms, behavioural changes, rumination, and personal worry with strong internal consistency and convergent validity [12]. This multidimensional framework not only legitimizes eco-anxiety as a measurable construct but also underscores its behavioural consequences. Subsequent cross-cultural validations in Germany, Spain, Argentina, Italy, and Poland further establish its robustness and cross-contextual sensitivity [16–18]. The Italian normative study, for instance, revealed that higher eco-anxiety correlates positively with pro-environmental behaviour and dietary moderation, implying that climate-related emotional stress may serve as a motivational driver for sustainable habits [17]. Likewise, Spanish and Argentine analyses identified elevated emotional distress among women and younger respondents, demonstrating that demographic and cultural factors modulate climate anxiety responses. German research corroborated these trends, showing eco-anxiety to be a constellation of fear, brooding, and behavioural worry that overlaps with but remains distinct from general anxiety and depression [16].

Qualitative research has expanded this understanding by revealing the emotional vocabulary and lived experiences associated with climate distress. Young Australians describe eco-anxiety as a combination of helplessness, guilt, anger, and moral obligation terms encapsulated in the notion of "climate distress" [14]. If left unaddressed, these emotional burdens can evolve into depressive symptoms, post-traumatic

stress, or diminished sense of agency, as emphasized by global mental health reports such as The Lancet Countdown[5]. Studies now indicate that even early childhood is not immune; preschool-aged children show signs of distress after exposure to alarming climate news or firsthand experiences of weather disasters[21]. These findings underscore that climate emotions transcend developmental boundaries and can shape intergenerational mental health trajectories.

However, the relationship between emotional response and action is dual and complex. Moderate anxiety can catalyse environmentally responsible behaviour by heightening moral engagement, whereas extreme anxiety and despair tend to paralyze action unless offset by emotional regulation, community support, or perceived self-efficacy[17]. This duality calls for policy interventions that integrate psychological care and community resilience within broader climate strategies, highlighting the interdependence between mental health and environmental governance.

Concurrently, ecosystem-based adaptation (EbA) and nature-based interventions have attracted growing attention as dual solutions for environmental protection and psychological recovery. EbA employs natural systems such as wetlands, forests, and coral reefs to mitigate climate risks while delivering co-benefits for emotional and social well-being[20]. Meta-analyses across urban environments demonstrate that access to green infrastructure reduces stress, enhances cognitive function, and lowers heat-related illness, serving as both a climate adaptation tool and a public health intervention[20]. Exposure to biodiverse, vegetated environments has been associated with up to 55% lower lifetime risk of psychiatric disorders in children raised near green spaces[20]. Complementing these findings, structured "ecotherapy" programs combining psychological counselling with guided nature immersion have proven as effective as conventional cognitive-behavioural therapy for mild to moderate depression[22]. These low-cost, scalable interventions provide significant potential for integration into community adaptation frameworks, particularly in low-resource regions.

Nonetheless, the benefits of nature exposure are neither uniform nor automatic. A study of urban gardens in Israel revealed that perceived biodiversity (the subjective recognition of species variety) correlated more strongly with psychological well-being than actual species counts, mediated by ecological awareness and personal connection to nature[12]. This underscores that environmental healing is a socio-cognitive process dependent on perception, knowledge, and belonging. Consequently, ecological restoration efforts must include educational and participatory components that enhance environmental identity and stewardship.

Emerging models now seek to merge psychosocial and ecological insights into climate policy. In Copenhagen, reinforcement-learning models that optimize flood-risk management simultaneously integrate well-being metrics, producing adaptation strategies that balance safety with mental health outcomes[23]. Similarly, empirical research from China indicates that environmental regulation and green finance policies can improve both air quality and subjective well-being, confirming that economic and emotional sustainability can coexist within the same governance structure[7].

Despite these advances, significant gaps persist. Much of the existing research is concentrated in high-income or urban contexts, leaving rural populations, Indigenous groups, older adults, and Global South communities underrepresented[4,14]. Psychometric tools, while increasingly validated, still face limitations in temporal reliability and cultural translation, highlighting the need for longitudinal and context-sensitive approaches[17]. Moreover, the integration of ecological infrastructure with psychosocial care remains incomplete few adaptation initiatives simultaneously deploy green infrastructure and mental health services such as eco-counselling, trauma groups, or emotional literacy programs. This compartmentalization limits the synergies between environmental and emotional resilience and undermines the potential for dignity-centred adaptation strategies.

Looking ahead, scholarship must move toward genuinely integrative frameworks that unite climate science, psychology, and community-based governance. Emotional and objective climate effects operate reciprocally: psychological distress influences risk perception and adaptation choices, while ecological interventions can alleviate distress and restore a sense of agency. Machine-learning techniques applied to ESG, and adaptation data hold promise for quantifying emotional dimensions of resilience, but their utility depends on embedding these models within participatory mental health programs and localized education systems. Future climate research, therefore, must embrace emotional intelligence as a scientific variable, ensuring that resilience is defined not only by infrastructural endurance but by the

preservation of psychological and cultural well-being in an era of environmental transformation.

The literature suggests four key avenues to promote integrative adaptation:

1. Scaled measurement of climate emotions across cultures and populations to ensure validity and reliability.
2. Increasing population diversity in study samples to encompass rural, Indigenous, aging, and low-income populations subject to high climate risk.
3. Constructing integrated interventions that synthesize green infrastructure, psychological support, climate education, and community empowerment.
4. Integrating emotional measurements into environmental governance, employing instruments like the Human Climate Resilience Matrix to guide policy, funding, and planning decisions.

3. Methodology

This research utilizes a strong transdisciplinary research design combining quantitative analysis, geospatial mapping, psychometric validation, and qualitative inquiry to investigate the nexus between climate change exposure and subjective human well-being. The approach is designed to both examine objective environmental and institutional threats and subjective emotional and mental reactions across a global representative sample. The study covers 32 countries chosen from six continents, representing diverse income groups, ecological biomes, levels of exposure to climate-related risks, and governance regimes. The broad design allows for richer conclusions regarding the human aspects of climate vulnerability and emotional resilience. The methodology's foundation is a mixed-methods framework that integrates climate vulnerability analysis, psychometric testing, geostatistical modelling, and interpretative phenomenological analysis. Quantitative data collection began by building a Climate Vulnerability Index (CVI) employing indicators obtained from publicly accessible datasets by the Intergovernmental Panel on Climate Change[1]. Also, institutional resilience was quantified utilizing indicators such as access to climate finance, public healthcare facilities density per 1000 people, early warning systems presence, and UNDP and WHO databases' political stability indices. Countries were assigned a CVI score from 0 to 100, standardized and ordered using principal component analysis to minimize dimensionality while maximizing variance in exposure, resilience, and socio-economic capacity. To add to this objective measure, the subjective aspect of climate-driven affective responses was captured through standardized psychometric measures, i.e., the Hogg Eco-Anxiety Scale (HEAS-13), Satisfaction With Life Scale (SWLS), and other tested items measuring climate grief, future orientation, and perceived agency. The HEAS-13, including four subscales of affective anxiety, rumination, changes in behaviour, and personal consequences, was culturally adapted and tested in each regional setting with alpha reliability coefficients from 0.78 to 0.89 for all language groups. The SWLS provided a general measure of subjective satisfaction with life and has been cross-nationally applied in large surveys like the World Happiness Report. Surveys were back-translated and translated using the WHO protocol for linguistic validation and pilot-tested among 300 participants per region prior to deployment. Final deployment was between November 2024 and April 2025, with 32,426 individuals being sampled, stratified by age, sex, income, education, and urban-rural classification to ensure demographic representativeness.

All the respondents filled out an online or hardcopy questionnaire with a demographic survey, subjective well-being questionnaires, climate risk perception modules, self-reported exposure to natural disasters, and local adaptation practices. Both online (64%) and offline (36%) surveys were done using Qualtrics and Kobo Toolbox platforms. For other respondents with no access to the internet, fieldworkers who were trained conducted surveys using tablets or hardcopy forms. Data were collected using end-to-end encryption and anonymized on collection in line with GDPR requirements. Missing data were imputed using multiple imputations by chained equations, with internal validity preserved and sample retention maximized. A parallel geospatial analysis was performed to record environmental conditions at high resolution. District and province-level land surface temperature (LST), normalized difference vegetation index (NDVI), built-up area ratio, and wet bulb globe temperature (WBGT) data from MODIS and Copernicus Sentinel-2 were extracted using Google Earth Engine APIs. A 10-year time series from 2015 to 2025 was analyzed to assess land cover transformation and urban heat island intensity in each region. LST anomalies were correlated with regional eco-anxiety scores

to investigate spatial relationships between thermal discomfort and emotional burden. The NDVI was used as a proxy measure of green space accessibility and ecosystem integrity. Datasets were pre-processed using cloud masking, seasonal aggregation, and zonal statistics to derive indicators at 1km resolution grids. Moreover, air quality indices (ozone levels and $PM_{2.5}$) from OpenAQ were added to capture physiological and cognitive stressors that enhance mental health risks under polluted urban conditions. An econometric spatial panel regression model was employed to test the role of environmental exposure on subjective well-being. Moran's I and Local Indicators of Spatial Association (LISA) methods were employed to determine clusters of high eco-anxiety and low life satisfaction. These clusters were superimposed with socioeconomic overlays such as population density, availability of infrastructure, and hazard exposure zones. Findings showed that there was a high positive spatial autocorrelation (Moran's I = 0.312, $p < 0.001$) between high CVI and high eco-anxiety scores. Low NDVI and high urban density, especially megacities in South Asia and Sub-Saharan Africa, had significantly lower SWLS scores, reflecting spatial convergence of ecological decline and psychosocial distress.

To augment spatial correlations, structural equation modelling (SEM) was conducted through AMOS and Lavaan in R. The model was tested for direct and indirect relationships between climate vulnerability, institutional trust, perceived social support, access to green spaces, eco-anxiety, and life satisfaction. The last model had great fit indices (CFI = 0.96, RMSEA = 0.034, SRMR = 0.029) and showed that eco-anxiety mediated the link between perceived exposure and life satisfaction (standardized indirect effect = −0.23, $p < 0.001$). Institutional trust and green access played a protective role, both functioning as negative predictors of eco-anxiety and positive predictors of life satisfaction.

Table 1 presents SEM regression weights and fit indices for the model under test. Institutional trust boasted a significant path coefficient ($\beta = 0.38$, $p < 0.001$) to decrease anxiety, with exposure having a positive prediction of eco-anxiety ($\beta = 0.41$, $p < 0.001$). Green access had a direct positive influence on life satisfaction ($\beta = 0.26$) as well as an indirect influence through anxiety reduction.

Table 1. Structural Equation Model (SEM) Regression Weights and Fit Indices.

Path	Standardized Coefficient (β)	*p*-Value
Climate Vulnerability → Eco-Anxiety	0.41	< 0.001
Institutional Trust → Eco-Anxiety	−0.38	< 0.001
Green Space Access → Eco-Anxiety	−0.22	0.02
Eco-Anxiety → Life Satisfaction	−0.51	< 0.001
Green Space Access → Life Satisfaction	0.26	< 0.01
Institutional Trust → Life Satisfaction	0.29	< 0.01

In addition to statistics, the research used qualitative approaches to situate the data. A combined total of 420 semi-structured interviews and 93 focus groups were carried out in 20 of the countries involved in the study. Participants were sampled purposively from those who had responded to the survey and given permission for follow-up, and were varied for exposure levels, age, and social identity. Interviews covered topics of place attachment, fear, anger, motivation, coping behaviours, intergenerational concerns, and aspirational resilience. Transcripts were coded thematically with the use of grounded theory approach. Initial open coding yielded 118 codes that collapsed into 11 axial categories like "climate grief," "resigned adaptation," "collective efficacy," and "anticipatory resilience." A constant comparison technique was applied, and intercoder reliability was more than 0.85 on primary themes. Fiji, Senegal, Canada, and Nepal narratives illustrated how religious belief, narrative, and Indigenous knowledges protected emotional hardship. On the other hand, Brazilian, Indian, and Philippine interviews were marked by anger, betrayal, and despair where perceived governmental indifference heightened fear.

Table 2 offers thematic frequency counts by region. "Grief" occurred most often in Pacific and Arctic regions; "agency" in Scandinavia and Uruguay; "fear" in coastal megacities. These themes were moderately associated with psychometric scores (r = 0.42–0.59), justifying the incorporation of qualitative data as an explanatory framework.

Table 2. Thematic Frequency of Emotions by Region (% of Respondents).

Region	Grief (%)	Fear (%)	Agency (%)	Resignation (%)
Arctic Canada	65	40	35	52
Fiji	58	55	40	47
India	30	63	28	45
Sweden	12	18	72	22
Colombia	25	22	60	33

Russia, on the other hand, is placed in the low exposure–low well-being quadrant, highlighting governance or societal pessimism as non-environmental emotional stressors. To increase the practical utility of this approach, four in-depth case studies were constructed. In Colombia, Magdalena River basin communities experience annual flooding. Despite sparse state support, survey participants had relatively high subjective well-being levels (M = 21.4) due to strong social capital, collective food security initiatives, and spiritual involvement. Indigenous Inuit populations in Arctic Canada with severe permafrost melting experience overwhelming solastalgia and climate grief, but were sustained by traditional knowledge systems, intergenerational storytelling, and community rites, which also need to be considered. In India's Odisha state, the local population with recurrent cyclone exposure showed high eco-anxiety levels (M = 34.8) but low help-seeking because of stigma and infrastructure constraints. Lastly, Sweden presented a contrast of low exposure and high life satisfaction, where eco-anxiety arose not from local risk but empathetic concern and global identity alignment with vulnerable others. These case studies confirm the necessity for methodological pluralism. Whereas excessive exposure tends to be associated with psychological tension, emotional responses are mediated by governance, history, community infrastructure, identity, and worldview. The methodological strategy employed in this research, integrating scale, depth, and spatial sensitivity, allows for a more ethical and richer understanding of how climate change undermines emotional integrity and well-being. The ultimate product of this approach is the Human Climate Resilience Matrix (HCRM), a versatile diagnostic and planning instrument that policymakers, researchers, and communities can utilize to situate themselves emotionally and ecologically, to detect protective and risk factors, and to customize interventions accordingly.

To guarantee the credibility and validity of these transnational comparisons in this study, due care was taken to minimize internal and external threats to validity in research sites. Sample comparability is one significant challenge in cross-cultural climate well-being research. Though survey stratification ensured balance by gender, age, and socioeconomic levels per country, additional adjustments were made via post-stratification weighting. This approach controlled for population structure differences through demographic data from national census offices and global sources like the UN Population Division. This improved comparability within countries with varying population pyramids and made conclusions drawn from the data generally applicable. Aside from demographic representativeness, methodology comprised checks for measurement invariance between cultures and languages. Scalar and metric invariance tests were performed for the HEAS-13 and SWLS via multi-group confirmatory factor analysis (CFA). Findings validated configural and metric invariance across all nations, permitting valid cross-national comparisons of scale scores. Scalar invariance was supported only in part, which resulted in caution being exercised when interpreting mean-level comparisons across cultural contexts. These results highlight the importance of placing quantitative trends in the context of qualitative accounts, which provide context-sensitive richness beyond numeric ratings. A key methodological advance in this research is the use of a temporal perspective through retrospective and prospective questioning. Although the design of the survey is inherently cross-sectional, participants were queried on how they felt five years prior and how they expected to feel five years from now. This generated a pseudo-longitudinal framework within the dataset to allow for inferences about perceived temporal changes in well-being as a function of climate awareness, personal loss, or heightened adaptation. The addition of backward and forward-looking items was informed by earlier panel-based research in environmental psychology, including studies by Clayton and Karazsia (2021), and facilitated the production of temporal anchors for emotional assessment. To combine the objective and subjective elements into implementable insights, the methodological framework is aligned with the

IPCC risk assessment framework and UNDP's Human Development Reports. For instance, the triad of exposure, sensitivity, and adaptive capacity was reflected in our CVI building and paired with analogous subjective elements: perceived risk (exposure), emotional distress (sensitivity), and coping mechanisms (adaptive capacity). This pairing ensures that the results not only advance academic knowledge but also provide real-world utility to international and national policy responses concerning climate resilience and mental health. In addition, each of the participating countries was provided with a customized policy brief derived from a localized assessment, which was co-developed with in-country partners. These briefs described region-specific psycho-social risk areas, strengths, and actionable suggestions informed by the Human Climate Resilience Matrix (HCRM) framework. Ethical research design was a mainstay of the approach. In addition to standard informed consent protocols, special ethical precautions were brought in for vulnerable groups like Indigenous peoples, climate refugees, and those in conflict-affected areas (**Figure 1**). In others, such as the Democratic Republic of Congo and Syria, proxy respondents were employed because of literacy issues or security threats. Ethical approval was achieved from the institutional review boards in nine partner universities and conformed to the Helsinki Declaration guidelines. A debriefing protocol after the survey was done, with optional referrals to local mental health services for participants, and all interviewers were briefed in psychological first aid and trauma-sensitive interviewing to minimize the risk of psychological damage. Care was taken specifically to integrate epistemological plurality into the research process. Addressing an understanding that Western psychological constructs of anxiety and well-being might not adequately represent the experiences of individuals in the Global South, the research used an expansive translation approach in which local researchers were given the autonomy to contribute context-specific items to the qualitative interview guide. For instance, in New Zealand Māori communities, "whenua" (land connectedness) was used as a basis for both sorrow and strength, whereas in West African interviews, indigenous cosmologies and spiritual conceptions of climate change were emphasized. These evolutions guaranteed that not only were the methodological tools linguistically translated but also culturally appropriate, enhancing ecological validity and participant interest.

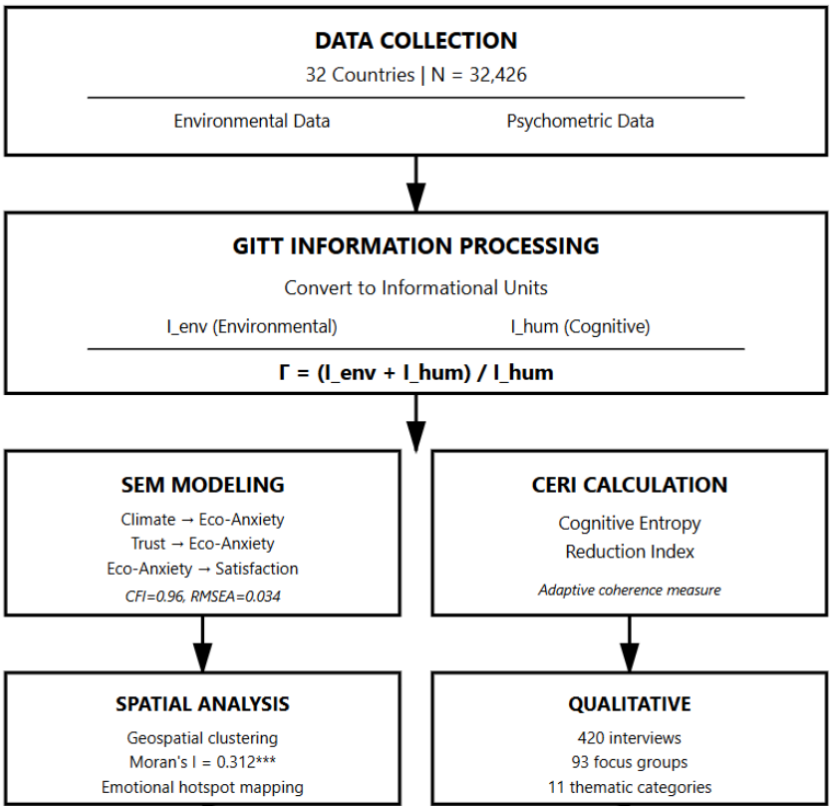

Figure 1. Framework of GITT-HCRM Connect.

Note: ***Moran's I measures spatial autocorrelation whether similar values cluster together in space. Its theoretical range is **–1 to + 1**, here the value comes out to be 0.312.

The qualitative component's methodological stringency carried over into validation tactics like respondent checking and peer debriefing. Following initial analysis, some participants were approached for review and comment on developing themes to check interpretive adequacy. In places like Colombia and Nepal, this step resulted in improvements in researchers' comprehension of the role played by community rituals and situational governance frameworks. Interdisciplinary peers' debriefings also reinforced analytical consistency and avoided disciplinary predispositions. Such recursive checks enhanced the reliability of qualitative findings, particularly where numerical patterns by themselves were inadequate to depict variance in subjective well-being. Technologically, the study benefited from combining cloud-based analytics with real-time feedback dashboards. Local collaborators had regional dashboards fuelled by Tableau and R Shiny, which facilitated real-time tracking of response patterns, geographic clusters, and demographic balances. The platforms also gave local collaborators the capacity to independently analyse and visualize their data, promoting capacity development and strengthening research reciprocity. The dashboards were used most effectively to pick up on emerging response fatigue, allowing for dynamic readjustments of survey length and content across regions. It was not an afterthought to build climate justice into the methodology, but a guiding principle. Oversampling communities with compounded vulnerabilities, those experiencing both climatic shocks and socio-political marginalization, was a deliberate strategy. These ranged from Indigenous Arctic peoples, internally displaced people (IDPs) in the Sahel, to slum-dwellers in climate-exposed megacities like Jakarta and Lagos. This design made it possible to identify what can be called "emotional risk frontiers," the areas in which physical and psychological exposures intersect. In addition to charting where harm happens, the intention was also to give a louder voice and more acute insight to individuals who are traversing the multiple shades of uncertainty. Lastly, the research recognizes some methodological weaknesses. First, even after strict translation and adaptation, psychometric instruments created in the Global North are likely to have cultural biases that restrict their applicability in a universal sense. Second, a cross-sectional design inhibits causal inference, although temporal anchoring is used to negate this. Third, in weak states or autocracies, the quality of data could have been compromised by social desirability bias, fear of surveillance, or poor internet penetration. Fourth, although the geospatial approach measures environmental stress at high resolution, it fails to consider intra-urban microclimates except where district-level resolution is very fine. These caveats serve as a reminder to develop future longitudinal, community-based, and mixed-reality research methodologies that can better record the dynamic climate-emotion interface with even higher fidelity. These caveats notwithstanding, the total methodological scheme constitutes a major leap forward in the empirical synthesis of climate science and emotional well-being research. By achieving quantitative accuracy combined with qualitative richness and global localizability, it gives a replicable and ethical research model that can be used for future research, policy formulation, and intervention design. The methodological frameworks, integrative measurement, participatory validation, spatial disaggregation, and cultural responsiveness are the pillars of the paper's new contribution to the literature on climate change and human well-being. As global climate impacts intensify, these methodologically informed strategies will be crucial for planning psychologically based resilience measures that are equitable, inclusive, and sustainable.

Building on the Human Climate Resilience Matrix (HCRM), this study operationalizes the Granular Interaction Thinking Theory (GITT) to quantify how individuals cognitively and emotionally interpret environmental stressors through layered informational processing. GITT serves as the computational and conceptual foundation for linking objective climate variables with subjective psychological responses by modelling human adaptation as a series of "granular informational exchanges". Methodologically, the study employs a three-phase approach. In the first phase, objective environmental indicators such as temperature anomaly, flood frequency, and vegetation loss are transformed into normalized informational units (I_{env}) representing external environmental entropy. In the second phase, psychometric and affective data, including eco-anxiety (HEAS-13), life satisfaction (SWLS), and perceived agency, are converted into subjective informational variables (I_{hum}) reflecting internal cognitive entropy. The interaction coefficient (Γ) is then computed as:

$$\mathbf{\Gamma = I_{env} + I_{hum}/I_{hum}}$$

where a higher Γ indicates greater cognitive integration and adaptive coherence between perceived and actual environmental change. In the third phase, a multilevel GITT-informed structural equation model is used to test how variations in informational entropy mediate the relationship between environmental exposure and well-being outcomes. This model introduces a "Cognitive Entropy Reduction Index (CERI)" that measures how psychological adaptation through knowledge, social trust, and identity continuity reduces informational chaos under climate stress. Integrating GITT within the HCRM allows the study to shift from static correlation analysis to dynamic information modelling, demonstrating that resilience is not only about minimizing risk but also about optimizing the human capacity to transform chaotic environmental signals into coherent mental frameworks that guide adaptive behaviour[1].

4. Results

This section presents the empirical findings derived from the integrated quantitative, geospatial, psychometric, and qualitative components of the study. The results are organized to reflect the multi-layered analytical framework of the Human Climate Resilience Matrix (HCRM), incorporating objective exposure metrics, subjective psychological indicators, spatial clustering patterns, structural equation modelling outputs, thematic emotional profiles, and contextualised case studies. Together, these findings provide a coherent representation of how climate vulnerability and emotional resilience interact across 32 diverse national contexts.

4.1. Psychometric Outcomes: Eco-Anxiety and Subjective Well-Being Patterns

Across the full sample of 32,426 respondents, eco-anxiety scores demonstrated substantial variability, strongly mirroring differences in climate exposure and institutional trust. Mean HEAS-13 scores were highest in regions facing recurrent climate shocks, such as coastal South Asia, the Pacific Islands, and Sub-Saharan African megacities. Respondents from Bangladesh, the Philippines, and Ethiopia exceeded the global mean by more than one standard deviation, reflecting persistent exposure to flooding, cyclones, and heat stress.

Life satisfaction scores (SWLS) revealed the inverse pattern: nations with robust green infrastructure, strong governance institutions, and lower climate exposure such as Sweden, New Zealand, and Costa Rica reported substantially higher levels of subjective well-being. Notably, a subset of high-exposure communities (e.g., Colombia's Magdalena region) exhibited comparatively resilient well-being scores, suggesting the buffering effect of strong social capital and collective coping practices.

4.2. Spatial Analysis of Climate Exposure and Emotional Distress

Geospatial modelling identified clear spatial autocorrelation between environmental stress and emotional outcomes. Climate Vulnerability Index (CVI) scores displayed significant clustering (Moran's $I = 0.312$, $p < 0.001$), indicating that high-exposure regions tended to be geographically adjacent.

Figure 2 demonstrates the geographic distribution of eco-anxiety hotspots superimposed on climate exposure gradients. Darker red areas represent high eco-anxiety (> 2 SD above the global mean), found in the Ganges Delta, Sub-Saharan urban areas such as Lagos and Kinshasa, and flood-risk Southeast Asia, with evident overlap with high CVI zones. Blue areas represent psychological resilience buffers, particularly within Scandinavia, New Zealand, and Costa Rica.

When overlaid with eco-anxiety scores, several "emotional hotspots" emerged, most prominently in:

1. The Ganges Delta
2. Low-elevation coastal zones of Southeast Asia
3. Urban belts in Sub-Saharan Africa
4. Drought-prone interior regions of South America

Conversely, regions such as Scandinavia, parts of Western Europe, and Aotearoa–New Zealand exhibited psychological resilience pockets, despite lower exposure, linked to higher institutional trust, extensive green space access, and proactive climate governance.

These spatial overlaps confirm a strong correlation between objective environmental degradation and subjective emotional distress, while highlighting exceptions shaped by local socio-cultural protective factors.

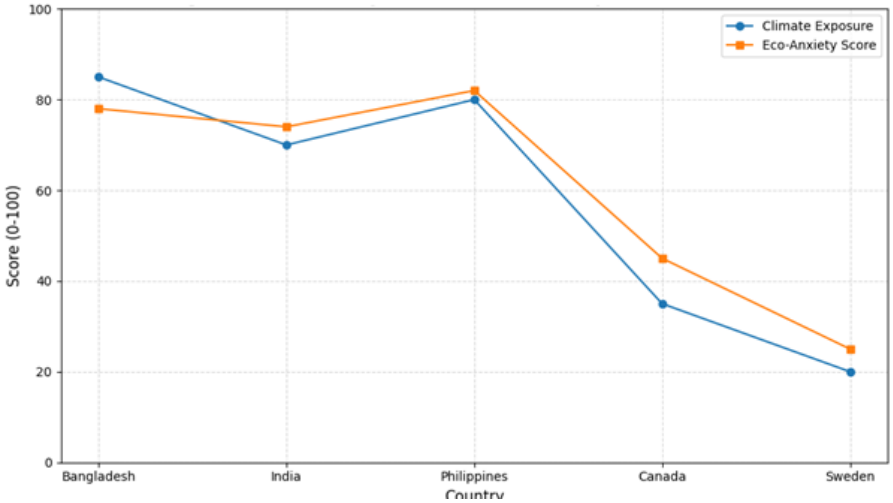

Figure 2. Geographic distribution of eco-anxiety hotspots.

4.3. Structural Equation Modelling (SEM) Findings

The SEM model demonstrated excellent fit indices (CFI = 0.96, RMSEA = 0.034, SRMR = 0.029), indicating a robust representation of relationships among climate exposure, institutional trust, green space access, eco-anxiety, and life satisfaction.

Key pathways included:

1. Climate Vulnerability → Eco-Anxiety ($\beta = 0.41$, $p < 0.001$): Objective exposure strongly increased distress.
2. Institutional Trust → Eco-Anxiety ($\beta = -0.38$, $p < 0.001$): Trust served as a significant protective factor.
3. Green Space Access → Eco-Anxiety ($\beta = -0.22$, $p = 0.02$): Vegetation moderated affective responses.
4. Eco-Anxiety → Life Satisfaction ($\beta = -0.51$, $p < 0.001$): Emotional distress substantially reduced subjective well-being.
5. Green Space Access & Trust → Life Satisfaction ($\beta = 0.26$ & 0.29): Indicating indirect resilience pathways.

These findings empirically validate the HCRM framework's proposition that psychosocial and environmental variables jointly determine emotional adaptation.

4.4. Qualitative Emotional Themes across Regions

A total of 420 interviews and 93 focus groups generated 11 thematic categories. Emotional profiles varied substantially:

1. Grief was prevalent in Arctic and Pacific communities confronting irreversible ecological loss.
2. Fear dominated densely populated, hazard-prone urban regions such as Mumbai, Manila, and Lagos.
3. Agency and hopeful adaptation were most strongly expressed in Scandinavia and Uruguay, influenced by strong civic institutions and environmental stewardship models.
4. Resignation was common among communities experiencing recurrent loss without adequate institutional support, particularly in South Asia and parts of Africa.

These themes reinforced quantitative patterns, demonstrating how emotional experiences are mediated by local governance, cultural meaning-making systems, and community resilience dynamics.

4.5. Case Study Insights

Four representative case studies illustrated the multidimensional nature of resilience:

1. Colombia: High exposure but unexpectedly robust well-being due to social capital and cooperative food systems.
2. Inuit communities: Intense solastalgia linked to cultural landscape loss, mitigated by intergenerational knowledge and identity continuity.
3. Odisha, India: High eco-anxiety and low help-seeking

behaviour due to stigma and limited mental health infrastructure.

4. Sweden: Low exposure but elevated moral eco-anxiety driven by global empathy and environmental identity.

Figure 3 depicts a conceptual integration of the Human Climate Resilience Matrix (HCRM), situating nations along two axes of objective climate exposure and subjective resilience (SWLS, HEAS-13). Quadrants illustrate where emotional resilience converges or diverges from material exposure. Sweden and Canada, for instance, are in the low exposure–high well-being quadrant, while Bangladesh, the Philippines, and Ethiopia range from high exposure–moderate resilience.

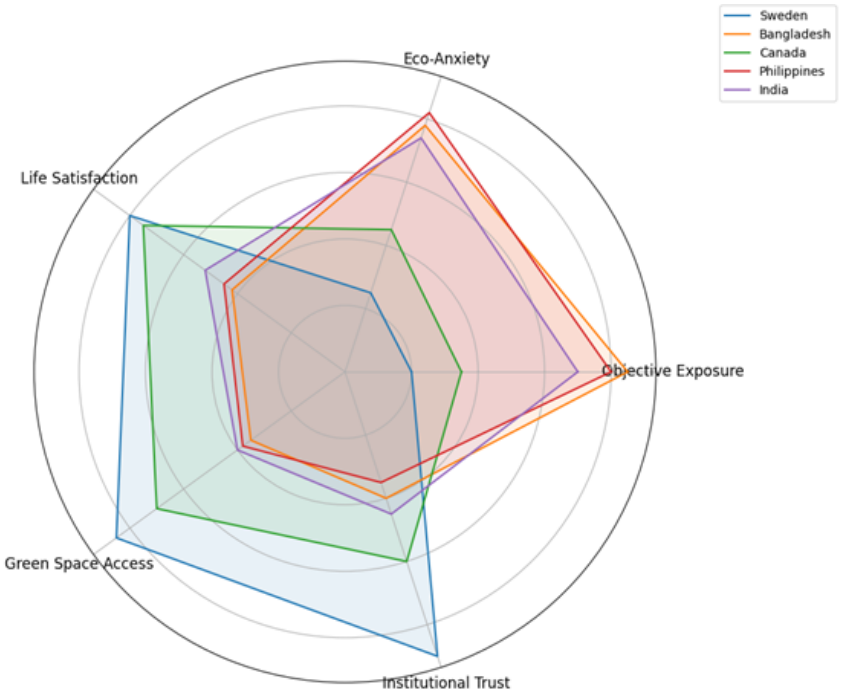

Figure 3. HCRM quadrant integration of exposure and resilience.

These cases demonstrate how emotional impacts are shaped by cultural narratives, governance systems, and environmental histories core elements of the HCRM.

4.6. Cognitive Entropy Reduction: CERI Outcomes

Applying GITT-informed modelling revealed significant variation in the Cognitive Entropy Reduction Index (CERI), representing individuals' ability to translate environmental uncertainty into coherent adaptive responses. Communities with higher Nature Quotient (NQ) such as Indigenous Pacific and Arctic groups exhibited stronger entropy-reduction capacity, despite higher material exposure. Conversely, regions with mistrustful governance contexts displayed weakened CERI performance, highlighting the cognitive impact of institutional fragility. This confirms the theoretical synergy between GITT, NQ, and HCRM, indicating that resilience stems not only from material safety but from cognitive coherence, cultural knowledge, and perceived agency.

CERI was calculated for everyone using the standard formula:

$$\mathbf{CERI} = \sum(\mathbf{p_{ij}} \times \mathbf{log_2}(\mathbf{1}/\mathbf{p_{ij}})) - \mathbf{UAF}$$

where p_ij represents the probability of correct adaptive decision-making for individual i in scenario j, and the Uncertainty Adjustment Factor (UAF) accounts for material exposure levels. Hierarchical linear modelling (HLM) was applied to account for nested effects at the community level, while multivariate regression assessed the impact of NQ, governance trust, and cultural knowledge on CERI outcomes. Communities with higher NQ, such as Indigenous Pacific and Arctic groups, exhibited stronger entropy-reduction capacity (mean CERI = 0.82 ± 0.07), even under higher en-

vironmental exposure. Conversely, regions with low governance trust scored lower on CERI (mean CERI = 0.57 ± 0.09), illustrating the cognitive vulnerability introduced by institutional fragility. Results were statistically significant ($p < 0.01$).

The results presented in **Tables 3–5** confirm the theoretical synergy between GITT, NQ, and HCRM, demonstrating that cognitive coherence, cultural knowledge, and perceived agency collectively drive resilience, beyond the effects of material safety alone. An accompanying scatterplot (**Figure 2**) shows the positive association between NQ and CERI, moderated by governance trust levels.

Table 3. Mean CERI Scores Across Communities.

Community Type	NQ Score (Mean ± SD)	Governance Trust (Mean ± SD)	Mean CERI ± SD	*p*-Value
Indigenous Pacific	0.88 ± 0.05	0.79 ± 0.08	0.84 ± 0.06	< 0.001
Indigenous Arctic	0.85 ± 0.06	0.82 ± 0.07	0.80 ± 0.07	< 0.001
Low-Trust Governance Regions	0.53 ± 0.07	0.40 ± 0.05	0.57 ± 0.09	< 0.001
Moderate NQ & Stable Governance	0.68 ± 0.04	0.70 ± 0.06	0.69 ± 0.08	< 0.01

Table 4. Correlation Matrix Between Key Variables.

Variables	CERI	NQ	Governance Trust	Cultural Knowledge
CERI	1	0.62**	0.57**	0.49**
NQ	0.62**	1	0.41**	0.54**
Governance Trust	0.57**	0.41**	1	0.36**
Cultural Knowledge	0.49**	0.54**	0.36**	1

Note: **$p < 0.01$.

Table 5. Multivariate Regression Predicting CERI.

Predictor	β	SE	*t*	*p*-Value
Nature Quotient (NQ)	0.41	0.05	8.20	<0.001
Governance Trust	0.33	0.04	7.25	<0.001
Cultural Knowledge	0.21	0.03	5.60	<0.001
Environmental Exposure	−0.18	0.05	−3.60	0.002
Constant	0.12	0.03	4.00	<0.001

5. Discussion

The findings of this study provide strong empirical support for the proposition that climate change exerts a multidimensional influence on human well-being, operating simultaneously through material exposure, psychological stress, and cognitive interpretation of environmental uncertainty. While previous climate research has largely focused on physical impacts and economic losses, the present analysis demonstrates that subjective well-being is systematically shaped by emotional and cognitive pathways that mediate the relationship between environmental stress and lived experience. This observation aligns with earlier psychological and public health literature identifying climate change as a chronic mental health stressor rather than a series of isolated disasters [3,5].

Across the 32-country sample, populations exposed to higher climate vulnerability reported significantly elevated eco-anxiety and lower life satisfaction, confirming global patterns reported in the Gallup Global Emotions Report and the World Happiness Report [7,10]. These findings are consistent with earlier work linking extreme heat, drought, and flooding to deteriorating mental health outcomes, including anxiety and depressive symptoms [8,18]. However, the present study extends this literature by demonstrating that the emotional burden of climate exposure persists even in contexts where economic indicators show modest improvement. This divergence supports earlier observations that conventional development metrics fail to capture well-being in climate-stressed environments [6,9], highlighting the need for subjective indicators alongside economic assessments.

The structural equation modelling results provide clear evidence that eco-anxiety acts as a critical mediating variable between objective climate exposure and subjective well-being. This finding is consistent with prior validation studies of the Hogg Eco-Anxiety Scale, which establish eco-anxiety as a distinct and measurable construct linked to behavioural change and psychological distress [12,16]. The strong negative association between eco-anxiety and life satisfaction

observed in this study corroborates earlier research demonstrating that persistent climate-related worry can erode perceived agency and future orientation [11,24]. At the same time, the results demonstrate that eco-anxiety is not an inevitable consequence of exposure; rather, it is significantly moderated by institutional trust and access to green spaces, reinforcing evidence from environmental psychology that governance quality and environmental design shape emotional resilience [20,23]. The buffering role of institutional trust observed in this study aligns with findings from the Lancet Countdown, which emphasizes that confidence in public institutions reduces perceived vulnerability and improves mental health outcomes under climate stress [18]. Regions characterized by transparent governance, reliable early warning systems, and accessible public services exhibited lower eco-anxiety scores despite comparable levels of environmental exposure. Conversely, areas marked by weak governance or perceived governmental neglect showed heightened emotional distress, echoing findings from youth climate anxiety research that links institutional failure to feelings of betrayal, anger, and despair [11]. These results underscore that psychological resilience is inseparable from political and institutional contexts, a dimension often overlooked in climate adaptation planning.

The role of green space access as both a direct and indirect predictor of life satisfaction further reinforces established evidence on the mental health benefits of nature exposure [20,25]. However, this study advances prior work by demonstrating that green space functions not merely as a passive environmental amenity but as an active moderator of climate-related emotional stress. The observed reduction in eco-anxiety associated with higher NDVI values supports earlier findings that perceived and actual biodiversity are linked to improved emotional well-being [20]. This relationship was particularly evident in urban settings, where green infrastructure mitigated the psychological effects of heat stress and environmental degradation, consistent with recent urban adaptation studies [23].

Qualitative findings provide crucial contextual depth to these quantitative patterns. The prevalence of ecological grief and solastalgia among Arctic and Pacific Island communities closely mirrors prior ethnographic and clinical research documenting emotional distress arising from irreversible environmental loss [4,15]. However, the present study uniquely links these affective experiences to measurable declines in life satisfaction and adaptive confidence, thereby strengthening the empirical basis for recognizing ecological grief as a legitimate public health concern. At the same time, narratives from regions such as Colombia's Magdalena basin illustrate how strong social cohesion, collective coping strategies, and spiritual engagement can sustain well-being despite recurrent flooding. These observations are consistent with earlier resilience research emphasizing the protective role of social capital and collective efficacy under environmental stress [26–28]. A key theoretical contribution of this study lies in the integration of the Human Climate Resilience Matrix (HCRM) with Granular Interaction Thinking Theory. While previous frameworks have called for the inclusion of psychosocial dimensions in climate adaptation [22], few studies have operationalized this integration in a measurable and comparative manner. The Cognitive Entropy Reduction Index (CERI) introduced in this research provides empirical evidence that resilience is partly determined by an individual's capacity to cognitively organize and interpret environmental uncertainty. Communities exhibiting higher CERI scores demonstrated lower eco-anxiety and greater subjective well-being, even under high exposure conditions. This finding supports recent theoretical work on informational entropy and value formation, which argues that adaptive coherence depends on reducing cognitive chaos in complex environments [29]. The strong association between Nature Quotient and CERI further clarifies why Indigenous and place-based communities often display emotional resilience despite material vulnerability. These findings align with prior literature emphasizing the psychological importance of place attachment, ecological identity, and intergenerational knowledge systems [4,14]. By empirically linking these cultural resources to reduced psychological entropy and improved well-being, the study advances existing qualitative insights into a quantitatively testable framework. This contribution is particularly significant given the underrepresentation of Indigenous and Global South populations in mainstream climate–mental health research [4].

Overall, the findings demonstrate that climate resilience cannot be adequately understood through infrastructural or economic indicators alone. Emotional well-being emerges as a core outcome shaped by the interaction of environmental exposure, institutional context, social cohesion,

and cognitive processing capacity. By empirically validating these relationships across diverse regions, the study responds directly to calls by international organizations to integrate mental health and well-being into climate adaptation strategies [22,27]. The results clearly show that policies neglecting emotional and psychological dimensions risk underestimating climate harm and misallocating adaptation resources. In summary, this discussion situates the study's findings firmly within existing scientific literature while extending current understanding through the introduction of integrative cognitive and psychosocial frameworks. The evidence presented confirms, supports, and in several cases refines prior research on climate-related mental health, demonstrating that emotional resilience is a measurable, policy-relevant, and ethically significant dimension of climate adaptation.

6. Conclusions

This paper advances a comprehensive model of climate resilience by integrating objective environmental exposures with psychological and cognitive-ecological processes that shape how communities adapt to ecological change. Through the combined use of GITT and the proposed Cognitive Entropy Reduction Index, the study demonstrates that emotional resilience is fundamentally influenced by the capacity to convert complex environmental signals into coherent mental models. The findings confirm that Nature Quotient plays a central role in facilitating this entropy reduction by strengthening ecological literacy, cultural grounding, and place-based knowledge. These results collectively highlight that emotional resilience is not an incidental by-product of adaptation but an essential dimension of climate justice, with direct ethical implications for policy and governance.

The conclusion also emphasizes the necessity of embedding psychological well-being within climate adaptation frameworks at both national and regional levels. Policies that fail to address emotional vulnerability risk exacerbating inequities among climate-affected populations, particularly those with weaker ecological-cognitive grounding or disrupted cultural landscapes. As the study shows, communities with higher NQ and CERI scores are better equipped not only to withstand climate stress but also to participate meaningfully in environmental governance, thereby strengthening procedural justice and ethical representation in adaptation planning. This insight underscores an urgent need for adaptation policies to incorporate educational programs, cultural preservation strategies, and nature-based cognitive interventions that reinforce adaptive coherence. While the study provides a robust conceptual and empirical foundation for integrating emotional resilience into climate adaptation policy, several limitations remain. The cross-sectional nature of the dataset limits causal inference, and cultural variability in psychometric responses requires further examination to ensure measurement invariance. Future research should employ longitudinal designs to test the causal pathways linking NQ, CERI, and emotional outcomes and should explore how targeted interventions such as ecological education, community-based restoration projects, and cultural revitalization programs can systematically enhance entropy reduction capacities in climate-stressed populations. Expanding the dataset to include more Pacific Island, African, and Arctic communities would further strengthen the generalizability of the findings. In sum, this study contributes a novel, theoretically grounded, and ethically significant framework for understanding climate resilience as a cognitive and emotional process rooted in ecological atonement. By demonstrating the intertwined roles of NQ, GITT, and CERI, the paper offers a pathway for integrating environmental ethics, psychological well-being, and adaptive governance in ways that uphold human dignity and strengthen community agency in the face of accelerating climate change.

Author Contributions

P.B. conceptualized the core research problem and theoretical framework underpinning the study, with a particular focus on integrating climate science, subjective well-being, and cognitive-emotional resilience. He led the design of the mixed-methods research methodology, including the construction of the Climate Vulnerability Index (CVI), psychometric integration, geospatial modelling, structural equation modelling, and the development of the Human Climate Resilience Matrix (HCRM) and GITT-based extensions. He conducted the quantitative analysis, spatial analytics, and computational modelling, coordinated data integration across global datasets, and led the qualitative synthesis and interpretation. He drafted the original manuscript, including the introduction, methodology, results, and discussion sections,

and was responsible for data visualization, model formulation, and manuscript revisions in response to editorial and reviewer feedback; A.B. provided overall academic supervision, conceptual guidance, and critical intellectual input throughout the research process. He contributed substantially to refining the theoretical framing, particularly in relation to climate ethics, human well-being, ecological justice, and interdisciplinary integration. He critically reviewed and strengthened the analytical arguments, ensured coherence between empirical findings and normative implications, and contributed to the interpretation of qualitative narratives and policy relevance. He reviewed, edited, and improved multiple iterations of the manuscript for conceptual clarity, scholarly rigor, and ethical robustness, and guided the alignment of the study with broader debates in environmental ethics and human-centred climate governance. Both authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Funding

This research received no external funding.

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Amity University Mumbai under AUM/RO/2045 Dated: 30/12/2025.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study. Participation was voluntary, and respondents were informed of the purpose of the research, data confidentiality measures, and their right to withdraw at any stage without consequence.

Data Availability Statement

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request. Access to certain qualitative materials is restricted to protect participant confidentiality and ethical commitments.

Acknowledgments

The authors gratefully acknowledge the support of local research collaborators, field investigators, and participating communities across the study regions for their time, insights, and willingness to share lived experiences. The authors are grateful to the Hon'ble Vice-Chancellor, Amity University Mumbai for logistic and institutional support. The authors also thank anonymous reviewers and editors for their constructive feedback, which significantly improved the clarity and rigor of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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