SCIENTIFIC Publishing Limited

Prevention and Treatment of Natural Disasters
https://ojs.ukscip.com/index.php/ptnd

Short Communication

Evaluating the Inequity Impact of Climate Change on Urban and Rural Communities

Sung Hee Joo *

Department of Engineering & Engineering Technology, College of Aerospace, Computing, Engineering, and Design, Metropolitan State University of Denver, Denver, CO 80204, USA
* Correspondence: sujoo@msudenver.edu

Received: 26 March 2024; **Revised**: 2 May 2024; **Accepted**: 14 May 2024; **Published**: 27 May 2024

Abstract: Extreme weather (heat waves, floods, drought, tropical storms, and tornados) has intensified as a result of climate change. In particular, the effects of climatic hazards on remote communities are more severe due their limited access to resources (e.g., health, socio-economics, sewer, stormwater, and drinking water systems), causing a dichotomy between urban cities and remote regions. For example, unknown and potentially emerging contaminants present in floodwater have detrimental effects on rural communities, causing an increased number of deaths given their lack of access to public health resources. Meanwhile, urban cities continuously rely on the natural resources of those same rural communities to confront climate change-induced natural disasters. This paper contributes to the development of a climate change resilience framework for urban and rural communities, exploring the approaches in mitigating disparate impacts between the two communities. Several discussions from the perspectives of policy and technical methodologies are provided, including watershed management. Furthermore, through analysis, this study outlays future directions and suggested resolutions of the inequity impact of climate change on rural and urban communities.

Keywords: climate change; resilience; disparate impacts; rural communities; access to resources

1. Introduction

Climate change has brought increasingly disparate impacts to urban and rural communities. A comprehensive understanding of climate change mitigation measures, climate change adaptation, adaptation feasibility, and critical factors affecting these disparate impacts is needed to minimize the environmental effects and mitigate the disparate impacts of climatic hazards on urban and rural communities through sustainable approaches suitable for both regions. The climate change brought to urban areas is characterized by increased surface runoff, high temperatures, and reduced evaporation compared to rural areas due to urbanization (e.g., the altered surface cover of an urban area) [1]. These distinctive characteristics of urban areas could become more substantial because of climate change. This paper reviews sustainable approaches to mitigating climatic hazards and analyzes the disparate impacts of climate change on rural versus urban communities. By analyzing climate change adaptation strategies and feasibility, suggested resolutions applicable to urban and rural communities are drawn and future research needs are recommended.

2. Methodology

The following research questions have arisen in each subsection (i.e., Perspectives on Sustainable Approaches to Mitigating Climatic Hazards; Sustainable Approaches, Including Watershed Management,

Involving Policy and Technical Methods; Review of the Disparate Impacts of Climatic Hazards on Rural Versus Urban Communities) on the analysis of inequity effects of climate change on rural and urban communities.

Question 1: What are the mitigation measures needed to address the disparate impacts of climatic hazards on urban and rural communities? What are considered to be sustainable approaches in mitigating climate change?

Question 2: To what extent could watershed management, involving policy and technical methods, be sustai nable? What are the climate change adaptation options in the water sector?

Question 3: What is the climate change adaptation feasibility in urban cities and rural regions? Could the fea sibility difference attribute to the disparate impacts on urban cities and rural regions?

Question 4: What are the climate change adaptation strategies? Do the strategies differ between urban and rural communities?

The literature search was focused on addressing the aforementioned research questions. Articles were sorted by those that specifically addressed the research questions and those that included broad and relevant content, which itself was then further sorted by critical to less critical. Various search tools were then applied, including ScienceDirect (https://www.sciencedirect.com), PUBMED (https://pubmed.ncbi.nlm.nih.gov), ACS (https://pubs.acs.org), Auraria Library (https://library.auraria.edu), CAS Source Index, and Google, as well as diverse internet resources (e.g., news media, press releases, and reports).

3. Analysis of the Inequity Effects of Climate Change on Rural and Urban Communities

3.1. Perspectives on Sustainable Approaches to Mitigating Climatic Hazards

Climate change has been a global challenge in various respects. Among these aspects, extreme weather conditions such as flooding, drought, and wildfires have caused substantial economic losses, threatening public health with increasing death rates. Unfortunately, global warming is expected to continue unless the current emission rates stop increasing. Under climatic hazards, some of the vulnerabilities identified include water resources, human health, ecosystems, food production, and infrastructure, which motivate setting the goal to limit temperature increase to 1.5 °C instead of 2 °C [2]. To mitigate fossil-based CO_2 emissions, the conventional negative emissions technologies (e.g., focusing on atmospheric carbon to reduce CO_2) are insufficient to meet the future goal set by the Paris Agreement, requiring the exploration of alternative methods for achieving net-zero CO_2 emissions. One alternative is biogenic-based sequestration techniques and radiative forcing geoengineering technologies through temperature stabilization [2]. However, it appears that more than one alternative method will need to be applied to address climatic hazards.

To cope with climate change, developing sustainable approaches, monitoring sustainability, evaluating assessment measures, and implementing adaptation and mitigation actions should be equally critical for future resilient urban and rural communities. Globally, numerous cities have been devoted to decreasing greenhouse gas (GHG) emissions. The climate change mitigation and adaptation actions of the Climate Change Action Plans were applied in only a few cities, which were faced with implementing more tasks in urban planning toward mitigation and adaptation [3]. With the co-benefits of mitigation and adaptation linked to sustainable development goals (SDGs), most cities accomplished SDG 1 (no poverty), SDG 11 (sustainable cities and communities), and SDG 13 (climate action), whereas almost no benefits were apparent in SDG 4 (quality education), SDG 5 (gender equality), SDG 7 (affordable and clean energy), and SDG 17 (partnership for the goals) [3]. An effective approach with unified, harmonized, and synergistic action is suggested for mitigating climate change to realize a more sustainable society in the future [4]. Nature-based approaches (climate change mitigation and adaptation), namely, ecosystem-based approaches, target slowing GHG emissions increase and preserving ecosystems to reduce the negative effects of climate change [5].

Primary mitigation technologies involving carbon capture and storage (CCS) (reducing current GHG emissions) and negative emissions technology (recapturing previous GHG emissions) are also suggested to achieve net-zero CO_2 emissions [6]. However, in reviewing assessment criteria, Haszeldine et al. (2018) [6] evaluated several technologies, including CCS, bioenergy with carbon capture and storage (BECCS), soil carbon and biochar (SCB), enhanced weathering (EW), afforestation (AFF), subsurface mineralization (SM), ocean direct injection (ODI), ocean alkalinity (OA), and direct air capture (DAC) in terms of theory, pilot operation, full operation, monitoring, security, and finance.

Theoretically, several technologies (i.e., CCS, BECCS, SCB, EW, AFF, and SM) are ready for application, whereas other technologies (i.e., ODI, OA, and DAC) are not fully ready. Most technologies failed financially, and full operation was not tried, although complete pilot operations were implemented from CCS, BECCS, and AFF, with partial monitoring in most technologies. Methods involving the distribution of zero-carbon energy technology, an energy transition from fossil fuels to renewables, and maximizing efficiency should be considered.

3.2. Sustainable Approaches Including Watershed Management Involving Policy and Technical Methods

Several case studies [7–10] have shown sustainable approaches tailored to urban and rural areas. As an example, the national-level Campaign-Based Watershed Management (CBWM) program introduced to farmers in Boset District, Ethiopia, demonstrates that sustainability is feasible with a focus on small watersheds, accessibility to micro-watersheds, local livelihood opportunities, improved performance and commitment of local leaders, and enhancement of farmers' education and motivation, along with a proactive planning approach on a socio-economic and biophysical framework [3].

Several factors were identified, including internal (e.g., watershed attributes, household attributes, the performance of actors and rules) and external factors (social and physical environments) in all three (planning, implementation, and post-implementation) stages of participation in the CBWM program [3]. In Southwest Ethiopia, the Ethiopian government introduced integrated watershed management in climate change adaptation as an adaptation program, revealing the efficacy of policy involvement in climate adaptation for rural areas [11]. This case study illustrates a successful environmental management and climate adaptation strategy with policy intervention for rural living, where climate change impacts vary.

In Indonesia, watershed management becomes ineffective primarily because of natural disasters (e.g., land degradation and climate-induced disasters) caused by an increasing climate change impact, suggesting that alternative approaches to watershed management, including community intervention, proper management in vulnerable regions, and collaboration among stakeholders and the government, are essential [10]. Based on the aforementioned case studies, it appears that government and private sector support, proper resource management, and community involvement with transparency are among the key strategies for sustainable watershed management in the climate adaptation of rural regions.

Increasing climatic hazards intensify water scarcity, leading to the implementation of several adaptation options in the water sector. Two case studies on flood management in Jakarta and Rotterdam and community-based watershed management in India and the dry corridor of Central America (Guatemala and Honduras) indicate that in rural areas, irrigation efficiency improvement (e.g., drip irrigation and watershed management) has several benefits, including feasibility and cost-effectiveness, despite issues with replicability and institutional barriers.

In contrast, in urban areas, flood management was demonstrated to be technologically feasible despite barriers to limit this feasibility due to unsuitable institutional measurements [12]. The adaptation feasibility was suggested on the basis of six dimensions: economic (cost and benefits related to an adaptation option), technological (technological knowledge and associated resources), institutional (accountability and transparency), socio-cultural factors, environmental, and geophysical (examining the potential physical barriers) aspects [12].

Several case studies of various countries illustrate that social protection (SP) effectively addresses risks related to climatic hazards in urban areas, including inequities in residents more vulnerable to high temperatures and more likely to need rapid medical treatment [13]. In one study, SP was a critical factor in supporting the water supply systems of Addis Ababa, Ethiopia, where prolonged drought has been an issue [13]. In rural areas, the climatic hazard-associated health impacts have been challenging, with gaps in assessing such impacts. For instance, the UNEP's Sustainable Development Goals (SDGs) are achievable, particularly by offering improved health care for the impoverished.

The climatic hazards (precipitation, heat, floods, and storms) affect public health through mediating factors involving environmental conditions (geography, weather, soil/dust, vegetation, and air/water quality), social infrastructure (flood damage, storm vulnerability, heat stress, allergens, increased water/air pollution, and mental stress), and public health capability and adaptation (warning systems, health and nutrition status, and

socioeconomic status) [11,14]. Addressing the gaps in the assessment of climate change impacts on health in rural areas should primarily focus on scenario-based health assessments, along with global-level assessments, by developing multidisciplinary collaboration in assessment strategies and models and alternative theoretical contexts (vulnerability assessment; different approaches to causing locations) [11].

Overall, improving irrigation efficiency and SUWM (sustainable urban water management) are feasible adaptation options (primarily involving issues with flooding, cyclones, and droughts) in rural and urban areas, respectively.

3.3. Review of the Disparate Impacts of Climatic Hazards on Rural Versus Urban Communities

In a case study in Australia, to assess the disparate impacts of climatic hazards on rural and urban communities, vulnerability to natural hazards such as wildfires, floods, and earthquakes was measured in five primary sectors: (a) socioeconomic status; (b) demographics and disability; (c) minority status and languages; (d) housing characteristics; and (e) built environment [9]. Unexpectedly, the inequality of vulnerability was more pronounced in urban rather than rural regions [9]. Unless proactive planning and actions are taken, the increasing urban–rural disparity is forecasted to continue until at least 2050, given the projection that at least two-thirds of the global population will live in urban regions [15].

Because of the dense population and infrastructure in urban regions, the disaster impacts could be severe despite more efficient responses and resources for medical needs and living being offered. Other factors that bring such disparate effects and need further consideration include social groups with different demographic characteristics, suggesting that place-based risk profiling and recovery guidelines should be developed [16]. However, challenges still exist in measuring the inequality of social vulnerability in urban and rural communities.

In addition to the efforts to mitigate climate change, applying climate adaptation policies also tackles natural hazards [17]. In one study, transformative climate change adaptation was applied using cases from the Global South affected considerably by climate change [17]. In most cases addressing transformative adaptation in response to rapid climate change, several aspects, including social, economic, and environmentally sustainable development goals, tend to be underestimated. These shortcomings correlate with issues of poverty, inequity, and environmental degradation [18].

Policy and interventions integrated with climate change adaptation in a socially and environmentally sustainable way apparently play a key role in reducing climate sensitivities. In one study, gradual (in the socio-ecological system) and evolutionary (structural transformation) climate change adaptations are suggested to address issues of climate-induced disparity, despite common obstacles such as lack of financial support and control of local authorities [17]. This study suggests that strong national funding can eliminate these issues by supporting climate-related initiatives toward more sustainable climate change adaptation.

The transformative adaptation approach is illustrated by equally considering three themes: (a) sustainability; (b) equity; and (c) governance, and incorporates multi-strategic actions (intersectionality; political support; institutional capacity; capacity building; social participation; communication tools; technological capacity; infrastructure; and economic resources) [17].

In the Global South, the impact of climate change has been considerable in rural communities, requiring the government to take remedial actions to cope with such disasters and build resilience and sustainability [19]. To address the negative impacts on rural communities, identifying gaps in implementing climate change adaptation appears to be a substantial precedent [20]. To address the greater vulnerability found in rural areas, the welfare of rural residents (e.g., healthcare services, government partnership, government participation strategies, and food production) should be explored beyond sustainable practices, with a proactive strategy against climatic hazards.

According to a comparative study [21] on the resilience of urban and rural areas under climate change, exploring the difference between urban and rural resilience could mitigate the disparate impacts on urban and rural communities, improving planning strategies and allocating resources. According to the binary logistic regression performed in this study [21], several key dominant abilities of urban and rural areas were identified. For instance, in urban regions, in order of prominence, the abilities are infrastructure resilience (with a coefficient value of 1.339), community age structure resilience (0.694), and Greenland resilience (−0.398). In

rural communities, residents' economic independence resilience (−0.398) and traditional resilience (−0.422) were more prominent.

These results indicate a primary dependence on the socio-economic structure in urban areas, while rural residents rely more on economic independence and their own knowledge. Identifying and addressing the inequality in urban and rural resilience abilities could support climatic hazard management (e.g., disaster mitigation, disaster preparedness, disaster response, and recovery).

4. Conclusions

In this study, the disparate impacts in urban and rural communities were reviewed to identify and analyze sustainable approaches, including watershed management associated with policy and technical feasibility to mitigate climatic hazards. In terms of mitigating climate change, reaching net-zero CO_2 emissions requires the integrated reduction of current GHG emissions and negative emission technology, but other technologies such as zero-carbon energy technology must also be explored.

Several case studies (in Southwest Ethiopia, Jakarta and Rotterdam, India, and Guatemala and Honduras) revealed that integrated watershed management in climate change adaptation is feasible and improved with irrigation efficiency and policy intervention, especially in rural areas, while flood management and reducing water use are more practicable for urban areas with SP as an efficient approach and particularly suitable for eliminating climatic hazard risk in areas with considerable drought issues.

Among the alternative options in addressing the disparate impacts of climate change on rural and urban communities, several resilience frameworks—including monitoring sustainability, evaluating assessment measures, and implementing climate change adaptation—are recommended. Even if watershed management did help rural communities cope with climate change-induced natural disasters, transparent community and policy involvement is still required. Similarly, irrigation efficiency improvement, healthcare services, government partnership, and food production are all high-priority areas for rural communities when it comes to addressing this issue. For urban cities, flood management is of relative importance based on the six dimensions: economical, technological, institutional, socio-cultural, environmental, and geophysical aspects. With social protection, risks related to climatic hazards were well-addressed in urban areas. The integrated irrigation efficiency and sustainable urban water management proved to be feasible adaptation options for both rural and urban communities (Table 1).

Table 1. Relative importance (weighting) of potentially affected community values, with higher weights indicating greater importance (1–5), according to the different alternatives.

Major Vulnerabilities	**Water Resources; Human Health; Ecosystems; Food Production; Infrastructure**		**Comments**
Alternative Options	***Rural Regions***	***Urban Cities***	
Monitoring Sustainability	5	5	Equally critical for future resilient urban and rural communities
Evaluating Assessment Measures	5	5	
Implementing Climate Change Adaptation (with support through national funding)	5	5	
Watershed Management	3	-	Based on the case studies (in Boset District Ethiopia and in Indonesia)
	Community involvement with transparency for rural areas		
Integrated Watershed Management with Policy Involvement	5	-	Based on the case studies (in Southwest Ethiopia and in Indonesia)
Irrigation Efficiency Improvement	5	-	Based on the case studies (in Jakarta, Rotterdam,

			India, Guatemala, and Honduras)
Flood Management	-	5	From the perspectives of economical, technological, institutional, socio-cultural, environmental, and geophysical aspects
Social Protection (SP)	-	5	Effectively addressed risks related to climatic hazards in urban areas
Healthcare Services; Government Partnership; Food Production	5	-	Gaps in assessing such impacts in rural areas; scenario-based health assessments are necessary
Integrated Irrigation Efficiency and Sustainable Urban Water Management	5	5	Feasible adaptation options both for rural and urban communities

Climate change adaptation strategies differ between rural and urban areas based on climate change adaptation feasibility dimensions due to climate change impacts (Figure 1). However, studies on urban and rural resilience in addressing climate change and mitigating its associated risks have been lacking. Thus, future research should investigate resilience in handling climate change and risk mitigation. Unexpectedly, urban cities have experienced more significant climatic impacts in terms of vulnerability, and such inequality will become more severe because of population growth and migration to urban regions. Unless proactive planning and actions are implemented, the disaster impacts will continue with high severity irrespective of efficient responses and the resources available in urban areas.

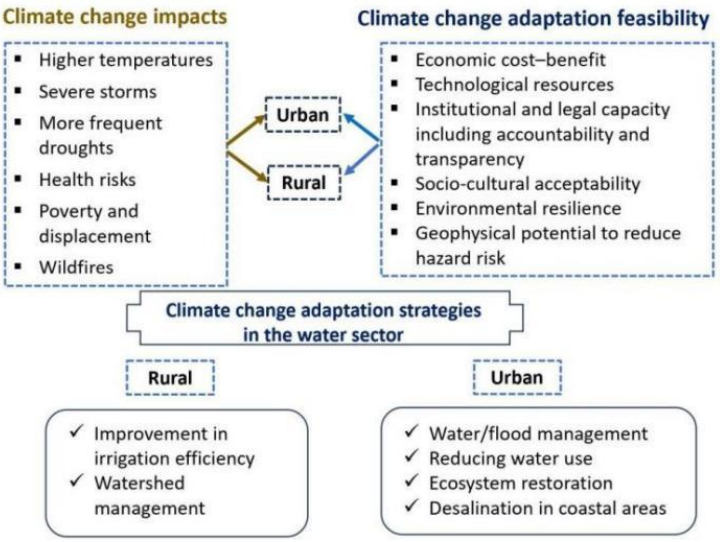

Figure 1. Illustration of the climate change adaptation strategies of rural and urban communities in the water sector, based on six feasibility dimensions (elaborated from [12]).

Funding

This work received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Conflicts of Interest

The author declares that there is no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Zeleňáková, M.; Purcz, P.; Hlavatá, H.; Blišťan, P. Climate Change in Urban Versus Rural Areas. *Procedia Eng.* **2015**, *119*, 1171–1180. [CrossRef]
2. Fawzy, S.; Osman A.I.; Doran, J.; Rooney, D.W. Strategies for Mitigation of Climate Change: a Review. *Environ. Chem. Lett.* **2020**, *18,* 2069–2094. [CrossRef]
3. Assefa, S.; Kessler, A.; Fleskens, L. Factors Affecting Farmers' Decision to Participate in Campaign-Based Watershed Management Program in Boset District, Ethiopia. *Land Use Policy* **2024**, *137*, 106995. [CrossRef]
4. Kılkış, S.; Krajačić, G.; Duić, N.; Rosen, A.M.; Al-Nimr, A.M. Effective Mitigation of Climate Change with Sustainable Development of Energy, Water and Environment Systems. *Energy Convers. Manage.* **2022**, *269*, 116146. [CrossRef]
5. Nature-based Approaches for Climate Change Mitigation and Adaptation. Available online: https://www.ecologic.eu/sites/default/files/publication/2014/eco_bfn_nature-based-solutions_sept2014_en.pdf (accessed on 27 December 2023)
6. Haszeldine, R.S.; Flude, S.; Johnson, G.; Scott, V. Negative Emissions Technologies and Carbon Capture and Storage to Achieve the Paris Agreement Commitments. *Philos. Trans. R. Soc. A* **2018**, *376*, 20160447. [CrossRef]
7. Sebestyen, V.; Dorgo, G.; Ipkovich, A.; Abonyi, J. Identifying the Links among Urban Climate Hazards, Mitigation and Adaptation Actions and Sustainability for Future Resilient Cities. *Urban Clim.* **2023**, *49*, 101557. [CrossRef]
8. Wolka, K.; Uma, T.; Tofu, D.A. The Role of Integrated Watershed Management in Climate Change Adaptation for Small-Scale Farmers in Southwest Ethiopia. *Environ. Sustainability Indic.* **2023**, *19*, 100260. [CrossRef]
9. Wang, S.; Zhang, M.; Huang, X.; Hu, T.; Sun, Q.C.; Corcoran, J.; Liu, Y. Urban–Rural Disparity of Social Vulnerability to Natural Hazards in Australia. *Sci. Rep.* **2022**, *12*, 13665. [CrossRef]
10. Supangat, A.B.; Basuki, T.M.; Indrajaya, Y.; Setiawan, O.; Wahyuningrum, N.; Purwanto; Putra, P.B.; Savitri, E.; Indrawati, D.R.; Auliyani, D. et al. Sustainable Management for Healthy and Productive Watersheds in Indonesia. *Land* **2023**, *12*, 1963. [CrossRef]
11. Challenges and Gaps in Assessing Impacts of Climate Change on Health in Rural Areas. Available online: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2019/03/Lloyd_background_paper_final2.pdf (accessed on 29 February 2024).
12. Singh, C.; Bazaz, A.; Ley, D.; Ford, J.; Revi, A. Assessing the Feasibility of Climate Change Adaptation Options in the Water Sector: Examples from Rural and Urban Landscapes. *Water Secur.* **2020**, *11*, 100071. [CrossRef]
13. Urban Climate Risks and the Role of Social Protection: Short Case Studies. Available online: https://www.preventionweb.net/publication/urban-climate-risks-and-role-social-protection (accessed on 20 February 2024)
14. Smith, K.R.; Woodward, A.; Campbell-Lendrum, D.; Chadee, D.D.; Honda, Y.; Liu, Q.; Olwoch, J.M.; Revich, B.; Sauerborn, R. Human Health: Impacts, Adaptation, and Co-Benefits. In: Field, C.B.; V.R. Barros D.J.; Dokken, K.J.; Mach, M.D.; Mastrandrea, T.E.; Bilir, M.; Chatterjee, K.L.; EBI, Y.O.; Estrada, R.C.; Genova, B.; Girma, E.S.; Kissel, A.N.; Levy, S.; Maccracken, P.R.; Mastrandrea, L.L., White (Ed.) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA, 2014.
15. Year to Transform Our Cities. Available online: https://unhabitat.org/2022-year-to-transform-our-cities (accessed on 18 February 2024).
16. Cross, S.H.; Calif, R.M.; Warraich, H.J. Rural-Urban Disparity in Mortality in the US from 1999 to 2019. *JAMA* **2021**, *325,* 2312–2314. [CrossRef]
17. Filho, W.L.; Salvia, A.L.; Balogun, A.-L.; Pereira, M.J.V.; Mucova, S.A.R.; Ajulo, O.M.; Ng, A.; Gwenzi, J.; Mashonjowa, E.; Aina, Y.A.; et al. Towards More Sustainable Responses to Natural Hazards and Climate Change Challenges Via Transformative Adaptation. *Cities* **2023**, *141*, 104525. [CrossRef]
18. Eriksen, S.; Aldunce, P.; Bahinipati, C.S.; D'Almeida Martins, R.; Molefe, J.I.; Nhemachena, C.; Ulsrud, K. When Not Every Response to Climate Change is a Good One: Identifying Principles for Sustainable Adaptation. *Clim. Dev.* **2011**, *3*, 7–20. [CrossRef]
19. Atkinson ,C.; Atkinson, A.M. Impacts of Climate Change on Rural Communities: Vulnerability and Adaptation in the Global South. *Encyclopedia* **2023**, 3, 721–729. [CrossRef]

20. Woroniecki, S.; Spiegelenberg, F.A.; Chausson, A.; Turner, B.; Key, I.; Irfanullah, H.M.; Seddon, N. Contributions of Nature-Based Solutions to Reducing People's Vulnerabilities to Climate Change Across the Rural Global South. *Clim. Dev.* **2022**, *15*, 590–607. [CrossRef]
21. Su, Q.; Chang, H.-S.; Pai, S.-E. A Comparative Study of the Resilience of Urban and Rural Areas Under Climate Change. *Int. J. Environ. Res. Public Health* **2022**, *19*, 8911. [CrossRef]