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Proactive Adaptation Responses by Vulnerable Communities to Climate Change Impacts

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Abstract: We explored the proactive responses of local communities against locally experienced climate change impacts and anticipated threats. This study interviewed 124 rural households from three community forestry user groups representing three ecological regions of Nepal using a semi-structured questionnaire. The study used eight criteria to distinguish the proactive nature of adaptation. Both qualitative and quantitative methods were used to analyze data, including the use of a chi-square (χ^2) test to determine the proactive measures and their association with livelihood options and the ordered logistic regression model to explain determining factors of choosing proactive adaptations. The results indicate that 83.9% of households adapted both proactive and reactive measures, while 10.5% applied solely reactive adaptation and 5.6% were earmarked only for proactive adaptation measures. Over 50 different proactive adaptation measures were implemented by the households. The measures were significantly associated with agricultural diversification, cash crop cultivation, livestock raising, small-scale enterprise development, and disaster control. Socio-economic and spatial factors such as a household's wellbeing, land holding size, geographical location, livelihood options, and the number of adaptation measures implemented by households were found to be decisive factors in choosing proactive adaptation. The study concludes that local people in Nepal are not only aware of escalating climate risks but also engage their cognition and knowledge proactively to adapt locally. The results suggest that even small proactive initiatives by households can offer multiple benefits against climate risks as an architect of individuals. Therefore, adopting a trans-disciplinary approach and nurturing local proactive actions in strategic connectivity between environmental, political, and societal functions is pivotal, which primarily takes a step to drive expediently successful climate change policy and strategy implementation. The findings of this study offer valuable insights into policy and strategy planning for the unsolicited consequences of climate change and highlight the importance of understanding the perspective of local communities in adaptation planning and implementation.

Keywords: climate change; climate change adaptation; adaptation strategy; proactive adaptation; climate change policy; Nepal

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1. Introduction

Climate change is unequivocally a global phenomenon; however, the impacts are local and differential [1–4], mostly based on geographical remoteness and temporal scales [5–8] and the vulnerability of individuals, groups, and communities [4,9,10]. Rising temperature and shifting precipitation patterns [11] and their wide-ranging consequences, particularly extreme weather events such as flash flooding, landslides, devastating forest fires, heat waves, and drought, have adversely impacted people's lives and several dimensions of livelihoods around the globe [12–17]. The subsequent Intergovernmental Panel on Climate Change (IPCC) assessment reports [6,18,19] confirm that the destructive impacts of climate change are being felt with increasing frequency and the intensity of severe weather events is profoundly causing changes in the livelihoods of remote and vulnerable communities. The amplification of these events has intensified the vulnerability of people in developing nations, particularly those who are predominantly entangled with natural resource-based climate-sensitive livelihoods [20,21] and subsistence farming. Climate change adaptation (CCA) has become an inescapable option in addressing climate change impacts. As mitigation strategies are no longer adequate to avoid loss and damage [22], CCA has immense importance in minimizing vulnerability to growing climate risks [20,23]. Climate change adaptation is a "process of adjustment to actual or expected climate and its effects" [18] (p. 5). It enables individuals and groups to foresee changes and adapt the response to minimize negative effects [24]. Thus, climate change adaptation has been an ongoing and dynamic process, thereby prompting societies across space and time to adjust to climatic stresses [25,26].

The adaptation is influenced by various spatial and socio-economic factors. Geographically fragile, poor, and developing countries face the need for a wide range of adaptation measures in terms of timing and scale. However, implementing these measures is challenging due to limited financial resources, inadequate infrastructure, and insufficient access to information and technology. So, the effects of climate change are often felt more acutely in these countries and communities.

Considering the nature, severity, and location of the impacts, CCA involves a range of attributes of adaptation strategies and actions aimed at helping communities, organizations, or countries to cope with multiple dimensions of vulnerability and impacts. A large body of literature on CCA has been devoted to explaining the characteristics of the six principal strategic responses of adaptation: timing relative to stimulus (proactive, concurrent, reactive, planned), intent (personal, collective), drivers (private, public), spatial scope (local, regional, national), form (technological, behavioral, financial), and degree of response (incremental, transformational) (e.g., [27–34]). While adaptation actions are categorized into several types based on their key attributes, there is growing recognition among climate scientists, policymakers, and planners about the timing of climate change adaptation, distinguishing proactive and reactive strategies to respond to highly erratic and uncertain future climatic threats and existential impacts (e.g., [35–37]), particularly in the local context. Differentiated impacts revealed from continuously changing climatic parameters force local affected communities or individuals to cope with self-initiated proactive and reactive adaptation measures or a combination of both through local means and knowledge acquired and shared over generations. Because local communities and/or individuals often have close connections to nature, this builds an intuitive understanding of the changing climate over long periods of time [38]. They have long been attuned to environmental changes, allowing them to discern and respond to these shifts [39]. As a result, they have employed adaptations that are intricately tailored to their unique contexts.

This emphasizes the crucial role of local communities as the initial and foremost responders, as they possess the potential to act to the best of their abilities, given that the impacts of climate change are intensely localized [4,9,40] despite it being a global burden [41,42].

There are several scholarly suggestions that the persistent knowledge of local people offers multiple solutions in abating environmental risk in favor of both nature and society (e.g., [43–48]). Applied adaptation measures in the view of society's efficacy and compatibility with local priorities are of paramount importance in the adaptation process and local development. Consistent interactions of individuals with daily weather conditions thereby change their adaptive behavior, which not only offers cognizant measures to cope with locally experienced climate change impacts [39] but also enhances the practical application of climate change policies and strategies. However, as concluded by Darjee, Neupane and Köhl [39], and Darjee, et al. [49], these practices and associated local knowledge have been hardly acknowledged in climate change policies and strategies. This might have been underpinned by the lack of grounded findings from such studies related to self-initiated proactive and reactive actions as the survival mechanism employed by climate-affected communities. This paper intends to identify such efforts and make them visible to decision makers.

Most studies predominantly focus on climate change trend and vulnerability analysis, policy process, policy coherence, local people perceptions, impacts on peoples' livelihoods, community adaptations, and participation (e.g., [14,39,44,48–63]). There is alarming scientific evidence pointing to the inevitability of constant modification of existing adaptation measures and identifying possible interventions building on local knowledge, local resources, and indigenous practices in consideration of dire and extremely unpredictable climatic change (e.g., [49,64–68]). Smit, Burton, Klein, and Wandel [27] suggest that adaptation to climate change and variability is a complex subject that requires thorough investigation. It is crucial to distinguish between different types and attributes of adaptation to effectively implement specific measures. This process involves understanding the intertwined nature of adaptation measures with both natural and socio-economic systems.

In this backdrop, this study aims at exploring the proactive responses of local communities in Nepal against locally experienced impacts and existential threats. As a mountainous country, Nepal has experienced an extremely unpredictable onset of monsoon seasons, increasing temperatures, and uncertain rainfall which has intensified vulnerability to glacial lake outburst, droughts, floods, and landslides [69]. Since 1971, the temperature has been exhibiting a positive trend, accumulating at an average annual rate of 0.06 °C with a higher rate of warming in the higher altitudinal range [39,70,71]. Geological and ecological fragility coupled with predominantly natural resource-based livelihoods and a low level of adaptive capacity due to poor socio-economic conditions and higher incidence of poverty have made Nepal one of the most vulnerable countries to climate change [62,72,73]. Compared to the long-term climate risk index (CRI) considering the period from 2000 to 2019, the 2021 global climate risk index has ranked Nepal as one of the ten most affected countries [42].

Exploring and distinguishing between the proactive and reactive measures of local communities has not been investigated and documented, although communities' responses have been a significant part of ongoing climatic challenges. Historically, most of the adaptation activities employed have been reactive [74,75]. As proactive choices rely on predictions about future events or challenges that are subject to uncertainty [76], these responses to future climate change have not been sufficiently interpreted into strategic or anticipatory planning, due to shorter-term priorities [77]. However, a changing climate suggests that there is an opportunity of proactive adaptation to tackle the anticipation of climate adversity predicted by scientists [78] to reduce losses and damages as well as costs of adaptation [79,80]. An unprecedented level of funding including a World Bank investment of more than USD 30 billion in 2022 has been allocated to support countries to address climate change and build resilience [81]. The Green Carbon Fund (https://www.greenclimate.fund/ (accessed on 28 April 2023) is in its second phase, building on its initial USD 10 billion to empower "climate action" in developing countries and to help vulnerable societies impacted by climate change. But the synthesis report of IPCC from the sixth reporting period in March 2023 draws global attention on the critical need to make strategic investments to accelerate the effectiveness of such funding and actions to address climate change [19]. While the need for a wise and equitable distribution of efforts and funding for remote communities to adapt and build resilience to climate change has been extensively discussed [82], it is important to address the scarcity of suitable practical adaptation measures that are tailored to the local context [49]. Furthermore, the recognition of the significance of enhancing overall societal choices and developments in terms of lifestyles and socio-economic factors in tackling climate issues has been realized [83,84]. In the backdrop of all, this study analyzes local climate-friendly proactive adaptation measures implemented by households against local impacts supporting their livelihoods. Findings from this study provide locally tailored solutions to increase the local ownership of ongoing responsibility for sustainable climate action.

2. Proactive and Reactive Adaptation: Concept and Analytical Framework

Climate change adaptation and its types have been classified based on several attributes. Commonly used attributes are distinguished with purpose, timing, temporal scale, and spatial scale [18,85–88]. Planned adaptation, which involves proactive measures and autonomous adaptation, which occurs reactively, are widely recognized [89] and are commonly observed and implemented. Proactive adaptation is recognized in the United Nations Framework Convention on Climate Change (UNFCC) (Article 3.3) urging its member counties to take precautionary measures without postponement in order to anticipate, avoid, or abate the causes of climate change and minimize its adverse effects to ensure global benefits at the lowest possible cost [90].

The definitions and use of the terminologies proactive and reactive are context-specific. It is used in multiple fields of studies, for example, population and health, e.g., [91–93], business and education, e.g., [94,95], organizational management, e.g., [96,97], psychological studies, e.g., [98,99], policy and institution, e.g., [76,80], climate and management, e.g., [100–102], and so on. Here, we accentuate these terminologies in the field of climate change adaptation to describe people's adaptive behaviors. This includes examining how individuals adjust their actions in response to changes in climatic conditions caused by multiple impacts. Tinch, et al. [103] defined "adaptive capacity" for proactive adaptation and "coping capacity" for reactive adaptation. Smit, Burton, Klein, and Wandel [27] explain that adaptation could be proactive or reactive considering timing—autonomous or planned based on degree of spontaneity—as well as economic, legal, institutional, and technical form. Autonomous or spontaneous adaptations are considered to be reactive responses. Planned adaptations can be both proactive or reactive [89]. While proactive measures are taken well in advance or now to maintain or increase resilience, reactive measures involve responding to issues as they have been immersed by repairing impairment and mitigating ongoing impacts [97]. Plummer [104] explained that resilience maintains stability with the absorption of coping capacity in the face of shocks and stresses; adaptability shows flexibility in modifying systems to cope with changes in their environment, and transformation tends to radically change or replace the current system with a new one. On these grounds, it suggests that proactive behavior concerns future circumstances or predicaments, preparing for unforeseen circumstances to avoid negative outcomes to favor of positive results, driving towards transformation and resilience, and reactive behavior often addresses an immediate response against uncontrollable circumstances or issues.

Carman and Zint [28] proposed a comprehensive definition of personal and household adaptation behavior consisting of "purpose (i.e., preventing harm or gaining benefits), timing (i.e., proactive or reactive), time scale (i.e., short-term or long-term), as well as who acts (i.e., the individual alone or with others), and who is affected by those actions (i.e., the individual, other people, or the environment)." Purposefulness and timing are the most commonly used distinctions [89]. Reinforcing timing, scientists, policymakers, and planners have raised attention about distinguishing proactive and reactive strategies, e.g., [35–37]. Robert, Thomas, and Bergez [75] classified adaptation using timing, temporal, and spatial scopes. The timing and scope include reactive response (after the shock) and proactive response (preventive) adaptation. The temporal scope encompasses strategic adjustments (long-term) and tactical adjustments (short-term), and spatial scope involves both localized (e.g., single crop) and widespread (e.g., farm system) adaptation. Rasmussen and Suedung [105] used the term "proactive" as a preplanned control approach for risk management. de Bruin, Weikard, and Dellink [37] illustrated that proactive (anticipatory) measures are taken before climate change happens and are often on a larger scale and irreversible, whereas reactive adaptation measures are considered a reaction after climate change has occurred wherein both costs and benefits are concurrently perceived. As suggested by Palmer, Reidy Liermann, Nilsson, Flörke, Alcamo, Lake, and Bond [79], the efforts of proactive management will abate risks and reduce the costs of management more than the reactive efforts taken only after the issues have arisen. Given the wide range of concepts and contexts, proactive adaptation seeks ways to decrease the risk of anticipated climate change impacts occurring in the future and reactive adaptation alleviates the undesirable impacts accompanying existential climate change.

Persuaded by the concept, context, and the escalating urgency of understanding ongoing and dynamic process of adaptation to cope with changing environments, this article aims at exploring the expedient climate change adaptation actions proactively adapted by affected households. In doing so, this research is motivated by the concepts and principles of the protection motivation theory (PMT) [106–108] which has been extensively employed to explain adaptation behaviors and the effects of fear on health hazards affecting individuals' attitudes and behaviors. PMT is a theoretical framework which explicitly addresses both risk and adaptation. It has widely been extended to natural environmental risk and hazards including droughts [109] and flood risks [110,111] as well as climate change adaptation and mitigation [102,112–117]. A PMT socio-cognitive model has been considered suitable for predicting proactive adaptation to climate change risk using impact indicators, e.g., flooding and drought effects and socioeconomic parameters [102] as it considers an individual's motivation to protect themselves from any risks and threats. A PMT socio-cognitive model postulates two cognitive processes—risk appraisal of climate change and adaptation appraisal (Figure 1).

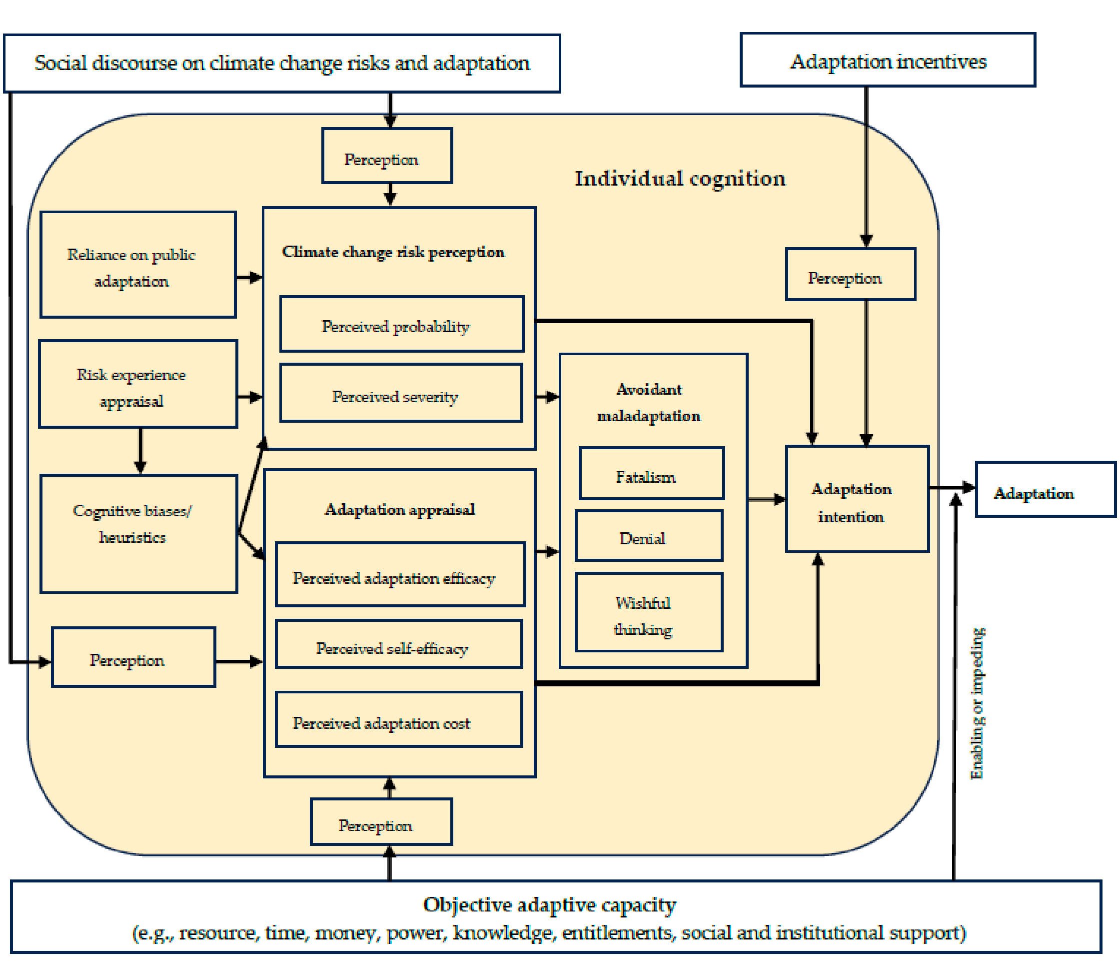

Figure 1. Socio-cognitive model of proactive private adaptation to climate change impacts developed by Grothmann and Patt (2005) [102].

Risk appraisal concentrates on the evaluation of sources of climate threats and factors that increase or decrease the possibility of likelihood severity. Risk appraisal apprehends the individual perception on the expectancy of being exposed to risks (perceived probability) and the perception on how severe the consequences of the risks would be (perceived severity), thereby assuming the probability of engaging in protective responses.

Adaptation appraisal refers to individuals' cognitive processes when evaluating their ability to avoid or reduce particular risks. Within the adaptation appraisal, three distinct components are interpreted to evaluate individual response measures: perceived adaptation efficacy, perceived self-efficacy, and perceived adaptation costs. Perceived adaptation efficacy evaluates believing in adaptive responses to be effective in preventing harm from perceived threats; perceived self-efficacy focusses on the person's perceived capability essentially to accomplish the adaptive responses; and perceived adaptation costs assess the costs of undertaking the adaptive responses. Individuals often have adaptation intentions; however, in some cases, they find themselves unable to carry them out in actual behavior due to a lack of objective adaptive capacity (e.g., lack of resources, time, money, power, knowledge or social support), see [102].

In the wake of this comprehensive and extensive theory and associated model, this article is framed for the subjective assessment of proactive measures, distinguishing perceived adaptation efficacy and self-efficacy and determining factors to choose these measures. Several studies have explored diverse adaptation options against the most noticeable forms of climate change impacts and indicators including extreme temperature, drought, ground water table reduction, decrease in the number of rainy days, increase in prolonged dry episodes, erratic rainfall, early starts and early ends of monsoon, cold wave, permafrost thaw, fire, intrusion/expansion of pest and pathogens, and multiple issues of human and livestock heath, e.g., [3,6,12,14,39,49,62,69,118–128]. Our analysis considered these impacts and indicators while exploring proactive measures.

To distinguish between different proactive measures, we used eight major criteria (Table 1) and analyzed their association with diversification of livelihood options which were locally practiced. The proactive measures were modeled with selective independent variables associated with socio-economic and demographic variations, i.e., diversity of household's livelihood options, wellbeing category, agricultural land owned, sex, number of adaptation activities employed, length of experiences in major occupation, and geographical variation of the dwellings to identify major determining factors. The independent variables were chosen by reviewing a wider range of pertinent literature, e.g., [73,103,109,115–117,129–134], and consultation with local experts and community members while keeping in mind the local circumstances. In the context of Nepal, these variables hold great importance in addressing adaptation issues. Nepal's diverse ecological and geographical features result in contrasting weather patterns, even within short distances of a few kilometers [135] and in small localities [39]. Additionally, the country exhibits significant socio-economic and cultural variations influenced by factors such as land ownership, wellbeing, location, gender roles, occupational engagement, and the diversification of livelihood options.

Building on the reviews of the concepts, theories, framework, and pertinent literature, our study mostly accentuates the empirical evidence of proactive measures of climate change adaptation markedly implemented in local surroundings. In doing so, we principally focus on two major leading questions: (1) how are local people proactively engaged in adapting uncontrolled and unexpected climatic risk? and (2) what are the determining factors associated with proactive adaptation of the households?

The findings from the results are discussed in relation to the expedient advancement of proactive measures and its vitality in achieving successful implementation of climate change policy and strategy. The discussion is predominantly framed under the socio-cognitive process model of proactive adaptation to climate change elaborated by Grothmann and Patt [102]. Finally, we argue that the responses of local people to climate change should be seen as widening opportunities of adaptation in maintaining and/or enhancing the functionality of the system considering the unavoidable uncertainty of climate and associated compounding risks.

Table 1. Criteria and indicators used for distinguishing proactive and reactive climate change adaptation measures.

Proactive Adaptation		Reactive Adaptation		
Indicators	**Explanation**	**Indicators**	**Explanation**	**Referenced Consulted**
Actions before possible shock	Solve a future problem, Activities implemented in advance, Type of activities implemented	After/during shock	Solve matters as they come up by repairing impairments and mitigating ongoing impacts, Types of activities implemented in advance, See record and verbal note	[75,97]
Investment for future benefits	Amount of funding invested for future benefits of climate change, Property insurance	Costs and benefits are felt simultaneously	Cost–benefit trade-off, Costs invested in climate change impact-related activities during last year, Benefits from invested costs for last year	[37]
Large scale (e.g., farm level)	Crop diversification in entire farm, Irrigation system development, Displacement of farm activities, Land use change	Small scale (e.g., crop level)	Measures for single crops, Measures for seasonal calendar for a year	[37,75]
Planned for long-term climatic shocks (at least for ten years)	Minimum ten-year periodic plan against expected climate change impacts, e.g., drought, flood, crop pest, hailstorm, Multi-year strategic plan, Conservation of water sources	Planned for short-term climatic shocks (e.g., yearly)	Short plan for experienced impacts, e.g., crop and livestock yield, price fluctuations, market fluctuations in food and input prices, Annual plan/short plan for existing stimuli, Seasonal plan in the year	[117,136,137]
Risk assessment of future climate change impacts	Use of information for plan to curb harm, Use of climate data to increase beneficial opportunities in the future	Instant implementation of measures	Based on available skills, resources, and opportunities for actions to contemporary/changed climatic condition	[138,139]
Aimed to reduce exposure to future risks	Investment/initiations at reducing anticipated risk and cost	Informed by direct experiences	Resources are targeted to already-known risks	[140]
Use of historical pattern for long- term plan	Considering the climate/weather trend of at least 10 years before while making plan	Individual experiences	No consideration	Based on local people, circumstances, and experts
Arrangement of emergency supports	Establishment of emergency support system within individuals/groups	Fund/trained person for disasters and risk	Not yet concern	Based on local people, circumstances, and experts

3. Materials and Methods

3.1. Study Area

We conducted this study in Nepal which is endowed with diverse ecological and geophysical variations from lowlands to high mountains. The physiographical heterogeneity caused not only demographical variations but also differentiated climate change impacts. This study represents three ecological regions of Nepal—high mountains, mid-hills, and lowlands (*Terai*) concentrated in Taplejung, Gorkha, and Kailali districts of the regions, respectively (Figure 2). The districts in Nepal serve as administrative divisions used to assess the climate vulnerability of different regions. According to a recent vulnerability report by the Government of Nepal, Taplejung has been categorized as having a very high vulnerability and Gorkha as having a high vulnerability to landslide disasters. Similarly, Kailali has been classified as having a very high vulnerability to floods [141].

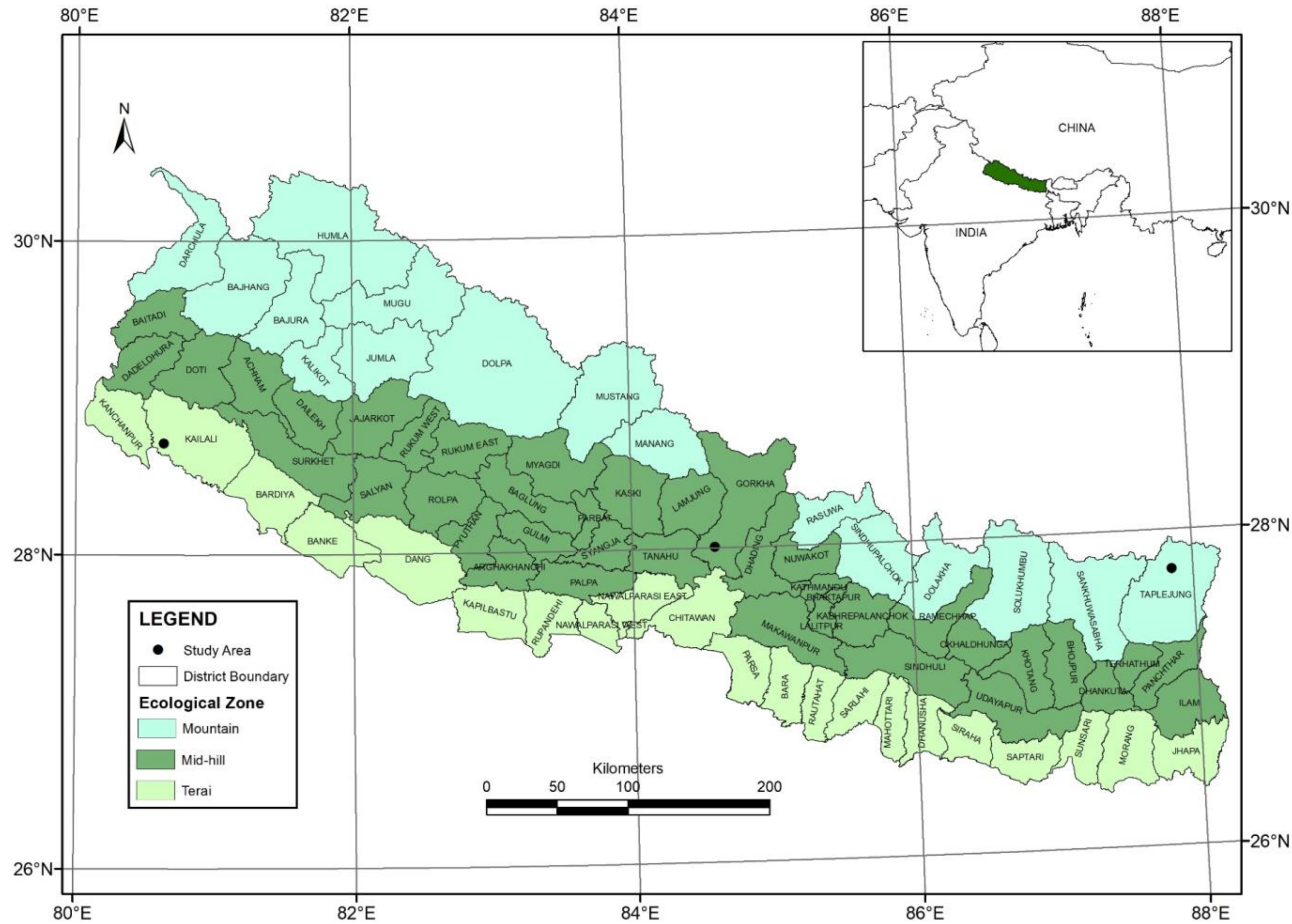

Figure 2. Map of Nepal showing three ecological zones and the study sites, which are indicated with black filled circles. Taplejung district is in the northeast in the high-mountains region, Gorkha district is in center in the mid-hills region, and Kailali district is situated in the southwestern part of the lowland *Terai* region.

Three community forestry user groups (CFUGs) with varied socio-economic backgrounds were chosen for the study, each representing a different ecological region (Table 2).

Table 2. Studied Community Forest User Groups (CFUGs) and number of interviewed households.

Name of CFUG and Location	Geographical Regions	Total Number of Households (HH) in the CFUG	Sampled HH (No)
Sinkechu CFUG—Pathibhara Yangbarak 2, Taplejung	Mountain	53	21
Dhandswara Kapre CFUG—Barpak Sulikot 7, Gorkha	Mid-hills	114	35
Taranagar CFUG—Dhangadi Sub-metropolitan City 5, Kailali	Lowland	338	68
Total		505	124

There are several reasons behind choosing the CFUGs. First, meteorological data of temperature and precipitation for the last 30 years (1988–2018) observed by meteorological stations located in the vicinity of the CFUGs have been analyzed by recent study. While the annual temperature increased in Taplejung, Gorkha, and Kailali districts at rates of 0.061 °C, 0.063 °C, and 0.0178 °C, the corresponding rainfall decreased by −9.7 mm, −3.6 mm, and −0.04 mm per year for the districts, respectively [39]. Although the trend of rainfall patterns was decreasing, the internal variability and concentration of rainfall distribution were observed to be becoming erratic, most noticeably in Kailali (ibid). This analysis provides an important relationship with the local impacts generated from climate change. Second, the climate and the attributes of climate change impacts vary between ecological regions. Darjee, Neupane, and Köhl [39] also discuss that mountain regions possess a cool temperate, alpine, and tundra type of climate and suffers from permafrost thaw, glaciers, and risks of bursting of glacial lakes incurred by climate change. The people from the mountain region of Taplejung experienced multiple impacts and indicators including shrinking snow layer, drying water source, and shifting seasonal calendar. The mid-hills contain warm-to-cool temperate climates and suffer a higher risk of landslides and erosion due to erratic rainfall. In the mid-hills region of Gorkha, prolonged droughts, dried-up water sources, and increasing rainfall intensity were commonly experienced by local people. The *Terai* comprises a tropical-to-subtropical climate having southern plains and the foothills of the Siwalik. The people living in Kailali district of the *Terai* region have been severely affected by flooding, inundation, and hot and cold waves. Given these facts and features, the selected sites are appropriately representative in studying climate change impacts and local people's responses.

3.2. Sampling Frame and Data Collection

This study employed a mixed methods research (MMR) approach which combined and integrated both qualitative and quantitative data collection and analysis. Several research methods were used, including household surveys, focused group discussions (FGDs), expert interviews (EIs), and interviews with key informants (KIs). Primary data were collected using social survey methods during the period from May to August 2022. The household survey conducted in this study exclusively focused on proactive responses of local communities to climate change impacts experienced at the local level, as well as determining factors influencing the implementation of these adaptations. A total of 124 households participated in the survey (Table 3). The sample size for household interviews was determined using Yamane's equation [142], which calculates the number of households to be interviewed based on a specified level of precision, as illustrated in the following formula.

$$n = \frac{N}{\left(1 + Ne^2\right)}$$

where n is the sample size, N is the population size, and e is the level of precision.

Table 3. Types of data collection methods and descriptions of the participants.

S.N.	Data Collection Tools	Number of Events	Number of Total Participants	Men	Women
1	Household survey (semi-structured interviews)	124	124 (25%) *	93	31
2	Focus group discussions	9	85	47	38
3	Key informant interviews	18	18	14	4
4	Expert interviews	20	20	15	5

* indicates "out of total households".

Semi-structured interviews were conducted with the households. These interviews involved a combination of predetermined and open-ended questions, focusing on households' observations of climate change impacts and their response strategies. The primary emphasis of the semi-structured interviews was to explore local proactive adaptation measures implemented by households following their experiences with climate change impacts. Given the study's focus on local adaptation practices among vulnerable groups, respondent diversity was ensured by including women, indigenous peoples, poor households, and those considered climate-vulnerable. To enhance the reliability of the interview responses, data triangulation was conducted through nine FGDs with three FGDs conducted in each district, comprising 8–10 participants per FGD.

Expert interviews were carried out to obtain insights into the consideration of locally practiced adaptation in policy. A total of twenty experts from various organizations, including the Ministry of Forest and Environment (MoFE), Department of Forest and Soil Conservation (DoFSC), REDD Implementation Centre, International Non-governmental Organizations (INGOs), and National Non-governmental Organizations (NGOs) were consulted. Additionally, 18 key informants from the Federation of Community Forestry Users Nepal (FECOFUN), the ex-chairperson of the studied CFUG, local health technicians, and local entrepreneurs provided valuable information. Furthermore, the study incorporated additional information and knowledge obtained from case studies and direct observation notes. For the FGDs, EIs, and KIs, a predetermined checklist was used to keep participants focused on the primary objective of the discussions.

The study employed a stratified random sampling method for the household survey and purposive sampling for the FGDs, considering different community categories identified in the CFUG's operational plan. Snowball sampling was used for expert interviews and key informant interviews.

3.3. Statistical Analysis

We used descriptive statistics to summarize and present the data. A chi-square (X^2) test of independence was used to determine the degree of association between indicators of varieties of proactive adaptation and the range of measures employed by local households. We tested the relations between eight distinct criteria of proactive adaptation (Table 1, Column 1) and the adaptation activities adapted to the six different categories, i.e., "Agriculture crop", "Cash crop", "Livestock", "Business", "Disaster", and "Other". All of the responses were dichotomous (1 for "yes" and 0 for "otherwise"). We employed the ordered logistic regression model to explain explanatory power of some essential socio-economic and demographic variables on the level of choosing proactive adaptations. We used the log likelihood ratio chi-square test to measure the goodness of fit of the model. This test has been widely used in many different similar studies, e.g., [102,129,130,132].

We used STATA 17 to analyze the data, mostly using the quantitative method. A detailed explanation of the variables is presented in Table 4.

Table 4. Summary statistics of explanatory variables for ordered logistic regression and chi-square test for categorical variables.

Variable	Explanation	Mean	S. D.
Livelihood option	Diversification of livelihood options of the households (HH) (1 = only one option, 2 = two options, 3 = three or more options)	-	-
Wellbeing category	Wellbeing rank of the HH (1 = poor, 2 = medium, 3 = rich)	-	-
Land area	Cultivated land areas owned by the HH (m sq.)	6.909	0.668
Sex	Sex of household head interviewed (0 = female, 1 = male)	-	-
Geographical variation	Geographical location of the household respondents (1 = *Terai*, 2 = mid—hill, 3 = mountain)	-	-
Number of adaptation activities	Number of climate change adaptation activities employed by the individual HH (1 = 1–2, 2 = 3–4, 3 = more than 4)	-	-
Average experience of major occupation	Duration of major occupation of respondents (years)	25.911	0.869
Adaptation measure before possible shock	1 = ”yes” and 0 = “otherwise”	-	-
Investment for future benefits	1 = ”yes” and 0 = “otherwise”	-	-
Large scale (e.g., farm level)	1 = ”yes” and 0 = “otherwise”	-	-
Planned for long-term climatic shocks (at least for 10 years)	1 = ”yes” and 0 = “otherwise”	-	-
Risk assessment of future climate change impacts	1 = ”yes” and 0 = “otherwise”	-	-
Acquired skill trainings for future possible shock	1 = ”yes” and 0 = “otherwise”	-	-
Use of historical pattern for long-term plan	1 = ”yes” and 0 = “otherwise”	-	-
Arrangement of emergency support/funds for uncertain shocks	1 = ”yes” and 0 = “otherwise”	-	-

4. Results

4.1. Key Characteristics of Household Interviewees

Table 5 displays the key descriptive characteristics of the households including sex, age, education, wellbeing, and land areas owned by households. The diverse inclusion of household respondents suggest that the qualitative responses are representative, ensuring not only a higher level of confidence, but also increasing the reliability and validity of information obtained from heterogeneous communities. We interviewed 124 households out of 505, representing 25% of the households of the studied communities. All of the households in the communities were directly and indirectly involved in subsistence agriculture for their livelihoods. In the rural communities of Nepal, a large proportion of women are vigorously active in agricultural works and day-to-day household chores, hence deemed to be more affected by climate change in the farming community. So, a quarter of the total number of women respondents in sampled households were chosen for the interview.

Household surveys included respondents with ages ranging from 28 to 87 years. Nearly two-thirds of the respondents were older than 50 years followed by the group with ages between 40 to 50 years. These groups have been considered being able to compare the past events at least 30 years prior with current experiential climatic events and execute appropriate proactive adaptations in every way possible and as much as they can. Nearly 17% of household respondents were from the age group below 40, and they were expected to be concentrated predominantly on recent changes of climate and its impacts and thereby apply adaptation measures. The study covers educated, literate, and illiterate respondents. Educated respondents included individuals with university- and school-level education. Literate individuals were those who could read and write, possessing little or no formal education but might have nonformal education, such as adult literacy classes. Illiterate individuals were considered to be those who could not read and write. The wellbeing categories of households were mentioned in the constitution of the studied CFUGs. More than 80% of respondents were from the "medium" category. The wellbeing categories are essential in determining the choice of adaptation options in rural communities. The mean agriculture land size of interviewed households was 0.34 ha, ranging from 0.006 ha to 2.7 ha. In Nepal, the majority of the farmers are small farmers operating on less than 0.5 ha [143]. The size of land for cultivation is considered a robust indicator for determining the wellbeing of rural dwellers. Thus, it influences the implementation of proactive and reactive adaptation measures related to agriculture and livelihood-based climate change adaptation.

Table 5. Basic socioeconomic attributes of studied households.

Characteristics	Sub-Characteristics	Total No. (*n*)	Percentage (%)
Sex	Male	93	75.0
	Female	31	25.0
Age (years)	>50	65	52.4
	40 to 50	38	30.6
	<40	21	16.9
Education	University level	11	8.9
	School level	54	43.5
	Literate	32	25.8
	Illiterate	27	21.8
Wellbeing category	Rich	7	5.6
	Medium	100	80.6
	Poor	17	13.7
Land description	Minimum	0.006 ha	
	Maximum	2.7 ha	
	Mean	0.34 ha	

4.2. Proactive Climate Change Adaptation Implemented by the Households

Residents in the communities who participated in the interviews and FGDs implemented several proactive and reactive adaptation activities to tackle the perceived severity of future and current existential climate change impacts. Given the experience of local people regarding the trends of climate change and its consequences over the last three decades, analysis shows that 22.6% of interviewed households assumed the present climate change scenario will continue in the future, while 77.4% of them predicted that the impacts of climate change will become even more perilous, and were initiating local level adaptations proactively.

Building on the eight criteria for proactive and reactive adaptation, 84% of the households adapted to climate change by implementing both proactive and reactive measures simultaneously, 10.5% households applied only reactive adaptation measures, and 5.6% were earmarked for climate change issues with the implementation of proactive adaptation measures only. To adjust with the changing climate, the households shifted livelihoods options in multiple ways through the implementation of more than 50 diverse adaptations activities proactively (details in Table S1 in the supplementary materials). Table 6 provides an overview of the six major categories of those adaptation measures related to rural livelihoods. The analysis revealed that a significant proportion of the adaptation measures undertaken by the households were focused on climate hazards and agriculture. Around one-third of the proactive measures were aimed at reducing the impacts of natural disasters (30%), followed by agricultural crop diversification (26%). Additionally, 18% of the measures included promoting and adjusting livestock practices to climate conditions. The promotion of small enterprises (16%) and the cultivation of cash crops were also identified as viable livelihood options. Other activities such as livestock insurance, promotion of solar energy, migration, and wage labor were also observed.

Table 6. Thematic areas of the climate change adaptation and climate change adaptation measures implemented by the local households.

Thematic Areas of Adaptation	**Activities Implemented by Households**	**Proportion**
Disaster/hazards control	• Plantation in flood- and landslide-risk zones (e.g., canal site bamboo plantation) to control landslide/flood, protect water source • Establishment of wind break • Control grazing on riverbank to make riverine erosion feeble and to avoid further expansion • Goat shed built 2–3 feet above ground level with aluminum roof that prevents the shed from heavy rain and hail • Wrapped livestock shed with wooden planks for warmth during winter • Storing of potato seeds wrapped with rice straw below the ground/hole inside the house • Hanging crop seeds on tree branches to protect from floods and inundation, used same tree for timber, fruits, shade, soil protection, and so on • Raised foundation of house for avoiding risk of intense flood and inundation • Promoted houses coated with mud and wood to prevent from extreme cold and heat, drainage/cabin box construction, and so on	30%
Agriculture crop diversification	• Switching to more adversity-resistant crops • Promotion of off-season crops and vegetable cultivation (e.g., cauliflower, lentils (*Lens culinaris*) instead of rice) • Testing of different varieties of crop cultivars (e.g., red potato, white potato, baby potato, locally known as Tharu Aalu, and other hybrids of potatoes; mango; rice varieties locally known as Ramdhan, Sabitri, Chainpur, and Radha-4; and upland rice (*Oryza sativa* L.), locally called Ghaiya being replaced by millet • Promotion of local crop variety	26%
Livestock raising	• Shifting to livestock (e.g., goat farming, chicken farming, fish farming, pig rearing) • Local livestock promotion • Local chicken promotion	18%
Small enterprise development	• Business in lieu of agriculture crops (e.g., local sugar juice production, electric shop, hardware shop, small retail shop, cycle repairing stall, stool-making business) • Local business enlargement	16%
Cash crop cultivation	• Promotion of cash crop variety (e.g., ginger, turmeric, Colocasia fruit/Yam)	6%
Other option	• Livestock insurance, promotion of solar energy, migration, labor	4%

4.3. Proactive Climate Change Adaptations and Their Association with Local Livelihoods Options

Table 7 presents eight indicators for proactive climate change adaptations (PCCA) and explains them in relation to six major aspects of local livelihood options that have been affected by climate change. Chi-square test statistics of the relationship between indicators of PCCA measures and local livelihood options depict noticeable associations. Out of the eight indicators of PCCA, five were significantly connected to PCCA activities, namely actions before possible shock, investment for future benefits, large scale, risk assessment of future climate change impacts, and use of historical patterns for long-term plan.

As adaptive measures, agricultural crop diversification was found to be strongly associated with prior actions of adaptation ($p \leq 0.003$), investment for future benefits ($p \leq 0.007$), expanding in larger farm scale ($p \leq 0.007$) at the significance level of 1%, and risk assessment of future climate change impacts ($p \leq 0.073$) at the significance level of 10%. The local people have a tendency towards cash crop cultivation which is significantly correlated with investment for future benefits ($p \leq 0.071$, significance at 10%) and use of historical patterns of weather and climate change for introducing crops to farmland ($p \leq 0.025$, significance at 5%). The adaptation actions related to livestock raising showed connection with investment for future benefits ($p \leq 0.002$, significance at 1%) and actions before possible shock ($p \leq 0.075$, significance at 10%). Shifting towards small enterprise development for adaptation displayed signs of significant relationship with larger scale coverage of farmland ($p \leq 0.026$) at the significance of 5%. Disaster control-related activities implemented by households were found to hold significant association with their own way of perceptual risk assessment of future climate change impacts ($p \leq 0.086$) at the significance level of 10 %. Other options, for example, livestock insurance, promotion of solar energy, and migration, showed no significant relations with any of the PCCA criteria; however, these activities' components are considered essential in adaptation to climate adversity. The results clearly informed that most of the rural adaptation activities are connected to the scope of proactive initiations against climate change impacts and risk. This indicates that individual households possess valuable knowledge about the local climate and have acquired it through their own traditional practices of assessing climate impacts and analyzing threats. This knowledge is closely intertwined with their livelihood strategies, leading them to implement local adaptation measures.

Table 7. Chi-square test statistics of the associations between the selected criteria of proactive climate change adaptation measures and major areas of adaptation of rural farm households.

Criteria of Proactive Adaptation Against Climate Change Impacts	Agriculture Crop Diversification X^2 (p-Value)	Cash Crop Cultivation X^2 (p-Value)	Livestock Raising X^2 (p-Value)	Small Enterprise Development X^2 (p-Value)	Disaster Control X^2 (p-Value)	Other options X^2 (p-Value)
Actions before possible shock	8.8837 (0.003 ***)	0.0194 (0.889)	3.1654 (0.075 *)	0.0013 (0.971)	0.4657 (0.495)	1.2783 (0.258)
Investment for future benefits	7.2650 (0.007 ***)	3.2570 (0.071 *)	9.7006 (0.002 ***)	1.4097 (0.235)	0.2996 (0.584)	1.6977 (0.193)
Large scale (e.g., farm level)	7.2188 (0.007 ***)	0.2657 (0.606)	1.9429 (0.163)	4.9887 (0.026 **)	0.4958 (0.481)	2.0239 (0.155)
Planned for long-term climatic shocks (at least for ten years)	1.1819 (0.277)	0.0024 (0.961)	0.4211 (0.516)	0.4211 (0.516)	0.0487 (0.825)	0.1352 (0.713)
Risk assessment of future climate change impacts	(3.2220 (0.073 *)	(0.9544 (0.329)	(0.6163 (0.432)	(0.6163 (0.432)	(2.9509 (0.086 *)	0.6235 (0.430)
Acquired skill training for future possible shock	0.6888 (0.407)	0.3119 (0.577)	0.0815 (0.775)	1.9429 (0.163)	1.7190 (0.190)	1.0472 (0.306)
Use of historical patterns for long-term plan	0.9518 (0.329)	4.9932 (0.025 **)	0.3391 (0.560)	0.3391 (0.560)	1.1719 (0.279)	0.1360 (0.712)
Arrangement of emergency support/funds for uncertain shocks	0.0130 (0.909)	0.4831 (0.487)	0.1661 (0.684)	0.1661 (0.684)	0.0386 (0.844)	0.3631 (0.547)

*** Significance at 1% level, ** 5% level, * 10% level.

4.4. Factors Affecting Households' Choice of Proactive Adaptation Measures

The results of an ordered logistic regression model of factors associating choices of proactive adaptation strategies are presented in Table 6. The likelihood ratio test showed that the model was significant with a chi-square value of 26.69 ($p \leq 0.0034$) and had a pseudo R^2 of 0.26. Our results showed that five out of eleven socio-economic explanatory variables were statistically significant with proactive adaptation measures taken by climate-affected households. Significant factors include the number of livelihood options, wellbeing of households, land area owned, geographical variations, and the number of adaptation activities (Table 8). In comparison to households relying on a single livelihood option, households with two livelihood options demonstrated a significant tendency towards proactive adaptation ($p \leq 0.047$) at a 5% level of significance. However, the proactive adaptation of households with three or more livelihood options was not statistically significant, although the coefficient value was positive. The findings suggest that there is a positive relationship between the number of livelihood options available to the households and their likelihood of taking proactive actions.

The analysis found that households with poor wellbeing had significantly negative impacts ($p \leq 0.009$) at a 1% level of significance compared to those households with a medium level of wellbeing. However, the comparison between the households with medium and high levels of wellbeing did not yield significant results, although the coefficient was positive. This suggests that the likelihood of taking proactive measures decreases significantly with increasing poverty and vice versa.

The analysis of proactive actions in relation to land ownership reveals a negative association. Households with smaller land areas for cultivation were significantly less likely ($p \leq 0.027$ at a 5% level of significance) to adopt proactive climate change adaptation measures. When examining the population across three ecological regions, it was observed that households residing in the mid-hills demonstrated a significant tendency ($p \leq 0.017$ at a 5% level of significance) to engage in proactive adaptation compared to those residing in the lowland region. This suggests that the variation in altitude influences the selection of adaptation strategies. One possible explanation for this observation is that higher-altitude areas are more susceptible to climate-induced hazards, leading to greater impacts on the populations living there. As a result, these populations are more likely to proactively engage in adaptation measures to mitigate the effects of such hazards.

The number of adaptation activities implemented by individual households emerged as a decisive factor. Households implementing more than three distinct adaptation activities were significantly more likely ($p \leq 0.068$ at a 10% level of significance) to include proactive adaptation measures, compared to the households implementing up to two activities. However, there was no significant association observed between proactive adaptation and factors such as sex or the length of major occupation experience. Nevertheless, the negative coefficient between sex and proactive adaptation indicated that women appeared less likely to implement proactive adaptation measures. The same trend was observed with occupational experience, suggesting that a shorter duration of experience reduced the likelihood of including proactive adaptation in overall adaptation measures.

Table 8. Ordered logit estimation explaining major socio-economic factors for proactive adaptation measures.

Variables **Number of Proactive Measures with Reactive**	**Coefficient**	**S.E.**	***Z*-Value**	***p*-Value**
No. of livelihoods options adapted by the households				
• Only one option adopted (Base)				
• Two options adopted	1.525	0.766	1.990	0.047 **
• Three or more options adopted	1.780	1.318	1.350	0.177
Wellbeing category of the households				
• Rich household	20.065	1394.114	0.010	0.989
• Medium household (Base)				
• Poor household	−2.617	0.999	−2.620	0.009 ***
Land area owned by the households	−0.185	0.083	−2.210	0.027 **
Sex of the respondent interviewed (Base Male)	−0.500	0.748	−0.670	0.504
Regional residential differences				
• Mountain-region residents (Base)				
• *Terai* residents (Lowland)	0.813	0.892	0.910	0.362
• Mid-hills residents	2.554	1.068	2.390	0.017 **
Number of adaptation measures implemented				
• One to two adaptation measures implemented (Base)				
• Three to four adaptation measures implemented	0.581	0.887	0.660	0.512
• More than four adaptation measures implemented	2.237	1.228	1.820	0.068 *
Experience of major occupation (years)	−0.031	0.045	−0.690	0.490

LR $chi^2(11)$ (*p*-value) = 26.69 (0.0034), Pseudo R^2 = 0.2648, Log likelihood = −36.435095; *** Significance at 1% level, ** 5% level, * 10% level.

5. Discussion

5.1. Proactive Climate Change Adaptation through the Lens of Local Communities Affected by Climate Changes

Based on the eight criteria for assessing the proactive nature of adaptation, the diverse range of local-level adaptation measures implemented by the households indicate proactive responses to the recurring impacts and escalating severity of climate events. Rural households have demonstrated a self-driven proactive approach by implementing diverse adaptation measures at the local level. The proactive measures implemented by the local households not only reflect the local community's efforts to address immediate challenges posed by climate change but also demonstrate their awareness of future environmental risks and their proactive measures to mitigate them.

The analysis of the responses indicates that the proactive adaptation process undertaken by households aligns with the motivation theory [106,108] and the process model of private proactive adaptation to climate change proposed by Grothmann and Patt [102]. Knowledge and the processes of adaptation, by which individuals or communities effectively adjust to changed environments over time, largely stem from empirical and analogical analyses [88,144–147]. The significant findings regarding the association between the cognitive evaluation of households in assessing the risks of future climate change impacts and their choice of livelihood options indicate that individuals actively assess the severity of climate conditions in their surroundings (risk appraisal) and make decisions based on this evaluation. The majority (77.42%) of the households interviewed expressed the anticipation that climate change will become more menacing in comparison to the current scenario, leading to more rapid and erratic fluctuations in temperature and precipitation. Conversely, the remaining respondents believed that the current trend and variability of climate change would persist without significant change (risk appraisal). These findings align with a previous study conducted in the same area, which examined the significance of meteorological records and local peoples' perceptions [39]. Subsequently, they anticipate a higher likelihood of being further exposed to the worsening of climate-related disasters, such as floods, inundation, landslides, extreme temperatures, heatwaves, cold waves, wind-throw, and wind damage (perceived probability). Based on these anticipations, the households predicted severe impacts, including property loss (such as houses, land, and livestock), reduced land productivity, crop quality loss, and the invasion of pests and pathogens (perceived severity). Consequently, they engaged in preparatory measures to avoid or minimize potential worst-case scenarios (adaptation appraisal). As suggested by Schwartzer [148], individuals contemplate the possibility of beneficial adaptation options and reflect on their suitability. Considering the predicted threats and the severity of impacts, local households have developed beliefs about certain adaptation measures that could reduce vulnerability (perceived adaptation efficacy). For instance, in this case, local people have recognized that diversifying crops and adopting more resilient and climate-adapted varieties can provide better protection against losses and damages caused by drought, heatwaves, cold waves, extreme weather events, and disease outbreaks. After careful consideration, the local households made decisions to pursue over 50 different proactive adaptation activities (perceived self-adaptation efficacy) based on their own knowledge, available resources, and perceived costs associated with adaptation (perceived adaptation cost). Subsequently, they implemented these chosen measures (adaptation).

Based on our findings, it is evident that the perceived severity of climatic threats, self-efficacy, and adaptation efficacy significantly influence an individual's motivation to actively engage in practical climate change adaptation measures. These results align with previous studies that have also demonstrated the predictive role of these factors in motivating individuals to take action towards climate change adaptation, e.g., [116,149–151]. Regarding the adaptation behavior of forest growers, our findings largely support the study conducted by Villamor, Wakelin, Dunningham, and Clinton [117] on risk appraisal. They found that local forest owners perceive climate risks such as heavy rain, floods, debris flow, landslides, wind damage, pests, diseases, forest fires, and market disruptions. However Bostrom, Hayes, and Crosman [114] argued that the perception and judgment of self-efficacy and response efficacy may differ between individual actions and those taken by the government or collective entities. They highlighted that these perceptions are context-specific and can be challenging to perceive precisely.

As indicated in the results, five out of the six clusters of adaptation activities aligned with one to four criteria of multiple forms of adaptive behavior observed in the studied households. These criteria included taking actions prior to potential climate change impacts, investing for future benefits, scaling up adaptation options at the farm level, and perceptual risk assessments of future climate change impacts. An illustrative example of proactive adaptation practiced by local people is the plantation of trees in risk-prone zones, which has been shown to save lives and properties. In Kailali district (*Terai*), for instance, a severe storm occurred in June 2019, causing significant damage to the Najaria and Dogara hamlets. While 20 to 25 out of 70 houses were destroyed in Najaria, 4 houses were affected in Dogara. According to the respondents, the presence of a large number of trees surrounding the houses in Dogara reduced the impact of the storm. Moreover, these trees served the additional purpose of hanging crop seeds, a traditional practice used to store seeds and protect them from floods. This example demonstrates how local people took proactive measures in anticipation of potential risks, indicating long-term planning, future risk speculation, and control as indicators of proactive adaptation. Other typical examples of proactive adaptation measures include building goat sheds raised 2–3 feet above ground level and constructing houses with raised foundations coated with mud and wood. These measures serve as protective actions against climate adversities such as floods, inundation, extreme heat, and extreme cold. They are precautionary measures aimed at mitigating future climate-related challenges. Several proactive actions serve multiple purposes, and one such example is the planting of trees by the households. Households receive multiple benefits from this, including mitigating the risks of soil erosion and wind damage, protecting agricultural lands from inundation, preserving seeds during floods, producing timber and fruit, and providing shade during extreme temperatures. It suggests that households' adaptation measures not only help them adjust to the changing climate but also serve as viable means of sustenance in rural areas.

These findings provide strong empirical evidence that households impacted by climate change tend to proactively engage in climate change adaptation. Proactive adaptation is widely recognized as an essential strategy for mitigating the cumulative effects of climate change and reducing adaptation costs. A study conducted by Melvin, et al. [152] on the economic impacts of climate change on Alaska's public infrastructure under high and low climate forcing scenarios (Representative Concentration Pathways RCP 8.5 and RCP 4.5) supports this concept. The study estimated that, without adaptation measures, the cumulative expenses for climate damage to infrastructure from 2015 to 2099 would amount to USD 5.5 billion for RCP 8.5 and USD 4.2 billion for RCP 4.5. However, with proactive adaptation measures in place, the total projected cumulative expenditures were reduced to USD 2.9 billion for RCP 8.5 and USD 2.3 billion for RCP 4.5. This projection highlights that proactive adaptation not only mitigates the severity of climate change impacts but also alleviates the economic burden on stakeholders involved in the adaptation system.

As described by Smit and Pilifosova [89], proactive (planned, anticipatory) adaptation has the potential to reduce vulnerability and capitalize on beneficial opportunities. In our study, shifting from subsistence agriculture to new livelihood options, such as small enterprise development, livestock raising, and cash crop cultivation, exemplifies the opportunities created by climate change. Many households recognized the increased sensitivity and riskiness of annual cereal crops to climate change variability as well as the higher incidence rates of pests and pathogens. Consequently, they made decisions to shift towards livestock production and vegetable farming, which are considered relatively less sensitive to climate change compared to cereal crop production. This demonstrates the local community's ability to consciously assess future climate risks based on historical patterns of impacts. Most farmers were expected to transition from cereal crop production to livestock and vegetable production, on a larger scale than before, for a period of 5 to 10 years. These hands-on processes and actions align with multiple criteria of proactive adaptation. A compelling case from a young farmer in Gorkha district supports the case. After facing multiple climate-related challenges and failures with cereal and cash crop cultivation (such as rice, black cardamom, and potato), he decided to venture into cow farming, pig rearing, and a local poultry farm. Despite the initial difficulties, he expressed contentment with his new endeavors, stating, "*I used to do agriculture for subsistence in the past, but now I am pleased with my business as I earn more than expected. This allows me to afford a good education for my children, sufficient food for my family, and even some savings in the bank for emergencies*". This illustrates that individual households not only proactively seek to diversify their usual choices but also perceive them as opportunities for improved livelihoods.

Our findings are consistent with the research conducted on farmers in Chile [151] and the coastal region of Bangladesh [153]. These studies also identified unpredictable weather, heat stress, water scarcity, and pest and pathogen invasions as significant risks impacting agricultural productivity and livelihoods. In response to these challenges, farmers employed proactive adaptation measures such as diversifying species, switching to more resilient crops, altering farming practices, and utilizing improved seeds or varieties for annual crops. Similar proactive practices were also observed in the study by Roche [154], which focused on livestock promotion, including strategies like grass banking, stocking conservation, and incorporating yearling cattle and other livestock types to increase flexibility. Smit and Pilifosova [89] documented the implementation of artificial systems to improve water utilization, prevent soil erosion, and adopt different crop varieties. Our findings are in accordance with numerous previous studies, e.g., [39,49,67,68,125,132,155–162], that have examined locally implemented adaptation activities. However, it is important to note that in some cases, such as in agriculture, abandoning existing occupational activities or ceasing farming options [151,163,164] can have immediate consequences for locally intertwined self-employment. In Gorkha (mid-hills), for example, a blacksmith (one interviewee) who had been engaged in manufacturing agricultural equipment was on the verge of abandonment of his traditional occupation because of reduced demand for agricultural equipment, resulting from decreased agricultural practices in his village. This situation is not unique to Gorkha but is also observed in the *Terai* region. The economically marginalized and small-land holders (interviewees) used to work agricultural wage labor in the region. Several wealthier farmers are now downsizing their farming size. This has significantly reduced the seasonal and local employment in the agriculture sector. These examples signify that climate change is having significant and ongoing impacts on the interlinked systems of people's livelihood choices and the drivers of the local socio-economic system. Furthermore, it suggests that developing and implementing context-specific adaptation measures is essential in ensuring the long-term sustainability of these systems.

5.2. Factors Affecting Households' Choices of Proactive Adaptation

The effectiveness of adaptations relies on the adaptive capacity of the human system, as various types of adaptations are expected to take place [89]. Within this system, several socio-economic factors influence the selection of adaptation measures. In our study, household wellbeing, the number of available livelihood options, the size of agricultural land for cultivation, geographical variations, and the number of implemented adaptation activities were identified as key factors determining the choice of proactive adaptation measures. Households with multiple livelihood options, a greater number of adaptation activities, and larger agricultural land size are more likely to opt for and adopt proactive adaptation measures, alongside other climate change adaptation strategies and livelihood approaches. These factors also play a significant role in determining an individual's economic status, whether they are well-off or living in poverty.

The negative coefficient observed for the wellbeing category indicates that poorer households are less likely to engage in proactive adaptation actions. This suggests that wealthier farmers have a greater capacity to explore and utilize multiple alternative adaptation options. The determinants of adaptation analyzed in the earlier studies, for example, the studies of Kabir, et al. [165] in Bangladesh, Tun Oo, et al. [166] in Myanmar and Tambo and Abdoulaye [125] in Nigeria, also support the case. Households possessing more agricultural land also tended to engage in a greater number of adaptation activities [39,132,167,168] by partitioning their farming land for multiple purposes, for example, cultivating various crops, growing vegetables, and raising livestock simultaneously. Households with larger landholdings have greater flexibility in utilizing their land which reduces risks and enhances their ability to afford losses from crop failures. This suggests that land plays a crucial role in increasing the implementation of proactive measures to address climate change challenges.

Altitudinal variation significantly influences the selection of proactive adaptation strategies, as different regions exhibit varying levels of exposure and vulnerability to climate risks. Our findings indicate that households residing in the mid-hills display a greater inclination towards proactive adaptation compared to those in lowland areas. The choice of adaptation strategies is influenced by various factors, including exposure, vulnerability, local culture, society, economy, and geography. High-altitude communities often bear the brunt of more climatic hazards, leading to increased adoption of adaptation measures. Mountainous regions in Nepal face a heightened degree of climate threats [169,170]. Perception of higher climate risk severity and extreme threats in mountain regions drive proactive adaptation. Numerous studies support the facts that higher-altitude regions experience greater climate severity, e.g., [22,171–175], thereby increasing the likelihood of households adopting proactive measures [102]. Individuals employ adaptation measures against climate change impacts based on their personal perceptions and observations of climate change [156,176,177].

Age and length of major occupation did not significantly influence proactive adaptation actions. Previous studies have highlighted age and farming experience as important factors in climate change adaptation. However, our findings align with the observation of Bui and Do [132] that age does not impact adaptation choices. While Nhemachena and Hassan [168] suggest that highly experienced farmers are more likely to possess knowledge and take adaptation actions, our results show an ambiguous and insignificantly negative correlation. This suggests that long experience and older age do not necessarily drive the selection of proactive adaptation measures. One possible explanation is that younger farmers often have better education and are more open to adopting novel ideas [167,178], while older and experienced farmers may be more reluctant to embrace new technologies [179].

We observed that the biggest challenge faced by innovative farmers was the market and market access for cash crops, vegetables, and livestock products (e.g., milk, meat, and eggs). Limited available markets are often dominated by outsiders and middlemen. This situation has two negative effects. Firstly, farmers struggle to obtain fair prices for their perishable local products, which are prone to price fluctuations. Secondly, the combination of climate change impacts and market inaccessibility discourages farmers from continuing with their adopted measures. The issue of market constraints has been raised in various studies, e.g., [180–182].

The adaptive capacity of local households is shaped by a variety of factors, which influence their decision making regarding the utilization of limited resources. Common factors that come into play include economic wealth, infrastructure, technology, information and skills, institutions, and equity [18,89,183,184]. The decision-making process for adaptation varies across different scales, including adaptation by private individuals, local communities or institutions, national governments, and international organizations [89]. In our study, we specifically focused on private individual adaptation through direct interaction with individual households, which allowed us to draw conclusions about entire studied communities. Since the selected communities in our study have not received any external support for adaptation, external interventions were not applicable and were not considered in our analysis.

5.3. Proactive Local Actions: Embracing Transdisciplinary Approaches Bridging Adaptation and Climate Change Mitigation

Proactive actions implemented at the local level not only pertain to adaptive measures but also make valuable contributions to climate change mitigation. Illustrative examples of proactive measures against climatic issues at the local level include planting trees in high-risk areas prone to floods, inundation, and erosion; promoting windbreak trees to protect homes and properties; utilizing trees to safeguard crop seeds from floods; encouraging the use of solar energy; engaging in vegetable farming; and shifting to small off-farm businesses. These measures are equally effective in adopting a mitigation approach. Climate change, driven by greenhouse gas emissions resulting from human activities, has led to approximately 1.0°C of global warming above pre-industrial levels [22,185]. Local proactive measures demonstrate how individual actions effectively contribute to reducing and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere (mitigation), while also addressing existing and anticipated climate change impacts (adaptation). The findings of our study suggest that the proactive actions implemented by rural communities in Nepal serve as triumphant examples of a transdisciplinary approach encompassing both adaptation and mitigation.

Transdisciplinarity is a holistic perspective that involves restructuring and reorganizing disciplinary knowledge to address real-world issues through collaborative efforts [186,187]. In this approach, no single discipline holds intellectual precedence [188]. It adopts a systemic approach that actively engages with local and regional concerns [189], incorporating not only scientists and academic disciplines but also non-academic participants such as land managers, user groups, and the general public [190,191]. By combining interdisciplinarity with participatory approaches, it fosters a collaborative and inclusive process [191].

Our research findings demonstrate that the implemented proactive measures reflect a concerted effort to address climate change mitigation and adaptation. These measures encompass various domains, including agriculture, livestock, business/enterprise, and disaster management. They embody a synergistic approach, inviting policymakers, decision makers, scientific institutions, and planning agencies to embrace a transdisciplinary perspective when dealing with adaptation and mitigation challenges.

6. Conclusions and Recommendations

In this paper, we attempted to identify proactive adaptation actions implemented by rural households that are specifically linked to the subsistence livelihoods of rural communities. Livelihood options such as agricultural diversification, cash crop cultivation, livestock raising, small-scale enterprise development, and disaster control have emerged as proactive actions taken by local communities. These actions are driven by the intention to address potential climate change impacts in advance, invest for future benefits, scale up suitable adaptation options at the farm level, and assess perceived risks of future climate change impacts. We found that the factors such as household wellbeing, available livelihood options, agricultural land size, geographical variations, and the number of implemented adaptation activities have a significant influence on the selection of proactive adaptation strategies. Based on the results of the implemented proactive adaptation measures, we can conclude that the proactive actions taken by households reflect an incremental approach to decision making in climate change adaptation. Instead of attempting to tackle complex decisions all at once, households are effectively reducing potential risks and coping with existential impacts by making smaller, gradual changes. While there is growing emphasis on the direct responsibility of governments and collective entities in proactive adaptation as public policy initiative increases, the findings of this research provide valuable insights into practical adaptation initiatives. These initiatives can be utilized by government actors, policymakers, and a wide range of official and non-official organizations and associations. The significance of these initiatives is particularly evident for developing nations, where there is a growing need to encourage farmers and local communities to actively participate in adaptation practices. By implementing the strategies identified in this research, governments can empower these communities and facilitate their engagement in effective adaptation measures.

Given these findings, this study has made valuable contributions to the field of climate change adaptation in four key ways:

1. Enhanced Understanding of Local Practices:

Our results strongly support the cognitive process of individuals' perception of self-efficacy in shaping their intention to adapt. Local communities have chosen adaptation measures based on their economic calculations and subjective assessments, with the aim of coping with current impacts and proactively addressing anticipated climate hazards. Understanding the impact of cognitive constructs on adaptive behaviors helps policymakers improve people's understanding and recognize and value the proactive responses and skill set of local communities during the process of appropriate policy formation;

2. Emphasis on Societal Efficacy and Compatibility in Policy Process:

Viewing the management of climate risks as a strategic interplay between environmental, political, and societal imperatives, effectively communicating the findings of locally appropriate proactive measures becomes a vital step in informing policymakers, scientists, and program designers. It is essential to recognize that local communities are not merely passive recipients of adaptation efforts but are the primary architects of addressing local issues through a combination of traditional, indigenous, and contemporary practices developed through sustained interactions with their local environment. This communication better informs policymakers, scientists, and program designers to consider proactive measures as a primary requirement in decision-making processes, in order to develop relevant interventions against climate risks for both immediate and long-term goals. Therefore, we recommend policymakers gain a better understanding of and prioritize climate change adaptation choices and strategies at the local level to ensure successful implementation of policy initiatives;

3. Contribution to Achieving Climate Goals:

Understanding perceived climate risks and analyzing applied adaptation measures in terms of their efficacy and compatibility with local priorities are crucial in the adaptation process and local development. Some of our findings indicate that the adaptation activities identified in this research not only contribute to climate change adaptation but also serve as mitigation measures and options for livelihoods. The activities, e.g., planting in high-risk areas, promoting windbreak trees, utilizing trees for seed protection, using solar energy, engaging in vegetable farming, and shifting to off-farm businesses, have been shown to be effective in reducing greenhouse gas emissions while simultaneously addressing the impacts of climate change along with benefitting livelihoods. This suggests that the proactive adaptation of the local community can contribute to limiting the anticipated temperature increase below the 1.5 °C goal of the Paris Agreement. The proactive actions individuals and society take today address the changing climate, contributing to the achievement of climate goals;

4. Need for Transdisciplinary Approaches:

This study highlights the important role of local households and communities in possessing skills, experiences, and practical knowledge that enable them to choose and implement appropriate options that enhance resilience. The findings underscore the necessity of incorporating transdisciplinary aspects in the development of both mitigation and adaptation measures. This approach facilitates the engagement of local communities and stakeholders in designing effective and sustainable adaptation strategies to address the complex and interconnected challenges of climate change at the local level.

Finally, we strongly recommend conducting further research to understand the possibility of maladaptation occurring within the local context when addressing climate change issues. Similarly, there is an urgent need for comprehensive research to delve into indigenous knowledge systems and their potential to counteract threats and adapt to climate change, aiming to minimize the likelihood of maladaptation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su151410952/s1, Table S1: List of major proactive adaptation measures adapted by households.

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