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Farmers' Perception of Climate Change and Its Impacts on Agriculture

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Citation: Shrestha, R.; Rakhal, B.; Adhikari, T.R.; Ghimire, G.R.; Talchabhadel, R.; Tamang, D.; KC, R.; Sharma, S. Farmers' Perception of Climate Change and Its Impacts on Agriculture. *Hydrology* **2022**, *9*, 212. https://doi.org/10.3390/hydrology9120212

Academic Editors: Md Shahriar Pervez, Naga Manohar Velpuri and Pierfranco Costabile

Received: 14 October 2022
Accepted: 24 November 2022
Published: 28 November 2022

Abstract: Climate change and climate variability drive rapid glacier melt and snowpack loss, extreme precipitation and temperature events, and alteration of water availability in the Himalayas. There is increasing observational evidence of climate change impacts on water resource availability and agricultural productivity in the central Himalayan region. Here, we assess the farmers' perception of climate change and its impacts on agriculture in western Nepal. We interviewed 554 households and conducted eight focus group discussions to collect farmers' perceptions of temperature and rainfall characteristics, water availability, onset and duration of different seasons, and the impacts of such changes on their lives and livelihoods. Our results indicate that the farmers' perceptions of rising annual and summer temperatures are consistent with observations. Perception, however, contradicts observed trends in winter temperature, as well as annual, monsoon, and winter precipitation. In addition, farmers are increasingly facing incidences of extreme events, including rainfall, floods, landslides, and droughts. These hazards often impact agricultural production, reducing household income and exacerbating the economic impacts on subsistence farmers. Integrated assessment of farmers' perceptions and hydrometeorological observations is crucial to improving climate change impact assessment and informing the design of mitigation and adaptation strategies.

Keywords: climate change; temperature; precipitation; agriculture; farmers' perception; mitigation and adaptation

1. Introduction

The Himalayan region is considered the water tower of Asia and plays a crucial role in water resources available for agricultural production in South Asia. The region is experiencing a strong influence of climate change on rainfall variability, extreme temperature, permafrost thaw, glacier melt, and river water degradation [1]. Climate change exacerbates hydroclimatic hazards (e.g., extreme rainfall, floods, and droughts) and the associated risks to water resources and agriculture [2–5]. Due to climate change, climate extremes, such as heat and cold waves, droughts, floods, and extreme precipitation events, are becoming more frequent, concurrent, and damaging [6–8]. Strategies to manage these risks rely on how local communities, decision-makers, and stakeholders perceive hazards and risks [9]. Risk perception can vary with livelihood, vulnerability, adaptive capability, and past encounters with climate-induced hazards [10–12]. Understanding local communities' perceptions of climate change can help inform the design of risk management strategies [13,14].

Climate change and climate variability pose a huge constraint on farmers' ability to make strategic agricultural practice decisions, from seeding to harvesting [15,16]. Climate change impact assessments are often constrained by observational data availability and data quality [17–19]. In hydrometeorological data-scarce regions, local knowledge is quite important in developing climate change mitigation and adaptation strategies [20–22]. While subsistence farmers are highly vulnerable to climate change [23], they also possess rich knowledge about local climatic conditions and historical extremes [24]. However, their knowledge is often ignored in risk management policies and programs [25,26]. Emphasis is given to the use and analysis of empirical observations and regional climate model outputs [27,28]. While such observations and climate model outputs are useful for adaptation planning at regional scales, they might not be representative at local scales.

The economy of the central Himalayan country Nepal is largely dependent on agriculture. The agricultural sector contributes one-third of the country's gross domestic product and provides employment for two-thirds of the population [29]. Agricultural practices mostly depend on rainfall [30]. Any changes in rainfall characteristics such as intensity, duration, and frequency can impact agricultural production and food security [15,31]. The recent increase in the frequency and intensity of extreme rainfall events, floods, and droughts have impacted lives and agriculture-based subsistence livelihoods across the country [32,33]. For example, the droughts of 2006 to 2009 affected over two million people [34]. A prolonged drought in 2013 induced an irrigation water shortage and forced the relocation of thousands of people in Northern Nepal [35,36]. Heavy rainfall in August 2017 resulted in widespread floods and landslides with agricultural damage of over 60 million USD [37]. These impacts are expected to increase in the future as changing climates can substantially alter temperature, precipitation, and river flow conditions in the Himalayan region [38–40].

Several studies [32,41–44] have focused on assessing farmers' perceptions of climate change in the central Himalayan region. For instance, Muench et al. [45] reported the development of adaptation strategies, such as crop diversification and soil conservation, based on the high awareness of climate change by the smallholder tea farmers of Eastern Nepal. However, their adaptation choices were constrained by the lack of access to information, financial and agricultural extension services, availability of irrigation facilities, and degree of training participation. Devkota [32] compared the climate change trends with people's perceptions in Western Nepal and found a close similarity between the observed and perceived trends. Shrestha et al. [41] reported that local people accurately perceived the shifts in temperature, but their perception of precipitation change differs from the observational records. Luitel et al. [42] focused on climate change impact assessment on crop yield in different ecological regions of central Nepal. Their study reported that the decreasing trend in rainfall across different elevations generally matched the views of respondents, with an exception in the temperate climatic region. People from the temperate climatic region perceived that the current onset of snowfall was delayed, but the amount of snowfall remained the same. Dawadi et al. [43] found a convergence between the people's perception and observational trends of precipitation and mean temperature in the mountainous region. Budhathoki and Zander [44] analyzed the impacts of farmers' climate change perceptions on their farming practices. They found that while perceptions of changes in maximum temperatures aligned with the observed trends, the perceptions differed for changes in minimum temperature and rainfall. The conclusions from these studies have been mixed. Some have reported the large impacts of climate change on agricultural practices and production [42], while others have found that the choice of crop varieties and cropping patterns are often driven by technological and market-related factors rather than climate change alone [44]. Hence, there is no consensus among previous studies suggesting that neither local perception nor observational trend alone is sufficient for climate change impact assessment on agriculture. Integrated analysis of farmers' perceptions and the hydrometeorological observational dataset is crucial to quantify climate change impacts on the agricultural sector and to inform the design of mitigation and adaptation strategies [41,46–50].

Most studies comparing the farmers' perception with instrumental observation have focused on smaller geographical areas. Very few studies have compared people's perceptions with scientific data covering multiple ecological regions. Such comparative studies are very rare in the Far-western region of Nepal (See, for example, [41,42,44]). To the best of our knowledge, this study is the first to compare farmers' perceptions in different ecological regions of Far-western Nepal with scientific data. This study compares farmers' perceptions of climate change and historical hydroclimatic observation in three different physiographic regions of Far-western Nepal. The objectives of the study are to (i) analyze temporal trends in historical temperature and precipitation observations, (ii) assess farmers' perception of changes in temperature and precipitation, and compare their perception with the observed hydroclimatic trends, and (iii) examine the perceived impacts of climate change on agriculture. Farmers' perceptions about hydroclimatic trends and impacts of climate change were gathered through the questionnaire survey and focus group discussions (FGDs). The insights gained from this study contribute to advancing our fundamental understanding of the impacts of climate change on agricultural practices (such as farming patterns, crop yield, mitigation, and adaptation strategies) in the Himalayan region that, in turn, could help to inform the design of adaptation and mitigation strategies.

2. Study Area, Materials, and Methods

2.1. Study Area

This study focuses on four districts of Western Nepal, including Kailali, Kanchanpur, Dadeldhura, and Baitadi (Figure 1). Western Nepal is highly vulnerable to climate change impacts [51]. The region has below the national average score on Human Development Index indicators such as health, income, and education [52]. The per capita income is lower [53], whereas the population proportion under absolute poverty is higher than in other parts of the country [54]. We selected the study region by adopting a purposive sampling strategy [55,56] to incorporate diverse hydroclimatic hazards, physiographic regions, and socioeconomic conditions. For instance, Kailali and Kanchanpur are located in the low-land Terai region, whereas Dadeldhura and Baitadi are situated in the Hilly region.

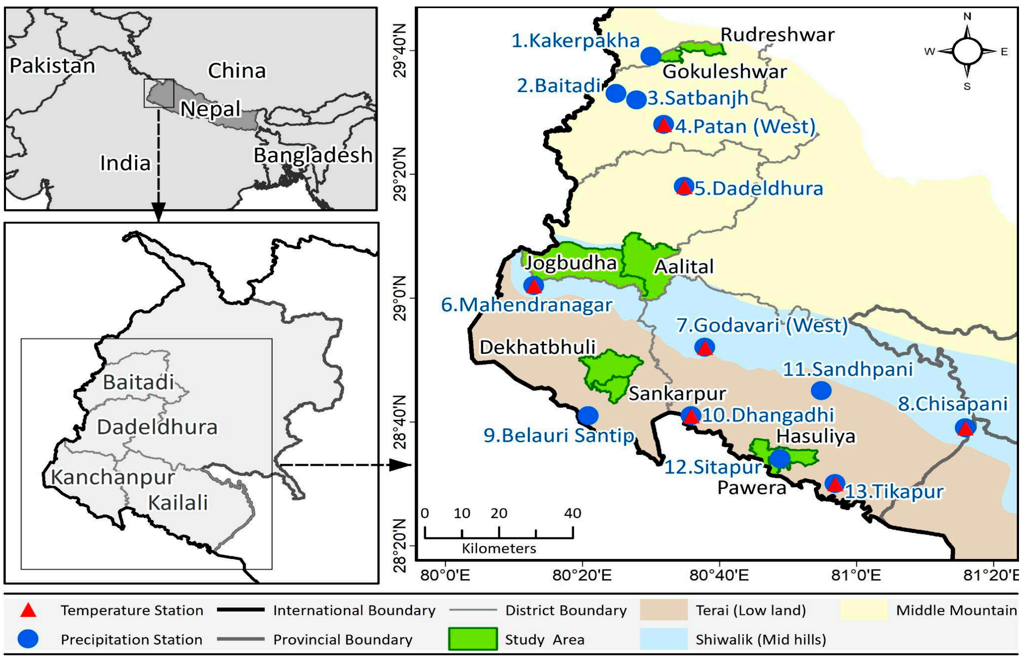

Figure 1. Map showing the study area and meteorological stations.

We analyzed temperature and precipitation observations at 7 and 13 stations, respectively (Figure 1). Farmers' perceptions of changes in temperature and precipitation parameters and their impacts were gathered from the farmers of eight different locations. Two survey locations from each district were selected based on their high vulnerability to climate-induced hazards as identified in the Disaster Preparedness and Response Plans (DPRPs) of respective districts [57–60].

2.2. Meteorological Observations

Temperature and precipitation datasets were acquired from the Department of Hydrology and Meteorology (DHM), Nepal. We assessed annual and seasonal trends for the period 1970–2014. The seasonal trends were assessed for Pre-monsoon (March–May), Monsoon (June–September), Post-monsoon (October–November), and Winter season (December–February). We evaluated the monotonic trends at each station using non-parametric rank-based Mann–Kendall tests [61,62]. The trend magnitude was estimated using Theil-Sen's approach [63,64]. The Mann–Kendall test is robust against data gaps and outliers, and the method is widely used in such hydroclimatic analyses. We show the trends at a 5% level of significance.

2.3. Assessment of Farmers' Perceptions

Farmers' perceptions of trends and impacts of climate change were gathered through the questionnaire survey and focus group discussions (FGDs). The survey was conducted from October 2016 to April 2017. The sample size (n) for the questionnaire survey of each of the surveyed locations was determined using the approach recommended by Arkin and Colton [65]:

$$n = \frac{NZ^2P(1-P)}{Nd^2 + Z^2P(1-P)} \tag{1}$$

where, N = total number of households, Z = Z-statistics (i.e., 1.96 at 95% confidence level), P = estimated population proportion (0.05; this maximizes the sample size), and d = error limit of 5%. Using Equation (1) and the population data from the census of 2011 (CBS, 2012), the sample size for the questionnaire survey was obtained as 554. The randomly selected 554 households were then interviewed to collect household perceptions on climate change trends and impacts over the past 30 years (1986–2016). The dominant respondents (52%) were of 50–60 years of age, followed by those over 60 years of age (30%), and the remaining 18% were of 18–49 years of age. Most of the questions for household surveys were designed as multiple-choice questions with answers in terms of one of the following: increased (I), decreased (D), no change (NC), and do not know. The key aspects of the questionnaire are shown in Supplementary Material, Table S3. The respondents who perceived an increase or decrease in climatic parameters were further asked to mention three major impacts of climate change on agriculture as well as mitigation and adaptation measures followed to minimize the impacts.

Eight FGDs were conducted with farmers—one in each of the surveyed locations. In total, 52 persons participated in the FGDs, of which 56% were female. Overall, 81% of the participants were above 50–60 years of age, 12% were above 60, and the rest were 18–49 years of age. Each FGD consisted of five to eight people of different ages, gender, and ethnicity. The participating farmers were asked about their perceptions of changes in temperature and rainfall patterns, water availability, onset and duration of different seasons, and the impacts of such changes on their lives and livelihoods. The demographic composition of the questionnaire survey and FGD participants are included in Supplementary Tables S1 and S2.

3. Results

3.1. Temperature and Precipitation Observation

Figure 2a–o present the temporal trends of temperature and precipitation. The annual daily maximum temperature (Tmax) has decreased in two stations (both statistically insignificant) and increased in the remaining five stations (refer to Figure 2n). Four stations, namely Patan (West) and Dadeldhura of the middle mountain region, and Godawari (West) and Mahendranagar of the siwaliks, show a statistically significant rising trend. The annual trends range from −0.02 °C y^{-1} to 0.1 °C y^{-1}. Monsoon Tmax is significantly increasing in three stations—two of which lie in the middle mountain and one in the Terai (lowland) region (refer to Figure 2f). Similarly, as indicated in Figure 2h winter Tmax is significantly increasing in Patan (West) and Dadeldhura stations—both of which lie in the middle mountains and is significantly decreasing in Mahendranagar and Chisapani stations—both of which are in the Siwaliks (mid-hills).

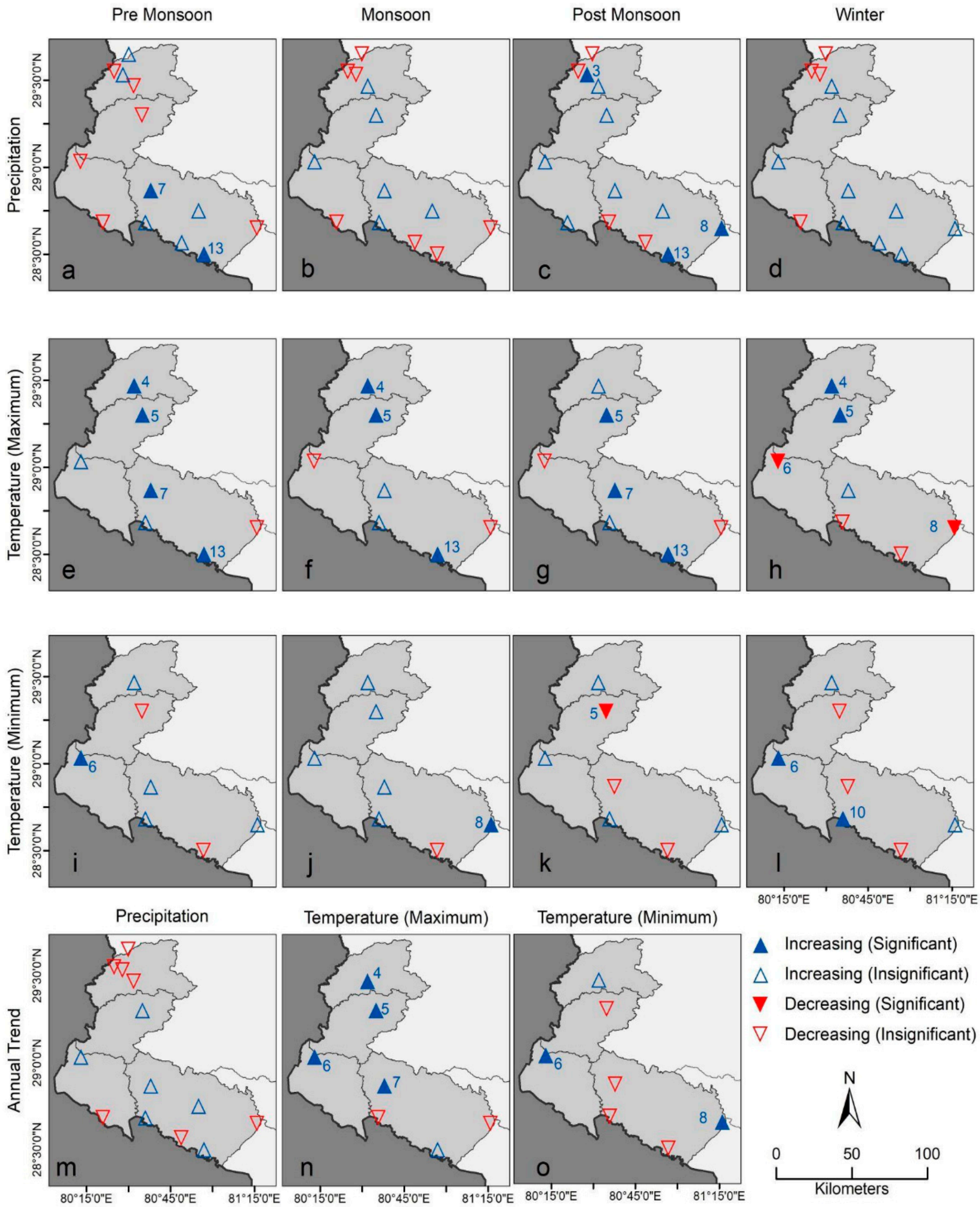

Figure 2. (**a**–**o**) Temporal trends in temperature and precipitation observations across meteorological stations.

As shown in Figure 2o, annual daily minimum temperature (Tmin) is decreasing in four stations (all statistically insignificant) and increasing in the remaining three stations, with a significantly increasing trend in two of those stations—Chisapani and Mahendranagar stations of siwaliks region. Mahendranagar station shows a statistically rising trend for both annual Tmax and Tmin. Likewise, Patan (West) station, which lies in the middle mountain region, shows an increasing trend for both annual Tmax and Tmin, whereas Dhangadhi station, which lies in the lowland Terai region, shows a decreasing trend for both annual Tmax and Tmin. The trends of annual Tmax and Tmin were just opposite for the remaining four stations indicating the diurnal temperature range is relatively higher in those locations (refer to Figure 2n–o). The annual trends range from $-0.04\ °C\ y^{-1}$ to $0.03\ °C\ y^{-1}$ at, respectively Tikapur station (elevation: 140 masl) of Terai and Chisapani station (elevation: 225 masl) of siwalik. Interestingly, these two stations are located in the Kailali district and are only 24 km apart, exemplifying that the climates can vary over a short distance. Such difference could be because of the multiple microclimatic regions generated by the complex physiographic properties of the Himalayas [66] and highlights the necessity of an adequate number of stations for climate change studies and adaptation planning. The monsoon Tmin is found to be increasing in all stations except for Tikapur (Figure 2j). Chisapani station shows a significantly increasing trend of monsoon Tmin (refer to Figure 2j), whereas Dhangadhi (Terai) and Mahendranagar (Siwalik) stations show a significantly increasing trend of winter Tmin (refer to Figure 2l).

In terms of precipitation, both the total annual and monsoon precipitation show a mixed trend, i.e., six stations have a rising and seven stations have a falling trend, but across different stations (Figure 2m). The winter precipitation has rising trends in most stations (9 stations) while falling trends in the remaining four stations (refer to Figure 2d). Note that the precipitation trends are statistically insignificant in all the stations, with their magnitude ranging from -8.4 mm y^{-1} to 17.5 mm y^{-1}. Please refer to Supplementary Tables S4–S6 for further details.

3.2. Farmers' Perception of Change in Temperature and Precipitation

Data collected through questionnaire surveys and FGDs indicate that the farmers perceived a considerable change in temperature and precipitation parameters (Figure 3). Figure 3a–i present farmers' perceptions of change in different climate parameters at different locations. More than 70% of the respondents to the household survey perceived that the overall summer and winter temperatures have increased over the last 30 years. Similarly, more than 80% of the respondents perceived change in the duration of the summer and winter seasons. While 82% of respondents perceived an increase in summer duration, 77% of them perceived a decrease in winter duration (refer to Figure A1 in Appendix A for further details).

There was a general consensus on the tendency of change in temperature patterns, with the majority of respondents perceiving an increase in annual and seasonal temperatures. However, the respondents have mixed perceptions of rainfall trends. While more than 50% of respondents perceived an increase in annual and monsoonal rainfall, a huge proportion of respondents—35% and 41% of respondents, respectively—perceived that the annual and monsoon precipitation might have actually decreased. Likewise, there was a greater consensus about the intensity of monsoon rainfall and the amount of winter rainfall. In all, 73% mentioned that the intensity of monsoon rainfall has increased, which has caused an increase in the occurrence of rainfall extremes driven hazards, such as floods and landslides in recent years. Similarly, 84% of respondents perceived that there had been a decrease in the winter rainfall amount. Likewise, 55% of respondents perceived a decrease in the number of rainy days. The majority of the FGD participants also highlighted the delay in the onset and offset of monsoon compared to before.

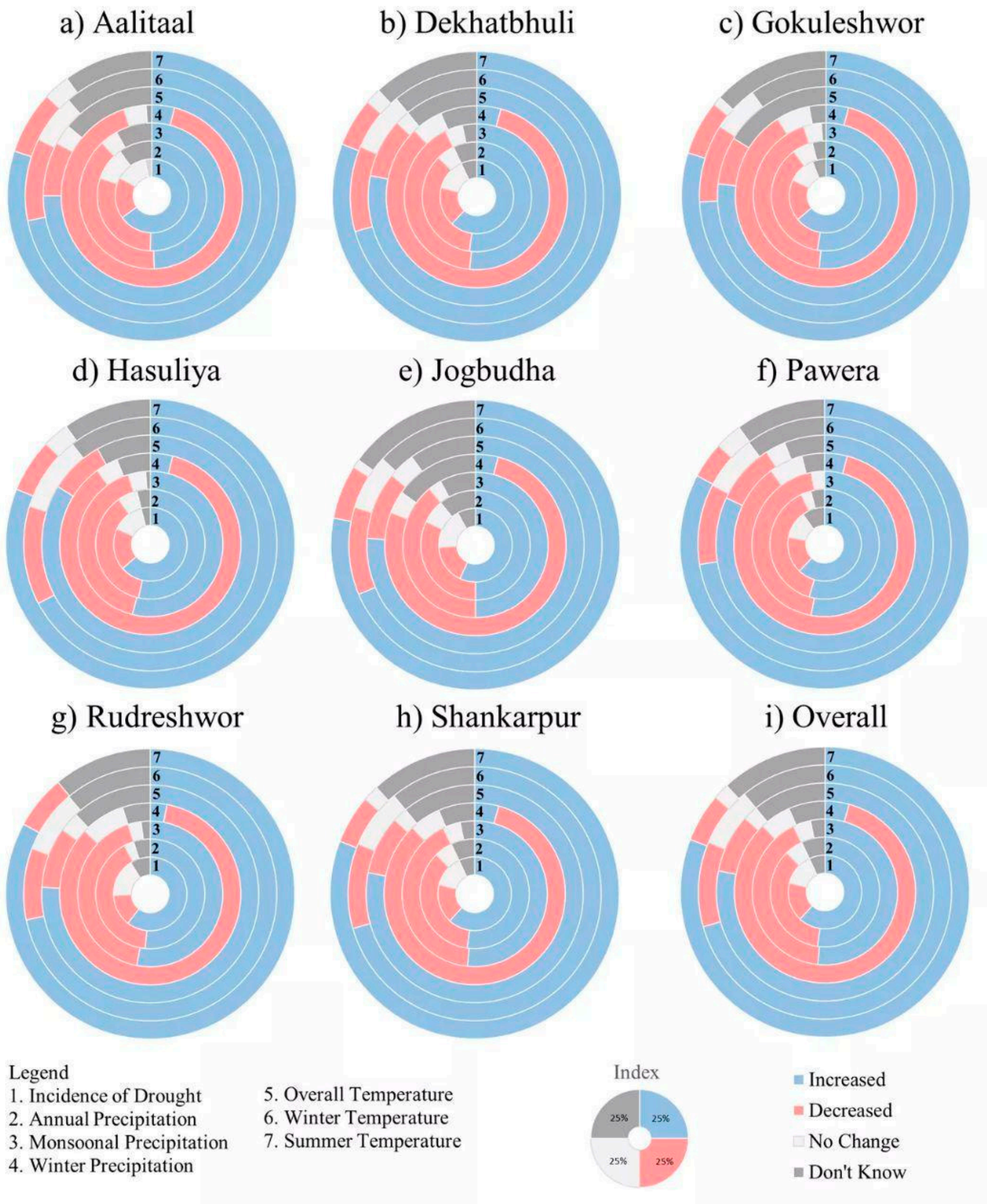

Figure 3. (**a**–**i**) Farmers' perception of temporal trends of temperature, precipitation, and drought.

3.3. Farmers' Perception of Climate Change Impacts on Agriculture

3.3.1. Farmers' Perception of Climate Change Impacts on Trends of Hazards' Incidences

Farmers have experienced not only changes in climate parameters but also the impacts of those changes on their livelihoods. More than two-thirds of the respondents of the questionnaire survey and participants of FGDs perceived that the incidences of floods and landslides have increased. The perception of an increase in flood and landslide incidences aligns with the disaster database maintained by the Nepal Government of Nepal Disaster Risk Reduction Portal (http://www.drrportal.gov.np/ accessed on 15 June 2022). The database shows the increasing trends of fatal landslide and flood events and the number of affected families in study districts. However, one should be careful while using and interpreting secondary databases because the increment could also be due to increased reporting in recent years [67,68].

Three-fourths of the participants perceived that water availability in wells, springs, and rivers for domestic purposes and irrigation has decreased, and more than 60% of the respondents of the questionnaire survey perceived an increase in the incidence of droughts (See Figure 3). The other noticeable hazards reported by the farmers during the questionnaire survey and FGDs were increased occurrences of forest fire and hailstorms in the Hilly region and cold waves in Terai. The higher perception of the increase in the incidences of floods, landslides, and droughts suggests the worrying situation of these hazards in everyday lives.

3.3.2. Farmers' Perception of Climate Change Impacts on Agricultural Production

Over 65% of the respondents to questionnaire surveys and FGDs mentioned that rice and wheat production has decreased due to the change and uncertainty in the onset and withdrawal of monsoon and winter rainfall. Variable timing and rainfall patterns have impacted farmers' decision-making in the seedbed preparation and transplantation of crops and vegetables. Many shared the bitter experience of having been forced to transplant older aged paddy and millet seedlings due to delayed rainfall. Approximately 80% of the respondents of household surveys and participants of FGDs shared that the increased incidence and severity of floods, flash floods, and landslides have led to reduced availability of food and caused damage to several hectares of agricultural land, making large areas of the farmland barren. The loss of agricultural land has further deepened the economic burden and has increased the dependency on access to food from the market. Floods and landslides cause the direct loss of agricultural land, crops, livestock, and infrastructure such as road networks, foot trails, and water supply facilities. In addition, the increased dry spells and decline in water availability for household and agricultural purposes, particularly in winter, lead to a decline in agricultural productivity. The winter dry spell has impacted winter crops and vegetables (wheat, barley, potato)—focused agricultural zones, livestock, and fodders. The perceived decrease in rainfall during winter has affected the sown area of the winter crop and, thereby, the food security of the communities/small-farm holders that are highly dependent on winter agricultural production and sales.

Farmers perceive that the rising temperatures have reduced the soil moisture and consequent decline in agricultural yield. The rising temperatures have also negatively affected livestock rearing and the production of quality livestock derivative products. In addition, farmers opined that pests, crop diseases, and weed infestation have increased due to the rise in temperature and irregular rainfall patterns. Such perception of an increase in pests, insects, and crop diseases is consistent with the study of Dawadi et al. [43] in Central Nepal and Manandhar et al. [69] in the Kaligandaki River Basin of Western Nepal. Some of the major problems shared by the farmers were the problems of aphids and caterpillars' invasion in vegetables, borer and red rot in sugarcane, and leaf blight and seed blight in rice plants. The farmers also shared their experience with the increase in the prevalence of pests and weeds in recent years that have caused a decline in agricultural production and the increase in their investment in weeding, chemical fertilizers, insecticides, pesticides, and irrigation.

Many FGD participants also shared that the outmigration of male members of the villages in search of alternative livelihood options has increased, which has ultimately increased the overall workload of women and has compelled the women, children, and elderly to live in vulnerable situations coping with climate-induced hazards like floods and landslides. Many respondents from the Hilly region also reported the issues of increased travel time in the collection of drinking water and fodder due to the reduction in their availability.

3.3.3. Adoption of Coping and Adaptation Strategies

Farmers are adopting diverse coping and adaptation measures to climate change. For example, in Terai region, many farmers reported shifting to flood-resistant hybrid paddy species and sugarcane plantations in their flood-prone fields. According to those farmers, sugarcane can withstand flooding more than paddy resulting in reduced losses. Many Terai farmers also followed riverbed farming to grow, consume, and sell products like watermelons, cucumber, pumpkins, bitter gourds, tomatoes, and other vegetables during the dry season, adding income to their families. Those practicing riverbed farming mentioned that they relied on the use of generators to irrigate water from nearby rivers and deep borings for watering the vegetables as required.

Terai farmers often used bio-dykes to mitigate flooding and bank-cutting. Many of them also mentioned that they abandoned land and allowed the forage and tree species such as Napier, Vetiver, wild sugarcane (Local name: *Kaans)*, and Acacia catechu to grow on the riverbanks and floodplains. Farmers in the mid-hills and middle mountains cleaned drainages and rivulets and diverted rainwater effluents away from landslide-prone areas by making canals, de-intensified or even abandoned cropping in landslide-prone fields for a few months to years, practiced intercropping and agroforestry, and allowed tree species to grow along the landslide-prone slopes to mitigate landslides. To cope with the loss associated with landslides or de-intensifying cropping, several families in the hilly region either adopted alternative livelihood options like opening tea and petty shops or worked as skilled or unskilled labor in road and other infrastructure construction sectors.

3.4. Comparison between Perceptions and Observed Climatic Trends

Farmers' perception of temperature aligned more than that of precipitation (Figure 4). Perception of annual and summer temperatures coincided more than that of winter temperatures with observed trends. There is a spatial variation in temperature perception. Highly converging perceptions with the observed temperature trend are seen in the middle mountain and mid-hills (siwaliks) regions compared to lowland Terai. Only two locations, Jogbuda and Aalital of mid hills region, represent a highly unmatched perception of winter temperature trends.

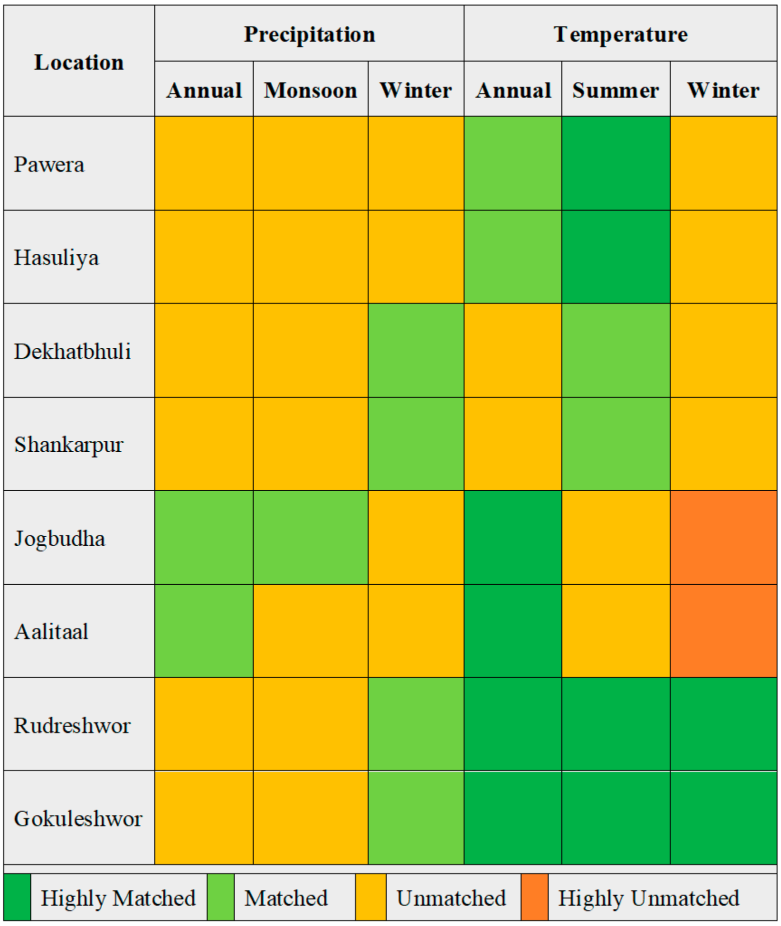

Figure 4. Comparison of farmers' perception and observed temporal trend of precipitation and temperature. Highly matched refers to the condition when the observed trend is significantly positive

(negative) in the nearest station, and the perception of more than 50% of the respondents also shows an increase (decrease). Matched refers to the condition when the observed trend is positive (negative) in the nearest station, and the perception of more than 50% of the respondents also shows an increase (decrease). Unmatched refers to the condition when the observed trend is positive or negative in the nearest station, but the perception of more than 50% of the respondents is just the opposite. Highly unmatched refers to the condition when the observed trend is significantly positive or negative in the nearest station, but the perception of more than 50% of the respondents is just the opposite.

Farmers' perception of precipitation trends is unmatched in most of the locations (Figure 4). Jogbudha (mid-hills) is the only station where the perception of precipitation during monsoon season tends to match with the observation. Monsoon precipitation has implications for agricultural productivity. Nepal receives more than 75% of the annual precipitation during the monsoon [70,71]. The monsoon season is the planting period of major agricultural crops, including rice. Any alteration in monsoon precipitation can impact the growth of rice crops and, in turn, the economy of the country. The lowland Terai region has records of large-scale agricultural loss due to heavy monsoon rainfall in recent decades [72]. Landslides and floods are often prominent during monsoons. Observational evidence shows that landslides and floods are often driven by precipitation variability and human activities, such as random earthen road construction, deforestation, and poor agricultural land management [73]. Managing the increasing impacts of monsoon rainfall, floods, and landslides on the agricultural sector requires improving the farmers' perception of climate change to inform the design of sustainable mitigation and adaptation strategies.

4. Discussion

This study compares the farmers' perceptions of climate change and its impacts in western Nepal. Our findings are consistent with the previous studies that underscore the need for integrated analysis of hydroclimatic observational records and people's perceptions in climate change impact assessment [48,74]. Our study brings three key novel understandings of climate change impacts. First, locals' perceptions do not correlate well with observational data across all instances. So, it is not wise to rely on local perception only while developing local adaptation plans. In our study, farmers' perception was, in general, consistent with the observed trends of annual and monsoon temperature but generally differed in terms of observed trends in winter temperature as well as annual, monsoon, and winter precipitation. These differences between the perceptions and observed data could be due to multiple reasons [75]. Spatial differences between the hydrometeorological stations and locations where perceptions were collected can introduce "negative bias" [15,41,76]. Farmers also tend to overestimate the risks if they are affected by hazards in the past [44,77]. For example, farmers' experience of a decrease in water availability for domestic and irrigation purposes in the latter years could have influenced their perception of a decrease in winter precipitation, although the longer-term observed winter precipitation shows increasing trends [46,78]. Farmers could be precautious about the impacts of drought risks on agricultural production regardless of what their nearest weather station recorded and might have overemphasized the risks [44]. Hence, both scientific and qualitative data should be used for such analyses, but this should be conducted with caution.

Second, our study highlights the farmers' ability to perceive greater climate change impacts, particularly when they have directly affected them. The majority of the farmers perceived a decrease in the number of rainy days and an increase in the intensity of monsoon precipitation, floods, and landslides occurrences. This finding is consistent with the study by Pandey [79] in Western Nepal, where a majority of respondents perceived an increase in flood and landslide incidences. The Desinventar database (http://www.drrportal.gov.np/ accessed on 15 June 2022) also exhibits increasing trends in the incidences of annual fatal events and fatalities due to floods and landslides during 1984–2016 [80]. In FGDs, the farmers also reported a decline in agricultural production as well as direct loss of agricultural land and livestock due to the increased incidence and severity of climate-induced hazards. Several other studies on climate change impact assessment in the central Himalayas (e.g., [32,81,82]) have reported increasing impacts of climate-induced hazards on agricultural productivity.

Third, our study highlights that the risk and impacts of climate change are further exacerbated by other anthropogenic activities. Many respondents of questionnaire surveys and FGD are concerned about the potential impacts of deforestation, stone mining, and haphazard development activities that can lead to floods, landslides, and water degradation. The participants also complained that the government support mechanism was largely response-focused, and pre-disaster preparedness activities were given very little attention. Climate change coupled with unplanned development practices such as haphazard earthen road construction can increase the incidences and impacts of floods and landslides [83]. Government and supporting agencies could strengthen efforts for proactive disaster preparedness and climate change adaptation [84]. Several mitigation and adaptation strategies, such as the provision of sustainable irrigation facilities, reliable agricultural extension services, adoption of rainwater harvesting, distribution of flood and drought-resistant crop species, and support for alternative livelihood opportunities, could help to develop agricultural resilience. Furthermore, development activities should be risk-sensitive and consider the fragile geology and climate change trends and projections.

Our study is not without limitations. This study is mostly focused on farmers' perception about climate change at annual and seasonal timescales; however, future study could explore the perception at sub-seasonal to seasonal timescales. We used the district-level secondary data to analyze the quantitative impacts of floods and landslides because the village or sub-district level data were not maintained by the government's database. We know that participatory tools could be applied to collect quantitative information for further research in data-scarce conditions. Additionally, we did not analyze differential perceptions and adaptation measures in relation to age, ethnicity, landholdings, and gender. In future research, such considerations could provide a better picture of climate change perceptions.

5. Conclusions

This study analyzes the historical trends of observed temperature and precipitation in western Nepal. We compare the farmers' perceptions with the observed temperature and precipitation trends. We use questionnaire surveys and focus group discussions to assess farmers' perceptions about hydroclimatic trends and the impacts of climate change on agriculture. Our results suggest that local perceptions can differ from the observed trend in hydroclimatic variables. However, they can complement each other in climate change impact assessment and support the formulation of resilient mitigation and adaptation strategies. Farmers' perceptions of an increase in annual and monsoon temperature generally coincide with observed trends. However, their perception of an increase in winter temperature contradicts the observed trends in most of the stations. This indicates that the farmers' perception is driven by certain changes in the climate and associated weather patterns of the winter season, which a single parameter cannot infer. Farmers also reported a substantial increase in annual and monsoon precipitation and a decline in winter precipitation. However, the observed hydroclimatic records in several stations reflect opposite trends. This could be partly due to the increasing frequency of extreme climate events and their direct impact on the livelihood of farmers. Many respondents also reported an increase in water scarcity and consequent impacts that compelled respondents to change the cropping time and crop varieties to cope with the climate change impacts. Several mitigation and adaptation strategies could help to enhance resilience to climate change impacts in the central Himalayas. Example strategies could involve strengthening agricultural extension services; promoting flood, landslides, and drought-resilient crop varieties; stimulating nature-based solutions for hazard mitigation; and developing reliable early warning systems for risk communication.

Further, the government support mechanism is generally response-focused. We call for proactive disaster risk reduction and climate change adaptation planning as neither instrumental observation nor local perceptions alone are suitable for adaptation planning.

Their comparison provides a better picture of climate change impacts and adaptation needs. Similarly, since public perception is dynamic and influenced by multiple factors like outreach activities conducted by NGOs, government agencies, and media, and past experiences of climate change impact, further research is needed to improve our understanding and confidence in making informed decisions. The issues of drought and decreases in water availability were raised by many participants in questionnaire surveys and GGDs. Another study on the types and impacts of drought in the study area could be of interest.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/hydrology9120212/s1, Table S1: Demographic composition of the participants of questionnaire survey, Table S2: Demographic composition of the participants of Focus Group Discussion (FGD), Table S3: Key aspects of the questionnaire used in the household perception survey, Table S4: Observed trends of change in precipitation at different stations, Table S5: Observed trends of change in maximum temperature at different stations, Table S6: Observed trends of change in minimum temperature at different stations.

Author Contributions: Conceptualization, methodology, software, validation, and formal analysis, R.S. and T.R.A.; investigation, R.S., R.K. and D.T.; resources, B.R. and D.T.; data curation, B.R., R.S. and T.R.A.; writing—original draft preparation, R.S., B.R. and T.R.A.; writing—review and editing, S.S., R.T., G.R.G. and R.K.; visualization, B.R.; supervision, T.R.A.; project administration, R.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Observed data of precipitation and temperature at the selected stations were collected from the Department of Hydrology and Meteorology (DHM) Nepal (http://www.dhm.np accessed on 15 March 2021). The data is not in open access. These data can be purchased (http://dhm.gov.np/pricelist.html accessed on 15 March 2021) and used by the individual(s)/institution for the academic/research work as authorized by the DHM. DHM data cannot be used for commercial purposes. The other data and materials used in this study will be provided on request.

Acknowledgments: The authors would like to thank the Department of Hydrology and Meteorology (DHM) Nepal for providing permission to use the meteorological data. This study was supported by Mercy Corps Nepal's Managing Risk through Economic Development (MRED) Program—phase I and II implemented in Sudur Paschim Province of Nepal from 2012 to 2019 with funding support from Margaret A. Cargill Foundation. We would like to thank the entire MRED team for their huge support in conducting the study. We would like to acknowledge the respondents of the questionnaire survey and participants of FGDs. Special thanks to the reviewers of the paper and editors of the journal for their constructive feedback in this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

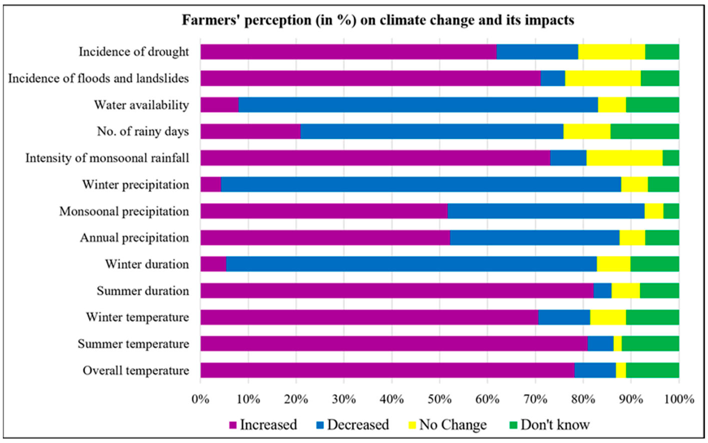

Figure A1. Farmers' perceptions of different parameters of climate change and its impacts.

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