environments

MDPI

Review

Drought Impact and Adaptation Strategies in the Mid-Hill Farming System of Western Nepal

Shankar Adhikari

Ministry of Forests and Environment, Kathmandu, Nepal; adhikarishankar@gmail.com; Tel.: +977-984-711-3360

Received: 31 July 2018; Accepted: 23 August 2018; Published: 3 September 2018

check for updates

Abstract: Climate-induced drought hazard has been emerging as one of the major challenges in the mid-hill farming system and rural livelihood in Nepal. Drought stress, in combination with century-long socio-political issues such as unequal social structure, gender discrimination, and marginalization of poor and disadvantaged groups have made smallholders more vulnerable in society. Climate changes are exacerbating issues within an already vulnerable society. Therefore, a review study on the impact of drought on the rain-fed hill farming system, and the potential adaptation measures, was carried out in the mid-hill region of western Nepal. Both agricultural impacts such as depletion of traditional varieties of crops, crop-specific diseases, low production, lack of water for irrigation; and non-agricultural impacts such as changing rural livelihood patterns, and social conflict due to agriculture and water issues were identified as major impacts. Some of the agricultural adaptation measures *viz.* the promotion of climate smart agriculture practices, crop diversification, and agroforestry practices seem to have been more effective in the region. At the same time, small-scale structural water harvesting measures, for instance, rainwater harvesting, conservation ponds, and irrigation channels, drip water irrigation, and an early warning system for drought events could also be an advantage in this context. Nonetheless, there are several adaptation barriers including ecological and physical constraints, human and information resource-shortages, and social barriers to adaptation. Therefore, local site-specific adaptation measures should be developed, and implemented, to increase the adaptive capacity of smallholders, and enhance the farming system in the face of the climate-induced drought scenario.

Keywords: adaptation; agriculture; drought; impact; mid-hill farming system; Nepal

---

1. Introduction

Nepal is one of the most vulnerable countries with respect to climate change, due to greater warming in recent years than that of the global average. While there was 0.6 °C global mean surface temperature rise, from 1975 to 2005, Nepal experienced a considerably higher temperature rise of 1.5 °C (0.06 °C year^{-1}) during a similar duration of time, from 1982 to 2006 [1]. Similarly, precipitation and the rainfall pattern are also becoming more erratic [2]. As a result, mean rainfall has been decreasing by 3.7 mm (−3.2%) per month, per decade [3]. These conditions have created a drought condition especially for the rain-fed hill farming system, where people depend on summer and winter rainfall for their major agricultural activities [4]. Moreover, the mean annual temperature is predicted to be increased between 1.3 °C to 3.8 °C by the 2060s, and 1.8 °C to 5.8 °C by the 2090s while annual precipitation reduction could be within the range of 10% to 20%, across the country [3].

In Nepal, winter precipitation has almost declined to zero, and groundwater has hardly been replenished. This situation has created a critical condition for water resource management, for agriculture in western Nepal [2]. This is because of both natural variability and anthropogenic influences, such as the arctic oscillation inter-annual variation (and its decadal trends towards negative phases), sea surface temperature (SST) warming in the southern Indian ocean (enhancing subsidence over much of Nepal), and increased loading of anthropogenic aerosols, both locally and from surrounding countries [2]. These are making mid-hill farmland and farming practices less resilient to drought.

Drought mostly occurs from the end of March through June, which is the arrival of monsoon season in many parts of the country [5]. However, some parts of the Trans-Himalayan regions are extremely dry throughout the year. Similarly, droughts are more common in the lowland and in the western hill of Nepal [5,6]. For example, hilly and mountainous districts of far and Midwestern part of Nepal are prone to drought risk [3].

Nepal experienced drought in 1972, 1977, 1982, and 1992. Similarly, the country has also experienced frequent dry spells since 2002, especially during the years 2002, and from 2004 to 2006—both in dry and wet monsoon [5]. Furthermore, the country received less than 50% of average precipitation during the period from November 2008 to February 2009, resulting in the 2008–2009 winter drought as the worst on record [5]. Several incidences of dry spell/drought were also observed during 2012, 2013, and 2015. Recent spells of drought in Nepal have been critical in the hill farming system, especially for crop production and the livelihood support of people dependent on it.

Along with climate-induced slow-onset hazards, a century-long deep-rooted chronic poverty and an unequal social structure are also contributing to the vulnerability of hill farmers as a hotspot of differential climate impact [7]. Within the hill farmers, marginal and poor farmers, and women with limited access to resources and livelihood options are most affected and at greater risk [8]. As a result, agriculture and agriculture-based communities are one of the major sectors affected by climatic and non-climatic stresses.

Agriculture is still a key economic activity for people in the rural area, and more than two-thirds of rural people depend on agriculture for their livelihood [9]. Crops and livestock farming, in different combinations, form a major way of life sustenance in the rural communities. Cereals crops, including rice, wheat, maize, millet, barley, and buckwheat, are the foundations of Nepal's agriculture, especially in western Nepal [5]. The agriculture sector accounts for almost one third of Nepal's GDP. Sixty percent of the farmland is rain-fed in nature, without any alternative irrigation measures [9,10], and over 50% of Nepalese farmers are smallholders, cultivating less than 0.5 ha [11]. Eighty percent of Nepalese people live in rural areas [9]. Increase in the occurrence of drought can result in agriculture becoming less stable, and have significant implications for crop productivity, food security, and the overall livelihood of people who are dependent on these resources [4].

However, droughts can create opportunities to explore different adaptations strategies that are suitable in such changing circumstances [8]. This article reflects on the causes of drought in Nepal in recent years, and its impact on agriculture practices especially in the hill farming system from environmental, social, political, and cultural perspectives. It also explores the different adaptation strategies and tradeoffs between these adaptation measures, and sheds some light on the barriers encountered by adaptation strategies especially sociocultural ones.

2. Drivers of Vulnerabilities

The vulnerability of mid-hill farmers in Nepal has been explained as a susceptibility to harm from exposure to different environmental stress, especially drought and social stresses, as well as not having enough capacity to adapt [12]. Therefore, the driver of vulnerability must be developed and explained through an integrated approach of risk-hazard and social constructivist frameworks [13–15].

From the risk-hazard point of view, continuing drought in the last decade has been a major factor in relation to the effects on the hill farming system, cropping pattern, and land productivity. This depoliticized approach does not incorporate the other socioeconomic factors of vulnerability but rather places more emphasis on technical kinds of solution. However, this remains dominant in the contemporary policy discourse. On the other hand, the social constructivist or political economy approach underscores the multiple causes rooted in the social structure as a major cause of vulnerability [15,16]. In the particular case of the hill farming system, an integrated approach, involving both the risk-hazard and political ecology approaches (that their roots in "the geography of human ecology"), could well explain the vulnerability situation.

This reflects the interaction between climate variability and drought in the mid-hill, with long held deep-rooted unequal social structure in the society [17]. Recent climatic stresses have been exacerbating the vulnerability, due to nature and the frequency of hazards that are already in place in their social setting. Rather than using either first generation climate impact research, that considers climate change as an environmental problem, or the second generation of climate research, that looks at climate change as a societal problem [18], the combined approach seems more appropriate in this case. However, the latter approach seems more relevant when it comes to adaptation.

3. Methods

The study is primarily based on a literature search in various web-based databases [19], including Google Scholar, ISI Web of Science, Science Direct, and Scopus. The methodological approach is illustrated in Figure 1. The search was focused on the drought impact and adaptation measures in agriculture of western Nepal. The key terms used during the search were "Drought" OR "Impact" OR "Adaptation" OR "Agriculture" OR "Nepal". Additionally, several kinds of word combinations were also used to find more articles (Figure 1). First-round screening was done based on a quick review of title, abstract, and keywords in the articles. In addition to peer-reviewed articles, conference proceedings, technical reports, government publications, and book chapters were also used during the review process.

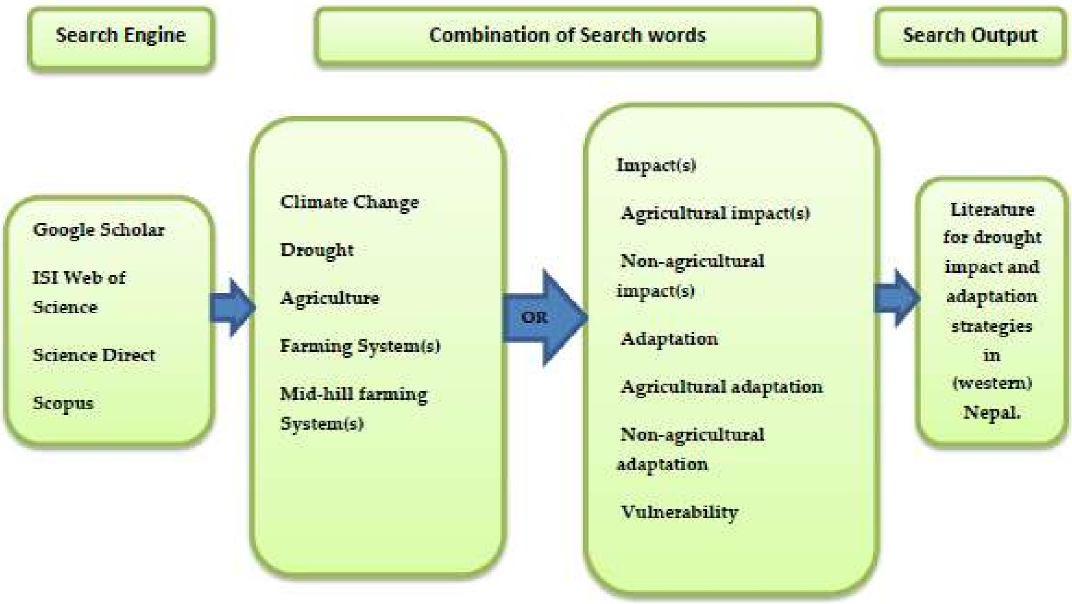

Figure 1. Methodology adopted for literature search using keywords in various web-based databases.

4. Impact

4.1. Agricultural Impacts

Impact of drought in agriculture and hill farming system has been observed in various areas including production and productivity, food security, and cropping pattern. A series of drought events, observed since 1972, have contributed to loss of production and productivity of major crops such as rice, maize, wheat and millet, among others, which is presented in Table 1.

Table 1. Impact of drought on production of major crops in different years in Nepal.

SN	Drought Year	Causes of Drought	Major Crop Loss (in Metric Ton)	Affected Regions
1	1972	Late onset of monsoon/rainfall	333,380	Eastern and Central
2	1976	Poor distribution of rainfall	218,480	Western
3	1977	Late onset of rainfall	322,320	Eastern and Central
4	1979	Late onset of rainfall	544,820	Western
5	1982	Late onset of rainfall	727,460	Eastern
6	1986	Poor distribution of rainfall during August and September	377,410	Western
7	1992	Late onset of rainfall	917,260	Eastern
8	1994	Poor distribution of rainfall	595,976	All regions
9	1997	Poor distribution of rainfall	69,790	Eastern
10	2002	Poor distribution of rainfall	83,965	Eastern and Central
11	2008	Poor distribution of rainfall during November 2008 to February 2009	56,926	All regions
12	2009	Late onset of monsoon	499,870	Eastern and Central
13	2012	Summer monsoon late onset and long dry spell	797,629	Eastern and Central
14	2013	Inadequate rainfall that affected rice plantation	56,000	Eastern and Central Terai districts
15	2015	Delayed monsoon and weak at the onset, which delayed paddy transplantation	Not available	Eastern Terai
16	Mid-November 2015 to Mid-March 2016	Poor monsoon and drought	300,000 people highly insecure	Mid- and Far-Western hills and mountains

Source: Joshi 2018 [5] and UNDP 2013 [6].

Table 1 illustrates the major drought events, possible causes of drought, and damage on important crops mainly rice, maize, wheat, and millet. However, this is not the comprehensive list, and some of the database might still be missing—the amount of crop data and area affected by drought could be even higher, as there is not proper comprehensive database on it. The major cause identified for the draught are late onsets of monsoon, poor distribution of rainfall, and reduced intensity of rainfall. For example, a delay in onset of monsoon possibly led to a delay in the sowing of rice, affecting the growth of maize, along with reducing the recharge of underground aquifer [5]. Because of the changes in water sources for agriculture, rain-fed farming practices are affected, production is reduced, and crop damage increases, especially in mid-hill region.

Changes in water sources, and their implication on farming system, have been reported on in the national climate change impact survey, from 2016 [20]. The survey result shows that 74.29% of total households observed changes in water sources, and 84.47% observed a decrease in amount of surface water. Likewise, the majority of households (74.56%) in mountain region reported surface water completely drying up, and a high percentage (48.81%) in hilly areas observed underground water sources dying up, due to insufficient rainfall [20].

Impact on crop production and productivity, due to drought, might be explained as a result of declining availability of water for agricultural uses, hindrances in operation of conventional irrigation systems, decreasing efficiency of water use, increasingly degrading agricultural land, and epidemics of diseases and pests [5]. These were further exacerbated by the poor availability of quality planting materials and technologies. Consequently, reduced availability of soil moisture, crop failures, and reduced crop productivity were reported in the hilly region. For example, in the winter drought of fiscal year 2008/2009, some districts received less than half the average winter rainfall, and crop yields reduced by more than half. Wheat and barley production dropped by 14% and 17%, respectively, during that period [5,21].

Some farmers have already abandoned some of their important traditional crops like rice, pulses, different cereal crops, tuber, and sweet potato—and have even abandoned agriculture on their land, which ends up becoming fallow. They cited that the lack of sufficient water, crop-specific diseases, low production, inadequate benefits, and unfavorable climate were the major reasons in this decision [7].

For example, rice, a major crop in Nepal, requires sufficient irrigation and temperature for proper growth and production. A study by Karn [22] reveals that rice yields are most sensitive to increase in daytime maximum temperature. Up to a cut-off point of 29.9 °C, a 1 °C rise in daytime maximum temperature during the ripening phase increases rice harvest by 27 kg per hectare. However, the productivity declines and yields are harmed when daytime maximum temperature goes beyond 29.9 °C. In Nepal, the daily maximum temperature has already crossed the cut-off point in many cases. Further, Karn [22] has predicted of future changes of rice yield, using two different modeling efforts, based on the predicted rainfall and temperature in the future. First, rice yields will decline by 4.2 percent relative to current levels by 2100. Second, an estimated loss of rice yield ranging from 1.5 percent by year 2030, to 4.2 percent by 2060, and 9.8 percent by 2090. These findings are also in line with many other studies that have projected a loss of crop yields ranging from 3 to 30 percent in the future for the region [23,24].

Maize yield is also found to be affected by the intensity and duration of rainfall. According to Nayava and Gurung [25], maize yield and production with relation to pre-monsoon rainfall (March–May) for the 1971–2008, showed that maize yield in Chitwan was badly affected in thirteen years particularly in the years, 1974, 1975, 1978, 1979, 1982, 1985, 1986, 1989, 1991, 1993, 1999, 2002, and 2005. The pre-monsoon rainfall during those years was much lower than normal rainfall, showing that the impact of rainfall on maize yield and production is evident.

A study by UNDP [26] found that about 90% of crop loss in Nepal was caused by meteorological hazards such as drought, and floods. In this study, drought had the most severe impact on crops. Out of the 850,000 ha of crops that was lost due to weather and climate related events during 1971 and 2007, drought accounted for 38.9% [26]. Moreover, such disastrous impact on agriculture is on the rise dramatically, especially since 1990 [5]. As a result, about one-third of the household are facing food scarcity due to drought followed by hailstorm (26.1%), disease/insect (21.7%), sporadic rain (20.8%), and flood (15.5%) in the last five years [5,20].

Similarly, Bhatt et al. [27] have also reported clear evidence of negative impacts on rice, maize and wheat yields in Koshi hill of Nepal, due to warming of the mean temperature during the growing season. However, they even observed positive changes in rice and maize production, due to warming in comparatively high-elevation areas within the same region. The phenomenon of agro-ecological extension of some crops might have been explained, due to temperature rise and increased number of warmers days in high mountain areas. This requires favorable conditions, like sufficient water availability and the maintenance of soil fertility, in order to realize positive yields in a sustainable manner—but it is unlikely to have these favorable conditions up in the hill area throughout the year under the current climate change scenario. Instead increased temperature and rainfall variability and shifts in agro-ecological zones could contribute prolonged dry spells, and higher incidence of pest and diseases [5]. Therefore, the impact on crop and productivity is likely to be mostly negative endangering food security in the future if the current climatic scenario continues. Palazzoli et al. [28] have also found results that agree with this finding, in their study on climate impact on the future agricultural crops in the same region.

As a result of drought impact observed in the mid-hill region, changes in cropping patterns, species composition and season of plantation have also been reported in many parts of Nepal [4].

4.2. Non-Agricultural Impacts

Climate-induced drought impact on agriculture does not only have an impact on crops and land productivity. It also has far-reaching implications on the socioeconomic aspect of the area and has a devastating impact on overall rural livelihood because most of the rural livelihood depends on rain-fed subsistence agriculture [4]. Similarly, it has created a major source of uncertainty in food production in Nepal, while also creating social conflict due to agriculture and water use conflicts [4].

Migration is another major cause, affecting agrarian livelihood indirectly related to climatic stress and agriculture production along with other factors. The increase in drought in agricultural lands can result in a chain of push factors in the rural area that affect livelihoods. For instance, drought decreases crop and livestock production, thereby giving rise to a loss in income and employment. This can push people to abandon agriculture work, and increase human mobility and out-migration [9]. As a patriarchal society, especially male people emigrate in search of job opportunities.

Furthermore, male out-migration, as an indirect consequence of both climate change and multiple political-economic stresses, has created a primary form of gendered vulnerability in an agrarian society [29,30]. It increases women's workload, apart from their current productive and reproductive role. Despite the fact that migration is a common phenomenon in almost all socioeconomic groups, women from marginal farmers and tenant households are most vulnerable creating a stratified pattern of vulnerability. This is due to their limited range of adaptation options and vulnerability is already deeply embedded in the social structure itself. Moreover, they do not have sufficient land to meet subsistence needs, and in most cases do not have the land ownership rights as well which will hinder access to government services [31]. Moreover, most of the off-farm jobs are considered part of the male domain, and it is therefore hard to find work opportunities as a women. If women do find work, they are also often paid less. In addition, significant male-outmigration has created the feminization of agriculture in the regions [32]. Increased remittance flow has also changed the gender relation of society and power [29].

5. Possible Adaptation Solutions

Rural communities in the mid-hill region have already perceived drought impact on their farmland and applied a range of possible agricultural and nonagricultural adaptation measures, based on their own indigenous knowledge and experience [33]. While designing possible adaptation strategies, the emphasis has been put on using available resources at the community and ecosystem level as a community using an (agro)ecosystem approach, among others.

5.1. Agricultural Adaptation

The promotion of climate smart agricultural practices, crop diversification and agroforestry practices seem to have been more effective in the region [4]. Farmers have switched from high water requiring crops, like rice, to low water requiring crops, such as maize. Even if farmers choose to plant rice, future agricultural research should focus on the development of drought-resistant varieties, as part of adaptation measures [22]. Similarly, millet is also found as one of the drought-resistant crops grown in Nepal, mostly in uplands regions under the rain-fed condition where it perform well even in low rainfall [34].

Similarly, promoting crops less sensitive to uncertain rainfall such as ginger, turmeric, and peanut as cash crops is also equally important as an adaptation strategy. Likewise, the integration of agroforestry, promotion of mixed cropping, changing crops varieties, changing timing of crops, increased use of farm yard manure, organic farming, replacing failed crops, use of bio-pesticide, creating fallow fields and promotion of conservation agriculture, and crop-livestock integration are some other important adaptation strategies used by farmers [17].

As part of climate smart agriculture practice, crop diversification, organic farming, and agroforestry practices have been carried out to fulfill the dual responsibility of food security, and livelihood support, while conserving soil and water resources. Ultimately, this creates new avenues to improve crop diversity, their productivity, sources of income, and environmental amelioration. However, there is a high potentiality of losing the traditional varieties of crops and cropping pattern, which the individual family and local society value the most. It might even create some types of resistance, especially from elder farmers, switching to a new form of farming, even though they have low returns from traditional crops in the face of drought impact. Similarly, conservation agriculture could also help maintain the moisture and crop productivity [35].

Installation of an early warning system for drought events, rainwater harvesting, irrigation channels, conservation ponds, and low-cost soil conservation technologies, are also structural adaptation measures to combat the effect of drought in farming systems [4]. The typical case of drought impact on agriculture and adaptation practices in mustang district is presented in Box 1.

Box 1. Drought Impact and Adaptation Practices in Mustang District.

The Mustang district is one of the drought-affected districts of western Nepal, where average annual rainfall is 450 mL. During the last 30 years, the maximum temperature has risen from 21–22 °C to 25–26 °C. However, the rate of snowfall has decreased to only once or twice a year from 5–6 times, during the same period. Due to reduced snowfall and increased temperature, winter chills and snowfall (the main sources of water) have reduced. This has contributed to water shortages, which in turn have adversely affected agriculture production in the district. In addition, severe water scarcity could force the communities to abandon their settlement. As a prime apple production area of Nepal, farmers have realized the negative impacts mainly on apple farming in recent years, Furthermore, apples have not been getting the type of texture and color in the skin that was seen in the past, and even found diseases in apples. The result has been the decline in apple production in the lower region, and farmers have started destroying their apple orchards in some cases.

Adaptation Practices:

- Shift in apple farming from lower to higher altitudes. Due to the changing weather pattern, the lower region has become less suitable for apple farming, and the higher altitudes that used to be produce very little apple due to the cold weather are now considered suitable.
- Farmers in the higher altitude, which used to depend more on livestock and trade, are now developing apple orchards and nursery farms.
- Use of organic pesticides, prepared by farmers from a concoction of various herbs grown locally to counter the problem of diseases.
- Farmers in lower Mustang are now increasingly turning towards production of green vegetables like cabbages, cauliflowers, cucumbers, chili peppers, and tomatoes in open gardens. This form of farming is slowly replacing apple farming.
- Vegetable farming has been practiced both in open garden as well as through the practice of a greenhouse (plastic green house) even in upper region.
- Construction of small ponds as water storage to cope with water scarcity for drinking and farming purpose.
- The local institution of Subba, which is stricter and functioning well in Mustang villages, especially in lower Mustang, taking more interest in water management, water rationing, and developing ponds for water storage for irrigation and drinking purpose.

Source: Adhikari 2013 [36].

5.2. Non-Agricultural Adaptation

The range of indicators that determine the goals of adaption, and their success, can only be understood in the social context in which adaptation takes place [37], therefore other socioeconomic adaptation measures, which help combat the underlying causes of vulnerability and improve the adaptive capacity of farmers, must be considered. These include: (1) financial support to the farmers to carry out agricultural adaptation work or find an alternative source of livelihood; (2) off-farm employment opportunities; and (3) mainstreaming climate adaptation in development activities, through bottom-up participatory planning and implementation. Furthermore, (4) increased access of farmers to information, training, knowledge networks, and social organizations could also provide opportunities to enhance resilience and adaptive capacity; and (5) democratic and participatory governance, and local institutional development for adaptation, could also play a crucial role in enhancing the adaptive capacity of farmers. Similarly, (6) migration is another potential adaptation measure.

Overall, some of these measures are hard structural measures in nature, such as the construction of rainwater harvesting, a cemented conservation pond, and an irrigation channel. Whereas livelihood diversification and multiple cropping are soft adaptation measures.

Small-scale structural water harvesting measures, rainwater harvesting, conservation ponds, irrigation channels, drip water irrigation, and an early warning system for drought events could be a great asset to tackle the drought stress. These water harvesting measures and irrigation channels will improve crop yields, enrich soil moisture and ground water, and decrease soil loss and erosion, ultimately contributing to farmland productivity and even maintenance of agro-biodiversity to support local livelihood [38]. Reviving "dying" springs emanating naturally, from unconfined aquifers, could help to fulfill crop water requirements [39]. However, these structural measures require some capital investment, and farmers may find it difficult to manage on their own. If they could be initiated with support from government, or some other external agency in an attempt to increase the adaptive capacity of farmers, it would complement their aim of increasing crop yields and productivity to secure their livelihood.

Similarly, though most of the measures seem to be incremental in nature, measures involving switching one cropping pattern to another is a transformational measure. However, all the adaptation measures cannot be applied in every situation within the mid-hill farming system, and therefore proper attention has to paid for location-specific adaptation strategies [33], based on the particular requirements and specificities of each particular area. NGOs and research institutions could carry out action research to find innovative and site-specific adaptation solution, and help them up-scale in similar localities [40].

In addition, as vulnerability of farmers and their farmland is quite related to social, economic, and political factors operating in society, addressing these socio-ecological factors including institutional and governance issues, policy constraints, socio-cultural issues, can be important to achieve the overall adaptation goal. Similarly, migration as a form of mobility can be another potential adaptation measure. It ensures less vulnerability among farmers with access to asset and other opportunities to build up resilience and adaptive capacity [9].

5.3. Adaptation Planning and Implementation

Climate adaptation planning involves cascading decisions from individuals, firms, and civil society to government bodies at the local, regional and national levels, and international agencies [24]. The Ministry of Agriculture Development with support from the District Level Agriculture Office will be primarily responsible for designing the agriculture-based adaptation strategy in terms of policy, and the annual program in Nepal. However, adaptation is also quite related to other sectors such as irrigation, development, forest, livestock, and society as well as other sectors. These need to have multi-disciplinary collaborations that include local organizations, the knowledge network, farmer groups, and other stakeholders.

When it comes to the success of adaptation measures, it should not be simply measured in terms of stated objectives, rather it should be assessed through broad principles of policy appraisal with due consideration of promoting equitable, effective, efficient, and legitimate action congruent with broader sustainability [41].

5.4. Barriers to Adaptations

Major challenges to adaptation involve specifying clearly the adaptation goal, learning, and applying the analogy, and understanding which enables and/or constrains climate adaptation [18]. Major adaptation limitations and barriers in mid-hill regions can be categorized into three distinct, yet interrelated, groups. Firstly, ecological and physical constraints comprise the natural limit to adaptation. For instance, certain altitudes (or even temperatures or water availability) can be limits beyond which rice cannot not be grown. Secondly, human and information resource-based barriers exist due to a combination of knowledge, technological and financial constraints. For example, these constraints include low level of awareness and information among policy makers about climate impacts, uncertainties about future climate projections and adaptation measures, and inadequate notions on adaptation intervention [42]. Thirdly, there are social barriers to adaptation, which are related to social characteristics that could influence or dictate adaptation options. These include cognitive (psychological) barriers, normative (cultural) barriers and institutional barriers [43].

Farmers in the regions are diverse in terms of socioeconomic and technical attributes such as access to resources, access to services and facilities. In addition, the government does not have sufficient resources, which is why the solution requires a cautious and well-targeted adaptation approach through the identification and prioritization of appropriate adaptation measures [4].

Rapidly changing socioeconomic contexts and climate change have influenced how the gender roles in rural livelihoods are created and reproduced, influencing the adaptation process [18]. With increased male outmigration, women have to hear the brunt of challenges of managing their farmland, adapting to climate change, and integrating into the social network, apart from managing household chores and developing their children. Though these all add more challenges for them, it has improved their decision-making process in society [44]. On the other hand, male out-migration to cope with drought in agriculture, and to diversify family income, has now become the trend in the stepping stone from agriculture to non-agricultural migration. For instance, poor people may move to a nearby city or to India, whereas middle class and rich people may emigrate to a middle income or a rich country. Once they start to send remittances back home, this becomes a stepping-stone to rural-urban migration, eventually semi-permanent to permanent and from agricultural to nonagricultural migration [9]. It has even challenged the contemporary human migration theories which revolve around socioeconomic factors but do not consider the linkage between environment and migration.

Though there are different public (local government and local agencies), private (private business and local organizations), and civic institutions (cooperatives, member organizations) [45] in the region working on adaptation issues, there does not seem to be adequate coordination in working on local level adaptation. Government agencies at the local level are supposed to work in collaboration to combat the impact of drought on agriculture, such as the district level agriculture office, forest office, water supply office, and social security office. However, they tend to work on a sectorial basis as per the program and directive of their respective ministries. Moreover, local government, in the form of rural municipalities and municipalities, has recently elected representatives that do not seem to introduce new ideas on adaptation issues. This can have profound implications on effective adaptation planning and implementation, coordinating other community-based groups for a collective response for adaptation, and coordination with decision makers in the district, province and central state level. Similarly, the National Adaptation Program of Action (NAPA) has also not given proper space to local government in the adaptation process, but has followed the sectoral approach to adaptation [46]. However, the Local Adaptation Plan of Action (LAPA) has recognized the role of local institutions in implementing the plan but the authorized coordinating body at the local level has only recently had a representative, so they are surrounded by several other important issues than that of adaptation planning and implementation.

Local knowledge also does not seem to have been incorporated into adaptation planning leading to fewer deliberations with local stakeholders while promulgating the adaptation policy, programs and actions [47]. Though the local level is critical in adaptation, actual adaptation requires measures carried out at different scales from national, regional to the local level [48]. Therefore, there needs to be a strong collaborative partnership between different institutions, not only to remove the barriers and enhance opportunities, but to harmonize the adaptation activities across scales and sectors to realize efficiency, efficacy and equitability of adaptation within and among societies [18]. Other institutional arrangements influencing adaptation decisions, notably the existing law and market mechanisms, should also be considered in adaptation planning.

Furthermore, here is a lack of understanding and a serious knowledge gap even among some of the policy makers on defining adaptation, whether it is agricultural or non-agricultural, and some perceive adaptation as a stand-alone approach which actually does not exist in practice. Therefore, mainstreaming climate adaptation into development either through technology, or a development-based view of adaptation [49], across scales and sectors including agriculture. This can help reduce baseline vulnerability, and ensure long-term sustainability of climate resilient development and avoid maladaptation [50].

Some farmlands in mid-hill are considerably vulnerable and no longer suitable for farming and living there. However, elder farmers, in particular, oppose the idea of moving to other places due to their entrenched cultural and emotional attachment to where they are. Similar situations have been reported from Kiribati [51] and Northern Burkina Faso, as a cultural barrier to adaptation [52].

In a different context, given the series of disasters (drought, flood, earthquake), and the devastating earthquake in April 2015, farmers seem to have lost confidence, and are not prepared on their own to tackle this situation, given their poor asset base and limited livelihood opportunities.

6. Conclusions

The climate-induced drought hazard in Nepal Himalaya has far-reaching consequences, especially in the mid-hill farming system and rural livelihoods who dependent on it. An integrated approach based on a hazard and constructivist framework has identified the vulnerability of the farming system, due to both hazard and sociopolitical factors, and has helped identify a range of adaptation measures. These include climate-smart agriculture practices, along with other non-agricultural measures including mainstreaming climate adaptation and gender in the development process, and environmental migration, as a plausible adaptation measure. However, there are several barriers and uncertainties in this regard. Rather than the blanket approach of "one size fits all", even within the hill-farming system, local site-specific adaptation measures should be developed and implemented to prevent adaptation practices turning into malpractices and to increase the adaptive capacity of smallholders and the farming system.

Funding: This research received no external funding.

Acknowledgments: I appreciate the constructive suggestions that reviewers made to improve the paper.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Bawa, K.S.; Shrestha, U.B.; Gautam, S.P. Widespread Climate Change in the Himalayas and Associated Changes in Local Ecosystems. *PLoS ONE* **2012**, *7*, e36741.
2. Wang, S.-Y.; Yoon, J.-H.; Gillies, R.R.; Cho, C. What Caused the Winter Drought in Western Nepal during Recent Years? *J. Clim.* **2013**, *26*, 8241–8256. [CrossRef]
3. Ministry of Education. *National Adaptation Programme of Action to Climate Change*; Ministry of Environment: Kathmandu, Nepal, 2010.
4. Ghimire, Y.N.; Shivakoti, G.P.; Perret, S.R. Household-level Vulnerability to Drought in Hill Agriculture of Nepal: Implications for Adaptation Planning. *Int. Sustain. Dev. World Ecol.* **2010**, *17*, 225–230. [CrossRef]
5. Joshi, G.R. *Agricultural Economy of Nepal: Development Challenges and Opportunities*; Sustainable Research and Development Centre: Kathmandu, Nepal, 2018.
6. United Nations Development Program. *Country Report Climate Risk Management for Agriculture in Nepal. Regional Integrated Multi-Hazard Early Warning System for Africa and Asia*; UNDP: New York, NY, USA, 2013.
7. Pradhan, N.S.; Sijapati, S.; Bajracharya, S.R. Farmers' Responses to Climate Change Impact on Water Availability: Insights from the Indrawati Basin in Nepal. *Int. J. Water Resour. Dev.* **2015**, *31*, 269–283. [CrossRef]
8. Dulal, H.B.; Brodnig, G.; Thakur, H.K.; Green-Onoriose, C. Do the Poor have What They Need to Adapt to Climate Change? A case study of Nepal. *Local Environ.* **2010**, *15*, 621–635. [CrossRef]
9. Chapagain, B. Withdrawing from Agrarian Livelihoods: Environmental Migration in Nepal. *J. Mt. Sci.* **2015**, *12*, 1–13. [CrossRef]

10. CBS—Central Bureau of Statistics. *Environment Statistics of Nepal*; National Planning Commission, Government of Nepal: Kathmandu, Nepal, 2008.
11. Central Bureau of Statistics. *Statistical Year Book Nepal*; Central Bureau of Statistics, National Planning Commission: Kathmandu, Nepal, 2011.
12. Adger, W.N. Vulnerability. *Glob. Environ. Chang.* **2006**, *16*, 268–281. [CrossRef]
13. Adger, W.N.; Kelly, P.M. Social vulnerability to Climate Change and the Architecture of Entitlements. *Mitig. Adapt. Strateg. Glob. Chang.* **1999**, *4*, 253–266. [CrossRef]
14. Brooks, N.; Adger, W.N.; Kelly, P.M. The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation. *Glob. Environ. Chang.* **2005**, *15*, 151–163. [CrossRef]
15. Füssel, H.-M.; Klein, R.J. Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. *Clim. Chang.* **2006**, *75*, 301–329. [CrossRef]
16. Füssel, H.-M. Vulnerability: A Generally Applicable Conceptual Framework for Climate Change Research. *Glob. Environ. Chang.* **2007**, *17*, 155–167. [CrossRef]
17. Biggs, E.M.; Tompkins, E.L.; Allen, J.; Moon, C.; Allen, R. Agricultural Adaptation to Climate Change: Observations from the Mid-Hills of Nepal. *Clim. Dev.* **2013**, *5*, 165–173. [CrossRef]
18. Barnett, J. Adapting to Climate Change: Three Key Challenges for Research and Policy—An Editorial Essay. *Wiley Interdiscip. Rev. Clim. Chang.* **2010**, *1*, 314–317. [CrossRef]
19. Adhikari, S.; Baral, H. Governing Forest Ecosystem Services for Sustainable Environmental Governance: A Review. *Environments* **2018**, *5*, 53. [CrossRef]
20. Central Bureau of Statistics. *National Climate Change Impact Survey 2016*; A Statistical Report; Central Bureau of Statistics: Kathmandu, Nepal, 2017.
21. World Food Program. *Winter Drought Worsens Food Insecurity in Nepal*; WFP: Kathmandu, Nepal, 2009; Available online: https://www.wfp.org/news/news-release/winter-drought-worsens-food-insecurity-nepal (accessed on 31 July 2018).
22. Karn, P.K. *The Impact of Climate Change on Agriculture—A Case Study from Nepal*; Policy Brief; South Asian Network on Development, Economics, and Environment: Kathmandu, Nepal, 2014.
23. Kumar, K.S.K. *Climate Sensitivity of Indian Agriculture Do Spatial Effects Matter? Working Papers*; South Asian Network for Development and Environmental Economics (SANDEE): Kathmandu, Nepal, 2009; ISSN 1893-1891.
24. Parry, M.L.; Rosenzweig, C.; Iglesias, A.; Livermore, M.; Fischer, G. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Glob. Environ. Chang.* **2004**, *14*, 53–67. [CrossRef]
25. Nayava, J.L.; Gurung, A.K. Impact of Climate Change on Production and Productivity: A case study of Maixe Research and Development in Nepal. *J. Agric. Environ.* **2010**, *11*, 59–67. [CrossRef]
26. United Nations Development Programme. *Country Report on Global Assessment of Risk*; ISDR Global Assessment Report on Poverty and Disaster Risk; UNDP: Kathmandu, Nepal, 2009.
27. Bhatt, D.; Maskey, S.; Babel, M.S.; Uhlenbrook, S.; Prasad, K.C. Climate Trends and Impacts on Crop Production in the Koshi River Basin of Nepal. *Reg. Environ. Chang.* **2014**, *14*, 1291–1301. [CrossRef]
28. Palazzoli, I.; Maskey, S.; Uhlenbrook, S.; Nana, E.; Bocchiola, D. Impact of Prospective Climate Change on Water Resources and Crop Yields in the Indrawati Basin, Nepal. *Agric. Syst.* **2015**, *133*, 143–157. [CrossRef]
29. Bhattarai, B.; Beilin, R.; Ford, R. Gender, Agrobiodiversity, and Climate Change: A Study of Adaptation Practices in the Nepal Himalayas. *World Dev.* **2015**, *70*, 122–132. [CrossRef]
30. Jaquet, S.; Shrestha, G.; Kohler, T.; Schwilch, G. The Effects of Migration on Livelihoods, Land Management, and Vulnerability to Natural Disasters in the Harpan Watershed in Western Nepal. *Mt. Res. Dev.* **2016**, *36*, 494–505. [CrossRef]
31. Sugden, F.; Maskey, N.; Clement, F.; Ramesh, V.; Philip, A.; Rai, A. Agrarian Stress and Climate Change in the Eastern Gangetic Plains: Gendered Vulnerability in a Stratified Social Formation. *Glob. Environ. Chang.* **2014**, *29*, 258–269. [CrossRef]
32. Maharjan, A.; Bauer, S.; Knerr, B. Do Rural Women Who Stay Behind Benefit from Male Out-migration? A Case Study in the Hills of Nepal. *Gender Technol. Dev.* **2012**, *16*, 95–123. [CrossRef]
33. Manandhar, S.; Vogt, D.S.; Perret, S.R.; Kazama, F. Adapting Cropping Systems to Climate Change in Nepal: A Cross-regional Study of Farmers' Perception and Practices. *Reg. Environ. Chang.* **2011**, *11*, 335–348. [CrossRef]

34. Acharya, R.N. The Effects of Changing Climate and Market Conditions on Crop Yield and Acreage Allocation in Nepal. *Climate* **2018**, *6*, 32. [CrossRef]
35. Baudron, F.; Jaleta, M.; Okitoi, O.; Tegegn, A. Conservation Agriculture in African Mixed Crop-livestock Systems: Expanding the Niche. *Agric. Ecosyst. Environ.* **2014**, *187*, 171–182. [CrossRef]
36. Adhikari, J. *Agriculture Adaptation Practices in South Asia. Case of Nepal*; SAWTEE Working Paper No. 01(iii)/14; South Asia Watch on Trade, Economics and Environment (SAWTEE): Kathmandu, Nepal, 2013.
37. Adger, W.N.; Barnett, J. Four Reasons for Concern about Adaptation to Climate Change. *Environ. Plan. A* **2009**, *41*, 2800–2805. [CrossRef]
38. Dile, Y.T.; Karlberg, L.; Temesgen, M.; Rockström, J. The Role of Water Harvesting to Achieve Sustainable Agricultural Intensification and Resilience against Water Related Shocks in Sub-Saharan Africa. *Agric. Ecosyst. Environ.* **2013**, *181*, 69–79. [CrossRef]
39. Tambe, S.; Kharel, G.; Arrawatia, M.; Kulkarni, H.; Mahamuni, K.; Ganeriwala, A.K. Reviving Dying Springs: Climate Change Adaptation Experiments from the Sikkim Himalaya. *Mt. Res. Dev.* **2012**, *32*, 62–72. [CrossRef]
40. Van Welie, M.J.; Romijn, H.A. NGOs fostering transitions towards sustainable urban sanitation in low-income countries: Insights from Transition Management and Development Studies. *Environ. Sci. Policy* **2018**, *84*, 250–260. [CrossRef]
41. Adger, W.N.; Arnell, N.W.; Tompkins, E.L. Successful Adaptation to Climate Change across Scales. *Glob. Environ. Chang.* **2005**, *15*, 77–86. [CrossRef]
42. Adams, R.M.; Hurd, B.H.; Lenhart, S.; Leary, N. Effects of global Climate Change on Agriculture: An Interpretative Review. *Clim. Res.* **1998**, *11*, 19–30. [CrossRef]
43. Jones, L.; Boyd, E. Exploring Social Barriers to Adaptation: Insights from Western Nepal. *Glob. Environ. Chang.* **2011**, *21*, 1262–1274. [CrossRef]
44. Giri, K.; Darnhofer, I. Outmigrating Men: A Window of Opportunity for Women's Participation in Community Forestry? *Scand. J. For. Res.* **2010**, *25*, 55–61. [CrossRef]
45. Agrawal, A. Local Institutions and Adaptation to Climate Change. In *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*; The World Bank: Washington, DC, USA, 2010; pp. 173–198.
46. Yates, J.S. Uneven Interventions and the Scalar Politics of Governing Livelihood Adaptation in Rural Nepal. *Glob. Environ. Chang.* **2012**, *22*, 537–546. [CrossRef]
47. Chhetri, N.; Chaudhary, P.; Tiwari, P.R.; Yadaw, R.B. Institutional and Technological Innovation: Understanding Agricultural Adaptation to Climate Change in Nepal. *Appl. Geogr.* **2012**, *33*, 142–150. [CrossRef]
48. Næss, L.O.; Bang, G.; Eriksen, S.; Vevatne, J. Institutional Adaptation to Climate Change: Flood Responses at the Municipal Level in Norway. *Glob. Environ. Chang.* **2005**, *15*, 125–138. [CrossRef]
49. Klein, R.J.; Eriksen, S.E.; Næss, L.O.; Hammill, A.; Tanner, T.M.; Robledo, C.; O'Brien, K.L. Portfolio Screening to Support the Mainstreaming of Adaptation to Climate Change into Development Assistance. *Clim. Chang.* **2007**, *84*, 23–44. [CrossRef]
50. Ayers, J.M.; Huq, S. Supporting Adaptation to Climate Change: What Role for Official Development Assistance? *Dev. Policy Rev.* **2009**, *27*, 675–692. [CrossRef]
51. Donner, S.D.; Webber, S. Obstacles to Climate Change Adaptation Decisions: A Case Study of Sea-level Rise and Coastal Protection Measures in Kiribati. *Sustain. Sci.* **2014**, *9*, 331–345. [CrossRef]
52. Nielsen, J.Ø.; Reenberg, A. Cultural Barriers to Climate Change Adaptation: A Case Study from Northern Burkina Faso. *Glob. Environ. Chang.* **2010**, *20*, 142–152. [CrossRef]