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# Perceived Changes in Ecosystem Services in the *Panchase* Mountain Ecological Region, Nepal

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**Abstract:** Ecosystem services (ES) are increasingly recognized as a means to facilitate adaption to environmental change. However, the provisions of ES are likely to be impacted by changes in climate and/or changes in land use. In developing countries, where people are typically dependent on these services for their livelihoods, these impacts are of concern; however, very little is known about the changes in provisioning of ES over time. In this study, we assess the perceived changes on ES in the Panchase Mountain Ecological Region of western Nepal. The study area accommodates three distinct ecoregions, ranging from lowland to upland ecosystems and communities. Focus group discussions and key informant interviews were used to collect information on how ES may have changed in the landscape over time. This approach was supported by transect walks, field observations, and secondary sources of information, such as climatic and remote sensing data. Perceived changes on ES in the study region include reduced availability of water, reduced food production, degradation of forest ecosystems, and changes in species compositions. These changes are thought to have impacted other ES, and, in turn, local livelihoods. Management actions that can help local communities foster ES are recommended.

**Keywords:** climate change; ecosystem services; livelihoods; land-use change; Nepal

## 1. Introduction

Ecosystems provide different goods and services, such as food, fiber, timber, flood protection, clean water, and clean air for human beings. The benefits people obtain from ecosystems are known as ecosystem services (ES) [1]. These ES can be further classified into provisioning, regulating, cultural, and supporting services [1]. Many forest ecosystems are rich in biodiversity and provide multiple services that promote human wellbeing [2,3]. People in developing countries, such as Nepal, are largely dependent on these services for their livelihoods [4,5].

Though forest and agro-ecosystems deliver a wide range of goods and services to human beings [6], environmental change, due to climate and/or land use changes, could reduce an ecosystem's ability to deliver such services [7]. Changes in climate typically impact on the biophysical processes that underpin ecosystem dynamics, ultimately affecting the provisioning of ES from these ecosystems [8–10]. A review by Runting et al. [11] found that recent climate change typically has had a negative effect on ES. In Southern Mali, frequent drought and windstorms, along with an early cessation of the rainy season, were found to be the important factors impacting the delivery of ES [12]. For Nepal, Baral et al. [13]

found that climate change will likely have a negative effect on forest, water, and agricultural resources and their associated ES. To date, a few studies suggest that, across many regions, including Nepal, ES will be increasingly impacted by climate change [14–16]; however, they will also be impacted by non-climate-driven changes in the ecological and social environment [17–19].

The effects of climate change on ES will vary based on the spatial and social context. The variability in response of ES to recent climate change has typically occurred in interaction with other biological, social, and economic factors [20], such as changes in ecosystem structure and composition and land use patterns [21]. Changes in land use can exacerbate the impact of climate change on ES. The impacts of climate change and land use change on ES have been widely observed across Asia [22,23], Europe [24,25], North America [26], and South America [27]. Forest cover change from 1973 to 2015 in Ethiopia contributed to a loss of approximately US$3.69 million in ES; in particular, through impacts on nutrient cycling, the provision of raw materials, and erosion control [28]. Similarly, in China, land use change in interaction with increased climate variability led to a decline in water yield, and increased soil erosion in arid regions [29]. In the Koshi Tappu area of Nepal, land cover change over a period of 34 years contributed to a decline in ES from forests, swamps, and rivers [30]. Paudyal et al. [31] found, however, that a shift to community forest management in the Dolakha district of Nepal led to a perceived increase by local inhabitants in forest-based ES over a 25-year period. This highlights that the effect of land use change on ES can be both positive and negative depending on the type of change that occurs. Deforestation in Nepal is likely to cause a reduction in ES [30], while afforestation may promote an increase the provisioning of ES [31]. Understanding the effects of both land use and climate change on ES is, therefore, important for providing scientific and targeted guidance for the sustainable management and use of ES [29].

Rural people are typically dependent on forests, agriculture, and associated ES for their livelihoods [22,32]. Millions of people in the Himalayan region rely on ES for maintaining and improving their livelihoods [33]. This is especially the case in mountainous regions of Nepal [34]. The strong connection between ES and livelihoods suggests that rural communities in Nepal are likely to be highly vulnerable to the impacts of future climate change [35]. This vulnerability, however, may vary from region to region, and is likely to be ameliorated or exacerbated by land use change patterns. Understanding how ES have changed over time and how these are impacting local livelihoods is, therefore, critical for improving decision-making on the management of ES [31].

Sherrouse et al. [36] identified that considering ES requires the holistic assessment of economic, biophysical, and social values, the latter of which are non-market services that have perceived value by stakeholders. Anderson et al. [37] divided these values in two classes: tangible qualities that are provided by ecosystems and beliefs people hold about the importance of them to their lives. These latter values are typically perceived, and may or may not be utilitarian though can aid decision-makers in managing ES [38]. The advent of participatory mapping has made it easier to engage local users on ES and elicit information on trends in ecosystem change and ES provisioning, even for remotely located areas that are largely inaccessible [31,39,40]. Remote sensing datasets can provide temporal information on the structure of, and processes in, ecosystems [41]. These approaches, however, require data that can link spatial data to the values being measured, some of which are not quantitative but qualitative [38]. Perception-based studies combined with participatory mapping of change in ES is a qualitative data approach that has been found to elicit information on trends in ES in Nepal [31]. This approach acquires information on what ES are being used, their value, the processes that govern their flow, and an understanding of the effect these flows have on human well-being [42]. Perceptions of change in ES based on local perspectives can provide valuable insights into the relationship between how ecosystems are functioning, human well-being, and livelihoods [39]. Perceptions of ES use and changes over time are dependent, however, on the social and biophysical context of the study area and the interactions between local users and these landscapes [39]. Nonetheless, considering the use and perceived value of ES and the how they change in response to management are important for promoting communication about the importance of ES between managers, users, and researchers for developing management practices that can foster the provision of all ES [39,43].

Nepal, and the surrounding Himalayan region, is regarded as being particularly vulnerable to climate change due to the abrupt ecological and climatic transitions in the region [33,35]. Warming over the last century in the Himalayas is higher than the global average [44,45]. The region's patterns have become more erratic, and the onset of the monsoon season has become increasingly unpredictable [35]. This is of concern, as greater than 60% of agricultural production in Nepal is reliant on monsoonal rainfall [35]. In addition, there has been an increase in glacial retreat and increased occurrence of storms, landslides, and drought over the last 20 years [35]. This has led to declines in crop and dairy production and an increase in household work [35,46]. Very little is known, however, about the trends in ES in the region, which is in part due to a lack of appropriate data, tools, and policies [31]. Understanding how ES have changed over time in response to observed climate change and changes in land use is important for predicting how they may change in the future. Such knowledge will enable adaptation to be undertaken in manner that can ameliorate the impacts of climate change and provide novel opportunities for maintaining or increasing local livelihoods [47–49]. The objective of this study was to explore the potential impacts of observed climate change and land use change on the ES and livelihoods of communities in the Panchase Mountain Ecological Regions of western Nepal. Understanding the changes in ES in the face of ongoing environmental change is an important step in informing decision-makers for the development of appropriate management actions [50].

In this study, we use a perception-based approach supported by climatic and remote sensing data to: (1) elicit information about trends in important ES over time; and (2) elicit information on perceived impact of environmental change on ES in the study region.

## 2. Materials and Methods

### *2.1. Study Area*

The study area is located in the Harpankhola catchment of the Panchase Mountain Ecological Region (PMER) between 28°8′36″ N to 28°18′17″ N latitude, and 83°43′69″ E to 83°59′5″ E longitude (Figure 1). It was selected as a case study because it provides range of provisioning ES, such as food, water, and forest products, along with regulating, habitat, and cultural ES [13,51]. More than 14,800 households in the area are dependent on ES for their livelihoods [44]. The study area was demarcated into three regions based on altitude: (1) Lowland representing the area around Thulakhet from 815 to 1300 m above sea level (m.a.s.l), (2) Midland representing the area from 1400 to 1900 m.a.s.l; and (3) Upland representing areas occurring above 1900 m.a.s.l (Figure 1). For some analyses, Middle and Upland regions were combined and classified as the Upland region.

The forest in the Lowland is mainly managed as a community forest, and is regarded as the fringe area of the Panchase protected forest (PPF). In contrast, the Upland region is characterized as a core region of the PPF, and is managed mainly for the conservation of biodiversity, provisioning ES (especially medicinal and aromatic plants [52] and water), regulating services (i.e., water purification), and cultural services (i.e., recreation, aesthetics, and spiritual values). Forest is the dominant land cover (61%) in the study area, followed by agriculture (34%), grassland (3%), and wetland (1.3%) [13]. Besides agriculture and forests, the study area also has significant cultural, aesthetic, and ecotourism values. Sacred areas, with cultural and religious importance for the indigenous Gurung culture, exist within the region. The Panchase area is also the source of drinking and irrigation water for both upstream and downstream communities; the Harpan River originates from the peak of the Panchase, and fulfills irrigation needs for agriculture in the Midland and Lowland regions of the watershed. It also serves as the main feeder stream for Phewa Lake, a major tourist attraction in the Pokhara valley.

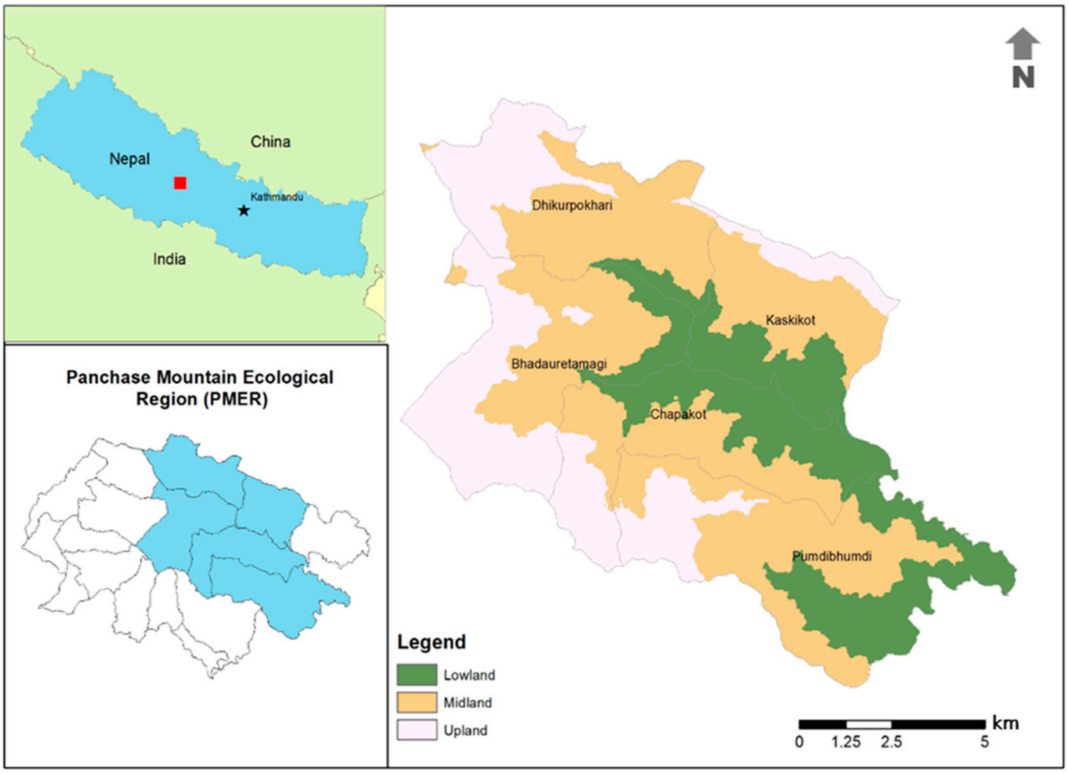


**Figure 1.** The study area in the Panchase Mountain Ecological Region of Nepal.

## 2.2. *Methodological Approach*

The study is based on the use of both qualitative and quantitative databases derived from field data collection and other relevant sources. The overall methodological approach of the study is illustrated in Figure 2.

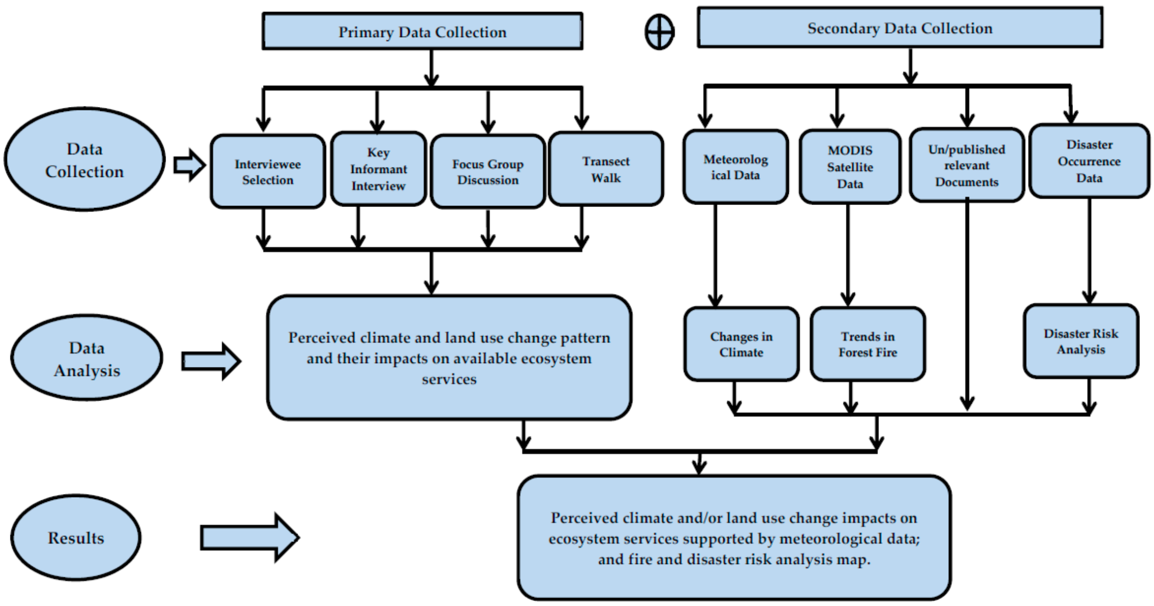


**Figure 2.** The methodological approach to elicit information on the importance of, and trends in, ecosystem services in the Panchase Mountain Ecological Region of Nepal.

### 2.3. Primary Data Collection

#### 2.3.1. Interviewee Selection

The first step was to select interviewees to participate in the structured and semi-structured interviews. For this, contact was made with the Panchase Protected Forest Program (PPFP), the District Forest Office in Kaski, and different non-governmental organisations (NGOs) working in the study region to identify potential interviewees and focus group participants. This was followed by field visits to the study region to identify additional respondents to participate in the individual interview component of the study and/or in the focus group discussions.

#### 2.3.2. Interviews

Non-proportional quota (purposeful) sampling was used to interview different people who play active managerial and decision-making roles in managing ecosystems in the study landscape. We conducted 37 in-depth semi-structured key informant interviews with forest users ($n$ = 24), forest managers ($n$ = 10), and representatives of an NGO working in the area ($n$ = 3). The interviewees from the forest user group included elderly people, people from indigenous and marginalized communities, social mobilisers, school teachers, and members of other community groups representing farmers, women, and disaster risk reduction (DRR) activities. Our aim with this sampling methodology was to solicit and engage a wide spectrum of values and stakeholders in order to gain insight into the topic instead of having a high sample size typical of proportional quota sampling [53,54]. Similar to the experience of Klain et al. [53], once we completed 30–35 in-depth interviews, new information diminished. The interviews were mainly focused on the perceptions of ES availability in the region, changes in climate, natural disturbances and land use patterns, and how the perceived changes in the availability of ES were influencing the livelihoods of people in the region. Responses from each respondent were crosschecked with other respondents to help triangulate perceived changes in the landscape's structure and ES that were then compared with observations collected during a transect walk through the study region.

#### 2.3.3. Focus Group Discussion

Following individual interviews, we conducted interactive focus group discussions (FGDs), one in each region, along with one with forest managers and experts in the field of forest management and ES. Generally, a FGD involves 5–10 participants moderated by the trained facilitator with particular focus on a specific set of issues to gain a broad range of views on the research topic [55,56]. Each FGD had five participants. Participants in the FGD were mainly executive members of community forest user groups (CFUGs), school teachers, members from community groups, indigenous ethnic groups, and community elders. FGDs with the managers and experts were carried out in the district headquarters among Forest Officers, Rangers, Managers of the PPF, and the Chairperson of the PPF council.

### 2.4. Secondary Data Collection

Major sources of secondary data used in the study included: (i) climatic data from nearby meteorological stations; (ii) Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data and disaster occurrence data; (iii) published and unpublished reports from relevant government and NGOs; (iv) the operational plan of PPFP and various community forest user groups; and, (v) the community-forest-based community adaptation plan of action. There were some limitations with the study design. For instance, though interviewees were selected to represent a range of values and perspectives, this might not represent the overall Panchase region. The region contains three districts: Kaski, Parbat, and Syangja. This study was based only in the Kaski district of the PMER. Similarly, field data collection was carried out at the peak of the farming season. This may have influenced people's perceptions of the importance of agricultural-based ES and also the impact of the current growing season's climatic patterns on crop production.

### 2.5. Data Analysis

Qualitative and Quantitative Data Analysis

Though most of the data collected were qualitative in nature, we used a mix of both qualitative and quantitative data for the study. Qualitative data were analyzed with Nvivo [57,58]. This analysis required the collation of interviews into a database and then the coding and interpretation of the data.

We assessed the potential sensitivity of forest ES to environmental change using geospatial tools and techniques. This mainly included an analysis of forest fire risk in the study area. We used forest fire occurrence data from 2001 to 2018 acquired from the MODIS satellite sensor to quantify the trend in forest fire activity in the study area and also to analyze the risk of forest fire occurrence. Forest fire risk was calculated following Matin et al. [59] and using the following variables: land cover, average summer land surface temperature, distance from settlement, distance from road, elevation, and slope. We also analyzed the disaster risk of the villages in the study area based on the disaster occurrence data from 2000 to 2014 acquired from the Ministry of Home Affairs.

## 3. Results and Discussions

### 3.1. Perceptions of Changes in Climate

Almost all respondents (98%) perceive that climate change is occurring in the region, with more than 60% of respondents identifying that temperatures in the summer have increased, while 39% of respondents perceived that the winter season has become colder (Figure 3). Temperature data from the last 30 years from both the Lowland and Upland regions supports the perceived changes in temperature patterns during this period (Figure 4). For example, the Upland region, near to the Lumle meteorological station (Figure 4), has experienced an increase in average annual temperatures of about 1 °C over the last 30 years, whereas the maximum temperatures in summer have increased by almost 2 °C during that period. Similar results were observed in the Lowland region, represented by the Pokhara meteorological station (Figure 4).

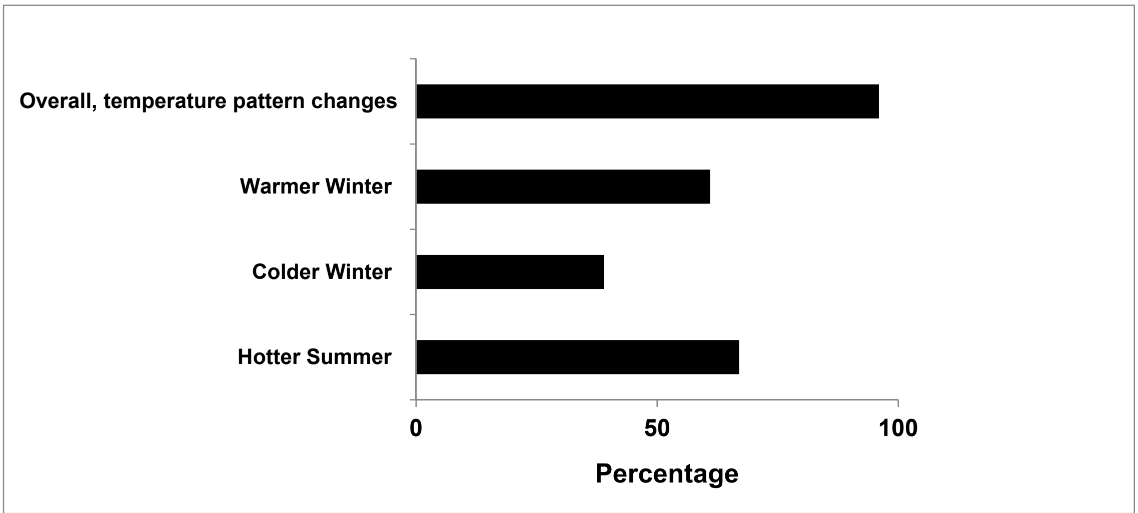


**Figure 3.** Perception of respondents from both the upland region and the lowland region on climate change in the *Panchase* Mountain Ecological Region.

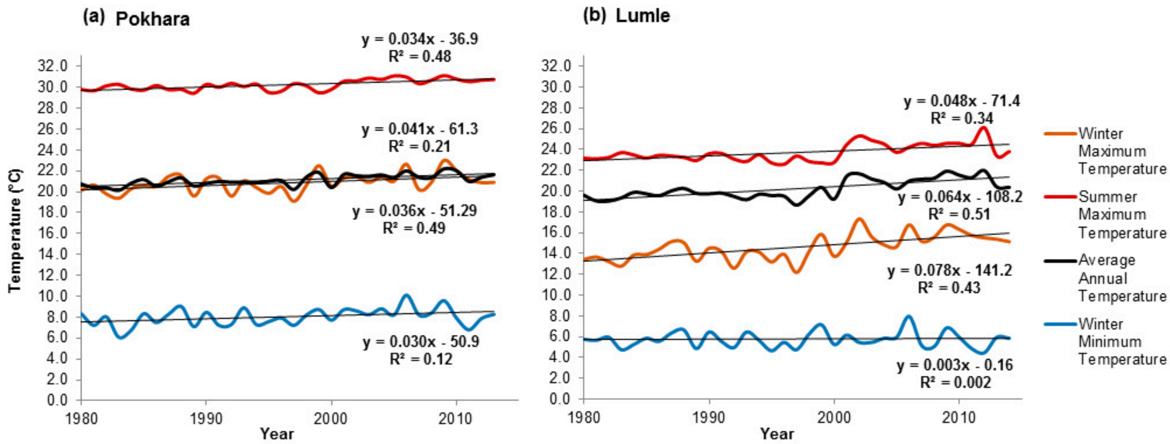


**Figure 4.** The annual and seasonal temperature at the Pokhara (**a**) and Lumle (**b**) meteorological stations, representing the lowland and upland regions of the study landscape, respectively.

## *3.2. Perceived Changes in ES and the Environment*

The local respondents from both Lowland and Upland perceived changes in ES, which included a decline in provisioning and regulating ES. For provisioning services, respondents identified a decline in the availability of water, forest products, and food production through agriculture. The perceived impact of climate change on food production was consistent across regions, while declines in water and forest product availability were more widely attributed to climate change in the *Lowland* region (Figure 5). For regulating services, an increase in landslides and floods was reported, but again, a regional difference was found with twice as many respondents from the *Lowland* region perceiving a change in the occurrence of these natural hazards.

The majority of respondents perceived an increase in the occurrence of invasive species across both regions (Figure 5). A large proportion of respondents from both regions identified that species compositions have changed, with fewer respondents perceiving a change in the occurrence of insects and pests and fire (Figure 5).

### 3.2.1. Impact on Provision of Water

The provision of water was identified as one of the major changes in the landscape over the last 20 years; 70% of the respondents in the Lowland region perceived a decline in water availability compared to 20% in the Upland region. The scarcity of water has affected the domestic water use in the Lowland region for both people and livestock, and reduced water use for the irrigation of food crops. Respondents reported that traditional water sources (springs) have virtually dried up (see Figure 6), and irrigation systems were no longer functioning in both regions. Some respondents attribute this decline to the recent changes in climate in the region; in particular, the increase in erratic rainfall patterns. Our findings of a decrease in water availability with a changing climate are consistent with the findings from similar studies from Nepal [60–62] and globally [63–65]. Poudel and Duex [61] also reported that recent declines in precipitation resulted in the drying-up of springs in the Thulokhola watershed located in the Nuwakot district of Nepal.

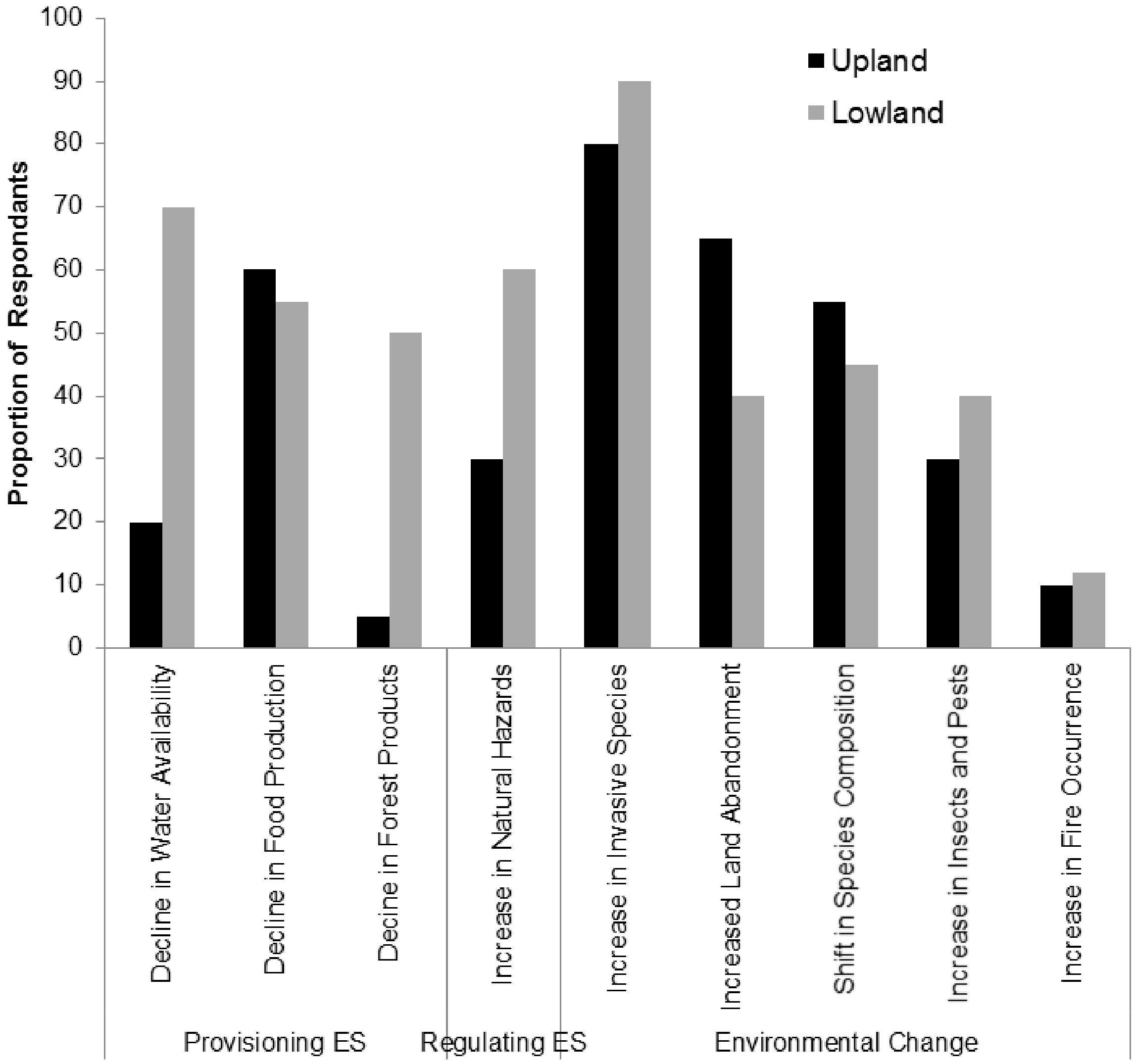


**Figure 5.** Perceived changes in ecosystem services (ES) and environmental attributes by respondents from the Upland and Lowland regions of the study landscape.

A key finding was that the perceived change in water availability was not consistent across the study region. The majority of respondents from Upland communities did not perceive a change in water availability, whereas people in the Midland and Lowland areas have observed a reduction in water availability. Expert respondents, however, reported that the availability of water in the Upland region has also decreased. The conflicting perceptions highlight the limitations of using perception-based studies to understand trends, but also provide a key insight into the impact of water availability on livelihoods in the region. Regardless of whether or not water availability has changed, due to climate or not, it is not affecting Upland livelihoods but it is affecting livelihoods in the Lowlands. This dichotomy in perceived impact may be due to outmigration, there is now a lower population pressure in the Upland, which would provide the remaining families with access to sufficient water resources. In contrast, population pressure has increased in the Lowland, which puts more pressure on water resources irrespective of changes in climate. Secondly, the increase in forest cover in the study area could explain the perceived change in water availability, as trees and other woody vegetation typically use a larger proportion of rainfall compared to other land uses, such as agriculture and pasture, thereby reducing the amount of water reaching streams and rivers [66,67]. Lemarque et al. [43] identified that, although local users of ES are able to perceive changes over time, they tend to lack the knowledge to discern processes that govern the provision of ES. These results highlight the importance of having baseline data to quantify the actual changes of water resources and compare the changes in the provision of water in the region.

**Figure 6.** The drying of water sources in the upland region. A respondent showing his traditional water pond, which is completely dry now and invaded by the invasive species *Ageratum conyzoides.*

### 3.2.2. Invasive Species

The invasion of alien plant species was reported by 80% of respondents in the Upland and 90% in the Lowland regions. Invasive species were reported in both farmland and forest ecosystems (Figure 7). *Ageratina adenophora* (Banmara) and *Ageratum conyzoides* were identified as the most common invaders of farmland, especially abandoned agricultural land and adjoining public spaces. In forests, common invaders identified were *A. adenophora* and the local species *Lyonia ovalifolia* (Angeri), Hadeunyeu, Katrekanda, and Bilaune. Invasive grasses were also reported to be spreading across the study area in both farm and forestlands. The increase in invasive species is perceived by respondents to be preventing the regeneration of locally preferable species and, thereby, affecting provisioning ES provided by forest products. Respondents identified that invasive grasses and shrubs, such as *A. adenophora*, and other thorny species have largely replaced palatable grasses, such as Banso or Khar. The increase in cover of invasive species in forests is believed to be affecting the regeneration of locally important tree species, such as *Castanopsis spp*. and *Schima wallichi*, in both the Lowland and Midland regions. These findings are consistent with the findings of Bhatta et al. [22], and suggest that the continual proliferation of invasive species in both forest and farmlands may have a negative impact on biodiversity and associated ES and, therefore, livelihoods [68–70]. Future increases in invasive species and their impact on ES may be further amplified by future climate change [71–73].

**Figure 7.** Invasive species encroaching upon the Midland farmland (**left**), and thorny bushy species covering the understory of forests in the Upland region (**right**).

### 3.2.3. Farm Land Abandonment

Our results provide evidence for a growing trend of farmland abandonment and associated decrease in ES in the rural mountainous areas of Nepal. Farmland abandonment in the Upland and Lowland regions was a major land use change observed during the last decade. The Lowland region, however, had comparatively lower land abandonment than the Upland. Respondents reported that increased climate variability was a contributing factor to farmland abandonment, as it has increased uncertainty in the production of food and forest products required to support their livelihoods. Due to a lack of water available for irrigation, farmers have not been able to grow enough crops, as most farmland areas are rain-fed systems (bariland). The increased marginalization of rain-fed farmland for agricultural production has led to an outmigration of farmers from the region in search of other livelihood opportunities.

The pattern of farmland abandonment found in this study is consistent with findings from other regions in Nepal [70,74] and in other countries [75–77]. Jaquet et al. [70] identified that a high proportion of men have been emigrating from areas where agricultural production has declined in search of other employment opportunities, thereby facilitating land abandonment. Consistent with the findings from other studies [75–77], the abandoned farm lands have gradually reverted into shrublands and forests; as a consequence, forest area has increased in the landscape. With proper adaptation measures to tackle the factors associated with farmland abandonment, abandoned farmlands could be re-cultivated to increase provisioning ES from agricultural systems in the region [78,79].

### 3.2.4. Shifting Species Composition

About half of the respondents, from both the Upland and Lowland regions, identified changes in species composition. Changes were reported as either shifting of species to higher elevations, local extinction of species, increased abundance of species in some locations, and changes in composition of species in the region. For example, respondents observed that *Schima wallichi* (Chilaune) and *Castanopsis indica* (Katus) have shifted their distributions to higher altitudes in recent years. *Castanopsis indica*, *Michelia species* (Champ), *Diospyros lanceifolia* (Teju), and *Toona ciliate* (Tooni), however, were reported to be gradually decreasing in abundance. Importantly, traditionally valuable timber species, such as "kalo Jangali Champ" *(Michelia Kisopa*), locally referred to as Champo, has become very rare, and a new species of Champ, which is locally known as "Thulo Pante Champ", has been introduced to provide timber for construction.

Respondents have also observed a decline in fruit trees in the forest, such as *Myrica esculenta* (Kaphal), *Choerospondis axillaris* (Lapsi), and *Castanopsis indica*. Similarly, some fodder species, such as *Quesrcus species* (Phalat) and *Ficus roxburghii*, and species used for non-timber forest products, such as *Paris polyphylla* (Satuwa), *Asparagus racemosus* (Kurio), *Zanthoxylum pepper* (Siltimur), *Taxus wallichiana* (Lauthsalla), and *Swertia chirayita* (Chiraito), were also reported to be in decline. These changes in species abundance represent a change in habitat and provisioning services from forest areas [31]. Some fodder species, notably *Litsea monopetala* (Kutmero), *Ficus subincisa* (Bedulo), and *Ficus semicordata* (Khanyeu), were reported to have colonised Upland regions. The expansion of these species may increase the habitat and provisioning services available in this region. Two species that were reported to have increased in abundance are *Daphniphyllum himalense* (Rakchan) in the Upland region and *Alnus nepalensis* (Uttis) across the landscape on landslide-affected sites. These species are able to take advantage of disturbed sites and, therefore, increase their abundance locally. The increase in *A. nepalensis* on landslide-affected areas is preventing further erosion and landslides in the region. This highlights an increase in regulating services provided by the increase in this species in disturbed areas [31].

Changes in species composition may be due to the overexploitation of some species for timber and other uses or due to forest dynamics [80]. For example, the recovery and maturation of forests following land abandonment can lead to changes in species distributions and community composition that emulate changes associated with climate change [80]. In our study region, an increase in land abandonment in Upland regions and the subsequent establishment of forests may explain the observed upward shift in the distribution of some forest species [80]; however, recent changes in climate cannot be excluded as having an influence [81].

#### 3.2.5. Availability of Forest Products

Major forest products extracted by people from the forests in the study area were timber, firewood, fodder, medicinal and aromatic plants, and fruit and other plants for food. Most of the Upland respondents mentioned that the availability of these products has remained unchanged; however, 50% of respondents in Lowland have experienced a decline in production over time. Major sources of these forest products were from community-managed forest in the Midland and Lowland regions, along with private forests and agroforestry.

#### 3.2.6. Forest Fire

In contrast to the general trend that the occurrence of forest fire is increasing due to recent climate change [82–84], fire was not found to have increased in the study landscape. Only ~10% of the respondents identified fire as a major issue in their landscape; however, there was the general understanding that fire was a major issue in earlier decades, but that the number of fire incidents has declined in recent years. We identified that the forest fire risk ranged from low to high in the study area, with most of the high forest fire risk areas falling in Lowland and Midland areas (Figure 8). We observed that the highest forest fire risk occurred in Pumdibhumdi and Chapakot, while a moderate risk occurred in Kaskikot and Bhadauretamagi, and finally the lowest risk in Dhikure Pokhari situated in the Upland area. The increased forest fire risk in Lowland areas is in part due to the easy access to forests, resulting in a high level of anthropogenic activities leading to an increased threat of ignitions from human activities.

The decline in fire incidents is likely due to increased awareness and education about fire risk and through community participation in forest management and conservation. Increased community awareness and participation has improved the local governance and management of forest fires. Another important change that has likely influenced fire risk is the abandonment of shifting cultivation practices, forest-based grazing, and the use of fire as a means of hunting wildlife. In the past, these activities were a major source of fire ignitions. Some respondents, however, reported fire as a major problem on southern aspects in the Parbat district within the Panchase landscape. Less fire in our study area may be due to the dominance of northern-facing forests and comparatively moister areas than that of the Parbat district, which is dominated by drier, southern-facing slopes. As a consequence of less fire, the forests throughout the region have largely been conserved intact, which in turn promotes access to a myriad of provisioning and regulating services to support livelihoods [5].

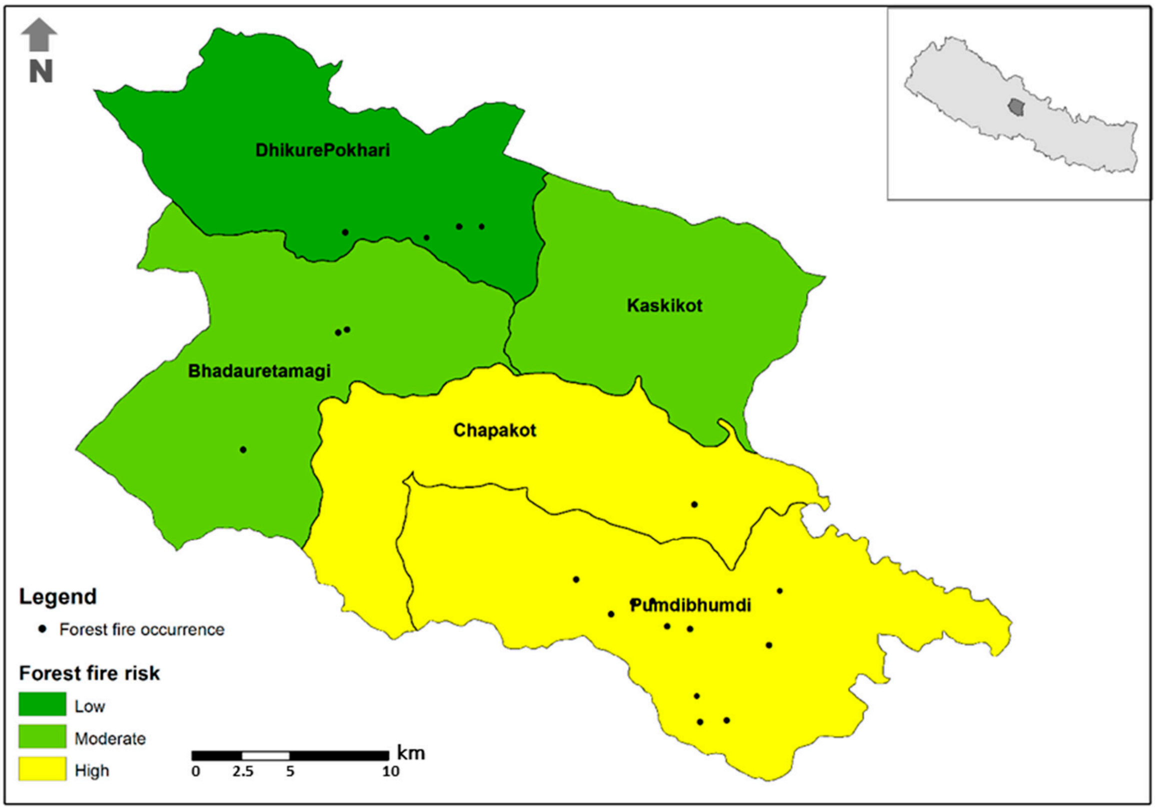


**Figure 8.** The forest fire risk in the study area using the forest fire occurrence data from 2001 to 2018 acquired from the MODIS satellite sensor.

#### 3.2.7. Food Production

Respondents identified that a shift in cultivation practices had occurred in the region. Farmers used to grow millet, maize, and potatoes in the Upland region, but these crops were identified as not growing as well anymore. Similarly, traditional varieties of rice, such as Resaly Ghaiya, have almost become locally extinct, and new crop varieties, such as Bagale Ghaiya and Chhumlungle Ghaiya, have been introduced. A lack of irrigation was one of the major issues hampering agriculture production, as much of the farming practices are rain-fed. In Upland regions, some respondents identified that rice cultivation is now possible in areas with suitable irrigation due to warmer temperatures.

The traditional pattern of a wheat/mustard–maize–paddy cropping cycle is gradually changing, with farmers shifting cropping species and patterns in innovative ways. For example, off-season vegetable farming has been initiated in the region. Farmers have also observed early ripening of agricultural crops relative to previous years. They are also using introduced varieties that have the potential to increase production in a warmer climate.

#### 3.2.8. Forest Insects and Diseases

Some respondents reported insect and pest problems in both forest and farmland in the study area. Farmers reported a perceived increase in potato blights, while foresters reported on the dieback of *Shorea robusta* in the Lowland region. According to the respondents from both the interview and focus group discussions, in 2013, canopy dieback of *Shorea robusta* trees occurred during the winter season, followed by recovery the following spring. Similarly, caterpillars infecting *Alnus nepalensis* and *Castanopsis* spp. were also reported. The perceived increase in the occurrence of insect and pest infestation over time by some respondents are in line with Alamgir et al. [85], who reported increased pest infestation in *Schima wallichii* and *Castanopsis indica* due to a higher summer temperature and delayed rainfall in a nearby forest adjacent to our study area.

### 3.2.9. Flashfloods and Landslides

Although natural hazards, such as flashfloods and landslides, were not perceived to be a major problem in the Upland region (5% of respondents) they were in Lowland regions (50% of respondents). Flashfloods in the lower regions of the Thulakhet area claimed the lives of 15 people and destroyed surrounding cultivated land in April 2015 [74]. Due to these natural disasters, floodplain areas in the valley bottom have increased, with the area that is covered by gravel and sand increasing since 2009, and increased rates of riverbank erosion along the Harpan river being reported (Figure 9). The increase in floodplain and riverbank erosion was reported as causing a loss in the land available for agricultural production.

In the Upland region, small incidents of landslides and erosion were also reported (Figure 9), mainly due to rural road construction practices. Past landslides in the region have already been reclaimed by tree vegetation [85], mainly *Alnus nepalensis.* Overall, fewer incidences of landslides were reported in the Upland region compared to the Lowland region. This may be due to the higher vegetation cover, the lower population pressure, and the reduced intensity of agriculture and grazing practices, which make the Upland regions less susceptible to the impacts of floods and erosion [70].

**Figure 9.** A landslide in the upland region (**left**), and a flashflood-affected area in the lowland region, which claimed the life of 15 inhabitants in April 2015 (**right**).

The disaster risk rating from floods and landslides ranged from low to very high in the study area (Figure 10); however, the variation in risk did not coincide with the altitudinal gradient. A very high disaster risk was observed in Pumdibhumdi, followed by high risk in Dhikur Pokhari, moderate risk in Chapakot, and low risk in Kaskikot and Bhadauretamagi. Further study is required to assess the role of forest ES in disaster risk reduction.

Provisioning of water, forest, and food products, and changes in species composition, are among the largest perceived changes in the PMER. These perceived changes provide an understanding of the importance of ES to people's livelihoods in the region and how these perceived changes are affecting their livelihoods. The study also identified that the importance of ES and perceptions of their availability varied by landscape context and stakeholder. The perceived change in ES varied across the topographic gradient of the study landscape, which represented a gradient of land use and social settings. This is consistent with Garrard et al. [39], who identified that perceptions, though informative, are strongly influenced by geographical setting. Lemarque et al. [43] and Adhikari et al. [86] also found that ES perceptions varied by stakeholders, and that by identifying these differences, communication can be enhanced to inform management practices. Further in-depth study is required to assess the actual impacts of land use and climate change on the identified ES; nonetheless, from this study, we can draw out two policy implications. First, the provisions of ES in the PMER have likely changed over time in both forest and agro-ecosystems. Second, changes in ES provision are not homogenous within the study region, highlighting that social and biophysical contexts influence perceptions of change that must be accounted for in the assessment of ES trends over time and space.

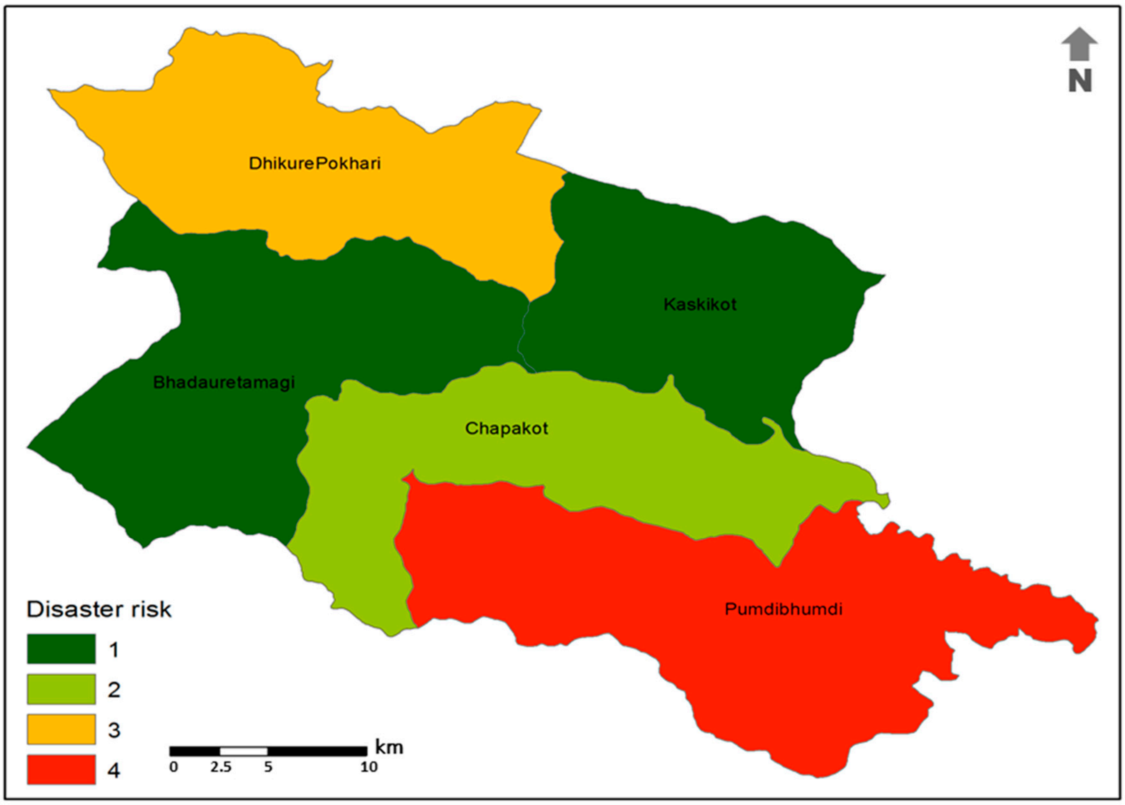


**Figure 10.** A disaster risk map of the study area depicting different levels of risk. The map was prepared based on the disaster occurrence data from 2000 to 2014 acquired from the Ministry of Home Affairs.

## 4. Conclusions

Our study found that the local communities have perceived the change in different ES and, as a result, on their livelihoods. Major perceived impacts occurred across forest, water, and agricultural sectors and their associated ES. An increase in forest cover was reported, but also a decrease in the quality and productivity of the forests, which has resulted in a decline in the use of forest products. The increase in forest area was mainly due to community-based forest management and land abandonment of traditional farmland, which has led to the gradual conversion of farmland into shrub and forestlands. An increase in invasive species was reported on both farmland (abandoned and cultivated) and in forested areas. The availability of water resources and associated ES has likely decreased over the last two decades. Other impacts include a shifting species composition, and extinction. Though these were the major impacts perceived by local communities, a detailed systematic study on the impacts of land use and climate change on these ES would be helpful to quantify the rates of change and the processes influencing their provisioning in order to elicit further understanding that can aid in the design and implementation of adaptation measures.

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