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Assessing the impact of climate change on *Ophiocardyceps sinensis, Agarcus bisporu, Fritillaria cirrhosu,* and *Paris polyphylla* in Nepal

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Abstract

Human survival is facilitated by medicinal herbs with their unique properties but it shows variation in their properties due to climate change and has a significant influence in production. Thus, this study was objectively conducted to assess the impact of climate change and the trend of production on *Ophiocardyceps Sinensis, Agarcus Bisporu, Fritillaria cirrhosu,* and *Paris polyphylla* in the Far-Western Himalayan region of Nepal. The research was based on qualitative and quantitative approaches with data analyzed using Microsoft EXCEL. The minimum and maximum temperature was in increasing trend at an average of –0.0193°C and 0.038°C where precipitation was in decreasing trend at an average of 10.88mm from 1999-2021. The total record of ANCA and DFO, the highest production of *Ophiocordyceps scinensis* was 1056kg in 2021 and the production of 327kg in 2020 was lowest ever recorded in ANCA. In 2018, the production of *Paris polyphylla* was the highest i.e., 8992kg, and 1,630 kg in 2016 was the lowest ever recorded. Apart from this, 7,196kg was the highest production of *Fritillatia cirrhosu* in 2018, and the lowest production was recorded 40kg in 2016. The highest production of *Agarcus bisporus* was 6,857kg in 2018 and only 645kg production in 2017 was recorded lowest. In 2017 *Agarcus bisporus, Ophiocordyceps scinensis,* in 2018 *Ophiocordyceps scinensis,* in 2019 *Fritillatia cirrhosu, Agarcus bisporus, Ophiocordyceps scinensis,* in 2020 *Fritillatia cirrhosu, Ophiocordyceps scinensis* in 2021 *Fritillatia cirrhosu,* and no species production in 2015, 2016 in DFO record. In contrast, people's response and recorded data in DFO and ANCA shows the negative impact of climate change on medicinal herbs in Darchula. This paper will be useful for academicians and policymakers to monitor the production and trend of medicinal herbs.

Keywords: ANCA, ımpact, medicinal herbs, trend

Introduction

The concept of climate change is defined as "a change in the global atmospheric composition that is directly or indirectly attributed to human activity" (Barros & Field, 2014). They are used to indicate changes in climatic variables over a specific period when compared to long-term statistics of the relevant climatic variables (Carrer & Urbinati, 2006). The average temperature of Earth has risen by 1.5°F in the last century, and over the next 100 years, it is projected to rise by another 0.5 to 8.6°F (Sapkota, 2016). Nepal lies in the Hindu Kush Himalayan area and is 4th among the ten countries that are most impacted by climate change (WFP, 2009). In Nepal, the maximum temperature has been rising both annually and seasonally, with inter-annual swings occurring every season (Panthi et al., 2015). Nepal's average minimum temperature tends to rise both annually and in monsoon season but during other seasons, the minimum temperature tends to decrease, however, these trends are lesser at a 95% confidence level (Ghimire, 2019). Nepal experiences a 1.3 mm yr-1 annual precipitation decline, with the post-monsoon season showing the steepest decrease (-0.3 mm yr^{-1}). None of the declining trends, however, is significant (Ghimire, 2019). Seasonal patterns, weather, temperature ranges, and other related weather and climate phenomena have changed globally; these changes have all been linked to and examined with global climate change (Das et al., 2016).

Human beings as well as the existence of medicinal herbs may be strongly harmed by these extreme climate changes (Das et al., 2016). There are an estimated 300,000 plant species in the globe, and 21,000 of those have the potential to be medicinally useful. Nepal, situated in the Himalayas, is home to 3,000 internationally traded species, with 2,000 primarily traded in European countries like Germany, Switzerland, and France (Kalaini & Joshi, 2018). According to Trade Policy 2009, one product with significant export potential for commercialization and export enhancement is medicinal herbs (Kalaini & Joshi, 2018). The study of the medicinal herbs identified in the Humla district revealed that 161 various species of plants, relating to 61 families and 106 genres, have been identified (Rokaya et al., 2010). Himalayan countries, such as China, Nepal, India, Bhutan, and Pakistan, are currently feeling the effects of climate change with greater intensity than many other regions of the world (GLORIA et al., 2010).

High-altitude districts of Nepal are dependent upon medicinal herbs for their survival and also as a means for their economic growth. Darchula district of far-western Nepal, some species i.e., *Ophiocordyceps silences, Agarcus bisporu, Fritillaria cirrhosu,* and *Paris Polyphylla,* etc of medicinal herbs are highly found in the Trans Himalaya areas. Collection and marketing of valuable herbs in the mountain region of Nepal has significantly helped the rural people to alleviate their poverty to a considerable extent and adds employment opportunities for the people with side jobs to lift their income (Sah & Mandal, 2020).

The study examined the impact of climate change on medicinal herbs production in the Humla district. Results showed increased rainfall led to higher production of *Morchella esculenta* (in 2010), *Nardostachy grandiflora* (in 2009), *Paris polyphylla,* and *Swertia chirayita* (in 2010) but a decrease in the production of *Delphinium himalayai, Rheum austral* (in 2005). The study found both positive and negative impacts of climate change on medicinal herb production. Therefore, this study will be useful in understanding the impact of climate change on medicinal herbs in the Himalayas (Shahi & Mandal, 2020). This research was conducted to assess the impact of climate change on *Ophiocardyceps Sinensis, Agarcus Bisporu, Fritillaria cirrhosu,* and *Paris polyphylla* in the Far-Western Himalayan Region of Nepal.

Material and methods

Description of the study area

The study area Api Himal rural municipality of Darchula district is located in the far western province of Nepal at 29°54’00” N and 80°55’11” E and 3653 m from sea level. Sub-alpine climate is found with an average maximum temperature of the district is 18.6 °C, a minimum is 5.7 °C, and annual rainfall of 2.129 mm. The total area of Api Himal rural municipality is 613.95 km^2 and the total population is 6798.

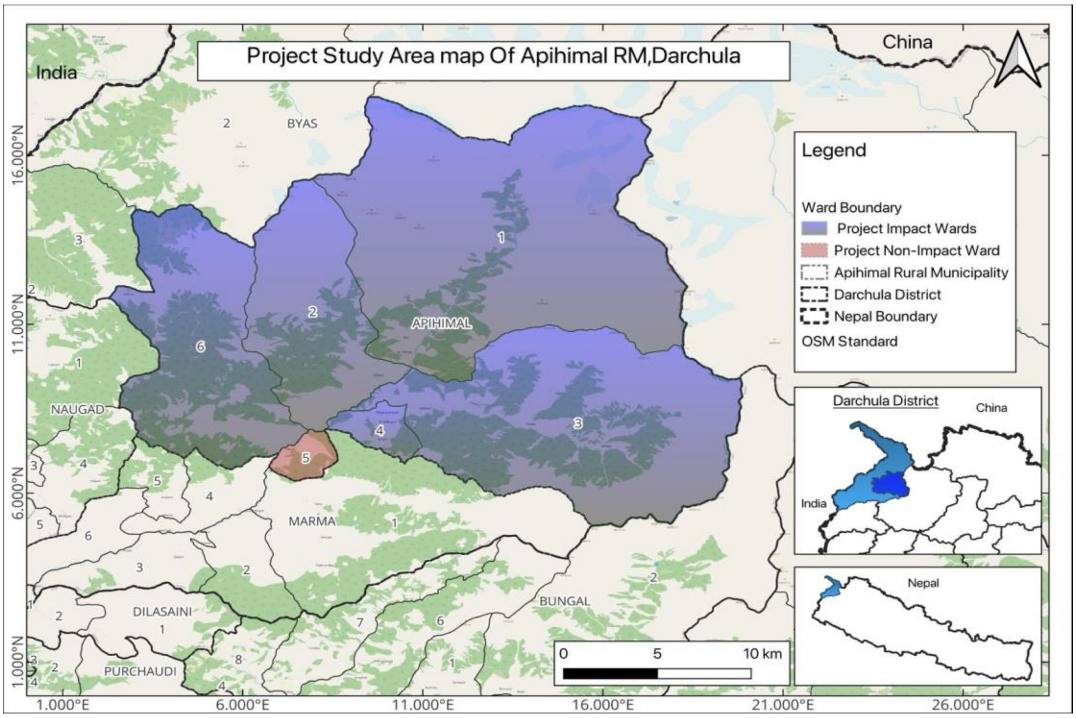

Figure 1. Map of the Study area

Api Nampa Conservation Area is recognized for its tremendous diversity of flora and fauna. *Panthera uncia*, *Moschus chrysogaster*, *Neofelis nebulosi*, *Ailurus fulgens*, *Hemitragus jemlahicus, Selenarctos thibetanus, Pseudois nayaur*, etc wild animal, *Lophopherus impejanus, Catreus wallichii, Crimson spp.* birds, *Pinus spp., Rhododendron spp., Cedrus deodara*, *Betula utilis*, *Quercus spp.*, and *Abies spectabilis* etc plants are found. Majorly found medicinal plants are *Dactylorhiza hatagirea*, *Neopicrorhiza scrophulariflora*, Yarsagumbu (Ophiocordyceps sinensis), Jatamansi (Nardostachys grand flora), Sarpagandha (Rauvolfia serpentine) and Sugandhawal (Valeriana jatamansi) etc. [Source: Api Nampa Conservation Area/Department of National Parks and Wildlife Conservation, Ministry of Federal Affairs and General Administration, Government of Nepal]

Method of data collection

Both primary and secondary data collected were used in the research. Field observation, household survey, 15 key informant interviews, and focus group discussion were carried out as primary data collection, and secondary data were collected from different journals, articles, books, websites, thesis reports, and different agencies from the district forest office and department of hydrology and meteorology. 31 years of Temperature data since (1990-2021) and rainfall data since (1990-2021) of the Darchula district were collected from the regional Department of Hydrology and Meteorology (DHM). The record of the quantity of medicinal herbs for 7 years was collected from the district forest office, Api Nampa Conservation Area, and Darchula.

Composition of household survey

Table 1. Distribution of people in the study area by age group and gender composition

Age Group	No of Respondents	Total percentage % of respondents
30-40	20	38%
40-50	14	25%
50-60	9	16%
60-70	7	13%
70-80	4	8%
Total	54	100%
Gender		
Male	30	56%
Female	24	44%
Total	54	100%

Data Analysis

After the collection of both primary and secondary data from various methods, the data were presented in MS Word and MS Excel. All the necessary tools like tables and graphs were calculated from those programs. The trend Analysis of Rainfall and temperature data were collected from the Department of Hydrology and Meteorology, Kathmandu to analyze scientifically. A normal trend line is used for the available dates and information was presented in the forms of tables, figures, and descriptive texts from different sections. Correlation analysis was done to study the relationship between temperature rainfall patterns and medicinal herbs production.

Results

Trend of Temperature and Rainfall Data

The 31 years of data on temperature (1991-2021) and 31 years of rainfall data (1991-2021) of Darchula district were analyzed. Those data were analyzed by using normal trends. Some rainfall data are missing and were not available in the respective years.

Temperature Trend Analysis

Annual Maximum Temperature Trend Analysis

Figure 2 shows the trend analysis of the annual maximum temperature of Darchula station from 1991 to 2021. It was the highest maximum temperature of 29.66 °C in 2021 and the lowest record maximum temperature was 26.34°C in 2002. The trend line equation was y=-0.0193x+28.105, which shows the annual maximum temperature decreased by -0.0193°C annually from 1991 to 2021.

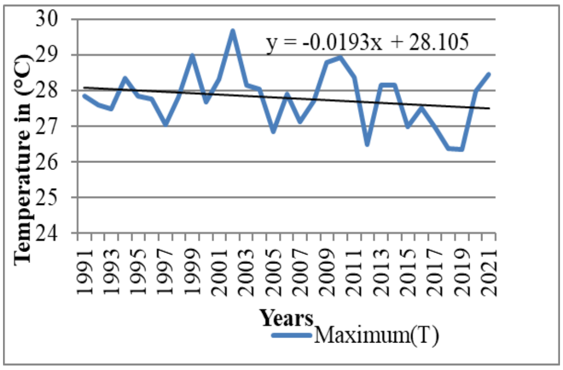

Figure 2. Annual maximum temperature

Average Temperature Trend Analysis

Figure 3 provides a trend analysis of the Darchula station's annual average temperature from 1991 to 2021. The lowest annual average temperature was 19.88°C in 1999, whereas the highest average maximum temperature ever recorded was 21.9°C in 2021. From 1991 to 2021, the average temperature increased by 0.0096°C annually, based on the trend line equation y= 0.0096x+20.602.

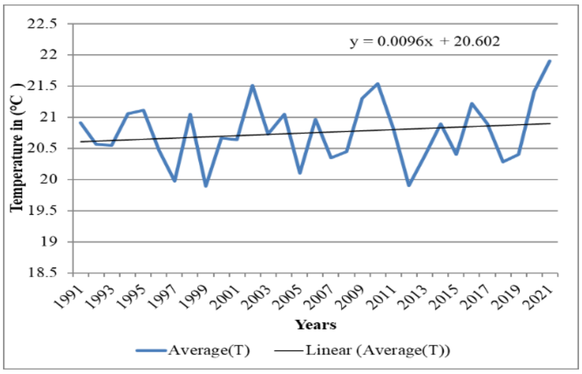

Figure 3. Average temperatures of Darchula

Annual Minimum Temperature Trend Analysis

Figure 4 shows a trend analysis of the Darchula station's yearly minimum temperature from 1991 to 2021. The highest minimum temperature record was 15.34°C in 2015, while the lowest minimum temperature recorded was 10.78°C in 1999. The trend line equation was y= 0.0384x+13.099, which indicates that the minimum temperature increased by 0.038°C every year from 1991 to 2021.

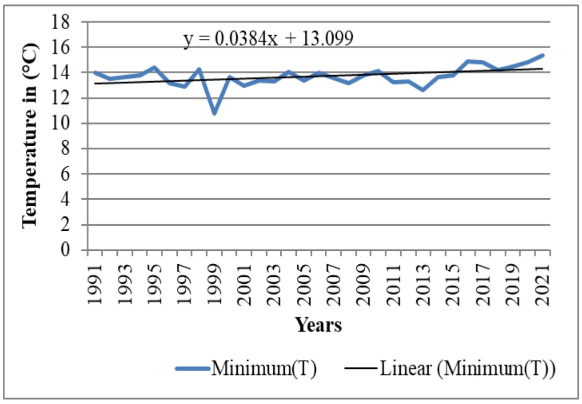

Figure 4. Annual minimum temperature

Trend Analysis Rainfall

Two station data, Darchula and Lumthi stations were taken for the rainfall trend analysis of the Darchula district from the respective year 1991 to 2021. And Lumthi station was taken for the rainfall trend analysis from 1999 to 2021.

A. Annual Rainfall Analysis of Darchula Station

Figure 5 shows the trend analysis of the annual rainfall of Darchula station from 1991 to 2021. It was the highest rainfall of 6073.0mm in 2016 and the lowest record of rainfall was only 336.0mm in 1999. The trend line equation was y= 108.9x+1332.6, it shows annual rainfall was increasing by 108.9mm annually from 1991 to 2021.

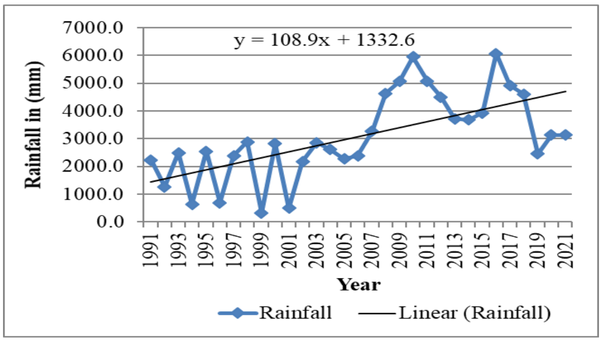

Figure 5. Annual rainfall of Darchula station

B. Annual Rainfall Analysis of Lumthi Station

Figure 6 provides a trend study of Lumthi station's yearly rainfall from 1999 to 2021. The highest annual rainfall record was 3029.9mm in 2002, and the lowest annual rainfall record was only 1011.8mm in 2008. The trend line equation was y= -10.88x+2171, which indicates that annual rainfall decreased by -10.88mm from 1999 to 2021.

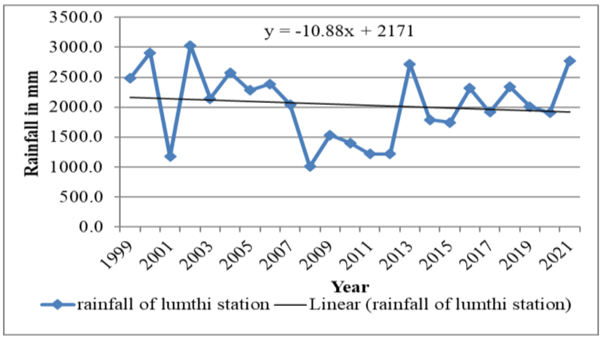

Figure 6. Annual rainfall of Lumthi station

Monsoon Rainfall at Lumthi Station

Figure 7 exhibits a trend study of Lumthi station's monsoon rainfall from 1999 to 2021. The highest rainfall ever recorded was 2768.9 mm in 2002, and the lowest rainfall ever recorded was 819.6 mm in 2008. The trend line equation, y= -11.122x+1765.8, shows that from 1999 to 2021, monsoon rainfall decreased by -11.122mm per year.

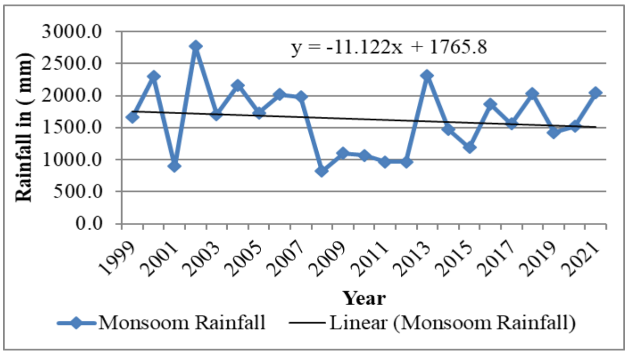

Figure 7. Monsoon rainfall at lumthi station

Pre- Monsoon Rainfall of Lumthi Station

Figure 8 shows the trend analysis of pre-monsoon rainfall at Lumthi station from 1999 to 2021. It was the highest rainfall of 430mm in 2000 and the lowest record of rainfall was only 29.2mm in 2007. The trend line equation was y= 3.6923x+148.98, which shows that pre-monsoon rainfall was increasing by 3.6923mm annually from 1999 to 2021.

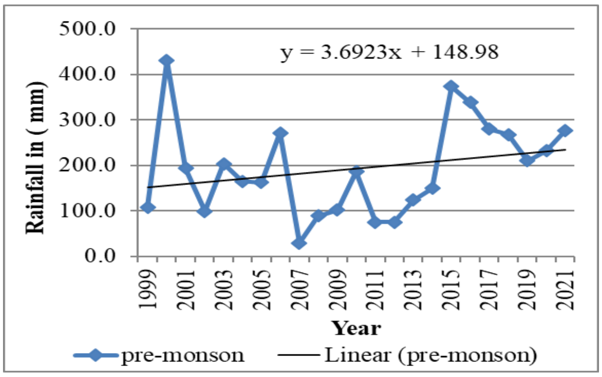

Figure 8. Pre-monsoon rainfall of lumthi station

Post-Monsoon Rainfall of Lumthi Station

Figure 9 depicts a trend analysis of Lumthi station's post-monsoon rainfall from 2000 to 2020. The highest recorded rainfall was 163.5mm in 2000, and the lowest recorded rainfall was only 5.0mm in 2002. The trend line equation was on y= -3.01x+103.67, indicating that post-monsoon rainfall reduced by -3.01mm every year from 1999 to 2021.

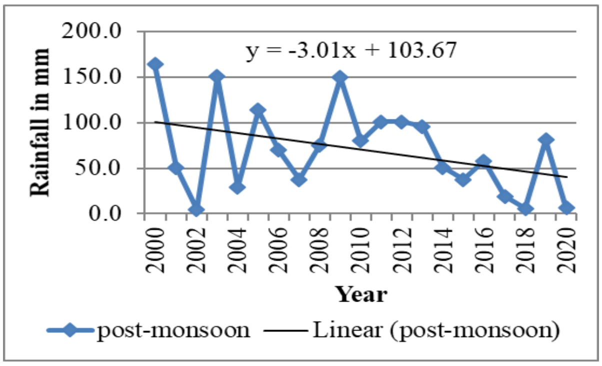

Figure 9. Post- Monsoon rainfall at lumthi station

Trend Production of *Ophiocardyceps cinensis, Agarcus bisporus, Fritillatia cirrhosu and Paris polyphylla* in DFO and ANCA, Darchula

Table 2. Production of *Ophiocardyceps scinensis, Agarcus bisporus, Fritillaria cirrhosu and Paris polyphylla* in DFO and ANCA, Darchula

S.N	Years		*Paris polyphylla* (kg)	*Fritillaria cirrhosa* (kg)	*Agarcus bisporus* (kg)	*Ophiocardyceps scinensis* (kg)	Remarks
1	2015	ANCA	4920.7	1,301	2,735	833.13	
		DFO	-	-	-	-	
		Total	**4920.7**	**1,301**	**2,735**	**833.13**	
2	2016	ANCA	1,630	40	4,474	1,029	

		DFO	-	-	-	-	
		Total	**1,630**	**40**	**4,474**	**1,029**	
3	2017	ANCA	2,697	1207	645	669	
		DFO	6,000	2,050	0	0	
		Total	**8697**	**3257**	**645**	**669**	
4	2018	ANCA	3,388	5,166	4,352	764	
		DFO	5,604	2,030	2,505	0	
		Total	**8992**	**7196**	**6857**	**764**	
5	2019	ANCA	3,331	3,973	3,687	764	
		DFO	150	0	0	0	
		Total	**3481**	**3,973**	**3,687**	**764**	
6	2020	ANCA	1,128	3,250	4,040	327	
		DFO	650	0	1,440	0	
		Total	**1778**	**3250**	**5480**	**327**	
7	2021	ANCA	1,400	1,044	1,540	305	
		DFO	750	0	2,300	751	
		Total	**2150**	**1044**	**3840**	**1056**	

Table 2 shows the production of Medicinal Herbs in the Divisional Forest Office (DFO) Darchula district of Nepal from 2015 to 2021. The production data was available from 2017 to 2021. The record was unavailable from 2015 to 2016 in DFO, Darchula. The highest production was 6000kg of *Paris polyphylla* in DFO in 2017. This was the lowest record production of 150kg of Paris *polyphylla* in DFO in 2019. Similarly, the highest production was 2050kg of *Fritillatia cirrhosu* in DFO in 2017. This is the lowest record production was 2030kg of *Fritillatia cirrhosu* in DFO in 2018. Again the highest production was 2505kg *Agarcus bisporus* in DFO in 2018. This was the lowest record production was 0kg of *Agarcus bisporus* in DFO in 2017. Similarly, the highest production was 7.51kg *Ophiocardyceps scinensis* in DFO in 2021. This was the lowest record production was 0kg of *Ophiocardyceps scinensis* in DFO in 2018. Similarly, table 2 the production of medicinal herbs in Api-Nampa Conservation Area, Darchula district of Nepal from 2015 to 2021.

In the Api-Nampa Conservation Area in 2015, the highest production of O*phiocordyceps scinensis* (Yarsagumba) was 833.13kg. The production of 305kg of O*phiocordyceps scinensis* (Yarsagumba) in the Api-Nampa Conservation Area in 2021 was the lowest ever recorded. Similarly, in the Api-Nampa Conservation Area in 2015, the highest production of *Paris polyphylla* (Satuwa*)* was 49200kg. The production of 1,128 kg of *Paris polyphylla* (Satuwa) in 2020 was the lowest ever recorded. Again in Api-Nampa Conservation Area in 2018, the highest production of *Fritillatia cirrhosu* (Bunlason) was 4,474kg. The production of 0kg of *Fritillatia cirrhosu* (Bunlason) in the Api-Nampa Conservation Area in 2019 was the lowest ever recorded. Similarly, in Api-Nampa Conservation Area in 2018, the highest production was

5,166 kg of *Agarcus bisporus* (Sadharan Chayu). The Api-Nampa Conservation Area's 40 kg of *Agarcus bisporus* (Sadharan Chayu) in 2017 was the lowest production ever recorded

Trend of Revenues of *Ophiocardyceps scinensis, Agarcus bisporus, Fritillaria cirrhosu* and *Paris polyphylla* in district forest office and Api-Nampa Conservation Area, Darchul

Table 3. Trend of Revenues of *Ophiocardyceps scinensis*, *Agarcus bisporus*, *Fritillaria cirrhosu*, and *Paris polyphylla* in district forest office (DFO) and Api-Nampa Conservation Area (ANCA), Darchula from 2015 to 2021.

S.N	Years		*Ophiocardyceps scinensis* (US$)	*Agaricus Bisporus* US$)	*Fritillaria cirrhosu* (US$)	*Paris polyphylla* (US$)	Remarks
1	2015	ANCA	196707.37	352.11	303.17	15490.79	
		DFO	-	-	-	-	
2	2016	ANCA	242953.54	352.11	9.44	513.14	
		DFO	-	-	-	-	
3	2017	ANCA	15795.52	50.76	284.98	8491.14	
		DFO	0	0	484.02	1416.64	
4	2018	ANCA	180385.33	3396.16	1219.73	1853,59	
		DFO	0	591.45	479.30	1323.14	
5	2019	ANCA	180385.33	290.17	938.05	1048.63	
		DFO	0	O	0	4.72	
6	2020	ANCA	77206.81	3179.57	7673.46	355.10	
		DFO	0	113.33	0	355.10	
7	2021	ANCA	7206.81	121.20	2464.95	440,73	
		DFO	1773.16	181.01	0	236.11	

The highest revenue was US$ 242953.54 for O*phiocordyceps scinensis* (Yarsagumba) in the Api-Nampa Conservation Area in 2016. This was the lowest US$ 7206.81 of *Ophiocordyceps scinensis (Yarsagumba)* in 2021. Similarly, the highest revenue was US$ 1549.79 for *Paris polyphylla* (Satuwa) in 2015. This was the lowest US$ 355.10 of Paris *polyphylla* (Satuwa) in 2020. Again the highest revenue was US$ 2464.95 for *Fritillatia cirrhosu* (Bunlason) in 2021. This was the lowest US$9.44 of *Fritillatia cirrhosu* (Bunlason) in 2016. Similarly, the highest revenue was US$ 3396.16 for Agarcus *bisporus* (Sadharan Chayu) in 2018. This was the lowest US$ 50.76 of *Agarcus bisporus* (Sadharan Chayu) in 2017. Similarly, table 3 shows the trends of revenues of medicinal herbs in the Divisional Forest Office (DFO) Darchula District of Nepal from 2015 to 2021. The revenue data was available from 2017 to 2021. The record was unavailable from 2015 to 2016 in the district forest office, Darchula.

The highest revenue was US$1416.64 for *Paris polyphylla* (Satuwa) in the district forest office in 2018. This was the lowest US$ 4.72 of Paris *polyphylla* (Satuwa) in 2019. Similarly, the highest revenue was US$ 484.02 for *Fritillatia cirrhosu* (Bunlason) in 2017. This was the lowest US$ 479.30 of *Fritillatia cirrhosu* (Bunlason) in 2018. Again the highest revenue was US$ 591.45 for Agarcus *bisporus* (Sadharan chayu) in 2018. This was the lowest US$ 0.0 of *Agarcus bisporus* (Sadharan chayu) in 2021. Similarly, the highest revenue was US$ 1773.16 for *Ophiocardyceps scinensis* (Yarsagumba*)* in 2021. This was the lowest US$ 0.0 of *Ophiocardyceps scinensis* (Yarsagumba*)* in 2018 recorded in the district forest office.

Seasonal calendar of *Ophiocardyceps scinensis, Agarcus bisporus, Fritillatia cirrhosu, and Paris polyphylla* in Api-Nampa Conservation Area and district forest office

Table 4. Seasonal calendar of *Ophiocardyceps scinensis*, *Agarcus bisporus*, *Fritillaria cirrhosu*, and *paris polyphylla* of the germination, growing, harvesting, and decay in Api-Nampa Conservation Area and district forest office.

Months	January	February	March	April	May	June	July	August	September	October	November	Dec
Ophiocardyceps scinensis* (Yarsagumba*)												
Germination												
Growing												
Harvesting												
Decay												
***Agarcus bisporus* (Sadharan chayu)**												
Germination												
Growing												
Harvesting												
Decay												
***Fritillatia cirrhosu* (Bunlason)**												
Germination												
Growing												
Harvesting												
Decay												
Paris polyphylla (Satuwa)												
Germination												
Growing												
Harvesting												
Decay												

O*phiocordyceps scinensis* (Yarsagumba) starts to germinate from early May till the end of June. It is growing from till mid-July. The harvesting starts from early June to mid-July. The decay starts in mid-August.

***Agaricus bisporus* (Sadharan chayu)** starts to germinate from after mid-June to early August. It is growing from mid-July to the first week of September. The harvesting starts from mid-August to the end of September. The decay starts from mid-June in the next year.

***Fritillaria cirrhosu* (Bunlason)** starts to germinate from after early May to the end of May. It is growing from after early May to end of May. The harvesting starts from the end of June to mid-August. The decay starts after mid-August.

***Paris polyphylla* (Satuwa)** starts to germinate from early April to the end of May. It is growing from mid-May to the end of June. The harvesting starts from early July to mid-August. The decay starts from after mid-August to mid-September.

Impact of climate change on *Ophiocardyceps scinensis, Agarcus bisporus, Fritillatia cirrhosu,* and *Paris polyphylla* Production in district forest office and Api-Nampa Conservation Area, Darchula

Production data of medicinal herbs for the last 7 years (2015-2021) were collected from the district forest office and Api-Nampa Conservation Area Darchula which is shown in the following tables. Show correlation with temperature and rainfall in those years. The data on the production of medicinal herbs are analyzed using trend Analysis.

Impact of Climate Change on *Ophiocardyceps scinensis* (Yarsagumba) in Api-Nampa Conservation Area and District Forest Office

Table 5 shows the impact of climate change on *Ophiocardyceps scinensis* in Api-Nampa Conservation Area and Division Forest Office Darchula District of Nepal from 2015 to 2021.

There was an inverse correlation between the production of *Ophiocardyceps scinensis* and total monsoon rainfall. As the monsoon rainfall increased the production of this species was decreased. It was the highest production of 1029 kg in 2016 while the monsoon rainfall was (low) 1865.3mm in Api-Nampa Conservation Area. On the other hand, the low production was recorded 305 kg in 2021 whereas the monsoon rainfall (higher) was 2013.3mm in the Api-Nampa Conservation Area. Similarly, it was the highest production of 7.51kg in 2021 while the monsoon rainfall was (low) 2013.3mm in the district forest office. On the other hand, low production was recorded o kg in 2018 whereas the monsoon rainfall (higher) was 2026.7mm.

Again, similarly, there was an inverse correlation between the production of *Ophiocardyceps scinensis* and annual maximum temperature. As the annual maximum temperature increased the production of this species was decreased. It was the highest production 1029kg in 2016 while the annual maximum temperature was (low) 27.0(°C) in Api-Nampa Conservation Area. On the other hand, the low production was recorded at 305kg in 2021 whereas the annual maximum temperature (higher) was 28.8(°C), in the Api-Nampa Conservation Area.

Impact of climate change on *Agaricus bisporus* (Sadharan chayu) in ANCA and DFO

Table 5 shows the impact of climate change on *Agaricus bisporus* in Api-Nampa Conservation Area and Division Forest Office Darchula District of Nepal from 2015 to 2021.

There was a direct correlation between the production of *Agaricus bisporus* and total monsoon rainfall. As the monsoon rainfall increased the production of this species increased. It was the highest production of 4474 kg in 2016 while the monsoon rainfall was (higher) 2315.5mm in Api-Nampa Conservation Area. On the other hand, the low production was recorded at 645 kg in 2017 whereas the monsoon rainfall (low) was 1916mm in ANCA. Similarly, it was the highest production of 2505kg in 2018 while the monsoon rainfall was (higher) 2336.7mm in the division forest office. On the other hand, the low production was recorded at 0 kg in 2017 whereas the monsoon rainfall (low) was 1916.0mm. Again there was an inverse correlation between the production of *Agaricus bisporus* and annual maximum temperature. As the annual maximum temperature increased the production of this species was decreased. It was the highest production 4474kg in 2016 while the annual maximum temperature was (low) 27.0(°C) in Api-Nampa Conservation Area. On the other hand, the low production was recorded at 645kg in 2017 whereas the annual maximum temperature (higher) was 27.4(°C), in the Api-Nampa Conservation Area. Similarly, it was the highest production of 2505kg in 2018 while the annual maximum temperature was (low) 27.2(°C) in the division forest office. On the other hand, low production was recorded o kg in 2017 whereas the annual maximum temperature (higher) was 27.4(°C) in the division forest office.

Table 5. Impact of climate change on *Ophiocardyceps scinensis* and *Agaricus bisporus* in Api-Nampa Conservation Area (ANCA) and division forest office (DFO)

Ophiocardyceps scinensis									*Agaricus bisporus*					
S.N			Highest Yield		Medium Yield		Low Yield		High Yield		Medium Yield		Low Yield	
			Q(kg)	Year	Q(kg)	Year	Q(kg)	Year	Q(kg)	Year	Q(kg)	Year	Q(kg)	Year
1		ANCA	1029	2016	619	2017	305	2021	4474	2016	1540	2021	645	2017
		DFO	7.51	2021	0	2017	0	2018	2505	2018	1440	2020	0	2017
2	Temperature(°C)	Maximum T(°C)	27	2016	26.9	2017	28.8	2021	27	2016	28.4	2021	27.4	2017
			28.8	2021	26.9	2017	27.3	2018	27.3	2018	27.9	2020	27.4	2017
		Average T(°C)	21.2	2016	20.8	2017	15.3	2021	21.2	2016	21.9	2021	20.8	2017
			21.9	2021	20.8	2017	20.2	2018	20.2	2018	21.4	2020	20.8	2017
		Minimum T(°C)	14.9	2016	14.4	2017	21.9	2021	14.5	2016	15.3	2021	14.8	2017
			15.3	2021	14.8	2017	14.2	2018	14.2	2018	14.8	2020	14.8	2017
3	Rainfall (mm)	Monsoon (mm)	1865.3	2016	1560.1	2017	2013.3	2021	2315.5	2016	2777.43	2021	1916	2017
			2013.3	2021	1560.1	2017	2026.7	2018	2336.7	2018	1903.2	2020	1916	2017
		Pre-monsoon (mm)	338.5	2016	280	2017	277.1	2021	338.5	2016	277.1	2021	280.2	2017
			239.9	2021	280.2	2017	208	2018	268	2018	231.9	2020	277.2	2017
		Post-monsoon (mm)	58	2016	19	2017	414.3	2021	58	2016	414.3	2021	19	2017
			6.5	2021	19	2017	6	2018	6	2018	6.5	2020	414.3	2017

Impact of climate change on *Paris polyphylla* (Satuwa) in ANCA and DFO

Table 6 shows the impact of climate change on *Paris polyphylla* (Satuwa) in the Api-Nampa Conservation Area (ANCA) and Division Forest Office (DFO) Darchula District of Nepal from 2015 to 2021. There was a direct correlation between the production of *Paris polyphylla* (Satuwa) and annual maximum temperature. As the annual maximum temperature increased the production of this species was increased. It was the highest production 4920kg in 2015 while the annual maximum temperature was (higher) 27.9(°C) in ANCA. On the other hand, the low production was recorded at 1128kg in 2020 whereas the annual maximum temperature (low) was 26.0(°C), in ANCA. Similarly, it was the highest production of 6000 kg in 2017 while the annual maximum temperature was (higher) 27.4(°C) in the division forest office. On the other hand, the low production was recorded at 150 kg in 2019 whereas the annual maximum temperature (low) was 24.9(°C) in the division forest office.

Impact of climate change on *Fritillaria cirrhosu* (Bunlason) in ANCA and DFO

Table 6 shows the impact of climate change on *Fritillaria cirrhosu* in the Api-Nampa Conservation Area (ANCA) and Division Forest Office (DFO) Darchula District of Nepal from 2015 to 2021. There was a direct correlation between the production of *Fritillaria cirrhosu and* annual maximum temperature. As the annual maximum temperature increased the production of this species was increased. It had the highest production 5166kg in 2018 while the annual maximum temperature was (higher) at 27.3(°C) in Api-Nampa Conservation Area. On the other hand, the low production was recorded at 40 kg in 2016 whereas the annual maximum temperature (low) was 27.0(°C), in the Api-Nampa Conservation Area. Similarly, it was the highest production of 2050 kg in 2017 while the annual maximum temperature was (higher) 27.4(°C) in the division forest office. On the other hand, the low production was recorded at 0 kg in 2019 whereas the annual maximum temperature (low) was 24.9(°C) in the division forest office.

There was a direct correlation between the production of *Fritillaria cirrhosu* and total monsoon rainfall. As the monsoon rainfall increased the production of this species increased. It was the highest production of 5166 kg in 2018 while the monsoon rainfall was (higher) 2026.7mm in the Api-Nampa Conservation Area. On the other hand, the low production was recorded at 40 kg in 2016 whereas the monsoon rainfall (low) was 1865.3mm in ANCA. Similarly, it was the highest production of 2050kg in 2017 while the monsoon rainfall was (higher) 1560.1mm in the division forest office. On the other hand, the low production was recorded o kg in 2019 whereas the monsoon rainfall (low) was 1422.1mm.

Table 6. Impact of climate change on *Paris polyphylla* and *Fritillaria cirrhosu* in Api-Nampa Conservation Area (ANCA) and Division Forest Office (DFO)

Paris polyphylla									*Fritillaria cirrhosu*					
S.N			High Yield		Medium Yield		Low Yield		High Yield		Medium Yield		Low Yield	
			Q(kg)	Year	Q(kg)	Year	Q(kg)	Year	Q(kg)	Year	Q(kg)	Year	Q(kg)	Year
1		ANCA	4920.7	2015	2697	2017	1128	2020	5166	2018	3250	2020	40	2016
		DFO	6000	2017	750	2021	150	2019	2050	2017	2030	2018	0	2019
2	Temperature (°C)	Maximum T(°C)	27.9	2015	26.9	2017	26	2020	27.3	2018	27.9	2020	27	2016
			27.4	2017	28.4	2021	24.9	2019	27.4	2017	26.3	2018	24.9	2019
		Average T(°C)	20.4	2015	20.8	2017	21.4	2020	20.2	2018	21.4	2020	21.1	2016
			20.8	2017	21.9	2021	20.3	2019	20.8	2017	20.2	2018	20.3	2019
		Minimum T(°C)	13.8	2015	14.8	2017	14.8	2020	14.2	2018	14.8	2020	14.9	2016
			14.8	2017	15.3	2021	14.4	2019	14.8	2017	14.2	2018	14.4	2019
3	Rainfall(mm)	Monsoon (mm)	1191.6	2015	1560.1	2017	1519.3	2020	2026.7	2018	1519.3	2020	1865.3	2016
			1560.1	2017	2043.5	2021	1422.1	2019	1560.1	2017	2026.7	2018	1422.1	2019
		Pre-monsoon (mm)	373.33	2015	280.2	2017	231.9	2020	268	2018	231.9	2020	338.55	2016
			280.2	2017	277.1	2021	209.8	2019	280.2	2017	268	2018	209.8	2019
		Post-monsoon (mm)	3.75	2015	19	2017	6.5	2020	6	2018	6.5	2020	58	2016
			19	2017	101.1	2021	81	2019	19	2017	6	2018	81	2019

People's perception of climate change and its impact on medicinal herbs

Knowledge about climate change

Knowledge of people towards climate change is shown in Figure 15%. During the household survey. Out of the total respondents, 45% of the respondents knew about climate change and the remaining 55% of respondents did not know about climate change.

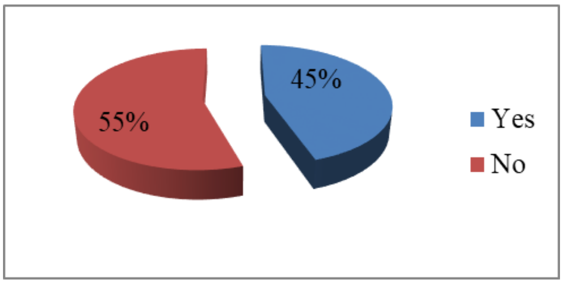

Figure 10. Knowledge about climate change

Rainfall

Precipitation of people towards rainfall precipitation is shown in Figure 11. From the field survey, 51% and 15.5% of the respondents said that both rainfall amount and time. Had a variation and is increasing. 35.5% and 75% of the respondents said that both rainfall amount and rainfall time are decreasing respectively. 5% and 3.5% of respondents said that there is no change in rainfall amount and time. Most of the respondents mentioned that there has been variation in rainfall as compared to the past. Previously the duration of rainfall used to be long but now the duration is less. Only 8.5% and 6% of the respondents had no idea about rainfall amount and time. Most of the respondents mentioned that there has been variation in rainfall as compared to the past. Previously the duration of rainfall used to be long but now the duration is less. The short duration and irregular timing of rainfall have hampered the medicinal herbs growth a lot.

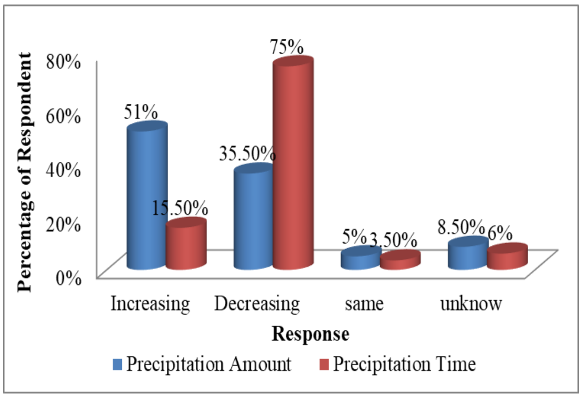

Figure 11. Responses on `Rainfall change

Temperature

Perception of people towards temperature patterns is shown in the figure from the field survey, 75% and 85% of the respondents said that summer temperature and winter temperatures are increasing. 15.5% and 9% of the respondents said that their summer and winter temperatures respectively. 7% and 5.5% of respondents said that there is no change in temperature. Only 3% and 2% of the respondents had no idea about temperature. Most respondents had no idea about temperature. Most respondents mentioned that there has been temperature variation compared to the past. It is very hot during summer and less cold during winter than before. Medicinal herbs are shifting their habitat to higher altitudes.

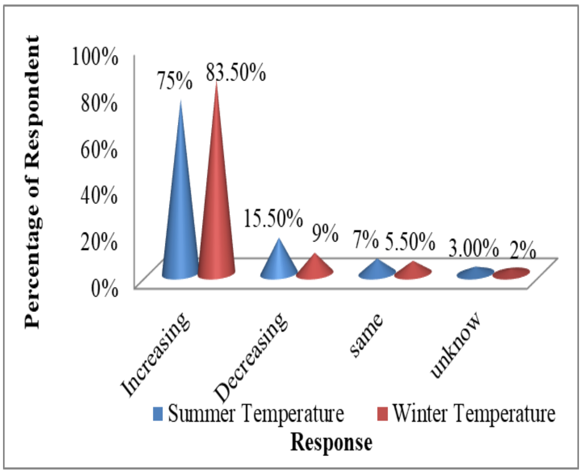

Figure 11. Responses on Temperature change

Discussion

Darchula is a cold arid climate region. Medicinal herb production is one of the major sources practiced by the people for their livelihood. As per the overall analysis of the temperature and rainfall trend of Darchula. The trend of maximum, average, and minimum temperature and rainfall in my study area has in increasing trend from the last 31 years since (1991-2021).

The average annual temperature of the study area has increased by 0.06 (°C) from 1977 to 1994 (Shreshtha et. al., 1999) which supports the finding of Nepal (DHM, 2016), which mentioned that the maximum temperature decreased by 0.132 °C from 1985 to 2015. Similarly, the annual minimum temperature of the study area increased by 0.009°C (DHM et. al, 2016). My finding and previous study shows significant outcomes. Several other studies reported that the annual maximum and minimum temperature of Nepal has increased by 0.044°C and 0.042°C (Devkota, 2014) His findings are that Darchula whose annual maximum temperature is in decreasing trend by 0.0193°C and annual minimum temperature is increasing trend by 0.038°C. Similarly, my study shows an increasing trend in average temperature also which is increased by 0.0096 °C signification to an average annual temperature of Nepal which has risen by 0.043°C (Devkota, 2014). Similarly, the total annual rainfall of the study area Lumthi station is on a decreasing trend. Annual rainfall of the study area, Lumthi station of Darchula is in decreasing trend by 10.88mm. This is not similar to the several other annual rainfall trends of Nepal which have increased by 0.004mm/yrs (Devkota et al., 2014). This shows a negative correlation. According to the people's perception towards rainfall pattern, the majority of people said that rainfall pattern is in decreasing trend as compared to before few years. Annual rainfall of Nepal also shows a decreasing trend (DHM., 2017)from 1971 to 2014 which is signification.

According to the data taken from Api-Nampa Conservation Area and the division forest office, the production of medicinal herbs is on a decreasing trend as shown in Table 2, temperature and rainfall are the most important climate factors for positive as well as negative impacts on production of medicinal herbs. The majority of medicinal herbs need cold weather for germination and growing. With the increasing trend of temperature, the production of medicinal herbs has decreased. Similarly, the duration of rainfall used to be long in the past but now the duration is less. The short duration and irregular timing of rainfall have also hampered the medicinal herbs production a lot. According to the people's perception of the impact of climate change on medicinal herbs, it was found that 60 % of the respondents of Api Himal rural municipality Darchula said that there is a change in medicinal herbs production while 30% of respondents said that there is no change had production of medicinal herbs. Only 10% of the respondents said that there is no knowledge about in impacts of climate change on the production of medicinal herbs. It means a majority of people say climate change had impacts on medicinal herbs. while reviewing the previous study it was found that due to the temperature rise some cold-adapted alpine species of medicinal herbs are migrating upward until there are no higher areas. To inhabit at which point they may be faced with extinction (Fang Z, 2009).

Similarly, in Medicinal herbs, there was an inverse correlation between the production of *Ophiocardyceps scinensis* and total monsoon rainfall. In Table 5, it was the highest production of 1029 kg in 2016 while the monsoon rainfall was (low) 1865.3mm in Api-Nampa Conservation Area. On the other hand, the low production was recorded at 305 kg in 2021 whereas the monsoon rainfall (higher) of 2043.3mm in the Api-Nampa Conservation Area. Similarly, there was an inverse correlation between the production of *Ophiocardyceps scinensis* and the annual maximum temperature, in Table 5.

There was a direct correlation between the production of *Agaricus bisporus* and total monsoon rainfall. In Table 6, it was the highest production of 4474 kg in 2016 while the monsoon rainfall was (higher) 2315.5mm in Api-Nampa Conservation Area. On the other hand, the low production was recorded at 645 kg in 2017 whereas the monsoon rainfall (low) was 1916mm in the Api-Nampa Conservation Area. Similarly, there was an inverse correlation between the production of *Agaricus bisporus* and the annual maximum temperature, in Table 6. There was a direct correlation between the production of *Paris polyphylla* and annual maximum temperature. In Table 7, it was the highest production 4920kg in 2015 while the annual maximum temperature was (higher) 27.9(°C) in the Api-Nampa Conservation Area. On the other hand, the low production was recorded at 1128kg in 2020 whereas the annual maximum temperature (low) was 26.0(°C), in the Api-Nampa Conservation Area. There was a direct correlation between the production of *Fritillaria cirrhosu* and annual maximum temperature. In the above table 8, it was the highest production 5166kg in 2018 while the annual maximum temperature was (higher) 27.3(°C) in the Api-Nampa Conservation Area. On the other hand, the low production was recorded at 40 kg in 2016 whereas the annual maximum temperature (low) was 27.0(°C), in the Api-Nampa Conservation Area. Similarly, there was a direct correlation between the production of *Fritillaria cirrhosu* and total monsoon rainfall. In Table 8, it had the highest production of 5166 kg in 2018 while the monsoon rainfall was (higher) 2026.7mm in ANCA. On the other hand, the low production was recorded at 40 kg in 2016 whereas the monsoon rainfall (low) was 1865.3mm in the Api-Nampa Conservation Area.

Thus, the overall analysis result clarified that climate change has a positive as well as negative impact on medicinal herbs.

Conclusion

This research utilized trend analysis of temperature and rainfall to observe the changing conditions in the rural municipality of Darchula in Api Himal. 31 years of temperature and rainfall data were collected from 1991 to 2021 for the trend analysis. Both temperature and the pattern of rainfall have changed noticeably. Maximum, minimum, and average temperatures all have increased from 1991 to 2021, according to trend analysis, by -0.0193°C, 0.0096°C, and 0.038°C, respectively. Similarly, the annual rainfall trend was analyzed which shows that the rainfall pattern is highly decreasing trend decreases by 10.88mm from Lumthi nearest station of Api Himal rural municipality which is lower than the annual rainfall of Nepal. Annual production of medicinal herbs shows both positive and negative trends when correlating with rainfall and temperature trends. From the field survey and people's perception, it was rectified that only a few people know about climate change. The majority of people were unaware of it. People also noticed several negative and positive effects of climate change, on medicinal herbs. Untimely rainfall, and increased/decreased temperature during unwanted times hurt medicinal herbs production. The variation in climate pattern must be the reason for the reason for shifting of medicinal herbs with altitude. This supports the people's perception as well during the entire period of research it was found that very little research documentation and importance is given to the impact of climate change on medicinal herbs production.

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