Groping climate vulnerability in western mountainous Nepal: applying climate vulnerability index

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GROPING CLIMATE VULNERABILITY IN WESTERN MOUNTAINOUS NEPAL: APPLYING CLIMATE VULNERABILITY INDEX

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Abstract

This study examines the relationship between the magnitude of climate vulnerability, location and altitude of the catchment areas of Sot Khola sub water basin in western mountainous Surkhet, Nepal by building climate vulnerability index by cluster based on the primary data sources. Household survey covering adaptive, sensitive and exposure was conducted in 642 households of the catchment areas for the primary data set. The study has built climate vulnerability index (CVI) of Sot Khola sub water basin's catchment areas, which provides sufficient evidence of heterogeneity in vulnerability of household across location and altitude of the catchment areas. In all clusters, all households are vulnerable at different level. About 69 percent household in all clusters is vulnerable in which 31 percent households are highly vulnerable. Lower cluster of the catchment areas (Lekhagaon and Kunathari) are more vulnerable than upper cluster of the catchment areas(Gadhi), except the lower cluster of Gadhi. Therefore, the altitude and magnitude of climate change vulnerability have negative correlation in case of water-induced disasters. In case of climate change vulnerability, household's socio economic and magnitude of climate change vulnerability have also negative correlation.

Key Words: *climate change, vulnerability, water basin, water-induced disasters, flood* etc**.**

1. INTRODUCTION

This study estimates the relationship between the magnitude of climate vulnerability, location and altitude of the catchment areas of water basin. This is not first one focusing on their relationship. There are different literatures responding on their relationship. However, there are still relevant issues in the context of increasing climate change and climate vulnerability in the world (Bista, 2018, Bista, Dahal & Gyawali, 2018 & Bista 2019) have focused on climate vulnerability in the catchment areas of water basin but heterogeneity of locations and of income groups have not clearly observed. Holistically, these two factors are entertained improperly. We believe that climate factor causes vulnerability but its magnitude depends on locations of the catchment areas and also income level of household because the magnitude of climate vulnerability is not same. Therefore, we should believe there is some extent of correlation between climate variability, location and income level of the community to increase the magnitude of climate vulnerability at household level.

Climate vulnerability is universally accepted threat in the world. It is due to extremely and gradually changes of climatic variables such as increasing temperature, declining rainfall, severe drought, forest fire and diseases (UNFCCC, 2007). Theoretical Literatures have observed theoretically dimensions, elements, characteristics of climate vulnerability in which UNFCCC (2007) and Fussel and Klein (2006) mention the susceptible, inability of geo physical, biological, socio economic systems to cope with, and adverse impacts of climate change. It just mentions trade off situation between resilience and climate change's effect. If it increases at local areas, there will make higher vulnerable to the community. In another words, this is vulnerable situation of geo physical, biological and socio economic systems. Its examples are low lying of water basin, coastal areas and islands. Such vulnerabilities depend on key impacts of climate change. Watts and Bohle (1993), Blaikie et al., (1994) and Kelly and Adger (2000) highlighted social and environmental vulnerability in their work. Theoretical and empirical literatures (Smith et al., 2001; Corfee-Morlot and Höhne, 2003; Hare, 2003; Oppenheimer and Petsonk, 2003, 2005; ECF, 2004; Hitz and Smith, 2004; Leemans and Eickhout, 2004; Schellnhuber et al., 2006) have mentioned key impacts on social, economic, biological and geophysical systems, like as the literatures of IPCC(2001a) and UNFCCC(2007). Its vulnerabilities associates with climate sensitive systems including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and modes of oceanic and atmospheric circulation.

There are large literatures on Magnitude and timing of climate impacts and vulnerability distribution across regions, sectors and population such as Corfee-Morlot and Agrawala, 2004; Schneider and Mastrandrea, 2005; Yamin et al., 2005; Jamieson 1992, 1996; Rayner and Malone, 1998; Adger, 2001; Gupta et al., 2003 and Gardiner, 2006. These literatures argue the magnitude of climate change and its vulnerability determined by its scale (e.g., the area or number of people affected) and its intensity (e.g., the degree of damage caused).

Literatures are large talking about its measurements to understand the magnitude of climate impacts. There are quantitative literatures (Fisher et al., 2007; Nordhaus and Boyer, 2000; Nicholls et al. 2005 and Li et al., 2004) providing different monetary units such welfare, income or revenue loss, cost of adaptation and willingness to pay to avoid. In addition, Indicator and qualitative literatures (Barnett, 2003; Arnell, 2004; Parry et al., 2004; Van Lieshout et al., 2004; Schär and Jendritzky, 2004; Stott et al., 2004) have also explored their space to measure the magnitude of climate impacts by measuring food and water shortages, morbidity and mortality from diseases and forced migration, along with heritage and biodiversity loss. Thus, vulnerability is measured by magnitude and timing of impacts, system at risk, uncertainty of impacts and potentiality to adapt.

Indicator Method to assess Climate Vulnerability is widely employed by including heterogeneous indicators as per requirement and availability in the different locations, geographical setting and income groups. Therefore, there are available diverse indicators based Index of vulnerability. Whatever, Kelly and Adger(2000) and Eriksen and Kelly (2007) believe it as source of reference point for evaluating framework for development, as provider of information for developing adaptation and mitigation plans and as standard of measures. Indicator measurement is one of qualitative and quantitative measures to measure vulnerability to climate change for understanding its status, nature, process, distributional pattern and intensity over time, location, income and geographical setting and also the impacts of climate change, along with understanding the effectiveness of development and climate resilient policy and programs in across locations, geography and income groups.

Literatures show two approaches in vulnerability Index construction and application in climate change and environmental disciplines. They are deductive and inductive approach in the construction of Climate Vulnerability Index (CVI). In large literatures, theory driven (deductive) conceptual framework was constructed and followed to identify relevant indicators for determining their relationships through construction of Index. Similarly, in many cases, data driven approach (inductive) was used to select vulnerability indicators based on their statistical relationship with observed vulnerability outcomes (Eriksen and Kelly, 2007). The application of inductive approach was specific climate sensitive systems in which deductive approach could not be applied in the absence of well-defined vulnerability outcome. In general, for urgency of coping climate change vulnerability, the inductive approach was popular to be used.

Literatures reveal three types of indices in practice such as global, national and regional for different objectives: rank of vulnerability and areas and priority of adaptation strategy and finance and mitigation. Sullivan and Meigh (2005) developed a Climate Vulnerability Index comprised of six indicators encompassing resource, access, capacity, use, environment, and geospatial dimensions to assess CVI of water to Mongolia for analyzing large data sets. They suggest their index has applicability and comparability across various scales of analysis from small island developing nations (SIDs) to the national level. However, there is no theoretical discussion of indicator choice or the specific indicators.

Eriksen and Kelly (2007) have assessedthe vulnerability level across countries in 2007 under the United Nations Framework Convention on Climate Change (UNFCCC) by developing five quantitative national level indices of social vulnerability to climate change: vulnerability resilience indicators (VRI), Environmental Sustainability Index (ESI), Dimensions of Vulnerability (DV), Index of Human Insecurity (IHI) and Predictive Indicators of Vulnerability (PIV). The study finds that "a lack of a clear theoretical and conceptual framework for the selection of indicators has hampered the robustness, transparency and policy relevance" of these indicator studies, and they note "a serious deficiency in existing studies, the limited testing and verification of indicators and of the validity of underlying conceptual frameworks" (p. 504). As a result, the three indices that provide a ranking of countries show "relatively little agreement regarding which particular countries are the most vulnerable, with only five countries ranked among the 20 most vulnerable in two or more of the studies and only one country ranked among the 20 most vulnerable in all three. This finding […] firmly underlines the challenge in making objective judgments about which countries are more vulnerable than others as a basis for allocating of funding" (p. 502).

Kim (2010) evaluated climate vulnerability index (CVI) of 16 local governments in South Korea by identify local scale 36 sub indicators to measure performance of water management. The study seems to be inductive approach based on availability of data, although there is a lack of theoretical framework. In addition, the study has not provided strong judgments in selecting sub indicators. In the selected sub indicators, there is a missing of data. However, it has higher possibility of policy implication.

Eakin and Luers (2006) express serious concerns regarding the validity of national-scale vulnerability assessments noting that "Ranking and comparing vulnerability across countries […] is challenged by everything from the quality of the available data, to the selection and creation of indicators, to the assumptions used in weighting of variables and the mathematics of aggregation. There are also problems in the interpretation of indices"(p. 377).

Other studies found that several aggregated vulnerability indices express strong sensitivity to the selection of specific proxy variables as well as to variations in the mathematics of index construction (Moss et al. 2001, Gall 2007, Schmidtlein et al.

2008).Hahn et al., (2009) employed the LVI to understand livelihood and climatic vulnerability in small island developing states (SIDS).

Despite available international literatures on Climate Vulnerability and Climate Vulnerability Index (CVI), the literatures on Nepalese context are handfuls, which have not focused in the western mountainous Nepal, have not applied indicator method including CVI. In this context, this study estimates climate vulnerability level in the catchment community and locations of Sot Khola Sub water basin in Surkhet, Nepal, where climate variability particularly rainfall was recorded in the rainfall stations of Surkhet and its induced heavy disastrous flood disaster event were badly experienced by the catchment areas and the community in 2014. Available literatures have not covered such issue, except the correlation between climate variability and vulnerability. Still, there is a query whether heterogeneous level of disasters in the catchment areas occur or not, whether heterogeneous level of vulnerability in the catchment areas occur or not and whether the correlation between disaster and vulnerability occur or not.

The paper examines climate vulnerability in the western mountainous Nepal by building climate vulnerability index (CVI) and analyzes extremity of climate vulnerability and its distribution across altitude and geographical setting.

This paper is organized into the following sections: Section 1: Introduction, Section 2: Life threating climate vulnerability in Nepal, Section 3: Method and Data, 4: Results andSection 5: Discussions and Conclusion.

2. LIFE THRENING CLIMTE VULNERABILITY IN NEPAL

Nepal is the fourth most vulnerable country in terms of Climate risks and 30th in terms of water-induced disaster (UNFCCC, 2007), although her GHG emission share is only about 0.025 percent of total annual GHG emissions of the world(Karki, 2007).There are climate risks: increasing dry periods, intense rainfall, floods, landslides, forest fires, glacier outburst flood etc. among which about 13 cases of Glacier Outburst Flood (GLOF) have damaged substantially to the people’s lives, livestock, land, environment and infrastructure (Rana et al., 2000). Further, National Adaptation Program of Action (NAPA) (2010) is the national policy document of climate change adaptation verifies it by explaining Nepal as highly vulnerable to climate change. Further, it projects 10 million populations in climate risk. Out of such population, about 1.9 million populations are in highly vulnerable to climate change. It finds its higher intensity in mid and far western regions. For example, Surkhet, where water induced disasters, flood happened in 2014. The flood unexpectedly and severely damaged house, asset, crops, bridge, road and life all over Surkhet(Bista, 2016 & DDC, 2015). MOH (2015) estimated10 billion in Rs worth loss of physical assets, along with 37 deaths and 3867 household affected.

In Surkhet, the flood of Sot Khola sub water basin with 10 feet's wild and high-sounding water level unexpectedly happened due to the heavy and intense rainfall continuously in three days and three nights. It carried everything in its course. It had affected its catchment areas (Gadhi, Lekhagaon and Kunathari) from the upper catchment areas to the downward catchment areas. Since the settlement of the community was the top hilly areas, the flood had not swept houses, except crops, banks of the river, agricultural land, water wheel, life and infrastructure (road, clean drinking water, irrigation drainage, bridge etc.). The estimated loss of the catchment areas of Sot Khola was 1, 33, 44,000 in Rs of house and asset, which was 0.13 percent of total loss of Surkhet (Bista, 2019 & MOH, 2015). In addition, there was a loss of crop, income and life. Thus, there was about 67 percent household vulnerable from the upper catchment areas to the downward catchment areas. Therefore, the higher intensity of the flood disaster occurs in the catchment areas of Sot Khola sub water basin in the different locations and altitude.

3. METHOD AND DATA

3.1. Theoretical Framework of Climate Vulnerability Index (CVI)

Climate vulnerability index (CVI) is a quite popular method to calculate socio economic vulnerability due to climatic variation. Hahn et al. (2009) developed this approach covering three indicators of livelihood vulnerability (i.e., exposure, sensitivity and adaptive capacity) to risk from climate vulnerability. Shah et al. (2013) and Turton (2000), Knutsson (2006) applied in Climate Change Vulnerability (CVI). Its basic assumption was IPCC's definition of vulnerability as a function of exposure, sensitivity and adaptive capacity (IPCC, 2001). It is called as balanced approach because it covers 1) the level of exposure of livelihoods to climate variability 2) socio economic characteristics influencing their ability to adapt and 3) the sensitivity of household to climate change. Its mathematical form is as follows

$$CVI_c=(e_c+s_c)-a_c\ldots\ldots(1)$$

However, we followed model applied by Dressa et al.(2008) to measure climate vulnerability index(CVI). In this model, the sum of sensitivity(S) and exposure (E) provides us the impact of climate-induced disaster. When it is higher, vulnerability is higher. If adaptive capacity (AC) is higher, vulnerability (V) will be lower. It is

$$V=(E+S)/AC\ldots.(2)$$

Where, e_c=the calculated exposure of the household

a_c=the calculated adaptive capacity of the household

s_c=the calculated sensitivity score of the household

To analyze vulnerability level of household and VDCs, we employed the factors of the catchment areas: Gadhi, Lekhagaon and Kunathari for adaptive capacity of household, sensitivity of household and exposure of household as follows: 1) Adaptive capacity has the following factors: proportion of economically active population, Proportion of literate people, Proportion of people employed in off farm activity, Proportion of household having more than one member involved in off farm activity, 2) Sensitivity has the following factors: Gini coefficient of inequality in income of the communities, Proportion of household having less than 6 months food sufficiency in a year, Proportion of household having not access to clean drinking water, Proportion of household having less than 3 km distance to access health post and Proportion of household with old age people, 3) Exposure has the following factors: Per household crop loss (in kg), Per household livestock damage (in number), Proportion of land loss in the community in kata and Proportion of house damage in the community.

Above factors were calculated by using actual values and then using standardized method for calculating scores of exposure, sensitivity and adaptive capacity separately. In CVI, each component was computed after getting standardized value from actual value by using standardized value method given below. Secondly, all standardized value of adaptive capacity, like sensitivity and exposure were sum and divided by total component. It gave the score of adaptive capacity, sensitivity and exposure separately. Finally, values of these three were kept above equation for getting CVI.

3.2. Data sets

The data set for the construction of CVI were primary nature collected from Household Survey 2015 through the structured questionnaire. Its sample size was 642 household. The collected and proceeded data were computed in accordance with 3 indices and their bundle indicators (13). Based on the above indicators mentioned in the factors of CVI, three indices (adaptive index, sensitive index and exposure index) were computed to measure their respect level of household of the catchment VDCs (Gadhi, Lekhagaon and Kunathari) by cluster and household level. Here, Lekhagaon and Kunathari are in the lower altitude while Gadhi is in the upper altitude.

4. RESULTS

4.1. Adaptive Capacity Index

Adaptive capacity index provides adaptive capacity of household and areas (ward and cluster) in the sub watershed basin and catchment areas. In other words, it is a coping capacity to climate change induced natural disaster including flood and landslide. This capacity is consisted of various variables such as individual capacity, institutional capacity and resources availability. In this study, there were employed four factors: literacy rate, economically active population, proportion of people engaging in off farm activity and proportion of people more than one engaging in off farm activity. The analysis for the construction of adaptive capacity index was to measure the coping capacity of climate change induced disaster: flood and landslide.

Above method of index equation was employed to calculate adaptive capacity of the study area. In accordance with the method, four factors: literacy rate, economically active population, proportion of people engaging in off farm activity and proportion of people more than one engaging in off farm activity were calculated and then adaptive index was calculated.

Adaptive index Table1 shows adaptive capacity of VDCs based on nine clusters to calculate already mentioned four factors: literacy rate, economically active population, proportion of people engaging in off farm activity and proportion of people more than one engaging in off farm activity. In the study areas, household had heterogeneous character and status of adaptive capacity in terms of literacy and economic sources. In Table 1, about 18.4 percent household of Kunathari (4,5 and 6) had the highest adapative capacity with 0.957. It was followed by about 13.9 percent household of Lekhagaon(7,8 and 9) and about 7.3 percent of Gadhi (ward 1,2 and 3) with 0.888 and 0.634 respectively. Thus, about 35 percent household had coping capacity to climate change vulnerabilities, although there were geophysically barriers and slow development work. Table1 shows about 5.3 percent household of Lekhagaon(1, 2 and 3) had zero adaptive capacity having relativesly not much literacy level and economic resources. It was followed by about 17.8 percent housheold of Kunathari(1, 2 and 3) with 0.212 and about 13.9 percent household of Kunathari (7, 8 and 9) with 0.344. It indicated no capacity to adapat vulnerability and need of urgency short and long term support to improve their adaptive capacity as preparedness to adapt climate change vulnerability.

Table1: Ranking of Adaptive Index by Cluster

VDC	ward	cluster	Literacy rate		Proportion of economically active population		Proportion of people engaging in non-agriculture activity		Proportion of people more than one engaging in off farm activity		Composite Adaptive Capacity (a+b+C+d)/4 (x_1)	Rank
			Value	Standardized (a)	Value	Standardized (b)	Value	Standardized (c)	Value	Standardized (d)		
Gadhi	1,2,3	1	93.7	1.00	3.93	0.39	2.2	0.58	1.97	0.57	0.634	III
	4,5,6	2	92.8	0.97	3.94	0.40	1.78	0.28	1.51	0.22	0.465	V
	7,8,9	3	93.1	0.98	3.7	0.21	1.93	0.39	1.82	0.45	0.506	IV
Lekhagaon	1,2,3	4	65.7	0.00	3.44	0.00	1.39	0.00	1.23	0.00	0.000	IX

	4,5,6	5	84.4	0.67	3.9	0.37	1.94	0.39	1.52	0.22	0.412	VI
	7,8,9	6	95	1.05	4.4	0.76	2.56	0.84	2.41	0.91	0.888	II
Kunathari	1,2,3	7	78.9	0.47	3.7	0.21	1.52	0.09	1.33	0.08	0.212	VIII
	4,5,6	8	88.9	0.83	4.7	1.00	2.79	1.00	2.53	1.00	0.957	I
	7,8,9	9	71.9	0.22	3.7	0.21	2.07	0.49	1.83	0.46	0.344	VII

Source: *Field Survey, 2015*

4.2. Sensitivity Index

Sensitivity is responding level of system to climate change induced disaster. Sensitivity index measures its degree. In this study, the index relates to responding level of household living in the study areas (ward and cluster). It provides sensitivity level of household living in the study areas (ward and cluster) in the watershed areas.

It is assumed that five factors (Inequality index, proportion of household (HH) with food sufficiency for less than 6 months, proportion of household (HH) without piped water, distance to health facility and proportion of old aged people) would construct Sensitive index of the study area where climate change induced disaster (flood and landslide) occurred.

This index analyzes sensitive level of household to flood and landslide based on above mentioned factors. Average standardized value of individual five factors contribute to the average score of sensitive index and rank.

Table2 shows sensitive index calculated as composite index of above mentioned factors through the use of above mentioned methods. The results of sensitive index are presented in Table 2 below. The result is evidence of different household sensitivity level in which the cluster 2 of Gadhi(4, 5 and 6 wards) has the highest score of 0.88. It indicates the highest sensitive these wards. It needs urgency to preparedness for safety of household. Similarly, the cluster of Kunathari (7, 8 and 9 wards) has lowest score with 0.36. It indicates the lowest sensitive to vulnerability. It doesn't need urgency but start to preparedness. Table 2 shows the second highest sensitive score of cluster 8 of Kunathari (4, 5 and 6), followed by the third highest cluster 6 of Lekhagaon (7, 8 and 9) with score of 0.645 and the fourth highest cluster 4 of Lekhagaon (ward 1, 2 and 3) with 0.57. It indicates more sensitive to vulnerability. It needs urgency for preparedness. However, then the Gadhi (7, 8 and 9) has score of 0.43. It is followed by Kunathair (1, 2 and 3) with score of 0.42, Lekhagaon (4, 5 and 6) with score of

0.38, Gadhi(1, 2 and 3) with score of 0.383 and Kunathari (7, 8 and 9) with 0.368 It indicates less sensitive to vulnerability.

Table2: Ranking of Sensitivity Index by Cluster

VDC	ward	cluster	Inequality index		Proportion of HH with Food Sufficiency for less than 6 months		Proportion of HH without piped water		Distance to Health facility		Proportion of old age people		Composite value of sensitivity (a+b+c+d+e)/5(x_2)	Rank
			value	Standardized(a)	Value	Standardized(b)	Value	Standardized(c)	Value	Standardized(d)	Value	Standardized (e)		
Gadhi	1,2,3	1	0.23	0.71	0.43	0.35	0	0.00	0.39	0.38	0.25	0.46	0.38	VIII
	4,5,6	2	0.23	0.71	0.625	0.98	0.125	0.96	0.83	0.93	0.33	0.82	0.88	I
	7,8,9	3	0.23	0.71	0.58	0.84	0	0.00	0.58	0.62	0.13	0.00	0.43	V
Lekhagaon	1,2,3	4	0.18	0.00	0.63	1.00	0.13	1.00	0.47	0.48	0.23	0.40	0.57	IV
	4,5,6	5	0.18	0.00	0.53	0.68	0.03	0.25	0.58	0.62	0.23	0.39	0.38	VII
	7,8,9	6	0.18	0.00	0.61	0.94	0.11	0.89	0.85	0.95	0.25	0.46	0.64	III
Kunathari	1,2,3	7	0.25	1.00	0.34	0.06	0.043	0.33	0.34	0.32	0.23	0.40	0.42	VI
	4,5,6	8	0.25	1.00	0.46	0.45	0.016	0.13	0.89	1.00	0.38	1.00	0.71	II
	7,8,9	9	0.25	1.000	0.32	0.00	0.044	0.35	0.07	0.00	0.25	0.496	0.368	IX

Source: *Field Survey, 2015*

4.3. Exposure Index

Exposure is a potential loss of household from climate change induced disaster. Exposure Index measures its degree. In this study, the index relates to damage and loss level of household living in the study areas (ward and clusters). It provides exposure level of household living in the study areas (ward and cluster).

The construction of Exposure Index to the study includes four factors (crop loss, livestock loss, household damaged, and land loss). This calculated index analyzes exposure level of household to flood and landslide based on above mentioned factors. Average standardized value of individual four factors contribute to the average score of exposure index and rank. The Index provides exposure level of different communities living in the areas (ward and cluster) of the watershed.

Table 3 shows exposure index calculated as composite index of above mentioned factors through the use of above mentioned methods. The results of exposure index are presented in Table3 below. The result is evidence of different household exposure level in which the cluster 7 of Kunathari(1, 2 and 3 wards) has highest score of 0.61. It indicates the highest exposure of these wards. It needs urgency to preparedness for safety of household. Similarly, the cluster of Lekhagaon (4, 5, and 6 wards) has lowest score with 0.040. It indicates the lowest exposure to vulnerability. It doesn't need urgency but start to preparedness. Table 3 shows the second highest sensitive score of cluster 7 of Lekhagaon (1, 2 and 3) with score of 0.56, followed by the third highest cluster 8 of Kunathari (5, 6 and 7) with score of 0.50 and the fourth highest cluster 3 of Gadhi (7, 8 and 9) with 0.33. It indicates more exposure to vulnerability. It needs urgency for preparedness. However, then the Kunathari (7, 8 and 9) has score of 0.30. It is followed by Gadhi (1, 2 and 3) with score of 0.18, Gadhi(4, 5 and 6) with score of 0.14 and Lekhagaon(7, 8 and 9) with score of 0.081. It indicates less sensitive to vulnerability.

Table3: Ranking of Exposure Index by Cluster

VDC	ward	cluster	Crop loss		Livestock loss		Household damaged		Land loss		Composite value of Exposure (a+b+c+d)/4(x_3)	Rank
			Value	Standardized(a)	Value	Standardized(b)	Value	Standardized(c)	Value	Standardized(d)		
Gadhi	1,2,3	1	0.125	0.19	0	0.000	0.0208	0.154	0.27	0.393	0.183	VI
	4,5,6	2	0.142	0.23	0	0.000	0.0357	0.264	0.142	0.066	0.140	VII
	7,8,9	3	0.310	0.66	0	0.000	0.0344	0.255	0.275	0.406	0.331	IV

Lekhagaon	1,2,3	4	0.053	0.00	0.0526	1.000	0.135	1.000	0.21	0.240	0.560	II
	4,5,6	5	0.056	0.01	0	0.000	0.0111	0.082	0.144	0.071	0.040	IX
	7,8,9	6	0.083	0.08	0	0.000	0.0333	0.247	0.116	0.000	0.081	VIII
Kunathari	1,2,3	7	0.350	0.77	0.0526	1.000	0.0081	0.060	0.359	0.620	0.612	I
	4,5,6	8	0.440	1.00	0	0.000	0	0.000	0.508	1.000	0.500	III
	7,8,9	9	0.247	0.50	0.0224	0.000	0.0449	0.333	0.269	0.390	0.306	V

Source: *Field Survey, 2015*

4.4. Climate Vulnerability Index (CVI)

Climate Vulnerability Index (CVI) is considered as a composite index of above three indices: adaptive capacity index, exposure index and sensitive index. This score of this composite index depends on above mentioned three indices and their scores. In general, the composite index is constructed by sum of exposure and sensitivity deducted by adaptive capacity. The results of the composite index are the evidence of higher and lower vulnerability of household due to climate change induced disaster. If composite index has higher score, its vulnerability level will be higher. If it has lower score, its vulnerability will be lower.

Table4 shows climate vulnerability index (CVI) calculated as composite index of above mentioned factors through the use of above mentioned methods. The results of CVI are presented in Table 4 below. The result is evidence of different household exposure level in which the cluster 4 of Lekhagaon(1, 2 and 3 wards) has the highest score of 1.14. It indicates the highest vulnerbaility level of these wards. It needs urgency to preparedness for safety of household. Similarly, the cluster of Lekhagaon (7, 8 and 9 wards) has the lowest score with -0.016. It indicates lowest exposure to vulnerability. It doesn't need urgency but start to preparedness. Table4 shows the second highest vulnerability score of cluster 7 of Lekhagaon (1, 2 and 3) with score of 0.88 followed by the third highest cluster 2 of Gadhi (4, 5 and 6) with score of 0.56 and the fourth highest cluster 9 of Kunathair (7, 8 and 9) with 0.33. It indicates more vulnerability to vulnerability. It needs urgency for preparedness. However, then the Gadhi (7, 8 and 9) and Kunathari(4, 5 and 6) has score of 0. 26. It is followed by

Lekhagaon (4, 5 and 6) with score of 0.02 and Gadhi(1, 2 and 2) with score of -0.07. It indicates less sensitive to vulnerability.

Table4: Ranking of Climate Vulnerability Index (CVI) by cluster

VDC	Ward	cluster	Adaptive Capacity (x_1)	Sensitivity (x_2)	Exposure (x_3)	Climate Vulnerability Index(CVI) $(x_2+x_3)-x_1=CVI$	Rank
Gadhi	1,2,3	1	0.634	0.383	0.383	-0.07	VII
	4,5,6	2	0.465	0.883	0.883	0.56	III
	7,8,9	3	0.506	0.434	0.434	0.26	V
Lekhagaon	1,2,3	4	0.000	0.578	0.578	1.14	I
	4,5,6	5	0.412	0.389	0.389	0.02	VI
	7,8,9	6	0.888	0.648	0.648	-0.16	VIII
Kunathari	1,2,3	7	0.212	0.425	0.425	0.82	II
	4,5,6	8	0.957	0.716	0.716	0.26	V
	7,8,9	9	0.344	0.368	0.368	0.33	IV

Source: *Field Survey, 2015*

Table5: Vulnerability Level by Clusters

Vulnerability category	Household Situation	Vulnerability Index	% of cluster Household
Extremely higher vulnerable	Extremely higher urgency level	>1 to 0.8	23.75
Higher vulnerable	Higher Urgent level	0.8 to 0. 5	7.3
Moderate vulnerable	Urgent level but temporary external assistance to recover	0.5-0.2	38.2
Less vulnerable	Vulnerable situation but still able to cope	0.2 to 0/(-)	30.7
total			100

Source: *Field Survey, 2015*

5. DICUSSION AND CONCLUSION

Considering above results of adaptive capacity index, the result provides sufficient evidence on the status and rank of adaptive capacity of household in which the index shows heterogeneity of household adaptation capacity based on the selected its four indicators: literacy rate, economically active population, proportion of people engaging in off farm activity and proportion of people more than one engaging in off farm activity. In accordance with the result of above Table 1, all household have adaptive capacity from zero score to nearly 1 (100 percent) score. If the score of adaptive capacity household is higher, it indicates about higher coping capacity to vulnerability. It further shows the effectiveness of development policy and initiation of the government. In other words, these household are well off. If not, it indicates about poor coping capacity to vulnerability and need to external assistance. It further shows ineffectiveness of development policy and initiation of the government. In other words, these household are poor. The result provides about 37 percent household of the study area (Gadhi, Lekhagaon and Kunathari) having lower adaptive capacity and higher vulnerability level in the absence of literacy and resources. The vulnerability may contribute them poorer more than natural disaster. The intensity of this result is serious issue. Out of it, about 5.3 percent household of Lekhagaon (1, 2 and 3) has zero score. Therefore, the significant household needs urgency short and long term support of the government to improve their adaptive capacity as preparedness to adapt climate change vulnerability. In addition, as supplementary, about 35 percent housheold has the highest score. It indicates the coping capacity to vulnerability and occurance of lower vulnerability. The remaining household (28 percent) needs only short term support for temporary management.

Table 6: Degree of Vulnerability

Vulnerability	Ward	VDC	Altitude	Cluster HH (%)
Extremely higher vulnerable	1,2,3	Lekhagaon and Kunathari	Middle and Lower	23.75
Higher Vulnerable	4,5,6	Gadhi	Higher	7.3
Moderate Vulnerable	4,5,6,7,8,9	Kunathari	Lower	38.2
Lower vulnerable	1,2,3, 4,5,6,7,8,9	Gadhi Lekhgaon	Higher & moderate	30.7

Source: *Field Survey, 2015*

Above result of sensitive index of household in the study area provides the evidence of heterogeneous sensitivity level of household to climate change induced natural disaster such as flood and landslide. All household are sensitive to vulnerability above lower level. About 40.9 percent households of the study area (2, 4, 6 and 8 clusters) are highly sensitive. Out of 40.9 percent household, about 7.3 percent household is extremely higher sensitive. It indicates these household having higher vulnerability level. If these household are not responded urgently, there will be a problem of safety of household and population. Meanwhile, 59.1 percent households of the study area (1, 3, 5, 7 and 9 clusters) are moderately sensitive. They need also urgent response for improving the safety of household and population.

Above result of exposure index of household in the study area provides the evidence of heterogeneous exposure level of household due to climate change induced natural disaster: flood and landslide. All household are exposure to vulnerability above lower level. About 40.9 percent households of the study area (2, 4, 6 and 8 clusters) are highly exposure. Out of 40.9 percent household, about 7.3 percent household is extremely higher exposure (highly damaged and loss). It indicates these household having higher vulnerability level. If these household are not responded urgently, there will be a problem of recovery of household and population. Meanwhile, 59.1 percent households of the study area (1, 3, 5, 7 and 9 clusters) are moderately exposure. They need also urgent response for recovering household and population.

Above results of climate vulnerability index (CVI) in the study area provides sufficient evidence of heterogeneous vulnerability level of household across from lower catchment areas to upper catchment areas. All household are vulnerable at different level in which about 23.75 percent household located in the lower cluster,Lekhagaon and Kunathari (1, 2, 3 wards of 4 and 7 clusters) of the study area is extremely higher vulnerable. About 7.3 percent household of Gadhi (4, 5, and 6 wards of cluster 5) is only higher vulnerable. About 38.2 percent household of Kunathari (4, 5, 6, 7, 8 and 9 wards of clusters 8 and 9) is moderate level. The remaining 30.7 percent household of, the upper clusterGadhi (1, 2, and 3 wards of cluster 1) is lower vulnerable (Table 6). If we ignore lower vulnerable, about 69 percent household is vulnerable in which 31 percent household is in higher vulnerable. . Lower cluster of the catchment areas (Lekhagaon and Kunathari) are more vulnerable than upper cluster of the catchment areas(Gadhi), except the lower cluster of Gadhi. Therefore, the altitude and magnitude of climate change vulnerability have negative correlation in case of water-induced disasters. In case of climate change vulnerability, household's socio economic and magnitude of climate change vulnerability have also negative correlation. Thus, climate change induced natural disaster: flood in the study area are unexpected disaster due to changing pattern and intensity of annual rainfall, particularly changing monsoon rainfall. However, sensitivity and exposure of such disaster are greater than adaptive capacity. Thus, about massive household are vulnerable in which there is possibility of increasing poverty level and inequality in the study area. In the absence of proper responding resilient local governance and resources, the vulnerability level is still as it is. Its negative contribution may be in HDI and GDI of the study district. Based on above findings, alternative hypothesis for objective 2 is accepted.

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