RESEARCH ARTICLE

Livelihood Vulnerability Associated with Forest Fire in Pauri-Garhwal, Western Himalaya

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Abstract:

Background:

The livelihood of mountainous communities of Himalayan region closely knotted with forest related activities. However, forest degradation especially forest fire significantly affects the mountainous livelihood and hence, there is an urgent need to describe, evaluate and understand specificity of mountainous areas to forest fire.

Methods:

In this view, a study on livelihood vulnerability with forest fire of High Altitude Zone (HAZ) and Low Altitude Zone (LAZ) was assessed with Livelihood Vulnerability Index (LVI). It uses 35 indicators, reduced to six components to create an overall index. Each component is composed of set of indicators and they are function of observable variables. The framework uses primary data and employs maximum-minimum normalization to restrict the value range of indicators between 0 to 1.

Results:

The value near to 0 shows lower vulnerability. The overall vulnerability of HAZ region is higher, that might be attributed to higher dependency on forest; live in proximity of forest; unstable socioeconomic condition; less infrastructural development and higher exposure to climatic extreme events.

Conclusion:

Therefore, the adaptive capacity of HAZ should be strengthened in a cross cutting manner for reducing livelihood vulnerability to forest fire. The sectors specific developmental policies/programmes should also be rationalized through bottom up adaptation planning with special reference to forest fire vulnerability.

Keywords: Adaptive capacity, Forest fire, Himalaya, Livelihood vulnerability index, High Altitude Zone (HAZ), Low Altitude Zone (LAZ).

1. INTRODUCTION

Forest is one of the most valuable terrestrial ecosystems that play a crucial role in maintaining environmental balance. It provides numerous goods and services, and maintains life support system essential for life on earth. Forests soak up carbon dioxide from the atmosphere offsetting anthropogenic emissions. Protecting forests, therefore, has a double-cooling effect, by reducing carbon emissions and by maintaining high levels of evaporation from the canopy (Dahal *et al*, 2009). However, forests are in great anthropogenic pressure due to the ever-increasing demand for forest products (Gulati and Sharma, 2000) and dependency of about 60 million forest dependents.

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(World Bank, 2006). The higher dependency of a larger section of rural population has an inhibitory effect on the productivity of forest. It has been estimated that more than 40% poor of the country are living in these forest fringe villages (MoEF, 2006). Thus, forest is a source of livelihood and providing opportunities for poverty reduction to a larger section of rural population (Sunderlin *et al*, 2005).

The anthropogenic pressure significantly increased the rate of deforestation and forest degradation (Mitra *et al*., 2013; Gurarni *et al*., 2010; Negi, 2009; Awasthi *et al*., 2013). One such reason is forest fire which has captured the attention worldwide due to the large-scale devastation in the forests of South East Asia, Amazon and the Rocky Mountains of the USA. Worldwide, forest fire is very common and frequent but in some case, it is devastating and destroys the forest at large scale. Such fires have not only led to threats to the biological diversity of these forests, but also cause large-scale suffering in neighboring lands (Narendran, 2001; CBD, 2001), herald ways for invasive species and modify the atmospheric concentration of gases (like GHG and aerosols) (Joshi *et al*., 2013) that lead to change in environmental variables (temperature, solar radiation and relative humidity). Thus, forest fires are considered to be a potential hazard with physical, biological, ecological and environmental consequences. In contrary to this, forest fire also has some beneficial impact on forest areas such as placid surface fire turns litter into massive nutrient contained ashes that nourish the soil and influence the healthy growth of annual herbs and grasses (Negi, 2007). But in long-term, it actually harms the soil dynamics and structure as fire drastically affects the soil properties due to hastily combustion of organic matter present on or near the soil surface.

The causes of forest fires have been both natural and anthropogenic (Kodandapani, 2001). However, more than 90% of all forest fires globally are started by intentional or unintentional human activities (Levine, 1999) like burning, over-grazing, felling, resin tapping, damage to trees/mortality, litter removal, *etc*. The natural cause of forest fire is also related to climatic conditions such as temperature, wind speed and direction, level of moisture in soil and atmosphere, duration of dry spells, the friction of bamboos and rolling of stone. Besides the different natural and human-induced responsive agents of a forest fire, the co-factors like forest composition, topography, aspect, altitude, inclination and soil type (Shank & Noorie, 1950) also liable for increasing intensity and frequency of fire up to certain extent.

In India, about 40% of the forests are degraded (Aggarwal *et al*., 2009, Bahuguna *et al*., 2004), 70% forest has no natural regeneration, 55% of the forest is prone to fire (MoEF, 2006) and 6% are prone to severe fire damage. The average annual tangible losses from forest fires in India have been moderately estimated at Rs 440 crores (US$ 107 million) (IFFN, 2002). India witnessed the most severe forest fires during the summer of 1995 in the hills of Uttarakhand and Himachal Pradesh in North West Himalaya. An area of 677,700 ha was affected by fires. The quantifiable timber loss was around Rs. 17.50 crores (US$ 43 million) (Parasar *et al*., 2014). Forest fire is very common in districts of Uttarakhand and 63.9% area is highly vulnerable to forest fire (Satendra and Kausik, 2014).

The livelihood of 1.6 billion people depends on the forest for a variety of goods (food, fodder, agriculture, housing, and an array of marketable minor forest produces) and services (amelioration of microclimate, water and air purification). Approximately 300 - 400 million people (MoEF, 2006) depend on forests directly for their survival, including about 60 million people of indigenous and tribal groups, who almost rely on forests. But the livelihood concerns of these millions of poor people living in and around forest contribute to forest degradation (Davidar *et al*., 2010; Tripathy *et al*., 2008; Arjunan *et al*., 2005; Sagar and Singh, 2004; Maikhuri *et al*., 2001; Silori and Mishra, 2001). The youngest mountain range of Himalaya is a source of livelihood to millions of people and is highly vulnerable str*etc*h of the world. The vulnerability is further compounded due to its susceptibility to forest fires. The intensity and frequency of forest fire have been increased drastically due to large-scale expansion of pine forests in many areas of the Himalayas. In this region surface fire is very common but its prevailing terrain occasionally converts surface fire to crown fires. The crown fire often ascends and spreads from pine forest to adjacent oak forests which are economically valuable and ecologically important. In this region fire often exceeds 4-5 km^2 with a recurrence rate of 2-5 years whilst 11% of forest faces annual fire (Negi, 2007). It is hard to find out any pine forest stand in this region without prior fire history. A study in Garhwal hills by Semwal (1996), reported that 63% of the total fire incidents were intentionally man-made and the remaining 37% were accidental.

The forest fires cause air pollution (Miranda *et al*., 2008), degrade quality of stream water (USGS, 2012), harm the soil dynamics and structure in long-term (Verma, 2012), threaten agriculture (Ladrach, 2009), augment erosion (Sharma *et al*., 2008; Kumar, 2010), degrade forest and spoil the aesthetics of an area. In totality, forest fire enhances the vulnerability of forest dependents or people living in the proximity of forest. The present study is designed to assess the vulnerability of communities due to forest fire living in proximity of forest in the Himalayan region with the help of index-based approach. The aim of the research is to fill an academic and policy demand for assessing the vulnerability

of communities from forest fire through developing forest fire vulnerability index. The present methodological approach is intended to bridge the gap between community requirements and priorities at the micro level and policy processes at the macro level, with an emphasis on the fact that higher-level policy development and planning must be informed by lessons learned and insights gained at the local level. The proposed index based on bottom-up approach, aims to provide recommendations for setting priorities for action while helping to develop a robust, integrated model approach to increase resilience to natural as well as anthropogenic risks at local levels. The developed social vulnerability may also be adjusted with inputs of the existing biophysical vulnerability assessments to create holistic and integrated scrutiny of the potential impacts of a forest fire in the regional settings.

2. METHODOLOGY

2.1. Study Area and Sampling Strategies

The spatial focus of the study was Srinagar (600 mean sea level) and Tarkeshwer (1800 mean sea level) of Pauri Garhwal District, Uttarakhand. The district is situated in the central part of Garhwal Himalaya and western part of Himalayas and lies between 29°20′ N-30°15′N latitude and 78°10′E-79°20′E longitudes lie at an elevation of 1,650 m above sea level encompassing an area of 5,440 sq. km. (Rajwar 1993) (Fig. **1**). According to the 2011 census, Pauri Garhwal district has a population of 687,271 (Male - 326,829 and Female - 360,442). The population density is 129 inhabitants per kilometer square which is much lower than the state (*i.e.* 189) (Census of India, 2011). The district has a sub-temperate to temperate climate, with mean monthly temperature ranges from 25°C to 30°C (maximum of 45°C in June and minimum of 1.3°C in January), average annual rainfall of 218 cm (90% receives during monsoon), and 54 to 63% of relative humidity with some snow in winter at the higher reaches.
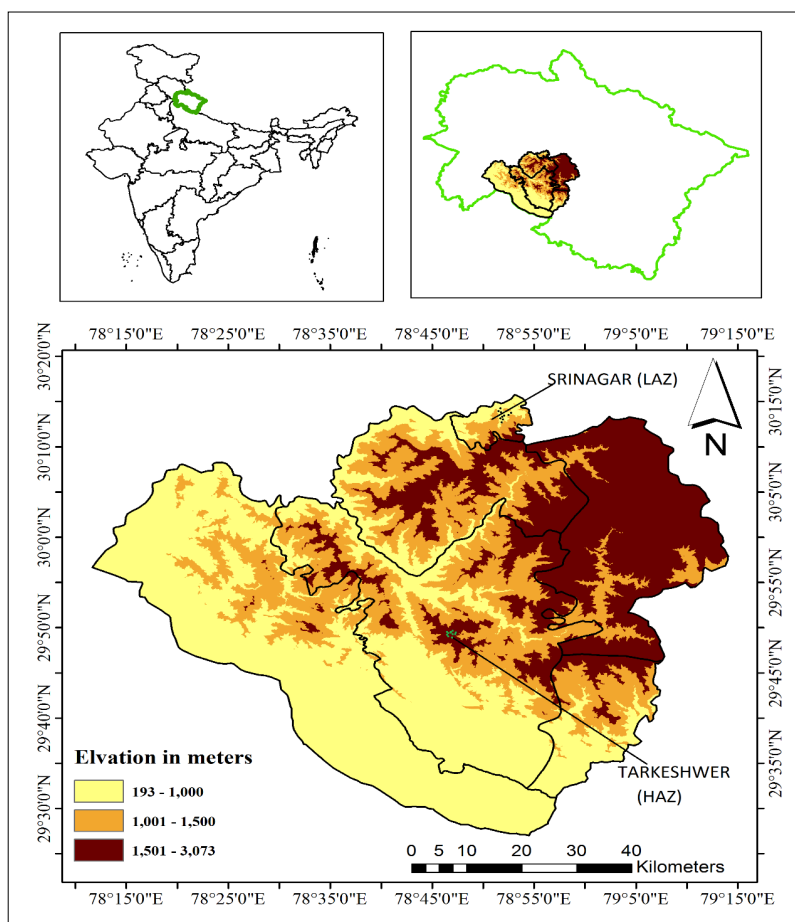

Fig. (1). Digital elevation model of Pauri district.

The districts of Uttrakhand located at hilly region are less developed in terms of infrastructure, *i.e*., electricity, roads and irrigation (Mittal *et al*., 2008). The study area is stratified on the basis of the infrastructure and developmental aspect. Being Tehsil (administrative division of the countries), the Low Altitudinal Zone (LAZ) should have more

access to the infrastructural facilities and more opportunities to earn livelihood the High Altitudinal Zone (HAZ). Villages such as Maletha, Dangchaura, Gahar, Dhari, Dungri, Kotki, Barkot, Kilkieshwar, Thapli and Supana are under LAZ (Fig. **2A**) and Gamlagoan, Agrota, Kundalkhet, Ghotla, Pastamalla, Pastatalla, Jhangoria, Jugunia, Chaura and Malara are under HAZ (Fig. **2B**). Due to the mountainous setting, households are sparsely distributed in the remote area. Therefore, a minimum of five households were selected for the interview and if the number of households was less than five, all the households were selected from each village. The total number of respondents from LAZ and HAZ is 109 and 102, respectively. The interview was conducted from January 2016 to October 2016. Each household was interviewed thrice (Pre-fire season (January- February); Fire season (March-June) and Post-fire (July-October)). Interviews were conducted in Hindi language and Garwali (local dialect) by researchers themselves with the support of one local fellow. Generally, the head of the household was interviewed, but if s/he was not available, the spouse or elder member was interviewed. The interview was conducted through a questionnaire to avoid the disadvantages of secondary data and dependency on climate models. Discussions were held with peers and locals to gain sufficient knowledge about the prevailing livelihood mechanism and climatic fluctuation of the region. Each interview lasted on average of 30 min. The survey questionnaire was framed on the basis of components of Socio-demographic profile; Livelihood strategies and infrastructural facilities; Agriculture and food; Drinking water; Natural resources and Extreme event. Data were coded, cleaned and analysis was carried out using MS Excel and SPSS.
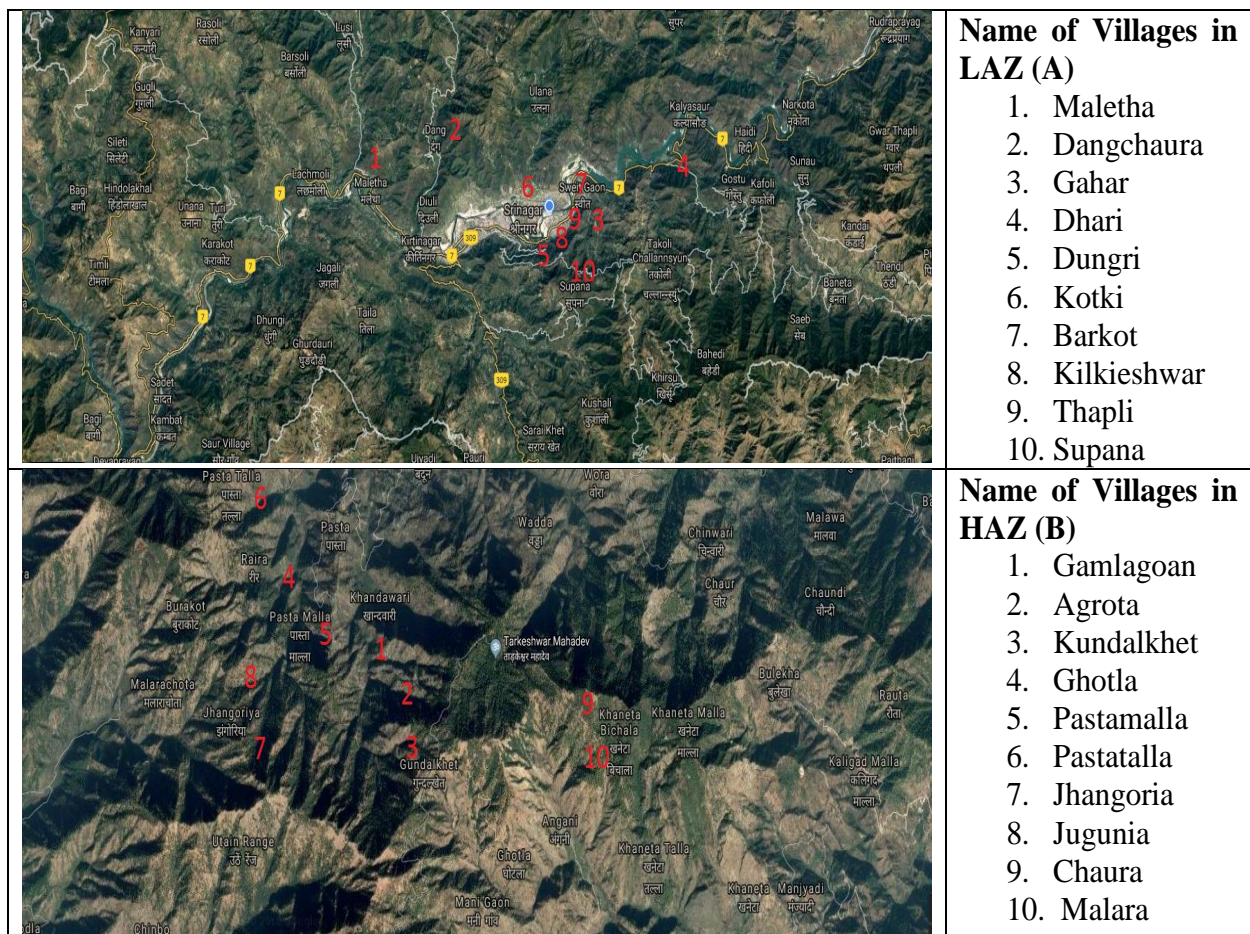

Name of Villages in LAZ (A)
1. Maletha
2. Dangchaura
3. Gahar
4. Dhari
5. Dungri
6. Kotki
7. Barkot
8. Kilkieshwar
9. Thapli
10. Supana

Name of Villages in HAZ (B)
1. Gamlagoan
2. Agrota
3. Kundalkhet
4. Ghotla
5. Pastamalla
6. Pastatalla
7. Jhangoria
8. Jugunia
9. Chaura
10. Malara

Fig. (2). Village location of LAZ (**A**) and HAZ (**B**).
Source: Google Map.

2.2. Conceptual Framework

Livelihood Vulnerability Index (LVI) is a pragmatic approach to identify the significance of contributing factors to livelihood vulnerability forest fire at the local or community level. The index comprises a range of interacting dimensions of social, economic and natural factors. The dimension of livelihood was fabricated appropriately in the scientifically designed questionnaire. The survey questionnaire consisted of six broad sections: socio-demographic

profile; agriculture and food; livelihood strategies and infrastructural development; natural resources and extreme event. The socio-demographic profile included information pertaining to lifestyle of mountainous people such as number of family member; education; house type and assets (movable - car, motorcycle, tractor, livestock, *etc*., and immovable – land, television, fridge, mobile phone, *etc*.), whereas information related to agriculture and food is gathered with the use of indicators like total land of household, agricultural assets, household's food requirement and sufficiency throughout the year. To know the strategies of household against forest fire vulnerability, information like varieties of crop; introduction of new crop; change in sowing time; receive or seek assistance through social network; nearest bus stop and hospital, were collected. The data on collection of fodder and fuelwood, time spent and distance of forest were taken to address the status of natural resources. Further, the information on intensity and frequency of forest fire, stress, injury and death were also collected to analyze the impact of extreme events.

Each component was composed of a set of site-specific indicators. The indicators were chosen based on a review of literature data and preliminary field survey. They are case specific and may be of qualitative characteristics with the potentiality to be expressed as quantitative factors through the use of proxies as elaborated by Deems (2010). The indicators are aggregated into index, that was quantified (Primary data sources) under two categories, *i.e.* LAZ and HAZ. The proposed index is an effective assessment tool for a diverse set of users and it uses a simple approach to apply equal weights to all components. The similar approach has also been followed by Sullivan (2002), Vincent (2004), Hahn *et al*., (2009) and Pandey and Jha (2011). This weighting scheme could be adjusted by future users as needed.

Table 1. Rationalization of indicators and potential linkages.

Components	Indicators	References
Socio-demographic profile	Household's dependency index	Hahn *et al*. 2009, Pandey and Jha 2011
	House type diversity index	Sinha *et al*. 2015
	Household's decision index	Pandey and Jha 2011
	Profession diversity index	Pandey and Jha 2011
	Livestock diversity index	Hahn *et al*. 2009
	Education index	Gerlitz *et al*. 2014
	Electricity index	Joerin *et al*. 2014
	Sanitation index	Madhury *et al*. 2014
Livelihood strategies and infrastructural facility	Agricultural crop variety index	Gerlitz *et al*. 2014
	New crop index	Pandey and Jha 2011
	Sowing/planting time index	Hahn *et al*. 2009, Madhury *et al*. 2014
	Assistance index	Joerin *et al*. 2014, Madhury *et al*. 2014
	Market accessibility index	Gerlitz *et al*. 2014
	Bus stop accessibility index	Gerlitz *et al*. 2014
	Health care index	Hahn *et al*. 2009, Gerlitz *et al*. 2014
Agriculture and food	Agricultural land index	Gerlitz *et al*. 2014, Sinha *et al*. 2015
	Irrigated agricultural land index	Gerlitz *et al*. 2014, Sinha *et al*. 2015
	Agricultural asset diversity index	
	Agriculture dependence index	Gerlitz *et al*. 2014, Madhury *et al*. 2014
	Food sufficiency index	Hahn *et al*. 2009, Pandey and Jha 2011
Drinking water	Natural water utilization index	Madhury *et al*. 2014
	Natural water collection index	Pandey and Jha 2011, Gerlitz *et al*. 2014
	Natural water degradation index	Hahn *et al*. 2009, Pandey and Jha 2011
	Water supply index	Pandey and Jha 2011, Joerin *et al*. 2014
Natural resource	Fodder and fuel wood collection index	Pandey and Jha 2011
	Forest-based energy index	Madhury *et al*. 2014
	Firewood collection index	Pandey and Jha 2011
	Fodder collection index	Pandey and Jha 2011
	Natural resources depletion index	Pandey and Jha 2011
	Natural resource diversification index	Pandey and Jha 2011

(Table 3) contd.....

Components	Indicators	References
Extreme event	Forest fire index	Joerin *et al*. 2014, Gerlitz *et al*. 2014
	Climate stress index	Pandey and Jha 2011, Gerlitz *et al*. 2014
	Injury or new diseases	Pandey and Jha 2011, Gerlitz *et al*. 2014
	Family death index	Pandey and Jha 2011, Gerlitz *et al*. 2014

The details of parameters, collected from households as per defined methodology are reported in Table **1**. A total of 35 indicators were selected for developing a vulnerability profile. They were in different units and scales and thus brought comparable levels through normalization on the basis of the functional relationship between the indicators and vulnerability. Two types of functional relationship were possible; vulnerability increases with increase in the value of the indicator, *i.e.* positive relationship (equation 1) and vulnerability decreases with increase in the value of indicator, *i.e.* negative relationship (equation 2). It is interpreted that higher the value of the indicator, more the vulnerability.

$$Index_{sv} = \frac{S_v - S_{min}}{S_{max} - S_{min}} \tag{1}$$

$$Index_{sv} = \frac{S_{max} - S_v}{S_{max} - S_{min}} \tag{2}$$

where:

S_v is the average value of indicator at respondent level;

S_{min} and S_{max} are the minimum and maximum values of indicator at the respondent level.

After normalization of each indicator, the components were averaged using equation 3 to calculate the value of each index.

$$M_v = \frac{\sum_{i=1}^{n} Index}{n} \tag{3}$$

where:

M_v is the one of the component;

Index is the indicator value of ith indicator;

n is the number of indicator in the index.

The indicators have been segregated into the six components. These were a socioeconomic profile (*SEP*), agriculture and food (*A*), livelihood strategies and infrastructural facility (*S*), drinking water (*W*), natural resources (*NR*) and extreme event (*EE*). Each indicator contributes equally to the overall index as also considered in other indexes such as Hahn *et al*. (2009), Pandey and Jha (2011) and Sinha *et al*. (2015). These components have been directly and indirectly; linearly and non-linearly related to the individual family's inherent quality, resources availability and accessibility. The index for overall feasibility has been calculated as in equation 4:

$$LVI = \frac{W_{e1}SEP + W_{e2}A + W_{e3}S + W_{e4}W + W_{e5}NR + W_{e6}EE}{W_{e1} + W_{e2} + W_{e3} + W_{e4} + W_{e5} + W_{e6}} \tag{4}$$

where:

We_1, We_2, We_3, We_4, We_5 and We_6 are the number of indicators for LVI.

3. RESULTS AND DISCUSSION

The assessment of various components along with respective indicators and estimated value of LVI are reported in Tables **2** to **7**. The results showed a varied response to LVI in LAZ and HAZ regions.

Table 2. Indexed indicators Socioeconomic profile.

Indicators	LAZ	HAZ
Household's dependency index	0.255	0.569
Household's decision index	0.475	0.490
House type diversity index	0.305	0.632
Profession diversity index	0.775	0.781
Livestock diversity index	0.469	0.514
Education index	0.192	0.427
Electricity index	0.174	0.419
Sanitation index	0.322	0.812

3.1. Socioeconomic Profile

Forest is deliberately linked to day to day activities of mountainous people and it significantly contributes to the socioeconomic status of households (Shrestha and Gautam, 2014). The HAZ was more vulnerable as compared to LAZ in socioeconomic profile. The higher vulnerability in LAZ region might be attributed to larger family size, higher household dependency (0.569) along with less opportunity to work in different professions (0.632) (Table **2**). However, the households of LAZ had the better educational background, more diversified livelihood opportunities and good income from different sources. The better educational background reinforces the decision-making ability of LAZ households and it strengthened the socioeconomic status of households.

In the rural Himalayan region, poverty is very high (Barua *et al.* 2013); a large proportion of households belong to BPL category and the majority of them possess small dwelling in sparsely distributed manner. In HAZ, possession of semi-concrete traditional dwelling is high, the wooden roof is generally used and is susceptible to fire. However, the possession of concrete dwellings in LAZ reduces the degree of damage during a forest fire and had lower vulnerability score as compared to HAZ (0.490) (Table **2**).

Livestock rearing is traditional and closely linked to mountainous rural culture; more than 70% of the rural population of Uttarakhand Himalaya depends upon animals for their economic needs (Tiwari and Pande, 2011). The practice is common in HAZ and LAZ of Pauri Garhwal. Most of the household of HAZ possess 1 or 2 livestock but they were of the indigenous breed. This leads to low milk production and higher pressure on the forest for fodder. While, households of LAZ possess livestock of hybrid variety, that contributes to household's income basket significantly. The possession of livestock is not directly correlated with forest fire but fodder shortage during forest fire considerably affects milk production in LAZ. Further, the shortage of fodder is a common phenomenon during a forest fire and hence alternate options such as availability of straw, cultivation of fodder, *etc*. are required. These practices are observed in LAZ (0.469) and hence are less vulnerable than HAZ (0.514) (Table **2**).

Easy access to basic facilities such as sanitation and electricity strengthens the adaptive capacity in the rural areas. Sanitation facility is particularly crucial to build up preparedness to disaster and its lacking influences incidence of infectious diseases (Tol *et al*. 2007). The accessibility to toilet facility is very low in HAZ (0.812) region, however, the majority of households in LAZ (0.322), Table **2** possesses a toilet facility. In addition, access to electricity plays a crucial role in socioeconomic status and has implications for the health, education and income of communities. The access to electric facility is lower in HAZ (0.419); subsequently, the contribution of electricity in enhancing adaptive capacity is lower.

3.2. Livelihood Strategies and Infrastructural Facilities

Mountainous fragile settings are highly vulnerable to the extreme event (Sonesson and Messerli 2002). Therefore, it is necessary to adopt some additional strategies or mechanisms to cope up with the extreme event. The households of LAZ, as well as HAZ, adopted a number of strategies to minimize the impact of extreme event such as a change in crop variety, sowing and planting time, the introduction of new crop, and seek/obtain assistance from others. These activities do not enhance or reduce the impact of forest fire directly but play a crucial role in the adaptive capacity of villagers against hazards. The households in both regions introduced new crop variety (LAZ-0.110 and HAZ-0.103) (Table **3**). after loss or effect of forest fire. The crop loss was slightly higher in LAZ (0.133) due to the shifting of traditional agricultural practice to modern. Although modern agricultural practice needs some technical support which is still lacking in LAZ. The agricultural strategies to cope the impact of forest fire are not enough for transforming the

subsistence agriculture to surplus agriculture and hence mountain specific policy or programme is required for strengthening agriculture.

Table 3. Indexed indicators of livelihood strategies and infrastructural facilities.

Indicators	LAZ	HAZ
Agricultural crop variety index	0.400	0.313
New crop index	0.110	0.103
Sowing/planting time index	0.233	0.161
Assistance index	0.500	0.443
Market accessibility index	0.121	0.315
Bus stop accessibility index	0.199	0.713
Health care index	0.299	0.672
Bank accessibility index	0.238	0.621

The villagers of both zones pursued or obtained help from the social network, *e.g.* relatives and neighbours, during extreme event specially forest fire. The households of LAZ (0.500) obtained assistance through social networks, on the other side lesser proportion of HAZ (0.443) households pursued assistance through social networks (Table **3**). The higher vulnerability score of HAZ might be attributed to a weak network and widespread poverty. The LAZ was comparatively more developed in terms of infrastructural facilities and has better connectivity to district headquarter. These results in less time spent to reach the local market (0.121), bank (0.238) and hospital (0.299) (Table **3**). The better accessibility to facility would strengthen the adaptive capacity and reduce the syn and post forest fire vulnerability.

3.3. Agriculture and Food

Agriculture is a minor land use in terms of spatial extent but has a significant influence on livelihood (Maikhuri *et al.*, 2003). It is the culture of mountainous communities characterized by harsh climates and rough terrains. Moreover, it is one of the major sources of livelihoods in the Himalayan region and majority of the respondents solely dependent on agriculture for livelihood. Except a few, all of the respondents possess agricultural land and the land-holding ranged from 0.25 to 4 hectare. The agriculture of both regions is rainfed and hence the vulnerability score for irrigated agricultural land was almost similar. The households of LAZ (0.527) (Table **4**) region have more agricultural assets but the agricultural practices especially orchards and rabi crop production are constrained by the incidence of forest fire. The forest fire also causes heating of neighbouring land that anguishes microbial growth (Dunn *et al.* 1985) and availability of nutrients/organic matter. Further, the increased soil temperature volatilizes the soil nutrients and favours the movement of smoke in soil that alters the chemical constituents of soil. Forest fire also causes burning on clay soils on slopes that tend to cause soil erosion (Mobley *et al.*, 1973) and thereby siltation of damaging constituents in agricultural land and crop as well. In LAZ, vulnerability score for dependency on agriculture for food was 0.475 while it increased to 0.839 in HAZ. The less productive mountainous agriculture do not satisfy the food demand in HAZ (01) and LAZ (0.965), results in higher vulnerability score for food sufficiency (Table **4**).

Table 4. Indexed indicators of agriculture and food.

Indicators	LAZ	HAZ
Agricultural land index	0.213	0.222
Irrigated agricultural land index	0.455	0.414
Agricultural asset diversity index	0.527	0.748
Agriculture dependence index	0.475	0.839
Food sufficiency index	0.965	01

3.4. Drinking Water

The forest fires release a lot of carbon, suspended sediment, particulate organic matter and nutrients (Ranalli 2004, Pike *et al.*, 2010) that also contaminate water. The degree of damage by using contaminated water positively correlated with dependency on it, higher the dependency more the damage. In HAZ, households were more dependent on the natural source of water as compared to LAZ and had the alternate option of drinking water such as motor pump and tanker. The better infrastructural facility lessens the time spent on water collection. The average time for water collection is 0.6 and 1.2 hours while the time increased to 0.7 and 1.4 hours during summer in LAZ (0.331) and HAZ (0.671), respectively (Table **5**). The households of both zones reported that in the last five years, the average time for

water collection has been increased and quantity of water at source is being deteriorated. A few households of HAZ also observed black shoot in the water and majority of them added that the taste of water is changed after forest fire and hence had higher vulnerability score (0.914). The deterioration in quantity of water causes water scarcity and increased the demand for water especially during summer. The water scarcity is more pronounced and frequent in HAZ (0.914) because of a higher dependency on natural sources of water. In addition, a large proportion of HAZ (0.932) households did not get a daily supply of potable water from Government. The local government supplies water, on an alternate day and it is increased to once in a week in summer. While LAZ (0.399) (Table **5**) household showed lower vulnerability score for the supply of drinking water because most of the household get water supply on daily basis. Along with this, a few of them have a personal water source as observed during the survey.

Table 5. Indexed indicators of drinking water.

Indicators	LAZ	HAZ
Natural water utilization index	0.200	0.824
Natural water collection index	0.331	0.671
Natural water degradation index	0.690	0.914
Water supply index	0.399	0.932

3.5. Natural Resources

Forests provide a wide range of goods and services that are vital for sustaining livelihood (Urothody and Larsen 2010). However, the livelihood concerns of millions of poor people living in and around forest contribute to forest degradation (Davidar *et al*. 2010, Tripathy *et al*. 2008, Arjunan *et al*. 2005, Sagar and Singh 2004, Maikhuri *et al*. 2001, Silori and Milaza 2001). Majority of households in the study area collects fodder and fuelwood from forest and collection is higher in HAZ (0.697) and is more vulnerable to LAZ (0.444) (Table **6**). The degradation or losses significantly affects the stability of forests and thus forests are unable to satisfy the needs of local people. The shortage of fuelwood is one of the common problems amongst the forest dependents and it augments forest degradation in Himalaya. The fodder and fuelwood collection is constrained by the incidence of a forest fire, especially during summer. It is difficult to collect fuelwood during monsoon due to more undestroyed vegetation and wild animals and hence, households of both the zone collects fuelwood especially during summer and store it for next season *i.e*. monsson. Hence, the vulnerability score for fodder and fuelwood collection was higher in HAZ, the region also lacks alternatives for fodder and fuelwood. In HAZ, majority of household used forest-based energy for cooking purpose and only a few uses other alternatives like LPG and kerosene stove. While the households of LAZ (0.691) were less dependent on forest-based energy and most of them possess alternative.

Table 6. Indexed indicators of natural resource.

Indicators	LAZ	HAZ
Fodder and fuelwood collection index	0.444	0.697
Forest-based energy index	0.691	0.934
Firewood collection index	0.507	0.468
Fodder collection index	0.960	01
Natural resources depletion index	0.830	01
Natural resource diversification index	0.211	0.615

The increasing demand and unsustainable harvest of natural resources degrade the forest in both zones. Therefore, average time spent on the collection of fodder and fuelwood in both the zones increased to 5 to 6 hours/day from 2 to 3 hours/day. Further, HAZ households reported depletion of natural resources at the considerably higher rate. The distance from forest to the village is increasing continuously in the last 8 to 10 years. Along with this, the majority of them added that major cause of forest degradation in the Himalayan region is a forest fire. The intensity and frequency of forest fire are increased significantly in the last 7-8 years. In a Himalayan region, more than 90% of all forest fires are started by anthropogenic intentional or unintentional anthropogenic activities (Levine *et al*. 1999) like burning, over-grazing, felling, resin tapping, litter removal. The remaining 10% is attributed by natural factors such as temperature; wind speed and direction; level of moisture in soil and atmosphere; duration of dry spells; friction of bamboos and rolling of stones. Besides, the different natural and human-induced responsive agents, the co-factors like forest composition, topography, aspect, altitude, inclination and soil type (Shank and Noorie, 1950) also liable for increasing intensity and frequency of fire. The households of HAZ live in proximity of natural resources but the natural

resource diversification was higher in LAZ (0.211) and had a lower vulnerability Table **6**. The vulnerability of HAZ was further enhanced by less awareness towards the value of natural resources.

3.6. Extreme Events

The degree of association with the sensitive environment; geographic location and unique economic, political, and cultural characteristics of areas (McCarthy *et al*. 2001, Dolan and Walker 2003) accelerates the impact of extreme event. The Himalayan ecosystem is very fragile (Sonesson and Messerli 2002) and exposed to multiple hazards (Kohler and Maselli 2009). The HAZ and LAZ are vulnerable to forest fire, however, vulnerability is slightly higher in HAZ (0.939) Table **7**. The higher vulnerability of HAZ might be attributed to higher dependency and proximity to forest. Vulnerability of the region is further aggravated by climatic variability (INCCA 2010) and higher susceptibility to forest fire (Negi, 2007). The change in rainfall and temperature relegates a lot of stress on the local people, especially on forest dependents. The vulnerability score due to climatic stress in both the zones showed almost similar response due to homogenous climatic (sub-temperate to temperate climate) and topographic setting. However, accessibility to health facilities is lower in HAZ and hence, reported higher vulnerability score. The extreme event begets injury, a new disease or even death of local people. The household of both regions reported injury or diseases but the loss is lesser in LAZ (0.765) than HAZ (0.875) Table **7**.

Table 7. Indexed indicators of extreme event.

Indicators	LAZ	HAZ
Forest fire index	0.835	0.939
Climate stress index	0.915	0.989
Injury or new diseases index	0.765	0.875
Family death index	0.050	0.122

CONCLUSION

People living in a rural area in the developing world are comparatively more vulnerable because of higher dependency on natural resources, widespread poverty, marginalization and less adaptation options. Moreover, poverty together with less diversified livelihood and illiteracy augments the vulnerability of mountainous rural communities. Therefore, the employment opportunity should be strengthened by inculcating livelihood diversification programme with the active involvement of Non-Government Organisations. Further education is the integral element for overall development and it lacks in HAZ. The quality education is significantly lacking in both the region. It should be made compulsory (at least up to intermediate) for all children. Higher literacy could also attribute to more diversification in livelihood opportunities, better decision making capability and lesser family dependency. It would strengthen the resilience of people to extreme events, especially during a forest fire.

The vulnerability of mountainous region is further augmented by higher dependency on agriculture for food. Although, mountainous agriculture is affected by a forest fire and exaggerated by a number of complexities. Therefore, promising technological intervention together with capacity building on agricultural techniques is required. Moreover, it should also be supported by governmental strategies like compensation for loss, distribution of improved seed, agricultural training or awareness, loan without interest and crop insurance. The mountainous region has always had either too much or too little water. Furthermore, proper supply of water is an essential constituent for facilitating adaptation. Therefore, watershed management at the micro level and pipeline supply of water should be encouraged.

Infrastructure in terms of communication, road network, bank, market and hospital facilitate adaptation in the rural communities. Strategies must be evolved to strengthen the basic requirements and facilities. In addition, the sustainable harvest of forest produce is being promoted. The rural poor should be compensated through payment/reward for ecosystem services for their activities that lead to mitigation. Vulnerability to extreme event in both regions especially forest fire could be reduced by strengthening fire-prevention measures in fire-prone areas. The improved scientific techniques for monitoring and detection should be incorporated. Moreover, suitable silvicultural practices and rehabilitation of burnt land with fast-growing should be considered as an integral element. Protection and rehabilitation can further be improved by the involvement of local people and dissemination of information about the impact of forest fire on livelihood is required.

CONSENT FOR PUBLICATION

Not Applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

REFERENCES

Forest fires – Origins and ecological paradoxes. *Resonance,* 6(11), 34-41.

Barua, A, Katyaini, S, Mili, B & Gooch, P (2013) Climate change and poverty: Building resilience of rural mountain communities in south sikkim, eastern himalaya, india. *Reg Environ Change,* 14(1), 267-80.
[http://dx.doi.org/10.1007/s10113-013-0471-1]

Bhatt, BP & Sachan, MS (2004) Firewood consumption pattern of different tribal communities in northeast India. *Energy Policy,* 32(1), 1-6.
[http://dx.doi.org/10.1016/S0301-4215(02)00237-9]

Certini, G (2005) Effects of fire on properties of forest soils: A review. *Oecologia,* 143(1), 1-10.
[http://dx.doi.org/10.1007/s00442-004-1788-8] [PMID: 15688212]

Davidar, P, Sahoo, S, Mammen, PC, Acharya, P, Puyravaud, JP, Arjunan, M, Garrigues, JP & Roessingh, K (2010) Assessing the extent and causes of forest degradation in india: Where do we stand? *Biol Conserv,* 43(12), 2937-44.
[http://dx.doi.org/10.1016/j.biocon.2010.04.032]

DeBano, LF (1990) The effect of forest fire on soil properties. *Symposium on management and productivity of western-montane forest soil,* Boise, ID, USA151-6.

Deems, HJ Vulnerability of rural communities in the Mediterranean region to climate change and water scarcity: The case of Cyprus. *Dissertation*Universitat Autonoma de Barcelona, Barcelona. 64

Disaster management fair 2007 *Risk reduction process – Reaching to people Available at:*.http://mfhevents.tripod.com/id10.html Assessed on 12-02-2016

Dolan, AH & Walker, IJ (2003) Understanding vulnerability of coastal communities to climate change related risks. *J Coast Res,,* S1(39), 0749-208.

Dunn, PH, Barro, SC & Poth, M (1985) Soil moisture affects survival of microorganisms in heated chaparral soil. *Soil Biol Biochem,* 17, 143-8.
[http://dx.doi.org/10.1016/0038-0717(85)90105-1]

Esteves, T, Rao, KV, Sinha, B, Roy, SS, Rao, B, Jha, SK, Singh, AB, Vishal, P, Nitasha, S, Rao, S, Murthy, IK, Sharma, R, Porsche, I, Basu, K & Ravindranath, NH (2013) Agricultural and livelihood vulnerability reduction through the MGNREGA. *Econ Polit Wkly,* 48(52), 94-103.

Gerlitz, JY, Banerjee, S, Hoermann, B, Hunzai, K, Machhi, M & Tuladhar, S (2014) *Poverty and vulnerability assessment – A survey instrument for the Hindu Kush Himalayas,* Kathmandu (Nepal), International centre for integrated mountain development, 102.

GOOGLE MAP (Tarkeshwer). https://www.google.co.in/maps/@29.839558,78.7926785,18z Assessed on 23-01-2018

GOOGLE MAP. https://www.google.co.in/maps/@30.2216242,78.801809,14z Assessed on 23-01-2018

Gurarni, D, Arya, N, Yadava, J & Ram, J (2010) Studies on plant biodiversity of pure *Pinus roxburghii* Sarg. Forest and mixed pine-oak forest in uttarakhand himalaya. *New York Science Journal,* 3, 1-5.

Hahn, MB, Riederer, AM & Foster, SO (2009) The Livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change – a case study in Mozambique. *Glob Environ Change,* 19(1), 74-88.
[http://dx.doi.org/10.1016/j.gloenvcha.2008.11.002]

IFFN. (2002). (INTERNATIONAL FOREST FIRE NEWS). Fire situation in india. *Int For Fire News,* 26, 23-7.

INCCA (indian network for climate change assessment) (2010).. (2010). *Climate change and India: A 4x4 assessment a sectoral and regional analysis for 2030s,* 160. Ministry of Environment & Forests, Government of India.

Joerin, J, Shaw, R, Takeuchi, Y & Krishnamurthy, R (2014) The adoption of a climate disaster resilience index in Chennai, India. *Disasters,* 38(3), 540-61.
[http://dx.doi.org/10.1111/disa.12058] [PMID: 24905710]

Kohler, T & Maselli, D Mountains and climate change – From understanding to action. Published by geographica bernensia with the support of the

swiss agency for development and Cooperation (SDC), and an international team of contributors. Bern. 75 p.

Ladrach, W The effects of fire in agriculture and forest ecosystem. ISTF NEWS. 5400 grosvenor lane. bethesda, maryland 20814, USA. Special report. 18 p.

Levine, JS, Bobbe, T, Ray, N & Singh, A (1999) *Wildland fires and the environment: A Global Synthesis,* UN Environment Program UNEP/ DEIAEW/TR.99-1, Geneva 46.

Madhury, Tewari HR (2014) Livelihood vulnerability index analysis: An approach to study vulnerability in the context of Bihar. *Jamba: Journal of Disaster Risk Studies,* 6(1), 1-13.
[http://dx.doi.org/10.4102/jamba.v6i1.127]

Maikhuri, RK, Nautiyal, S, Rao, KS & Saxena, KG (2001) Conservation policy – people conflicts: A case study from nanda devi biosphere reserve (A world heritage site), india. *For Policy Econ,* 2, 355-65.
[http://dx.doi.org/10.1016/S1389-9341(01)00037-5]

Maikhuri, RK, Rao, KS, Patnaik, S, Saxena, KG & Ramakrishnan, PS (2003) Assessment of vulnerability of forests, meadows and Mountain ecosystems due to climate change. *ENVIS Bull Himal Ecol Dev,* 11(2), 1-9.

Malik, ZA, Bhat, JA & Bhatt, AB (2013) Forest resource use pattern in Kedarnath wildlife sanctuary and its fringe areas (a case study from Western Himalayas, India). *Energy Policy,* 67, 138-45.
[http://dx.doi.org/10.1016/j.enpol.2013.12.016]

McCarthy, JJ, Canziani, OF, Leary, NA, Dokken, DJ & White, KS (2001) *Climate change 2001: Impacts, adaptation and vulnerability,* Cambridge University Press, Cambridge, UK 417-50.

Mitra, M, Kumar, A, Adhikari, BS & Rawat, GS (2013) A note on transhumant pastoralism in niti valley western himalaya, india. *Pastoralism,* 3, 1-6.
[http://dx.doi.org/10.1186/2041-7136-3-29]

Mobley, HE, Jackson, RS, Balmer, WE, Ruziska, WE & Hough, WA (1973) *A guide to prescribed fire in southern forests.* USDA Forest Service.

MoEF (Ministry of Environment and Forests). (2006). *Report of the National Forest Commission.* Ministry of Environment and Forests, Government of India, New Delhi.

Narendran, K (2001) Forest Fires – Origins and Ecological Paradoxes. *Resonance,* 6(11), 34-41.
[http://dx.doi.org/10.1007/BF02868242]

Negi, GCS (2007) Ecological impacts of forest fire in the indian central himalaya. *Workshop Proceedings,* Pillar Human Resource Development Centre, Madurai, India 30-1.

Negi, SP (2009) Forest cover in indian himalayan states – An over view. *Indian J For,* 31, 1-5.

Pandey, R & Jha, SK (2011) Assessing climate change vulnerability of water at household level. Mitigation and adaptation strategies for global change. *Mitig Adapt Strat Gl Chang,* 20(8), 1471-85.

Pandey, R, Kala, S & Pandey, VP (2014) Assessing climate change vulnerability of water at household level. Mitigation and adaptation strategies for global change. *Mitig Adapt Strategies Glob Change,* 20(8), 1471-85.
[http://dx.doi.org/10.1007/s11027-014-9556-5]

Pike, R, Feller, M, Stednick, J, Rieberger, K & Carver, M (2010) Water quality and forest management. *Chapter 12 in: Compendium of forest hydrology and geomorphology in british columbia:* 401-.

Rajwar, GS (1993) *Garhwal Himalaya: Ecology and environment.* Ashish Publishing House, New Delhi.

Ranalli, AJ (2004) *A Summary of the scientific literature on the effects of fire on the concentration of nutrients in surface waters US department of the interior.* U.S. Geological Survey.

Sagar, R & Singh, JS (2004) Local plant species depletion in a tropical deciduous forest of northern India. *Environ Conserv,* 31(1), 55-62.
[http://dx.doi.org/10.1017/S0376892904001031]

(2014) Forest Fire Disaster Management. *National Institute of Disaster Management, Ministry of Home Affairs*

SCBD (Secretariat of the Convention on Biological Diversity) (2001). Impacts of human-caused fires on biodiversity and ecosystem functioning, and their causes in tropical, temperate and boreal forest biomes. Montreal, SCBD. CBD Technical Series No 5. 42 p.

Shank, RE & Noorie, EN (1950) Microclimate vegetation in a small valley in eastern Tennessee. *Ecology,* 11, 531-9.

Sharma, S, Sharma, RC & Kant, S (2008) Assessment of biotic interference and ecological degradation in Birhum watershed, Jammu and Kashmir. *Environ Ecol,* 26, 1539-44.

Shrestha, P & Gautam, DR (2014) Improving Forest-Based Livelihoods through Integrated Climate Change Adaptation Planning. *Int J Interdiscip Stud,* 2(1), 135-46.

Silori, CS (2001) Assessment of livestock grazing pressure in and around the elephant corridors in mudumalai wildlife sanctuary, south india. *Biodivers Conserv,* 10, 2185-95.

Sinha, B, Jha, SK & Khare, AK (2015) Assessing the potential of incentive based plantation involving people's participation. *Indian For,* 141(4), 439-47.

Sonesson, M & Messerli, B (2002) The Abisko Agenda: Research for mountain area development *Ambio Special Report,* 11, 3-103.

Sullivan, C (2002) Calculating the water poverty index. *World Dev,* 30(7), 1195-210.
[http://dx.doi.org/10.1016/S0305-750X(02)00035-9]

Tiwari, L & Pande, PC (2011) Traditional animal husbandry practices of central Himalaya. *FAO Available at:*.http://agris.fao.org/ agris-search/search. do?recordID=IN2013000519 Accessed on 22-11-2016

Tol, RSJ, Ebi, KL & Yohe, GW (2007) Infectious disease, development, and climate change: A scenario analysis. *Environ Dev Econ,* 12, 687-706.
[http://dx.doi.org/10.1017/S1355770X07003841]

Tripathy, C & Behera, PK (2008) Socioeconomic and socio-ecological study of sambalpur forest division, orissa. *J Hum Ecol,* 23(2), 135-6.
[http://dx.doi.org/10.1080/09709274.2008.11906064]

Urothody, AA & Larsen, HO (2010) Measuring climate change vulnerability: A comparison of two indexes. *Banko Jankari 20(1): 9-16 USDA 2007 The US Department of Agriculture Available at:* .http:/ /www.fs.fed.us/ecosystemservices
[http://dx.doi.org/10.3126/banko.v20i1.3503]

Verma, S & Jayakumar, S (2012) Impact of forest fire on physical, chemical and biological properties of soil: A review. *Int Acad Ecol Environ Sci,* 2(3), 168-76.

Vincent, K Creating an index of social vulnerability to climate change in Africa. Norwich, UK: Tyndall Centre for Climate Change Research. Working Paper 56. 50

World Bank. World Development report 2003: Sustainable development in a dynamic world: Transforming institutions, growth and quality of Life. *The World Bank: Washington DC Available at:*.https://openknowledge.worldbank.org/handle/10986/5985