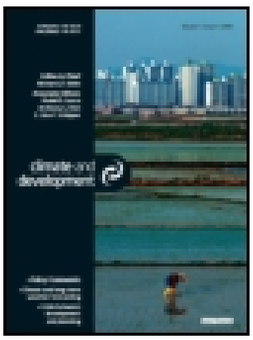

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RESEARCH ARTICLE

Quantifying household vulnerability triggered by drought: evidence from rural India

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Drought is a complex, slow-onset phenomenon that imposes serious challenges on human beings and ecosystems. The vulnerability associated with drought may vary at different social, geographical and temporal scales. These differences emphasize the need for regional-level vulnerability assessments, which in turn helps to formulate efficient adaptation policies and strategies that are suitable for the region to mitigate the drought risk. The objective of this paper is to quantify the livelihood and socio-economic vulnerability of rural households that are affected by drought in rural India. The Livelihood Vulnerability Index and Socioeconomic Vulnerability Index were applied to analyse the vulnerability of rural households. A sample size of 157 rural households from the state of Odisha in India was surveyed in 2015. Socio-demographic characteristics such as low literacy rates, high dependency ratios and weak housing structures make people more vulnerable, whereas access to social networks plays a significant role in supporting poor rural households. The research concludes that the impacts of drought make people who are already vulnerable due to poverty, inequality and marginalization even more vulnerable. The outcomes of this study may be considered in formulating effective coping strategies and policies that may help mitigate the drought risk. The findings and recommendations of this study will find applicability in other rural, natural resource-dependent countries with similar socio-economic profiles such as other south Asian countries.

Keywords: adaptive capacity; assessment; exposure; natural disaster; risk; sensitivity

1. Introduction

Drought is a climate-induced natural disaster that differs from other hazards because it has a slow onset, evolves over months or even years (Tate & Gustard, 2000) and is one of the most frequently occurring natural disasters and covers extensive geographical areas (UNDP, 2004). The changing climate may increase the likelihood of drought and very likely impacts the characteristics and severity of drought across the world (Arshad, Amjath-Babu, Kächele, & Müller, 2015; Wanders & Wada, 2015). Drought is considered the most complex but least understood phenomenon, and it affects more people than any other natural disaster (Wilhelmi & Wilhite, 2002). Nearly half of all countries around the world have suffered from drought over the past several decades (Wu, Bake, Zhang, & Rasulov, 2015). Managing the risks of an increased frequency and magnitude of drought is an important global challenge (IPCC, 2012).

Regions in south Asia have been among the perennially drought-prone regions of the world, and countries such as India, Afghanistan, Pakistan and Sri Lanka have reported droughts at least once in every three-year period for the past five decades (Miyan, 2015). Recurrent drought has been a common phenomenon in different regions of India, which is caused by a lack or decreased amount of rain over a long period of time. According to the database of the Center for Research on Epidemiology of Disasters, droughts affected nearly 1061 million people and killed 4.25 million people in India in the 1900–2015 period (CRED, 2015). Drought affects the national economy adversely in terms of a decline in agricultural production, an increase in rural unemployment and a decrease in purchasing power and household food security (Rachakulla et al., 2005).

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change and extremes such as droughts, floods and cyclones (IPCC, 2007). Vulnerability relates to the concepts of exposure, susceptibility and adaptive capacity (Smit & Wandel, 2006). Exposure is defined as the presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social and cultural assets in areas that can be adversely affected (Aleksandrova, Lamers, Martius, & Tischbein, 2014);

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susceptibility is the predisposition of a system to be negatively affected by climate variability or natural disaster (Birkmann et al., 2013); and adaptive capacity is the ability of a system and its components to absorb or recover from the effects of a hazardous event (IPCC, 2012). Vulnerability to natural disaster varies across time and space and differs across groups and individuals (Maru, Smith, Sparrow, Pinho, & Dube, 2014). There is sufficient discrepancy between the extent of vulnerability in developed and developing nations. Developing countries are comparatively more vulnerable to climatic vagaries, mainly due to their weak coping capacity and unclear institutional frameworks (Yohe & Tol, 2002). Other possible reasons for their increased vulnerability are (i) relatively greater physical impacts, given low levels of preparedness and ad hoc nature of mitigation measures; (ii) a heavy dependence of the majority of the population on natural resources for livelihood and, hence, the excessive exploitation that leads to their degradation; and (iii) limited economic and technological capacity, which hinders adaptation processes in rapidly occurring climatic extremes (Gray & Mueller, 2012).

The differences in the demographic, social, economic and political characteristics of a society can influence the impact of disaster damage and the ability of communities to reconstruct following a disaster (Burton & Cutter, 2008). Drought vulnerability is spatially variable among nations, regions, communities and individuals (Arouri, Nguyen, & Youssef, 2015). When people are faced with vulnerable situations due to drought, they are forced to make choices regarding the necessary adjustments in socio-economic, cultural and environmental contexts. These adjustments are formulated within the vulnerability of different systems that are constituted by both the human and natural environments. A micro-level vulnerability analysis helps to identify the most vulnerable sections of the population and the most impacted livelihood resources of a particular region. Thus, it is important to identify the most vulnerable sections of a population as well as the degree and extent of vulnerability on a regional or country basis to develop the most suitable coping strategies and policies to overcome the risk associated with drought for a specific region (Aryal, Cockfield, & Maraseni, 2014).

Several studies have identified the vulnerability due to natural disaster; however, only limited studies are available that explain the vulnerabilities of rural households that are affected by drought, especially in south Asian countries (Eriksen & O'Brien, 2007). India, which is home to the largest number of poor and malnourished children on the planet, has several regions that are prone to frequent recurrences of drought. However, there is no information on the degree of vulnerability of the rural communities with regard to drought. Therefore, the aim of this paper is to quantify the degree of vulnerability of rural households that are affected by drought in economically fragile regions and, more specifically, to investigate (1) the degree of livelihood vulnerability of rural farming households and (2) the socio-economic vulnerability of rural farming households that are affected by drought. The results of the study may help in the formulation of coping strategies and polices to mitigate the drought risk and effective targeting of vulnerable rural communities.

2. Study region

Odisha is located on the eastern coast of India (Figure 1). The state has been affected by major disasters 90 times over the last 100 years: floods have occurred in 49 years, droughts in 30 years and cyclones in 11 years (Government of Odisha, 2013). Odisha was selected as study area for three main reasons: (1) the Government of Odisha (2013) has documented that the state has faced droughts or moisture stress in 22 years during the 1950–2013 period. (2) Though agriculture contributes only 15.4% to the gross state domestic product, approximately 70% of the rural population of the state still depends on agriculture for their livelihood (Government of Odisha, 2015). Even under normal conditions, agricultural production in Odisha is marked by low productivity, and its simultaneous susceptibility to droughts results in wide fluctuations in output (Arora, Bansal, & Ward, 2015). (3) Odisha is considered the least developed state in India based on monthly per capita consumption expenditures, education, health, household amenities, poverty rate, female literacy, proportion of Scheduled Caste/Tribe population, urbanization rate, financial inclusion and physical connectivity (Savath, Fletschner, Peterman, & Santos, 2014).

3. Sampling and household survey

A multi-stage sampling procedure was used for the study. Six stages of sampling frames were developed to select the final sampling unit viz. households. In India, there are four different administrative layers[1]: the state, district, block and *grama panchayat*. Odisha was selected specifically because of the occurrence of frequent droughts, poverty and a high dependence on agriculture. The Balangir district of the state was selected from among 30 districts because it had faced 16 droughts during the 1970–2013 period (Government of Odisha, 2013). The Balangir district is less developed in terms of basic infrastructure such as roads, electricity, irrigation and communication networks and has very poor basic amenities for health, sanitation and drinking water. The two blocks selected randomly from the Balangir district were the Patnagarh and Puintala blocks. The Tamian and Mahimunda *grama panchayats* were selected randomly from the Patnagarh and Puintala blocks, respectively. The Aintalunga and Bagbahali villages were selected randomly from Tamian *grama panchayat*, whereas Bilaikani and Sirabahal villages were selected randomly from Mahimunda *grama panchayat*.

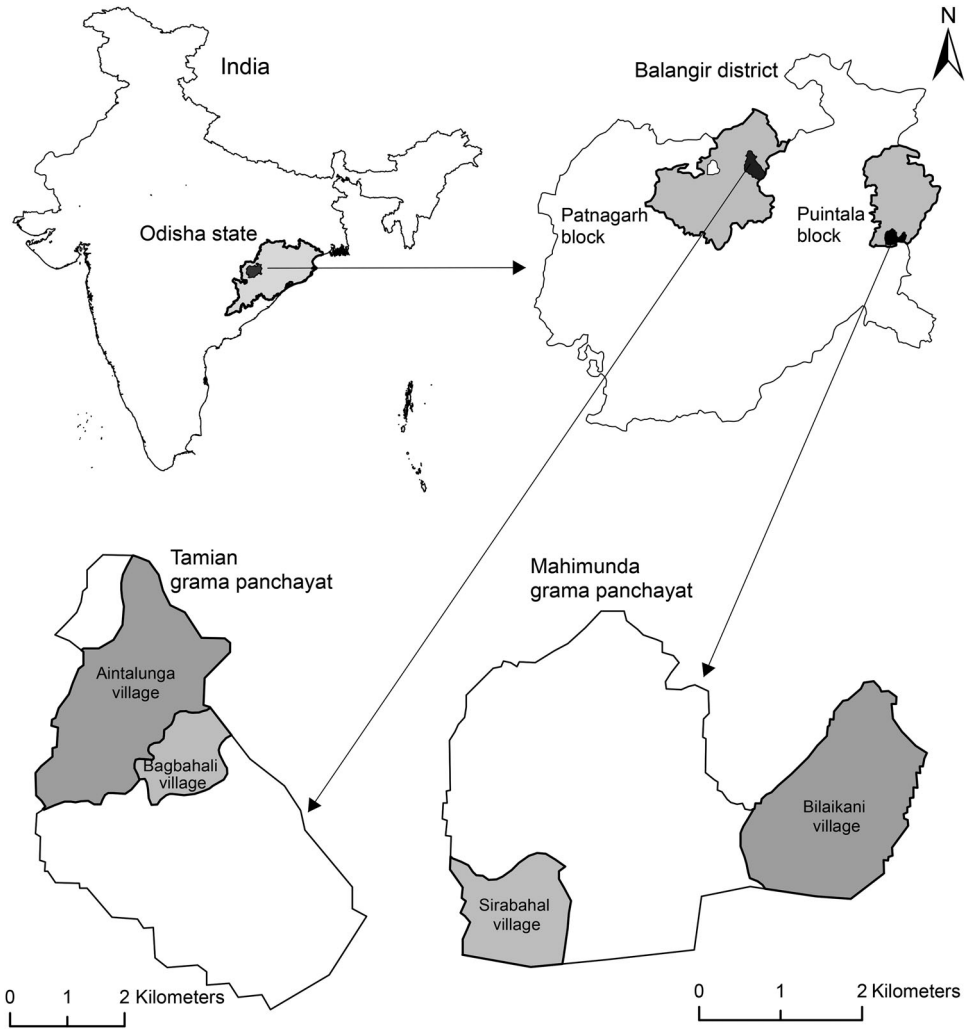

Figure 1. Map of study area. Source: Author.

Finally, the sample households were selected from these four villages using a simple random sampling technique.

The sample size required for this study was calculated at 95% confidence interval and 7% precision level. The total number of households in the studied villages is 689. The minimum total sample size of households required for this study from all four villages was 157. The minimum sample size of households needed for each village was as follows: Sirabahal, 31; Bilaikani, 44; Aintalunga, 54 and Bagbahali, 28. The data were collected from the households by four trained interviewers from March to June 2015.

4. Methodology

To measure the vulnerability of drought-affected rural households, the Livelihood Vulnerability Index (LVI) (Hahn, Riederer, & Foster, 2009) and Socioeconomic Vulnerability Index (SeVI) (Ahsan & Warner, 2014) were used. The LVI and SeVI approaches were used separately to estimate the vulnerability associated with climate change and natural disasters. Studies have used a single approach to identify any household vulnerability which may incur bias of some sort. The households may be vulnerable in terms of livelihood but may not necessarily be vulnerable in terms of socio-economic aspects and vice versa. In this context, analysing both vulnerabilities in the same household helps to identify various vulnerable aspects of each household. Hence, the present study used both the LVI and SeVI approaches for the first time to estimate the livelihood and socio-economic vulnerability of the same area. This method helps in the formulation of adaptive strategies and effective targeting under the given financial limits for both local communities and the government.

4.1 *Livelihood vulnerability index*

The LVI approach integrates climate exposure and the household adaptation practices that are needed to

comprehensively evaluate the livelihood risks resulting from natural disasters (Hahn et al., 2009). The LVI comprises seven major components: socio-demographic profile (SDP), livelihood strategies (LS), social networks (SNs), health, food, water and drought. Each major component has further sub-components. Thus, these seven major components consisted of a total of thirty-one sub-components. These vulnerability sub-components are potentially useful means of observing vulnerability over time and space by identifying the processes that contribute to vulnerability, prioritizing strategies for reducing vulnerability and evaluating the effectiveness of these strategies in different social and ecological settings (Adger, 2003). This study has modified the sub-components according to their relevance to rural communities in India. Table 1 consists of major components, sub-components and explanations of the sub-components.

The LVI calculation consisted of five steps. Step 1: the raw data collected from the villages were transferred into appropriate measurement units, including counts, ratios, percentages and indices, under each sub-component. Step 2: because each of the sub-components was measured on a different scale, they were standardized as an index value by using Equation (1).

$$\text{Index}_{\text{sv}} = \frac{S_{\text{v}} - S_{\min}}{S_{\max} - S_{\min}}, \tag{1}$$

where S_{v} is the original sub-component for village v and $S_{\min}$ and $S_{\max}$ are the minimum and maximum values, respectively, for each sub-component, which were determined using data from four villages.

For sub-components measured in percentages, the maximum and minimum values were 100 and 0, respectively. Some components were measured in indices. This was due to the assumption that certain sub-components had a negative relationship with vulnerability. By taking the inverse of the crude values of such sub-components, a new number with a lower value was assigned to them. The maximum and minimum values of such sub-components were also modified according to the logic. Step 3: to calculate the index score of the major components, the standardized sub-components were averaged (Equation (2)):

$$M_{\text{v}} = \frac{\sum_{i=1}^{n} \text{index}_{\text{sv}i}}{n}, \tag{2}$$

where M_{v} is one of the seven major components for village v; $\text{index}_{\text{sv}i}$ represents the sub-components, indexed by i, that make up each major component; and n is the number of sub-components in each major component.

Step 4: the index score of the major components were multiplied by their corresponding weights (Equation (3)) to obtain the weighted major-component score index. A balanced weighted approach was used in LVI, assuming that each of the sub-components contributes equally to the overall index (Sullivan, Meigh, & Fediw, 2002). The weights of each major component were determined by the number of sub-components that it comprised.

$$\text{Weighted major component score } (\text{WMS}_{\text{V}}) = M_{\text{V}} \times W_{\text{M}}, \tag{3}$$

where WMS_{V} is the weighted major-component score of each major component for village v, M_{V} is the index values of one of the major component for a village, and W_{M} is the weight of each major component for a village.

Step 5: the weighted scores of the major component were averaged to obtain the final LVI for each village (Equation (4)). The LVI was scaled from 0 (least vulnerable) to 1 (most vulnerable).

$$\text{LVI}_{\text{v}} = \frac{\sum_{i=1}^{7} W_{\text{M}i} M_{\text{v}i}}{\sum_{i=1}^{7} M_{\text{v}i}}. \tag{4}$$

4.2 *Socio-economic vulnerability index*

According to IPCC (2007), the three dimensions of climate change are adaptive capacity, sensitivity and exposure. SeVI identifies vulnerability in community-level settings in light of various interacting fabrics of social and economic relationships (Ahsan & Warner, 2014). Adaptive capacity consisted of SDP, LS and SNs. The sensitivity component comprised health (H), food (F) and water (W). Exposure was measured by the effects of drought (D) in the previous six years (2009–2014). By using the same data (Table 1), SeVI was estimated, and Steps 1 to 4 of LVI were used to calculate SeVI. The SeVI differed from LVI when the major components were combined under three IPCC dimensions using the following equations. The index for adaptive capacity (Equation (5)), sensitivity (Equation (6)) and exposure (Equation (7)) were calculated as follows:

$$\text{Adp Ca p}_{\text{v}} = \frac{W_{\text{SPD}}\text{SDP}_{\text{V}} + W_{\text{SN}}\text{SN}_{\text{V}} + W_{\text{LS}}\text{LS}_{\text{V}}}{W_{\text{SPD}} + W_{\text{SN}} + W_{\text{LS}}}, \tag{5}$$

$$\text{Sen}_{\text{v}} = \frac{W_{\text{H}}H_{\text{V}} + W_{\text{F}}F_{\text{V}} + W_{\text{W}}W_{\text{V}}}{W_{\text{H}} + W_{\text{F}} + W_{\text{W}}}, \tag{6}$$

$$\text{Ex p}_{\text{v}} = W_{\text{D}}D_{\text{V}}. \tag{7}$$

SDP_{V}, SN_{V}, LS_{V}, H_{V}, F_{V}, W_{V}, D_{V} are the index values of each major component for each village.

W_{SPD}; W_{SN}; W_{LS}; W_{H}: W_{F}: W_{W}; W_{D} are the weights of each major component for each village.

To calculate the SeVI, the indexed values of adaptive capacity, sensitivity and exposure were combined (Equation (8)). SeVI possessed a direct relationship with the system

Table 1. Major components and sub-components of LVI and SeVI.

Major component	Sub-components	Explanation of sub-components	Source
SDP	Dependency ratio	Ratio of the population under 18 and over 65 years of age to the population between19 and 64 years of age	ICF International (2011)
	Per cent of female-headed households	Percentage of households where household head is female. If a male head is away from home for more than 6 months per year, the female is considered the head of the household	ICF International (2011)
	Per cent of illiterate household heads	Percentage of households that report the head of the household attended 0 years of school	ICF International (2011)
	Per cent of backward caste households	Per cent of households that belong to backward castes, such as OBC, SC and ST[a]	World Bank (1997)
	Housing structure index[b]	The inverse of (type of housing structure[c] of a household + 1)	Pandey and Jha (2011)
LS	Average livelihood diversification index[b]	The inverse of the (the number of livelihood activities of a household + 1)	World Bank (1997)
	Per cent of households depending solely on agriculture for livelihood	Percentage of households that have only agriculture as a source of income	World Bank (2006)
	Per cent of households without migrant members	Percentage of households that report no migration as a source of income	Joarder and Miller (2013)
	Average livestock asset diversification index[b]	The inverse of (the number of livestock raised by a household + 1)	World Bank (2011)
	Average durable asset diversification index[b]	The inverse of (the number of durable assets of a household + 1)	World Bank (2000)
SN	Per cent of households without assistance from NGO/SHG[d]	Percentage of households that report that they have not received any assistance from NGO/SHG in the past 6 months	Developed for this study
	Per cent of households with access to informal credit institutions	Percentage of households that report access to informal credit institutions	Börner, Shively, Wunder, and Wyman (2015)
	Per cent of households without bank access	Percentage of households that report no banks access	Günther and Harttgen (2009)
	Per cent of households without school access	Percentage of households that report no schools access	World Bank (2007)
Health	Per cent of households afflicted with diseases not due to drought	Percentage of households that report at least 1 family member with any type of illness during any time of the year apart from drought period	World Bank (2007)
	Average distance to the Public Health Center	Average distance from each household to the nearest health facility	World Bank (2007)
	Per cent of households without health insurance	Percentage of households without health insurance	Vladeck (2003)
	Average monthly health expenditure of the household (US$)	The average monthly health expenditure of households in US$	Government of India (2004)
Water	Per cent of households depending on public resources for household activities	Percentage of households that depend on public sources of water for household activities such as cooking, drinking, washing, bathing, etc.	World Bank (1997)
	Per cent of households depending on natural resources for household activities	Percentage of households that depend on natural sources of water for household activities	World Bank (1997)
	Per cent of households with problems accessing water for household activities	Percentage of households that have problems accessing water for household activities	World Bank (1997)
	Per cent of households with problems accessing water for irrigation	Percentage of households that have problems accessing water for irrigation	World Bank (1997)

(*Continued*)

Table 1. Continued.

Major component	Sub-components	Explanation of sub-components	Source
Food	Per cent of households with insufficient food for consumption in a year	Percentage of households with food insecurity problems	World Bank (1997)
	Average number of months in which households struggle to obtain food	Average number of months in which households struggle to obtain food for their families in the last twelve months	Hahn et al. (2009)
	Average monthly food expenditure of the household index[b]	The inverse of the average monthly food expenditure in US$	Government of India (2004)
	Per cent of households depending on own farm for food	Percentage of households that obtain their food primarily from their own farms	Hahn et al. (2009)
	Per cent of households not depending on public distribution system (PDS)	Percentage of households that do not depend on PDS for subsidized food items	World Bank (2012)
Drought	Per cent of households with diseases due to drought in the last six years	Percentage of households that report any disease in any family members due to drought during the 2009–2014 period	Hahn et al. (2009)
	Per cent of households with yield reduction/loss due to drought in the last six years	Per cent of households that report any yield reduction/ loss due to drought during the 2009–2014 period	UNDP (2002)
	Per cent of households that report average temperatures have increased in the last six years	Per cent of households that report any increase in the average temperature during the 2009–2014 period	Developed for this study
	Per cent of households that report variation in average rainfall in the last six years	Per cent of households that report any decrease in the average rainfall during the 2009–2014 period	Developed for this study

[a]OBC: Other Backward Caste, SC: Schedule Caste, ST: Schedule Tribe (backward caste classification of India).
[b]The assumption of this study is that higher numbers/values for these sub-components will make the household less vulnerable. Taking the inverse of the crude value of such sub-components will provide a lower index score value to households with higher numbers/values.
[c]Leaf-thatched roof with mud wall = 1, Leaf-thatched roof with brick and cement = 2, Tile-thatched roof with mud wall = 3, Tile-thatched roof with brick and cement = 4, Concrete roof with brick and cement = 5.
[d]NGO: Non-governmental organization; SHG: Self-help group.

exposure and sensitivity and inverse relationship with its adaptive capacity (Ford & Smit, 2004). Hence, for the SeVI index calculation, one minus the adaptive capacity component index score was used. In this study, the SeVI scale was from 0 (least vulnerable) to 1 (most vulnerable).

$$\mathrm{SeVI_v} = \frac{(1 - \mathrm{Adp}\ \ \mathrm{Ca\,p_v}) + \mathrm{Sen_v}\ + \mathrm{Ex\,p_v}}{3}. \qquad (8)$$

5. Results and discussions

The results are presented in three segments. The first segment consists of the results of individual major components along with their corresponding sub-components. The second segment consists of the results of LVI, and the third segment consists of the results of SeVI. The possible reasons for different vulnerability patterns are discussed in detail along with the results. The sub-component values with their minimum and maximum values for four villages in the Balangir district are given in the Appendix (Table A1).

Table 2. Indexed values for SDP and sub-components of villages in the Balangir district.

Sub-component/major component	Sirabahal	Bilaikani	Aintalunga	Bagbahali
Dependency ratio	0.160	0.141	0.180	0.188
Per cent of female-headed households	0.129	0.091	0.130	0.536
Per cent of illiterate household heads	0.194	0.182	0.259	0.429
Per cent of backward caste households	0.903	0.977	0.685	1.000
Housing structure index	0.395	0.338	0.263	0.563
SDP	0.356	0.346	0.304	0.543

5.1 *Major component-wise vulnerability*

5.1.1 *Socio-demographic profile*

The ability of a community to respond, recover from and adapt to natural hazards is influenced by socio-demographic characteristics (Cutter, 2006). A good SDP can enhance the adaptive capacity of households. Table 2 consists of the indexed values for the SDP and its sub-components. Among the four villages, Bagbahali was socio-demographically the most vulnerable village. A high dependency ratio increases the vulnerability of households, especially in times of scarcity, such as in the aftermath of extreme droughts (Block & Webb, 2001; Shah & Dulal, 2015). The dependency ratio index was highest for Bagbahali village. A higher rate of dependency ratio would indicate that economically active individuals have many others to support and, hence, resources for coping with the natural disasters would be more limited (Brenkert & Malone, 2005).

Female-headed households are more vulnerable to the risks associated with natural hazards (Cutter, Boruff, & Shirley, 2003) due to the poor overall literacy rates and lack of networking ability among them. Ninety per cent of households in rural India are headed by men (Chudgar, 2009). The index values for female-headed household and illiterate household heads were highest for Bagbahali. In this village, most of the families are nuclear families, and when men migrate to cities or other states, the women, children and elderly people are left behind, with women acting as the household heads. Better education of household head has a negative association with natural disaster and climate change risks (Brody, Zahran, Vedlitz, & Grover, 2008). Most of the female-household heads are illiterates because when they were school-aged, several restrictions prevailed in the society that prevented them from going to school (Chudgar, 2011).

The Indian caste system[2] is historically an important rural dimension by which people are socially differentiated through class, religion, region, tribe and language (Deshpande, 2010). The social hierarchy in rural India keeps a majority of the population in backward or scheduled castes, and scheduled tribes lack many social and economic privileges. Accessibility to resources, assets and social protection programmes by the government is still precarious in these regions. All four villages include people who belong to backward castes. Among the four villages, Bagbahali is a tribal village, where 100% of the sample households belong to the *Gond* tribe. The index score for the type of housing structure was also highest for Bagbahali and lowest for Aintalunga. Though every household has their own house, most of these houses are temporary structures (constructed with mud or brick wall with straw-thatched roofs). These houses are highly vulnerable to natural disasters. Most of the households fall below the poverty line, rendering them impossible to obtain a permanent housing structure.

5.1.2 *Livelihood strategies*

The LS and activities of poor people are often complex and diverse. Table 3 consists of the indexed values for LS and its sub-components. Livelihood is comprised of the capabilities, assets and activities required to live (Chambers & Conway, 1992). A livelihood is considered as an important strategy for households to cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets, both now and in the future (Paavola, 2008).

The diversification of LS helps households to choose more defensive strategies, which in turn help them survive during natural disasters (van den Berg, 2010). The most common livelihood in the studied villages is agriculture. More than 80% of households in the studied villages depend on agriculture as a major livelihood source. Apart from agriculture, people work as casual agricultural labourers and resort to migration. The highest percentage of households that solely depend on agriculture was in Aintalunga village (44%). Agriculture is highly dependent on nature, and a slight variation in rainfall or temperature adversely affects production. Therefore, the people who are engaged in subsistence agriculture are the most vulnerable to a situation such as drought.

Migration is considered an ex-ante risk management strategy (Osawe, 2013). The remittance sent to households increases their assets, which in turn reduces its vulnerability (Nyberg-Sorensen, Van Hear, & Engberg-Pedersen, 2002). Aintalunga village had the highest per cent of non-migrant households, and Bagbahali had the lowest number of non-migrant households. The main push factors of migration are drought and low wages in the villages (Jülich, 2011). The young males of these villages usually migrate to other districts or states in search of jobs, and as most are less educated, they work in construction sites, factories, restaurants, brick kilns, and so on. The migration of Bagbahali villagers is distress migration. The households reported that during the period of drought, the household members become unemployed as most are farmers or casual labourers working in farms. To escape the aftermath of drought, poor households take out loans from the moneylenders at high interest rates. Most agree to work in the brick kilns of these moneylenders to repay the loan. They work in the brick kiln for six to eight months and then return to their villages. Every year, drought affects these villages, and whole process repeats, leaving them in vicious circle of distress migration.

The more diverse the household asset base is, the more drought-resilient it is likely to be (Wilhite, 2005). Livestock and other durable assets are important adaptation strategies in extreme climatic condition (Stringer et al., 2009). The livestock assets found in the studied villages include cows, buffalo, goats and chickens. The average livestock asset index was highest for Bilaikani, and the physical asset diversification index was highest for Sirabahal. The

Table 3. Indexed values for LS and sub-components of villages in the Balangir district.

Sub-component/major component	Sirabahal	Bilaikani	Aintalunga	Bagbahali
Average livelihood diversification index	0.432	0.636	0.756	0.524
Per cent of households depending solely on agriculture for livelihood	0.129	0.432	0.444	0.250
Per cent of households without migrant members	0.516	0.500	0.556	0.429
Average livestock asset diversification index	0.303	0.518	0.423	0.299
Average durable asset diversification index	0.276	0.273	0.234	0.246
LS	0.331	0.472	0.482	0.349

common durable assets found in these study villages were bicycles and mobile phones.

5.1.3 *Social networks*

The people most vulnerable to natural hazards are those with inadequate access to economic and social capital (Thomalla, Downing, Spanger-Siegfried, Han, & Rockström, 2006). Some examples of SNs are NGOs, savings and credit institutions, and other social institutions such as schools and hospitals (Rakodi & Jones, 2015). Table 4 shows the indexed values for SNs and their sub-components. Sirabahal was the most vulnerable village in terms of SNs. As the access to many SNs increase, households found themselves less vulnerable to shocks as their ability to cope with risks increases (Lokshin & Yemtsov, 2001). The highest percentage of households seeking assistance from NGO/SHGs was in Bilaikani village. In Sirabahal village, no NGO/SHG was present to assist the villagers. NGOs play a significant role in natural disaster mitigation and preparedness as they work with poorer and more marginalized groups in a society (Benson, Twigg, & Myers, 2001).

In many developing countries, the non-institutional credit institutions, such as informal moneylenders, landlords, and traders, charge very high rates of interest compared to those levied by institutional lenders (Chakrabarty & Chaudhuri, 2001). The index value for the percentage of households with access to informal credit facilities was one for all four villages, indicating that formal credit institutions are inadequate for meeting the requirements of these villagers, who frequently approach private moneylenders for credit needs. Bilaikani village had the highest index value for the percentage of households without access to banks. Most migrant households have access to banks as the migrant members send remittances to their families through banks.

Bilaikani village had the highest percentage of households without access to school. People belonging to remote rural areas have meagre incomes. Children from these families are not sent to schools; instead, they assist the earning members of the family to generate extra income. The primary and upper primary schools are located within villages, whereas high schools and higher secondary schools are situated outside the village limits. Most villages have poor connectivity between different areas. Because of this, children walk miles to reach these schools, and this often demotivates them from attending school on a regular basis. Access to education is perceived differently for males and females in the rural areas. If a family has to choose between educating a son or a daughter because of financial restrictions, the son will typically be chosen. Girls are often taken out of school to assist with family responsibilities, such as caring for younger siblings.

5.1.4 *Health*

Natural disasters often imply a heavy negative toll on human health and well-being (Morrissey & Reser, 2007). Table 5 consists of the indexed values for health and its sub-components. Sirabahal village had the highest health vulnerability index score. The disease index score was highest for Aintalunga village. More than 95% of households in all four villages lack toilets. Defecation in open areas increases the risk of water contamination, which leads to diarrhoea. Moreover, the other common diseases found in the villages include allergies, skin diseases and respiratory diseases. The distance to the nearest Public Health Center was highest for Sirabahal (12.6 km). When people in rural areas become affected by disease, they use

Table 4. Indexed values for SNs and sub-components of villages in the Balangir district.

Sub-component/major component	Sirabahal	Bilaikani	Aintalunga	Bagbahali
Per cent of households without assistance from NGO/SHG	1.000	0.341	0.741	0.714
Per cent of households with access to informal credit institutions	1.000	1.000	1.000	1.000
Per cent of households without bank access	0.419	0.636	0.426	0.357
Per cent of households without school access	0.387	0.523	0.333	0.357
SN**s**	0.702	0.625	0.625	0.607

homemade remedies, and they opt go to public health centres only when such remedies fail.

Only the residents in Bagbahali village had health insurance provided by the government. *Rastriya Swathya Bima Yojana* is a national health insurance scheme launched by the government of India to provide health insurance coverage for Below Poverty Line (BPL) families. This scheme is to provide protection to BPL households from financial liabilities arising from illnesses that involve hospitalization. Beneficiaries need to pay only Rs. 30 (US$ 0.50) as a registration fee while the central and state government pays the premium to the insurer and covers hospitalization charges up to Rs. 30,000 (US$ 500) annually (Singh, Gonzalez, & Thomson, 2013).

Large healthcare expenditures likely require the sacrifice of the consumption of other goods which make households more vulnerable (Flores, Krishnakumar, O'Donnell, & van Doorslaer, 2008). Aintalunga village had the highest index score for average monthly health expenditure, and the average monthly health expenditure of households in Aintalunga village was US$ 1.45. Bagbahali had the lowest index score for the average monthly health expenditure of households, with an average monthly health expenditure of US$ 0.18.

5.1.5 *Water*

Water is the most essential element that supports a wide range of domestic and productive needs of households. Table 6 consists of the indexed values for water and its sub-components. The index score for the major-component water was one for all the villages. None of the households had their own sources of water (index score: 1). All households depend on public tube wells (ground water) and natural sources for water needs.

Problems accessing safe and ample amounts of water for drinking and domestic needs are found in the villages, and the index score was one for all the villages. The natural sources of water dry up during the summer months, leading to overdependence on ground water for domestic needs, which in turn results in the depletion of the ground water table (Kelkar, Narula, Sharma, & Chandna, 2008). The public tube wells in the villages are nonfunctional or become dried up during the drought period. Other problems, such as the poor operation and maintenance of water sources and inadequate rainwater harvesting facilities, are also found in the rural areas. In rural areas, women with pitchers on their heads walk an average of half a kilometre daily to fetch water from the nearest ground water source for cooking and drinking. For other household activities such as bathing and washing clothes, they depend on natural resources such as ponds and lakes.

Access to irrigation water is a prominent issue in the villages, especially during the summer months. Eighty per cent of the rainfall is received during June–September. Due to the lack of proper rainwater harvesting systems, most of the rainwater generated during monsoons is lost as runoff to the sea. Most of the rivers remain dry for two-thirds of the year, leading to an increase in the dependency of ground water for irrigation purposes. All these factors lead to a severe scarcity of irrigation water, especially during the summer months (Rejani, Jha, & Panda, 2009).

5.1.6 *Food*

According to Baro and Deubel (2006), the principal consequence of drought is a considerable decline of food consumption, which results in massive social disruption and long-term resource depletion. Table 7 consists of the indexed values for food and its sub-components. Most households in the four villages face food security issues. Aintalunga village was the most vulnerable village in terms of food issues. In Bagbahali village, 78.6% of the households reported insufficient food consumption year round, and households in this village struggle for food for an average of three months. The reason for the high percentage of insufficient food for consumption is the low average monthly income of households (US$ 52 per month). The index value of the average monthly food expenditure of households was highest for Bagbahali. Household farms provide the primary source of food for many households. November to January are the harvesting months for agricultural produce. During these months, they sell most of their produce to obtain cash and conduct certain household activities and repay loans. The farmers retain only a small portion of the agriculture produce for their own consumption year round.

The PDS is a nationwide network that sells rice and other essentials at subsidized prices to poor people. Households with access to PDS are considered less vulnerable. Only in Bagbahali village did 100% of the households depend on PDS, and the index score was found to be zero for this village. In this village, most of the families lived below the poverty line.

5.1.7 *Drought*

Between 2009 and 2014, the Balangir district faced drought for three years. Bagbahali was the village that was most vulnerable to drought. Table 8 consists of the indexed values for drought and its sub-components. The sub-components revealed that the households are highly prone to drought. During the drought period, people are affected by many diseases such as hepatitis, dysentery, chicken pox and skin problems. The number of diseases affecting households increases during drought periods compared to the rest of the year. Crop loss/yield reduction is also a very common phenomenon during drought periods in the study area. The index score for yield loss/reduction was

Table 5. Indexed values for health and sub-components of villages in the Balangir district.

Sub-component/major component	Sirabahal	Bilaikani	Aintalunga	Bagbahali
Per cent of households afflicted with diseases not due to drought	0.323	0.500	0.741	0.607
Average distance to the Public Health Center	0.811	0.045	0.170	0.078
Per cent of households without health insurance	1.000	1.000	1.000	0.464
Average monthly health expenditure of the household (US$)	0.032	0.118	0.174	0.021
Health	0.542	0.416	0.521	0.293

Table 6. Indexed values for water and sub-components of villages in the Balangir district.

Sub-component/major component	Sirabahal	Bilaikani	Aintalunga	Bagbahali
Per cent of households depending on public resources for household activities	1.000	1.000	1.000	1.000
Per cent of households depending on natural resources for household activities	1.000	1.000	1.000	1.000
Per cent of households with problems accessing water for household activities	1.000	1.000	1.000	1.000
Per cent of households with problems accessing water for irrigation	1.000	1.000	1.000	1.000
Water	1.000	1.000	1.000	1.000

Table 7. Indexed values for food and sub-components of villages in the Balangir district.

Sub-component/major component	Sirabahal	Bilaikani	Aintalunga	Bagbahali
Per cent of households with insufficient food for consumption in a year	0.516	0.545	0.667	0.786
Average number of months in which households struggle to obtain food	0.244	0.360	0.466	0.606
Average monthly food expenditure of the household index	0.171	0.190	0.162	0.295
Per cent of households depending on own farm for food	0.742	0.727	0.852	0.821
Per cent of households not depending on PDS	0.484	0.341	0.611	0.000
Food	0.431	0.433	0.552	0.502

Table 8. Indexed values for drought and sub-components of villages in the Balangir district.

Sub-component/major component	Sirabahal	Bilaikani	Aintalunga	Bagbahali
Per cent of households with diseases due to drought in the last six years	0.677	0.659	0.889	0.857
Per cent of households with yield reduction/loss due to drought in the last six years	0.742	0.818	0.889	0.857
Per cent of households that report average temperatures have increased in the last six years	0.516	0.659	0.537	0.714
Per cent of households that report variation in average rainfall in the last six years	0.452	0.750	0.593	0.750
Drought	0.597	0.722	0.727	0.795

highest for Aintalunga village. Drought diminishes dietary diversity and reduces overall food consumption, which may lead to food insecurity problems. Most farming families were self-subsistence farmers, and crop loss/yield reduction has a direct impact on food security.

The fourth assessment report of the IPCC reveals that towards the end of the twenty-first century, the temperature will increase by more than 3°C in South Asia (Cruz et al., 2007). Seventy-one per cent of households in Bagbahali reported that average temperature had been increasing in the previous six years. For both the south Asian and Indian monsoon systems, studies have indicated an increased inter-annual variability in rainfall events (Panda & Kumar, 2014). Seventy-five per cent of the households in Bilaikani and Bagbahali villages reported variations in average rainfall over the last 6 years.

5.2 *Livelihood vulnerability index*

The results of the LVI are exhibited in Table 9. To compare the extent of vulnerability of the major component among the villages, a supporting graph is given in Figure 2.

The LVI of households provides a clear indication of the capabilities, assets, and activities required for a sustainable means of living for the respective household (Chambers & Conway, 1992). All villages had similar LVIs with slight variations. Aintalunga had the highest LVI (0.586), indicating relatively higher vulnerability. This may be due to the high index values of sub-components such as LS, food and water. LVI was the lowest for Sirabahal village, showing less vulnerability in terms of livelihood strategy, food and drought, which had made this village the least vulnerable to livelihood.

Table 9. LVI of villages in the Balangir district.

Index	Sirabahal	Bilaikani	Aintalunga	Bagbahali
LVI	0.547	0.558	0.586	0.573

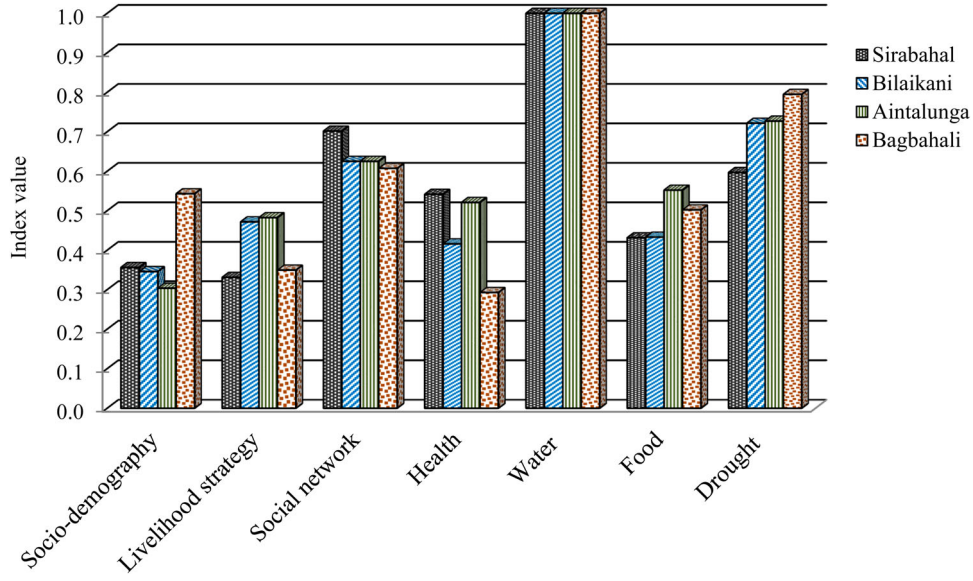

Figure 2. Index values of major components of villages in Balangir district.

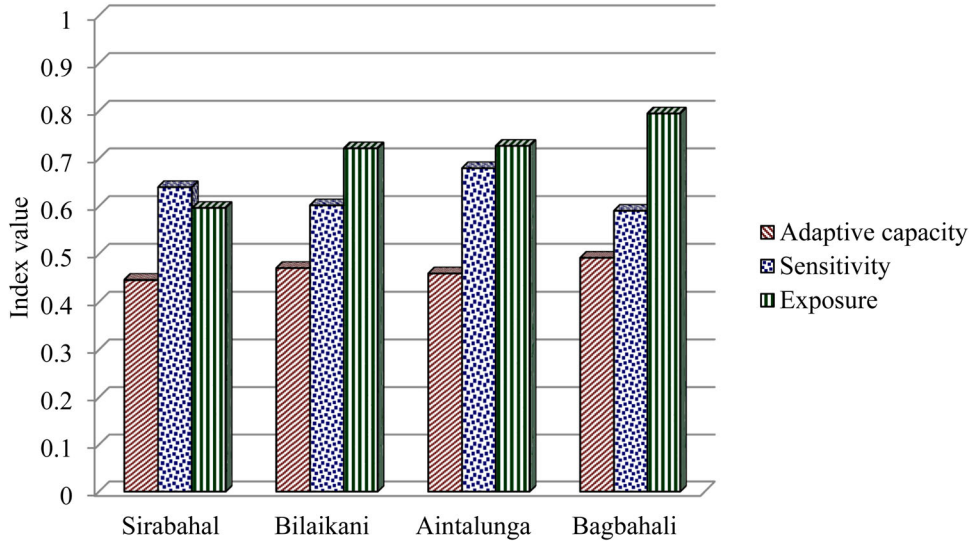

Figure 3. Index values of the IPCC dimensions of villages in Balangir district.

Bilaikani had a LVI of 0.558. This village had the highest scores for sub-components, such as livestock assets, lack of access to banks and schools. The LVI of Bagbahali was 0.573; this village had the highest vulnerability level in terms of SDP.

5.3 *Socio-economic vulnerability index*

Figure 3 illustrates the index values of three IPCC dimensions of vulnerability, and Table 10 shows the results of the SeVI. SeVI was highest for Aintalunga village (0.649) and lowest for Sirabahal village (0.597).

Table 10. SeVI of villages in the Balangir district.

Index	Sirabahal	Bilaikani	Aintalunga	Bagbahali
SeVI	0.597	0.618	0.649	0.631

Bagbahali had the highest vulnerability level in the case of adaptive capacity (0.492). The high index value of the SDP had led to the high vulnerability of the adaptive capacity of Bagbahali. The index value for sensitivity was highest for Aintalunga (0.680). A high level of disease-affected households, lack of health insurance, lack of own water sources and a high dependency on public tube wells or natural sources of water made Aintalunga village highly sensitive to drought risk. The index value for exposure was highest for Bagbahali village (0.795), followed by Aintalunga (0.727), Bilaikani (0.722) and Sirabahal (0.597). All villages were affected by droughts on a yearly basis. Because most of the households in these villages listed agriculture as the primary occupation, drought affects agriculture leading either to crop loss or to yield reduction. The people reported that drought is a common scenario and had become part of their life.

The results of the LVI and SeVI had the same trends in all four villages. The results of both LVI and SeVI showed that Aintalunga was the most vulnerable village among the four, followed by Bagbahali and Bilaikani. Sirabahal village had the lowest LVI and SeVI.

Studies related to LVI have been carried out in some countries such as Mozambique (Hahn et al., 2009), Trinidad and Tobago (Shah, Dulal, Johnson, & Baptiste, 2013), Ghana (Antwi-Agyei, Dougill, Fraser, & Stringer, 2013), Nigeria (Ahmed et al., 2014), Nepal (Aryal et al., 2014) and Ethiopia (Simane, Zaitchik, & Foltz, 2016). On the other hand, one study focusing SeVI was conducted in Bangladesh (Ahsan & Warner, 2014). The findings of these studies depict that livelihood diversification, social networking, infrastructure development and effective policy formulation may help households in coping with the negative impacts of drought.

6. Conclusions

The adaptation process usually starts with an assessment of risk and vulnerability associated with climate-induced extreme weather events and the impact it has on poor households with limited access to capital assets. The need for adaptation-enhancing measures could vary quite significantly depending on household access to endowments and entitlements. This study suggests some specific intervention strategies to reduce the vulnerability of rural households. The most favoured interventions to strengthen the SDP of households and ultimately reduce vulnerability would be to raise the level of formal education of all people, especially that of household heads. The most advantageous intervention for reducing livelihood vulnerability would be the diversification of LS that could provide opportunities for at least one member of the household to earn an income outside of a natural resource-dependent activity.

Sensitivity factors such as food, water and health must be addressed with the greatest importance by the local governing bodies and the local communities. Improved health facilities, safe and adequate water supplies and food security of households will help to reduce vulnerability. The lack of improved infrastructure and access to health and water infrastructure indirectly increases the vulnerability of households. For example, long travel times to distant health centres and water sources consume household time that could be spent in wage-earning activities, and hence, such situational conditions of access and infrastructure may be required to deliver relief for households during natural hazards.

As far as exposure is concerned, the failure of crops, food shortage and diseases due to drought increase the vulnerability of rural households to a great extent. Local drought disaster management and relief plans need to be developed in conjunction with local communities. Ex-post impact assistance must also be developed to ensure speedy recovery from the negative effects of droughts. Along with the increasing severity of impacts temporally as well as spatially, systemic changes may be required by different stakeholders in the rural community, especially financial sectors and government institutions that handle social protection and welfare administration. The outcomes of this study may be taken into account to develop location-specific strategies, policies and programmes that would reduce the vulnerability of rural households, particularly in India.

It is likely that the findings and recommendations of this study will find applicability in other rural, natural resource-dependent countries with similar socio-economic profiles such as other south Asian countries. A comparison of LVI and SeVI between countries with different socio-economic characteristics is inconsistent as the sub-components used are different according to the region. Hence, it paves the way for a future research endeavour on standardizing these sub-components so that it can be applied to different countries that are affected by natural disasters to calculate and compare the LVI and SeVI on a common scale.

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No potential conflict of interest was reported by the authors.

Notes

1. Depending on the geographical area and population, India is divided into several states. Each state comprises of several districts. The blocks are administrative subdivisions of a district that is again divided into village level local bodies called *grama panchayats* (GPs). Each GP is comprised of several small villages.
2. The Indian population is categorized into four social castes: forward caste, backward caste, scheduled caste and scheduled tribes (Pruthi, 2004). Each caste category includes several castes, depending on the state/regions.

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Appendix

Table A1. Sub-component values with their maximum and minimum values of villages in the Balangir district.

Sub-components	Units	Sirabahal	Bilaikani	Aintalunga	Bagbahali	Maximum value[a]	Minimum value[b]
Dependency ratio	Ratio	0.64	0.56	0.72	0.75	4	0
Per cent of female-headed households	Per cent	12.90	9.09	12.96	53.57	100	0
Per cent of illiterate household heads	Per cent	19.35	18.18	25.93	42.86	100	0
Per cent of backward caste households	Per cent	90.32	97.73	68.52	100	100	0
Housing structure index	Index	0.30	0.28	0.25	0.35	0.5	0.17
Average livelihood diversification index	Index	0.36	0.41	0.44	0.38	0.5	0.25
Per cent of households depending solely on agriculture for livelihood	Per cent	12.90	43.18	44.44	25	100	0
Per cent of households without migrant members	Per cent	51.61	50.00	55.56	42.86	100	0
Average livestock asset diversification index	Index	0.44	0.61	0.54	0.44	1	0.2
Average durable asset diversification index	Index	0.40	0.39	0.36	0.37	1	0.17
Per cent of households without assistance from NGO/SHG	Per cent	100	34.09	74.07	71.43	100	0
Per cent of households with access to informal credit institutions	Per cent	100	100	100	100	100	0
Per cent of households without bank access	Per cent	41.94	63.64	42.59	35.71	100	0
Per cent of households without school access	Per cent	38.71	52.27	33.33	35.71	100	0
Per cent of households afflicted with diseases not due to drought	Per cent	32.26	50.00	74.07	60.71	100	0
Average distance to the Public Health Center	Kilometers	12.55	2.59	4.20	3.02	15	2
Per cent of households without health insurance	Per cent	100	100	100	46.43	100	0
Average monthly health expenditure of the household	US$	0.27	0.98	1.45	0.18	8.33	0
Per cent of households depending on public resources for household activities	Per cent	100	100	100	100	100	0
Per cent of households depending on natural resources for household activities	Per cent	100	100	100	100	100	0
Per cent of households with problems accessing water for household activities	Per cent	100	100	100	100	100	0
Per cent of households with problems accessing water for irrigation	Per cent	100	100	100	100	100	0
Per cent of households with insufficient food for consumption in a year	Per cent	51.61	54.55	66.67	78.57	100	0
Average number of months in which households struggle to obtain food	Months	1.22	1.80	2.24	3.03	5	0
Average monthly food expenditure of the household index	Index	0.03	0.04	0.03	0.05	0.12	0.02
Per cent of households depending on own farm for food	Per cent	74.19	72.73	85.19	82.14	100	0
Per cent of households not depending on PDS	Per cent	48.39	34.09	61.11	0.00	100	0
Per cent of households with diseases due to drought in the last six years	Per cent	67.74	65.91	88.89	85.71	100	0
Per cent of households with yield reduction/ loss due to drought in the last six years	Per cent	74.19	81.82	88.89	85.71	100	0
Per cent of households that report average temperatures have increased in the last six years	Per cent	51.61	65.91	53.70	71.43	100	0
Per cent of households that report variation in average rainfall in the last six years	Per cent	45.16	75.00	59.26	75.00	100	0

[a]Maximum value in four villages of the Balangir district.
[b]Minimum value in four villages of the Balangir district.