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ORIGINAL ARTICLE

Fishery livelihoods and adaptation to climate change: a case study of Chilika lagoon, India

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Abstract Climate change combined with human activities poses significant risks to people's livelihood especially in developing countries. Adaptation at the community level is of crucial importance in enabling them to respond to the direct and indirect effects of changes in climate. In a case study of fishing communities in Chilika lagoon, India, the focus is made on understanding climate change adaptation at the community level and scaling it up into the policy perspective through application of Sustainable Livelihood Approach. This article challenges the research and policy community to encourage the identification of locally negative constraints and positive strengths toward climate resilient communities in rural areas.

Keywords Climate change · Adaptation · Livelihood · Sustainable livelihood approach · Chilika lagoon

1 Introduction

Over the past decades, changes in climate have been commonly observed in many parts of the world. It is apparent that changes in temperature and rainfall and resulting increases in frequency and intensity of flood and drought events have affected ecological and social systems on the earth. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, warming atmosphere of the climate system is now unequivocal (IPCC 2007). Climate change poses significant risks to the livelihoods, culture and health of millions of people (Barnett 2003). Ecological and climatic disasters—hurricanes,

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tornadoes, draught, flooding, landslides—are becoming more frequent, resulting in devastation to family and communities, especially the poor living in precarious environments (Ogata and Sen 2003). Related to this, the number of climate-led disaster events and affected populations has been increasing during the last decades according to the data from EM-DAT (2008) reference.

Vulnerability is usually characterized as forms of the characteristics, extent and frequency of exposures and sensitivity, and people's capacity to adapt to these hazards. In the discipline of climate change, Bernett and Adger (2007, p. 641) argued, "the vulnerability of people to climate change depends on the extent to which they are dependent on natural resources and ecosystem services, the extent to which the resources and services they rely on are sensitive to climate change, and their capacity to adapt to changes in these resources and services". Given that the climate is becoming more variable and creating various risks, people will need to adapt to the impacts from changes that are already unavoidable (UN/ISDR 2007). Thus, the last third function (adaptive capacity) of vulnerability is a critical key in building people's resilience to climate change.

Efforts to combat climate change at the community level are of special concern for livelihood security especially in developing countries. As a matter of fact, local communities are already reporting the effects of variations in climate that tend to affect some of the poorest and most vulnerable communities around the world (Rojas Blanco 2006; Shaw 2007; Sperling 2003; UNDP 2007). Poor communities are often most exposed to climate change because of where they live or their livelihood activities occur (DFID 2004). Obviously, coastal areas are one of the most vulnerable places due to sea-level rise, increased level of inundation and storm flooding, coastal erosion, seawater intrusion and increased temperature (Torresan et al. 2008). Communities in the coastal areas tend to be dependent on climate sensitive resources and coastal people do not have the means to adapt fast enough (Ziervogel et al. 2006). The vulnerabilities of those who live in coastal areas and need to build their resilience to cope with such climatic fluctuation are among the more important challenges in adapting to increasing climate change (FAO 2007). Among the poor, the case study evidence found that poor farmers have reduced their vulnerability and have increased their adaptive capacity to climate variability by diversifying their strategies and the crops they plant (Ziervogel et al. 2006). It is important to address people's needs to develop an adaptive strategy to adjust to ecological-social-economic system in response to actual or expected climatic change and its impacts (Smit et al. 1999).

Based on the above, this article aims to understand climate change adaptation at the community level by applying 'Sustainable Livelihood Approach (SLA)'. Firstly, we introduce the concept and significance of SLA which enables to integrate the results from sample communities to the larger archetypal livelihood region with design of expected fishery strategies for climate change adaptation. Secondly, this article describes the profile of the field study site (Chilika lagoon) and illustrates the trend of climate variability and related people's perception. Thirdly, we analyse each livelihood asset in fishing communities and identify vulnerability to climate changes. Based on these analyses, we finally draw implications about community-based climate change adaptation in Chilika lagoon.

2 Livelihood perspective for identification of climate change adaptation

Although climate change adaptation has been discussed over the past several years through organizational and adaptive responses, not enough attention has been paid to focus on adaptation at the community level and to integrate adaptation methods into a policy perspective (Shaw 2007). Specially, adaptation faces some difficulties in scaling up from case studies (Van Aalst et al. 2008). Identification of adaptive capacity is context-specific and varies from community to community, among social groups and individuals, and over time (Smit and Wandel 2006). Local experiences may provide effective information to plan for the future in certain communities, but the lessons learned from the case studies are not necessarily applicable to other communities or regions. Thus, community-based adaptation to climate change requires the recognition of multiple stimuli beyond those related to climate, including political, cultural, economic, institutional and technological forces (Smit and Wandel 2006).

Under the circumstances, addressing the principle of livelihood approach in rural society can be considered effective adaptation at the community level and can be integrated into policy-making strategies. In rural areas, people depend on rather climate sensitive occupations such as fishing, farming and forestry that are closely linked to people's lifestyle. In particular, small-scale fishermen that are targeted in this article are subject to strong restriction of nature's forces so that for instance, they tend to adapt to migratory fish distribution on the basis of climate related seasonality and fish ecology. In other words, their practices must adjust to these biological factors, causing the fishermen to separate their living area from other communities (Pollnac 1991). This linkage between climate and practice means that climate change adaptation measures can be commonly scaled up from the sampling communities to the larger archetypal livelihood region of which it is a part.

In addition, the livelihood perspective provides a good entry point to develop a meaningful understanding of pressing constraints and positive strengths toward climate resilient communities. In terms of climate preparedness, Ziervogel and Calder (2003) pointed out that ability to predict seasonal patterns causes effects of not only occupational activities but also the multiple dimensions of rural livelihoods that have secondary effects and determine people's capacity to handle future stress. The impacts of climate change cover multifaceted aspects of rural livelihoods so that there is an urgent challenge in understanding the broad relevance to livelihood contexts and their linkage with climate change.

Based on these discussions, this article applied the 'Sustainable Livelihood Approach (SLA)' in an effort to understand climate change adaptation at the community level and scale up from the sample communities to the larger archetypal livelihood region. SLA represents a new paradigm of poverty reduction, and is an innovative tool originally developed by UNDP on the basis of the 1987 UN Environment Summit and Chambers and Conway (1992). SLA provides a way of thinking about livelihoods of poor people in the context of vulnerability (DFID 1999). The application of SLA in the form of climate change adaptation helps researchers and practitioners identify pressing constraints and positive strengths of climate resilient livelihoods in rural areas with overlaps between micro and macro links. According to the SLA model developed by DFID (1999), the framework compromises three components: 'livelihood assets (natural, financial, social, human and physical capital)', 'vulnerability context (vulnerability analysis)' and 'structure and process (institutional analysis)' (Fig. 1). The SLA has been applied flexibly in various ways, but the framework places high emphasis on the linkages among the three components so that users are encouraged to draw up the best adaptive strategies called 'livelihood strategy' with 'livelihood outcomes'. However, the SLA has seldom been applied to field situations especially in the field of fisheries (Allison and Ellis 2001; Allison and Horemans 2006). Carney et al. (1999) argued that the reason for limited applications in part because the framework is so broad, seemingly too abstract for field level staffs. There is a need to apply

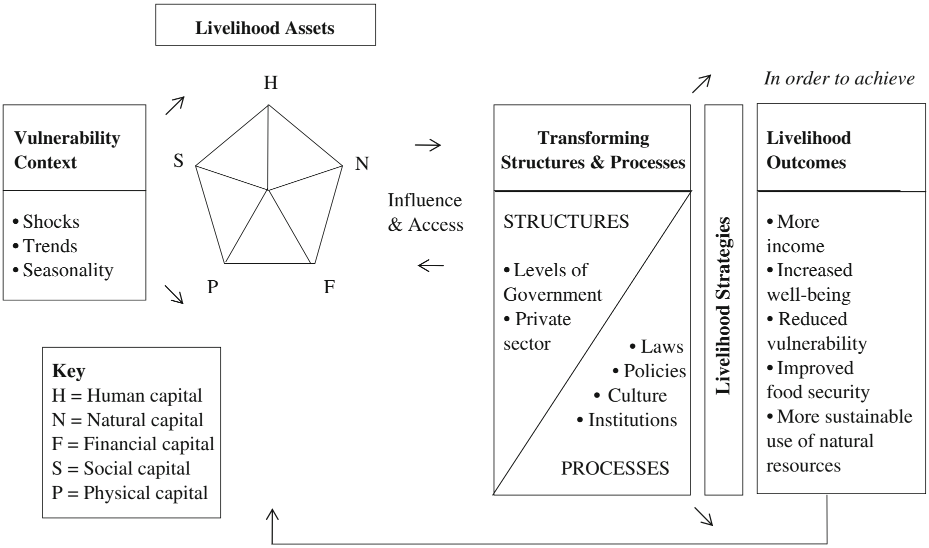

Fig. 1 Sustainable livelihoods framework (from DFID 1999)

the SLA in a much narrower and more precise term. In this respect, this research tries to put the principle of the SLA into the discipline of community-based climate change adaptation in a specific way, enabling us to compensate for the weakness of the SLA.

Our field survey was conducted in Chilika lagoon during November and December 2007. The case study was carried out in four fishing communities of Chilika lagoon where two communities are located in inland and two are coastal areas along the Bay of Bengal. Even for a particular livelihood or region, vulnerability is unlikely to be the same for climate stimuli (Smit et al. 1999; Smit and Wandel 2006). Therefore, there is a need to understand the differences among exposures, sensitivity and adaptive capacity between inland and coastal areas of Chilika lagoon. The research used both qualitative and quantitative data, including structural questionnaires, participatory rural appraisal (PRA), key informants interviews and secondary data. In this article, the primary data from structural questionnaires were collected from 25 households in each fishing community, bringing the total to 100 household samples. The questionnaires used a multiple-choice format and were compiled into six sections: general household information, climate risk perception, economic, social and environmental impacts of climate change, and coping mechanism. Further, venn maps, problem trees and seasonality maps were applied as a PRA exercise for identification of vulnerability. Likewise, semi-structured interviews with key informants (government officers, village leaders, NGOs, researchers) were carried out to validate and complement the information.

3 Trend of climate variability and people's perception

3.1 Profile of field study site (Chilika lagoon)

Chilika lagoon is the largest lagoon in India, and is situated between 19°28′ and 19°54′ North latitude and 85°05 and 85°38′ East longitudes (Fig. 2). The lagoon extends from southwest corner of Puri and Khurdra districts to the adjoining Ganjam district of Orissa

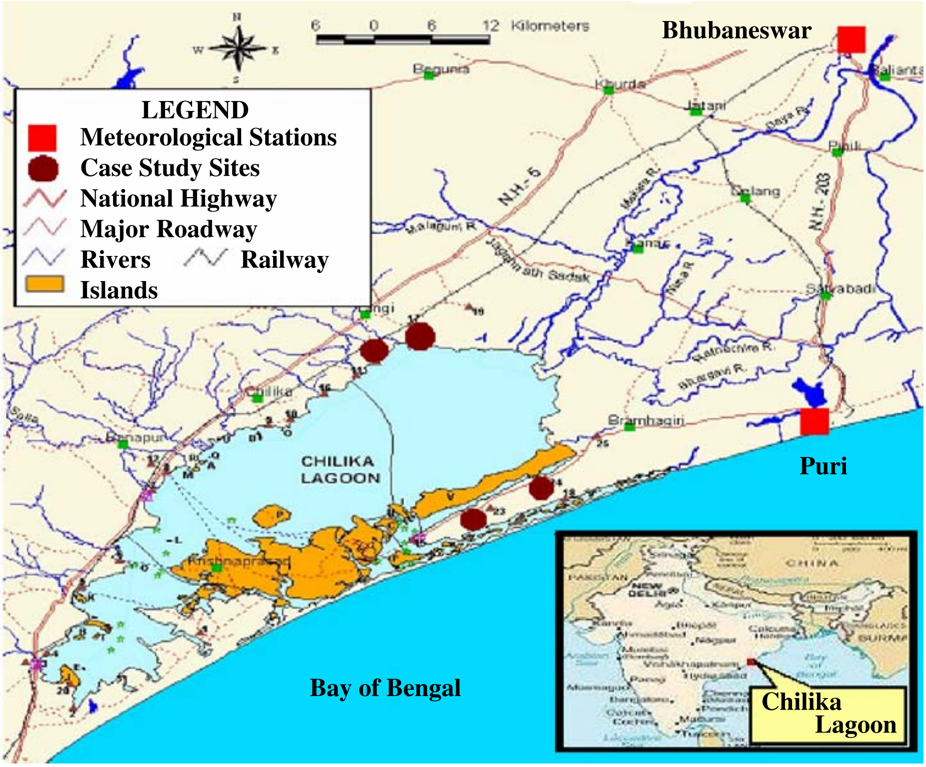

Fig. 2 Map of Chilika lagoon (revised from CDA data)

state. The average lagoon area is 1,055 sq. km. which increases to 1,165 sq. km. July to December and shrinks to 906 sq. km. December to July (Pattnaik 2002). Chilika lagoon becomes less saline during the rainy season due to flood waters from 52 rivers and rivulets. It becomes more saline during the dry season as the supply of flood water is cut off when the south wind begins to blow and saline waters enter from Bay of Bengal at high (Patro 2001).

The water environment in Chilika lagoon is a unique assemblage of marine, brackish and fresh water ecosystem with estuarine characteristics. This combination has endowed a highly productive ecosystem and a valuable biodiversity including endangered species like the Irrawady dolphin (*Orcaella brevirostris*). These valuable characteristics allowed Chilika lagoon to be listed as a wetland of international importance under Ramsar Convention and became the first Ramsar site of India in 1981. There are reported to be 132 fishing communities in Chilika lagoon. The rich ecosystem of Chilika lagoon enables more than 200,000 fishers and thousands of local persons who are engaged in allied fishery business activities to support their livelihoods (CDA 2005). In regard to fishing occupation, traditional fishermen include seven sub-caste groups: Keuta, Niari, Kartia, Kandara, Gokha, Tiara and Nolia (Mitra and Mahapatra 1957). Most of them belong to Schedule Caste (SC) and their societal status is quite low as they belong to the poorest of the society.

3.2 Trend of climate change in Chilika lagoon

Chilika lagoon which is a part of Orissa state, India is considered to be climate-prone area in India. Although limited quantitative data on climate change effects in Chilika lagoon are available, floods, droughts, heat waves and sometimes cyclones are common features at the state level. The socio-economic condition of the people in Orissa state is strongly influenced by various natural forces (Gupta and Sharma 2000).

3.2.1 Temperature

Chilika lagoon is typically tropical with average annual maximum and minimum temperatures of 39.9°C and 14°C, respectively (CDA 2008). Changes in temperature, even small changes in water temperature are expected to exert strong pressure upon fish ecology (WWF 2005). Temperature variations also affect people's health undermining their capacity for operating the fisheries. According to the statistical fixed-point observations in two meteorological stations (Bhubaneswar and Puri), it seems that the apparent warming trend has not been seen in Chilika lagoon (Fig. 3), as opposed to the world's expectation (IPCC 2007). However, it seems that there is a slight warming trend of mean maximum and minimum temperature especially in the hottest month.

On the other hand, some districts of Orissa state experienced in severe unusual high temperature in 1998 where 954 people died, the worst tolls in all India (IDR team 2000). As well, in 2004 strong sunstroke prevailed in 16 districts of Orissa state from April to June, causing the deaths of nine people in Chilika lagoon area (SRORD 2005).

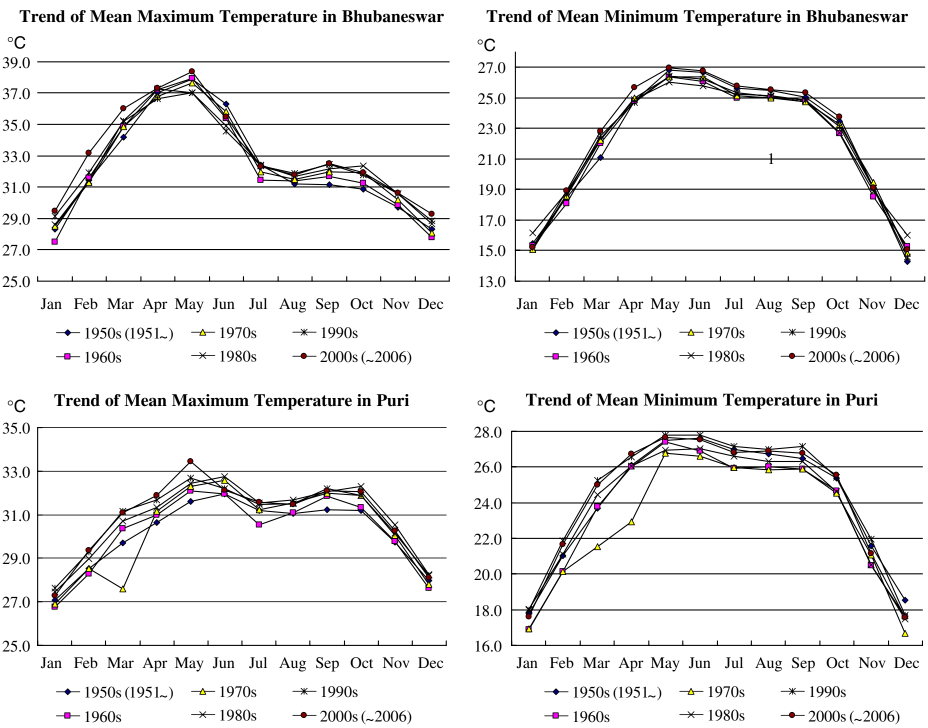

Fig. 3 Trend of mean highest and minimum temperature in Bhubaneswar and Puri

3.2.2 Cyclones

Chilika lagoon which covers Khurda, Puri and Ganjam districts is classified in 'very high damage risk zone (50 m/s)' in terms of wind and cyclones. The lagoon is situated along with the Bay of Bengal which is one of the six major cyclone-prone regions of the world. The annual cyclone from the Bay of Bengal normally occurs in the months of April to May and October to November. Increasing warm sea temperature (approximate 26.5°C) in the Bay of Bengal induces the cyclone to become more intense as it gets close to the coastal areas of India (Gupta and Sharma 2000). On an average, every year four to five cyclones strike the coastal regions of India (Shanmugasundaram et al. 2000). Coastal districts of Orissa state have been hit by 11 severe cyclones and 55 cyclone storms with a probable maximum storm surge height between 3.2 m to 5.5 m in the last 120 years (Gupta and Sharma 2000).

Importantly, Orissa state in 1999 experienced a 'Super Cyclone', its worst catastrophic cyclone in 100 years. The super cyclone swept the entire Orissa coastal area, affecting 15,681,072 people, 14,586 villages, causing 9,893 deaths and damaging 1,661,683 houses (Gupta and Sharma 2000). Fortunately, Chilika lagoon avoided much of the possible loss of human life though the cyclone caused tremendous damage to fishing gears and houses in and around the lagoon. Cyclones have a short-term as well as long-term impact on fishery livelihoods in terms of damages to vital infrastructures (school, hospital road network) and less access to medical supports, water use and official loan provision. Those losses were evident in the Chilika lagoon after the 1999 super cyclone, led to the traumatic perceptions for fishing communities.

3.2.3 Floods and droughts

In addition to cyclones, floods are common in Chilika lagoon. The majority of the annual rainfall occurs from June to November (Fig. 4). The southwest monsoon brings much rainfall from June to September while the northeast monsoon brings some rain in October and November. The highly concentrated rainfall in July and August provoked flooding of the major streams. Chilika lagoon receives fresh water from 52 channels, especially two

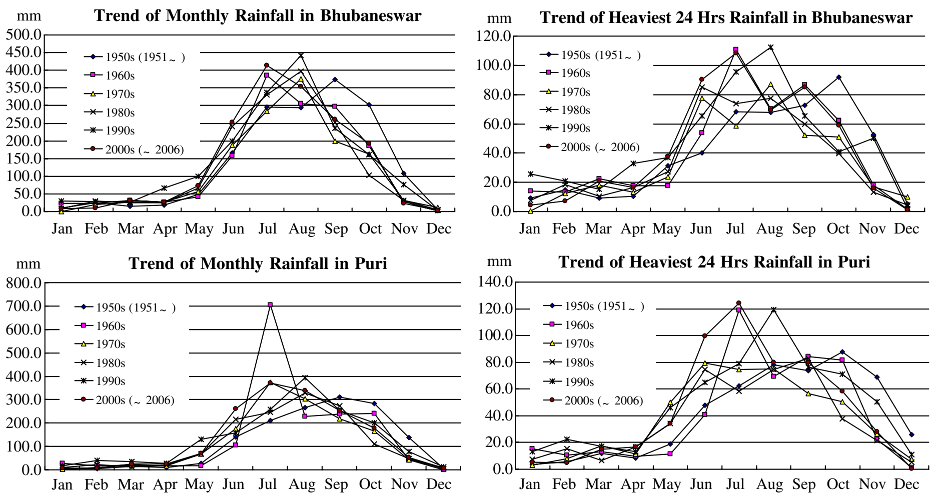

Fig. 4 Trend of monthly and heaviest 24 hrs rainfall in Bhubaneswar and Puri

principal streams (i.e. river Daya and Bhargavi) which are sub-branches of the Mahanadi river system which is prone to be affected by extreme floods.

From 1834 to 2007, 76 flood events were recorded in Orissa state (OSDMA 2007). Although flood control efforts have been completed by the Orissa state government (e.g. construction of dams, weirs), there were 11 floods records during the past quarter century (1988 to 2007) while there were 32 floods records during the century from 1834 to 1933. The report indicates that vulnerability has been slightly increasing for decades both in terms of frequency and intensity of floods. Importantly, flood events have been continuously recorded in Orissa state since 2003. In terms of flood, the fishermen tend to suffer losses or damages of fishing boats and materials. There is a need to promote a coordinated flood response which people move their boats and nets to a secure location.

Droughts are also of concern for the people's livelihoods. It is likely that average monthly rainfall near Chilika lagoon is significantly decreased except during the monsoon season (Fig. 4). In the last decade (1995 to 2004), there have been six moderate and severe droughts in various parts of Orissa state (SRORD 2004, 2005). Although fishing communities are less vulnerable to droughts than agrarian communities, the former are faced with some difficulties in having an access to adequate water for drinking, cooking, bathing, and available water often is of low quality. The water scarcity and pollution combined with anthropogenic pressures endanger the health of the people and interfere with every aspect of life.

3.2.4 Environmental degradation

Apart from direct effects of climate stimuli, a range of human activities on the landscape induce various types of environmental degradation. In particular, siltation is broadly recognized by stakeholders as a key environmental issue in Chilika lagoon. A large quantity of silt from the upstream has been deposited in the lagoon due to the combination of increased flooding and anthropogenic pressures such as deforestation and overgrazing. Pattnaik (2005b) estimated that around 1.6 million tones of sediment annually flowed into Chilika lagoon. The silt accumulation reduces the water spread area and hinders the exchange of water between the sea and river, resulting in decreased salinity and lower availability of fish species in the lagoon. Siltation into the lagoon also encourages prolific growth of freshwater invasive species. The area of Chilika lagoon dominated by invasive plants increased 20 sq. km. in 1972 to 685 sq. km. in May 2000 (CDA 2005). These changes reduce the area of fishing grounds in Chilika lagoon. That, in turn, leads to loss of income that can render fishers more vulnerable to climate change. Further, the weed invasion presents physical difficulties for boat navigation, further undermining people's adaptive capacity to climate change.

3.3 Risk perception of climate change

While various exposures to climate changes in Chilika lagoon have been reviewed through secondary data and research papers, people's perception is also of importance to consider their behaviour and responsive actions (Grothmann and Patt 2005). According to the results of the questionnaire survey, many people, irrespective of inland versus coastal areas, perceived the phenomenon of climate change in the form of increasing drought (65%) and high temperature (78%) in Chilika lagoon. Likewise, most of them (72%) believe that a catastrophic cyclone like 1999 super cyclone will occur in Chilika lagoon in the near future. On the other hand, inland versus coastal people have different perceptions of climate change especially in the form of floods. 70% people in inland areas tend to feel that flood frequency and intensity are the same as they used to be. However, 62% of those who live in coastal areas feel the variability has increased.

As for climate exposures and sensitivity, there is a consensus about the risk perception between the two areas (Table 1). Most of people ranked cyclones as the most prevalent climate hazard. Each climate hazard (cyclones, floods, droughts and high temperature) was regarded as risky or most risky. In this respect, it is worth noting that the perception of people in inland areas was higher than that of people in coastal areas. The former seem to be more aware of climate variability and extreme events than the latter. According to the informant interviews, differences can be related to the super cyclone of 1999. The super cyclone affected in Chilika lagoon, though the cyclone did not strike there directly. In contrast, fishermen in inland areas incurred heavy losses from the cyclone because they went to fish in Chilika lagoon. Before the cyclone made landfall, the government issued numerous early warnings. Despite that, people in inland areas did not take the warnings seriously. They did not believe that the hazardous cyclone would strike Chilika lagoon, nor did they believe the predictions of damage to human health and boats. On the other hand, coastal communities bore the brunt of the cyclone to a great extent because the fishermen chose not to fish in those areas. Responses between people in these two areas were reflected in their perception of vulnerability; the vulnerable people in coastal areas were identified as disabled persons, followed by women, fishers and children. In contrast, people in inland areas as most vulnerable fishers, followed by women, children and disabled persons. Also, due to proximity to the sea water, the coastal communities may have more experience to related impacts rather than the inland communities. The different experiences between the two areas likely changed their perceptions of risk due to climatic change hazards.

4 Livelihood assets analysis

This section aims to assess each livelihood asset (natural, human, financial, physical and social capital) and link it with climate change in community context. The research is based on the SLA framework (DFID 1999).

4.1 Natural capital

Chilika lagoon has experienced severe environmental deterioration primary from siltation since the 1980s. In combination with anthropogenic pressures such as deforestation, overgrazing and industrialization, seasonal climate forces such as cyclones and floods brought a lot of silt into the lagoon. Silt promotes agglutination and precipitation reactions when it flows into salty water, leading to silt accumulation in the lagoon area especially near the sea mouth. That causes a cut-off of the sea mouth between the sea and lagoon. The

Table 1 Ranking of risk perception of climatic change hazards

	Cyclones	Floods	Droughts	High temperature
Inland	1st (3.7)	2nd (3.5)	4th (3.0)	3rd (3.1)
Coast	1st (3.2)	2nd (2.8)	4th (2.6)	3rd (2.7)
Total	1st (3.5)	2nd (3.1)	4th (2.8)	3rd (2.9)

*The ranking is based on the total numbers of risk perception. Value in blackets shows the average number of risk perception (Most risk–4, Risk–3, Less risk–2, Least risk–1)

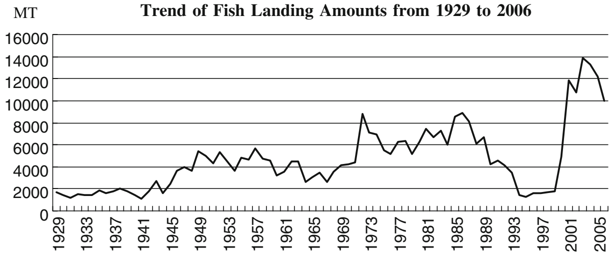

Fig. 5 Trend of fish landing amounts from 1929 to 2006 (revised from DFGO 1970; DFGO CDA 2005; CDA data)

closure of sea mouth affects salinity level in the lagoon and prevents exchange of migratory fish species, which account for nearly 80% of lagoon fisheries catch (Pattnaik 2005a). Climate changes affect not only fish in the eco-system but also fishing activities in certain periods. Fishers are forced not to fish during monsoon heavy rainfall and cyclones.

In an effort to solve the serious situation, Chilika Development Authority (CDA) implemented a successful wetland restoration project around the year 2000. In short, CDA, which was established in 1991, enforced innovative hydrological interventions (opening of a new mouth and dredging water channels) in collaboration with research institutions, NGOs and the local people. The hydrological interventions resulted in the dramatic improvement of the natural and social lagoon environment (CDA 2005). Fish production remarkably improved (Fig. 5). At maximum, the amounts of fish landings were recorded to be around 14,053 metric tons in 2003 to 2004, compared to around 1,600 metric tons prior to the interventions. Related to this, the government estimated that fisher family income increased around ten times in 2003 to 2004 compared to before interventions in 2000 (DFGO CDA 2005).

It should, of course, be kept in mind that the technical interventions can be just temporal end-of-pipe measures to cope with siltation. There has been a gradual decrease of fish landing amounts after the hydrological implementations (Fig. 5). In response to this situation, CDA adopted a concept of participatory micro-watershed management that seeks to involve the local people in the project, in order to mitigate the impacts of siltation caused by climate extreme events combined with anthropogenic pressures from upstream. These changes at the watershed level are expected to play an important role in reducing silt accumulation in the lagoon, leading to sustainable lagoon fisheries.

4.2 Financial capital

The livelihoods of fishing communities largely depend on the fisheries from Chilika lagoon. Most of them (97%) have no secondary occupation, so fishing is a sole income source for them. The fishermen normally use traditional small-scale boats with various fishing gears. On the whole, members of fishing boats in Chilika lagoon are limited to family or neighbors, and their profits are equally distributed among them. Household incomes per month in inland and coastal areas are Indian Rupee (INR) 1,190 (approximately US$ 30) and INR 1,332 (approximately US$ 34) in rainy season while INR 2294 (approximately US$58) and INR 2564 (approximately US$65) in dry season, respectively.[1] The income is not sufficient to cover their living expenses especially during

[1] An exchange rate of US$1 = INR39.25 is used throughout this study.

the rainy season because they cannot often go fishing due to extreme rainfall and winds. In fact, 90% of respondents borrowed money from fish merchants at an average of INR 29,483 with interest free. The loan provisions are addressed through purchasing or repairing fishing gears, instead of informal fish trade promises at lower price. As a result, the dependency pushes households to the brink and led to nearly-defunct fishery cooperative societies in terms of fish marketing (Iwasaki and Shaw 2008). Due to lack of money, around 50% of households have poor housings that are highly vulnerable to climate hazards. On account of this, expenditures for food and fishing gears were regarded as the highest priorities while electric products and savings were identified as lowest ones.

Although private and government banks provided loans to the fishermen for the purpose of reducing dependency on fish merchants, the attempts were failed due to loan defaults with psychology of 'loan waiver' (Samal and Meher 2003); debtors could easily escape the duty for loan repayment from the lenders while continuing to lie about who were debtors. Indeed, only 57%, 49% and 10% of total loan amounts were repaid to private banks, government banks and National Cooperative Development Corporation, respectively (ARCSCCB 2005). On account of this, the formal banking institutions were forced to withdraw the loan scheme for small-scale fishermen. It created more space for control of the fish economy by fish merchants combined with informal money lending, resulting in the high vulnerability of livelihood conditions against future climate.

4.3 Human capital

Changes in climate may endanger health condition. According to problem tree analysis on climate change, all fishing communities commonly identified disease issues affected by climate change. In particular, the local people were vulnerable to increasing temperature and water pollution. Due to increasing temperature, the local people often developed eye inflammation (48%). Likewise, water pollution affected their health in various ways. In all targeted communities, there is no tap water available. Water supply depended upon three types of well waters (pipe well, tube well and well) and ponds. In response to climate changes and anthropogenic pressures, these drinking water sources have become scarce and muddy. Both quantitative and qualitative changes in water resources increased people's exposure to various diseases such as cholera (17%), diarrhea (26%) and viruses (35%). On the other hand, there are no sanitary facilities in fishing communities so that once heavy rainfall occurs, people are forced to move to public spaces or even within villages for toilets, a situation are susceptible to social disputes among villagers or among neighbor villagers. Given that they have less access to medical support due to remote distance and lack of money, their low health resistance may undermine their fishing activities and livelihoods.

Related to education, around 25% of people over 15 years (N=410) had no educational experience while only around 5% could enter college or university. Most of the people (59%) dropped out before high school. On account of this, only 55% people can read and write their native language (Oriya), resulting in various constraints on alternative jobs, health care and formal credit taking that are largely linked to enhancement of other capital assets. Lower education limits alternative jobs except fishing and related industries so that there is an increasing trend of fishing population in Chilika lagoon. It creates high competition over limited fishery resources and triggers disputes among fishers related to social capital. More importantly, children who have started fishing can be commonly observed in Chilika lagoon. They are more vulnerable to climate variability and extreme events than the adults, but there is no choice for them but to engage in the fisheries. The root cause for that was mainly attributed to lack of money, but also linked to affairs of formal schooling. According to the problem tree analysis, some people in coastal areas tend to be reluctant to go to high school because of caste discrimination. High school situates in non-fishing villages where the sense of caste discrimination remains leading to one or more obstacles for entering high school.

4.4 Physical capital

Natural calamities in combination with climate change often result in great degree of devastations to basic infrastructures and physical goods as well as a large number of causalities. The physical environment surrounding the fishing communities is very poor. The fishermen force to make use of unreliable boat jetties attached to just raised ground. Villagers stressed that the catastrophic cyclones and floods damaged physical capital, including infrastructures (e.g. community roads and fish landing centers) and physical goods (e.g, boats, nets and houses). Once such climate hazards occur, community roads are easily damaged by fallen trees. At the same time, poor housing conditions are affected to a great extent and various diseases are caused by unsanitary environments (as discussed in Section 4.3).

Among physical capital assets, villagers identified fishing boats as the most seriously vulnerable to climate change (76%). 48% reported loss of boats. The loss leads to suspension of fishing activities, resulting in danger to family maintenance. Some of them may attempt to apply for loan finance from fish merchants. Confronting with this, Department of Fisheries and Animal Resources Development tries to encourage a disaster insurance scheme to fishermen through their fishery cooperative societies in order to mitigate impacts of climate hazards on lost or damaged fishing materials and causalities. That consideration could play a significant role in preventing the local people from experiencing disruption of fishery livelihoods.

4.5 Social capital

Regarding the sense of social cohesion within communities, differences are observed between inland and coastal areas. In coastal areas, 84% respondents regarded their communities' ties among villagers as strong. On the other hand, only 30% of respondents in inland areas regarded ties as strong while the others considered them as weak or very weak community. The difference seems to be related to population density. A major national highway touches Chilika lagoon along inland areas which bridges the route between rural and urban areas (Fig. 2). The easy transportation attracted a large number of people and as a result inland areas have become densely populated. In contrast, access from coastal to urban areas is not yet well developed so that the communities in coastal areas are relatively isolated from each other and need to build a give-and-take relationship within the villagers where appropriate. For this reason, it seems that the sense of social cohesion among villagers in coastal areas is higher than those in inland areas. The unity of social cohesion among villagers was strongly related to the different impacts of super cyclone between the two areas (Section 3.3).

However, it needs to be mentioned that the social cohesion in both areas is not adequate in terms of disaster preparedness. The local people have rarely prepared for keeping boats and nets in a safe place when cyclones or floods attack in their areas. Thus, the lack of mutual help combined with disaster awareness sometimes resulted in losses or damages of boat materials that undermined the people's capacity for fishery livelihoods.

5 Responding to climate change

On the basis of Section 4, this section explores adaptive strategies for climate change in the case of Chilika lagoon. Figure 6 shows expected fishery strategies under climate change, showing the impacts of vulnerability and institutional contexts. The strategies can be complied into two components: integrated lagoon basin management related to natural capital and climate resilient fishing communities related to the other capitals.

5.1 Toward integrated lagoon basin management

In the debates between fishery livelihood and climate change, the fishery resource (natural capital) is the core point to be addressed. The resource is the principal form of livelihood for survival and affects lives in various ways. However, the coastal zone that includes Chilika lagoon is considered to be a vulnerable water ecosystem. It is affected by the confluence of various aspects from the upland to the marine. In the case study of Chilika lagoon, siltation (soil erosion) is identified as among the most serious environmental problems in combination with climate variability such as extreme floods and cyclones. Exposure to silt accumulation reduces the water spread area and hinders the exchange of water between the sea and river, resulted in decreased salinity level and subsequent prolific growth of freshwater invasive species. As a result, the amounts of fish landing in Chilika lagoon rapidly decreased until 2000, thereby leading to the poorest people not being effectively able to adapt to climate variability and extreme events. Furthermore, the weed invasion obstructs passages from boat jetties to fishing grounds, sometimes leading to boat clashes and the subsequent disputes among fishers.

In an effort to maintain (and preferably improve) fish stocks, there is a need to integrate fishery resources into a watershed perspective. In this respect, Chilika Development Authority (CDA) has conducted a successful hydrological intervention (sea mouth management) in the short period, and also has adopted participatory micro-watershed management at the watershed level in the long period (Section 4.1). Practices regarded as integrated lagoon basin management help developing a pathway for strengthening adaptive

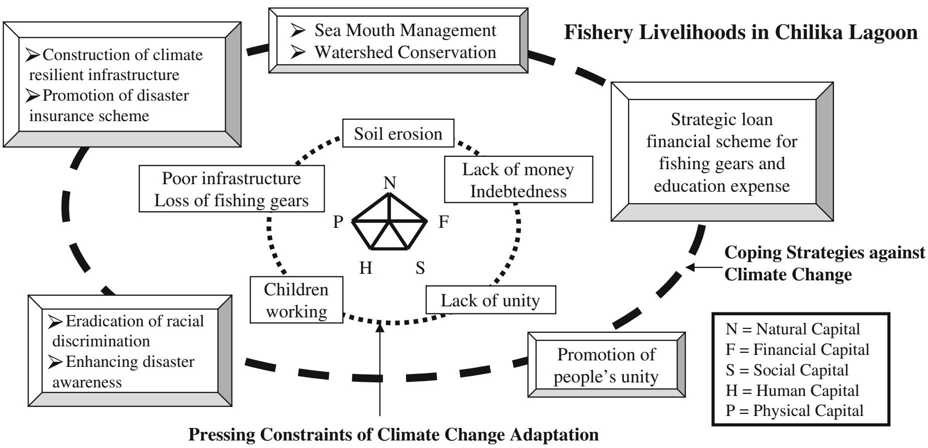

Fig. 6 Expected fishery strategies for climate change adaptation in Chilika lagoon

capacity to climate change as well as sustaining fishery resources. There is a further need to build multi-level collaborations and partnerships such as governments, NGOs, researchers and local people including in the upstream area as CDA did.

5.2 Enhancing climate resilient fishing communities

Practicing fisheries itself is very prone to be physically affected by various types of climate variability and subsequent environmental problems. Tremendous natural hazards that frequently occur in Chilika lagoon cause serious damages to fishing communities. In particular, people such as the aged, the disabled, women and children are vulnerable. Despite the early ages, for instance, children forced to start fishing are being exposed to climate hazards such as strong sunshine and cold winds. There is no choice for them but to engage in the fisheries; the entrance to schooling disallowed mainly due to lack of financial resources (Section 4.3). In this respect, the fishermen previously had opportunities for loan finance from private and government banks, though they failed to repay their loan amount to the banking institutions partly due to prevailing psychology of ‘loan waiver’ (Section 4.2). The failures induced a high dependency on fish merchants (Samal and Meher 2003) that undermined their capacity to adapt to climate change in terms of proper marketing activities and saving. In this respect, it is interesting to note an innovative approach developed by South Indian Federation of Fishermen Society (SIFFS). SIFFS provided loan finance from banks to a large number of fishing communities in the south of India after appropriate capacity assessment. Financing decisions were made on not only capacity assessment but also introduction of automatic deduction of the loan repayment from payment through cooperative fish marketing. SIFFS encouraged the fishermen to join the cooperative marketing activities for economic improvement as well as solution of ‘loan waiver’ after due consultation by NGOs and researchers. These efforts may offer one way to improve their livelihoods and make sure that their children are able to go to school and keep them in a safe environment. In addition, another effort needs to be made to eradicate caste discrimination in formal schooling (Section 4.3). Discrimination induces school children to join the fisheries in spite of that lifestyle being physically vulnerable to climate hazards. Therefore, a strategic loan financial scheme for fishing gears and education expense, and deliberate discussions on castism among various stakeholders is of high importance to climate change adaptations.

In addition, their physical capital is so low that it will be easily damaged or lost when disastrous events happen in Chilika lagoon. In this respect, promotion of natural calamity insurance supported by Department of Fisheries and Animal Resources Development is considered to be one of the best initiatives to enhance climate resilient fishing communities (Section 4.4). The insurance scheme enables all people including the poor to mitigate sudden shocks from climate variability and extreme events. Taking into account the increased intensity and frequency of natural disasters in Orissa state, the initiatives will play a greater role in responding to the direct and indirect effects of climate change in the long period. There is, of course, negative aspects to be considered. People in inland areas did not take early warnings by the government seriously when the super cyclone of 1999 made landfall. It led to tremendous damages to human and physical capitals (Section 3.3). Furthermore, irrespective of inland versus coastal areas, many people do not tend to adjust themselves to the changes in climate, even though catastrophic climate extreme events such as cyclones and floods attack their private and public goods including fishing materials (Section 4.5). Hence, enhancing disaster awareness and the sense of unity among the local people is recommended to mitigate the impacts of climate hazards.

6 Conclusions

Regional changes in climate have been observed in many parts of the world. They pose significant risks to people's livelihoods especially in rural areas where most of them depend on rather climate sensitive resources. Given that such occupations are subject to strong restriction of nature's forces combined with climate variability, their livelihoods are largely required to adjust to these climate factors.

Based on the above, this article applied a Sustainable Livelihood Approach (SLA) that enables researchers and policy makers to identify a wide range of livelihood aspects which give a clue to find pressing constraints and positive strengths of climate resilience. The research aimed to integrate the results from sample communities into the larger archetypal livelihood region (Chilika lagoon) with the design of expected fishery strategies for climate change adaptation. On the basis of this attempt, two major findings were identified to adapt to climate change in the context of fishery livelihoods in Chilika lagoon.

First, it is important to note that the impacts of climate change cover not just occupational activities but also multifaceted aspects of rural livelihoods that determine the extent of their capacity to adapt to changes in climate. As shown in Fig. 6, the range of expected fishery strategies covers all encompassing aspects including fishing, marketing, schooling, social cohesion and environmental and disaster awareness. Increase of fish species, for instance, meets an important requirement of capability for climate resilient communities but is not a necessary precondition for such communities. Dominance of fish marketing by fish merchants undermines fishermen's capacity to adapt to climate change while access to fishing grounds also affects them to a great extent. These vulnerabilities triggered dropouts of schooling and causes younger people to enter the fishing industry plaguing human lives, livelihoods and dignity. In this way, climate change does not occur independently of other processes impacting upon fishing communities so that there is an urgent challenge in linking the change with developmental processes (Thomas and Twyman 2005). Each vulnerability factor among their livelihood assets influences the extent of their capacity to adapt to climate change. Therefore, a holistic approach seeking climate change responses needs to be developed.

Second, it is worth noting that vulnerability is unlikely to be the same for climate stimuli even within a particular livelihood or region. In addition to exposures and sensitivity, the hazardous risk strongly depends on adaptive capacity that is attributed to multifaceted livelihoods. The case studies revealed that the vulnerability of people to 1999 super cyclone depended on to the extent of social cohesion and disaster awareness among the villagers, compared inland with coastal areas. As shown in Section 3.3, there were different risk perceptions and behaviours in response to climate extreme events between inland and coastal areas of Chilika lagoon. It is probable that the impacts of 1999 super cyclone can be explained by those differences as well as infrastructure conditions. Thus, practicing community-based case studies can provide deep information to fishing communities' climate resilience especially through human and social capital assets analysis. It provides a good baseline to help researchers and policy makers understand different impacts of same climate hazards even within a particular livelihood or region. In this respect, SLA may play a leading role in analysing adaptive capacity to climate change through livelihood assets analysis at the community level.

Finally, the application of SLA is rather new and still evolving, so the research method has been applied flexibly in various ways by researchers and policy makers. In this article, this analysis related to climate change requires more examination of the interaction among households on how to allocate their own resources and services to their family members.

The consideration can develop a better understanding of climate change adaptation in community context.

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