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Mangrove Conservation as Sustainable Adaptation to Cyclonic Risk in Kendrapada District of Odisha, India

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The state of Odisha, situated at the eastern coast of India, is highly vulnerable to climate variability and change due to the combination of poverty and high frequency of cyclonic related events. During the past few decades, severe cyclonic storms have disrupted the livelihoods of vulnerable coastal population. Since people's livelihoods are especially dependent on the region's rich biodiversity, it is necessary to understand the linkages between eco-systems and human societies in order to identify ways to reduce vulnerability and enhance resilience. These linkages are investigated through a case study of Kendrapada district, Odisha, based on focus group discussions and review of existing studies. The study finds that there are four reasons for the multiple threats on the mangroves: unsustainable economic growth, high population density, sea level rise and change in government policy. However, the study shows that conservation of mangroves can drastically reduce the physical impacts of cyclones and at the same time provide income generating opportunities to coastal communities, hence contributing to both environmental integrity and social equity, or 'sustainable adaptation'. Important measures to support such adaptation include generating awareness, creating long-term eco-system based employment opportunities, and improving local governance for the management of coastal mangroves.

Keywords: Mangrove; Cyclonic events; Coastal protection; Sustainable adaptation; Vulnerability; Odisha.

1. Introduction

The state of Odisha can be considered highly vulnerable to climate variability and change due to the combination of poverty and a high frequency of cyclones and floods. Odisha is geographically situated on the eastern coast of India (see Figure 1), at the head of the Bay of Bengal, highly prone to violent tropical cyclones, with a coastal stretch of around 480 km. This stretch covers six coastal

Figure 1 Geographical Map of Odisha.

districts, namely Balasore, Bhadrak, Kendrapada, Jagatsinghpur, Puri and Ganjam, which have a varied physiography ranging from forests, lofty peaks, and rolling uplands through extensive riverine systems, brackish waters, coastal mangroves and coastal plains. These have endowed Odisha with a wide range of ecological habitats providing a diverse and broad spectrum of flora and fauna.

Odisha is amongst the poorest states of India. It has a population of 36.71 million people.[1] Around 85% of the population lives in rural areas and about 65% depend upon agriculture for their livelihood.[1] The state's agricultural share in the Net State Domestic Product (NSDP) at current price factor cost, however, is low and declining. While it was 51.79% in 1950, it was down to 38.15% in 1993 and 20.18% in 2008.[2] Further, the poverty statistics show that 39.9% of the population lived below the poverty line in 2004-05, compared to 21.8% in India as a whole.[2]

Odisha's coastline is highly prone to cyclonic events.[3–10] A slight change in the behavior of the sea (e.g. cyclonic storm and sea level rise) causes significant impact on several districts within Odisha[a], but most particularly upon the six coastal districts[b].[7,10] During the period 1891–2007, 1148 cyclonic disturbances have

[a]Government of Odisha (hereafter GoO), for instance, shows that more than half of the districts of Odisha are always affected by cyclones and floods during the period of 1994-2008.[11]

[b]Kumar *et al.* stated that 22% of the Odisha coastline is in the high vulnerable category, 62% medium

occurred in the Bay of Bengal, including 659 depression/ deep depression, 273 cyclonic storms and 216 severe cyclonic storms; which are 85.48% of total cyclonic disturbances that occurred in both the Bay of Bengal and the Arabian Sea in India.[12] Odisha, in particular, has faced approximately a third of the cyclonic events (i.e. 106 out of 306 events) that affected four of India's east coast states (e.g. West Bengal, Odisha, Andhra Pradesh and Tamil Nadu) during the period 1891–2007.[12] These events cause significant economic and environmental losses to the state economy. Combining floods, cyclones and droughts, it is estimated that the property lost was around INR 1050 million (i.e. approximately US$ 23.33 million at the rate of US$ 1 = INR 45) during the 1970's, and was increased by seven times during the 1980's and by more than 10 times during the 1990's[4], even though the estimates are incomplete[c]. Importantly, during the past few decades, the state experienced severe and super cyclonic storms[d] in the years 1971, 1982 and 1999 (the latter, e.g. 1999. included two severe events within a 15 day period).[5,13–16] While the estimation of crop loss was around US$ 100 million (i.e. roughly US$ 1 = INR 8) in the year 1971[5], the total loss of human lives was 9177 in the 1999 super cyclone.[13,14] These events disrupted the livelihoods of poor and vulnerable people living in the fragile coastal environments.

The occurrence of cyclonic events is anticipated to increase as a result of anthropogenic climate change,[17] and hence, the susceptibility of the coastal population will be increased in the decades to come, in addition to currently persisting chronic poverty. In particular, the cyclonic events have generated lots of direct impacts that affect livelihood, e.g. high tide, flood, intrusion of salt water, water logging etc. Coastal communities therefore have to undertake pro-active adaptation measures to buffer against these events. In order to do so, it is necessary to understand the linkages between ecosystems and human societies that can help to reduce vulnerability as well as enhance the resilience capacity of these communities,[18] especially in the light of the dependency of coastal livelihoods on the region's rich biodiversity.

Studies have emerged at the global level, particularly following the aftermath of the 2004 Indian Tsunami, showing the importance of coastal vegetation in the context of reducing physical impacts,[18–22] in addition to providing a great variety of goods and services, e.g. fish, fuel wood and non-wood forest products (NWFP) like honey.[23,24] Tri *et al.* stated that mangrove planting is a 'win-win' solution for reducing future cyclonic risk and minimizing vulnerability in Vietnam.[25] Adger *et al.* highlighted that the force of Tsunami waves was reduced by natural barriers like mangroves in Sri Lanka.[18] Further, Dahdouh-Guebas *et al.* assert that the

vulnerable category, and 16% in the low vulnerable category (p. 532).[10]

[c]It only focuses on direct market loss, but omitting direct non-market/ intangible loss (e.g. loss of ecosystem and lives, and damages to historical and cultural assets etc), and indirect loss (higher order effects and spill over to other sectors of the economy, e.g. loss of agricultural output due to natural disaster would have significant impact on food inflation).[31]

[d]For history of the cyclonic events occurred in Odisha since eighteenth century.[5]

mangroves play a critical role in storm protection that based on their post-tsunami observations; they argued that it depends on the quality of the mangrove forests.[20] In the context of India and particularly Odisha, recent studies have proposed that mangrove conservation could be considered as an adaptive strategy for coastal communities as it acts as a natural barrier and also provides a wide range of goods and services to the people.[21,24,26–29] Despite the noteworthy efforts mentioned above, further research is required to identify the effectiveness of mangrove conservation for mitigating future cyclonic risk whilst improving social equity, reducing poverty and supporting environmental integrity in the short and long-term.

Drawing on the lessons from Kendrapada district of Odisha state, the paper seeks to understand how conservation and restoration of mangroves can provide a sustainable adaptation option in the context of acting as a buffer to cyclonic storms and also enhancing resilience capacity of the coastal communities through generating alternative income opportunities. Following the principles of 'sustainable adaptation',[30] this paper initially examines vulnerability of Kendrapada district to cyclone, and then assesses multiple threats to conserving mangroves, and potential for sustainable adaptation. It particularly addresses issues related to social equity, poverty and environmental integrity.

2. Study Area and Methods

2.1. *Study area*

The mangroves of coastal Odisha are distributed in four zones: the Budhabalanga-Subarnarekha Delta, the Brahmani-Baitarani delta, the Mahanadi delta and the Devi delta, and cover a total area of 203 km^2. Geographically, this represents 0.125% of total geographical area, and 0.414% of total forest cover of the state.[32] Out of the total, Kendrapada district has maximum mangrove forests in the state (175 km^2), followed by Bhadrak (20 km^2), Jagatsinghpur (4 km^2) and Balasore districts (4 km^2) (as per the state of Forest Report 2005). Kendrapada district contains over 80% of mangrove forest cover in Odisha, consisting of the entire Brahmani-Baitarani delta and part of the Mahanadi delta.[33] The district is therefore taken as a case study due to dense mangrove forests and as the earlier studies identified it as a highly vulnerable district[e] among the coastal districts of Odisha.[7,9,10] Importantly, it includes the 'Bhitarkanika mangrove ecosystem' which is the second largest mangrove forest of mainland India.[21]

Kendrapada district is located between 86014'E-87083'E longitude and 20021'N–20047'N latitude that covers TGA of 2644 km^2. The coastline of the district covers 48 km stretching from Dhamara delta to Batighar, and most of the coastal

[e]The 1971 cyclone, for example, was especially hardly hit Mahakalpada block of the Kendrapada district, 15 and further, 1.915 million people are affected during the 1999 cyclones.[13,14]

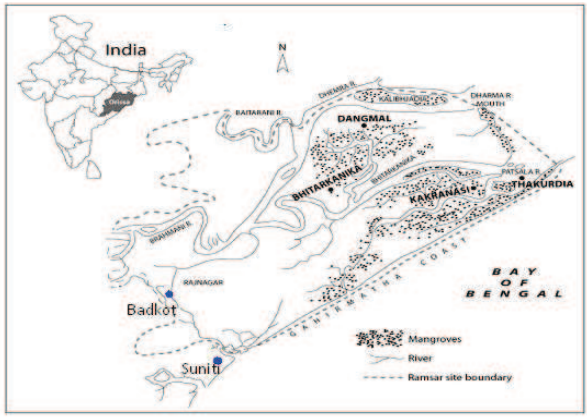

Figure 2 Location of Study Villages in Kendrapada District, Odisha.

regions are situated on the river delta formed by the Brahmani, the Baitarani and branch rivers of the Mahanadi; which is the crucial cause behind large coastal vegetation. Since the Kendrapada district is highly prone to cyclone[10], the livelihoods of the people are significantly affected. The recent studies have prominently shown that mangroves have played a significant role in reducing death toll and level of property damaged during the 1999 super cyclone in Odisha.[21,27–29] Administratively, these are within the Rajnagar and Mahakalpada blocks of the district. In this study, two villages, namely Badakota (Rajnagar block) and Suniti (Mahakalpada block) were selected for comprehensive empirical investigation of issues associated with sustainable adaptation.

3. Methods

This study analyses household survey and Focus group discussions (FGDs) data that are carried out during the periods March-April 2010, and February-March 2011 in Badakota and Suniti villages, in addition to relying on secondary data through a comprehensive review of available studies. These two villages are selected to examine two questions relating to: first eagerness for restoring mangroves to buffer cyclonic impacts as well as to protect the villages from river erosion, and second the role of mangroves to sustain livelihood. In order to address these two questions, two villages were compared. The first village named as Badakota is situated 4–5 km from the sea with less mangrove forests around the village but near to the river 'Ansupa'. The second village named as Suniti is situated within 1–2 km from the sea with comparatively dense mangrove etc. Importantly, there is high probability of salt intrusion in both the villages. In both the villages, people are cultivating paddy crop during monsoon due to lack of rainfall and increasing salinity on land during the other season. They are able to get good

paddy production if the quantity of rainfall is at least equal or more than the normal rainfall. Having no other income opportunity, the coastal communities are also depending on fishing to sustain their livelihood. The women, particularly of women headed households as well as widows, are catching mud crabs and prawns throughout the year to maintain their livelihoods.

Two groups of households (around 10 households in each group) were selected for FGDs based on the purposive random sampling, which contains at least 30% of women participants. We used the local (*Odia*) language to conduct FGDs, and here we predominantly asked them about the importance for conserving mangroves on their livelihoods, and how they perceive that it may support the process of poverty reduction as well as environmental integrity. Since most of the people are engaged in both agriculture and fishing activities in both the villages, this study purposively selected those households who are depending on both activities to maintain their livelihood.

In the context of household sampling, we interviewed 157 households (i.e. 49 households from Badakota village, and 108 households from Suniti village). As per the Census 2001, there are 56 and 962 households in Badakota and Suniti villages respectively. Though we intended to survey all the households in Badakota village as it is small one, we could only contact 49 households (81.66% of male and 18.34% of female respondents), as the remaining 7 households were not available in the village during the survey period. They were migrated either seasonally due to lack of income opportunities or permanently to other villages due to continuous river erosion. On the other hand, we have selected only a part of Suniti village (e.g. only sixth wards) as it is relatively large, and interviewed 108 respondents (78.7% of male and 21.3% of female respondents). The selected sample represents more than 10% of the total households.

4. Results

4.1. *Vulnerability of study region*

In the climate change discourse, a wide range of studies have asserted an integrated approach to vulnerability, which is the complex interaction of socio-economic (e.g. economic structures, livelihood options, coping strategies, dependence on agriculture etc, driven by development policies and poverty patterns) and bio-physical vulnerability (e.g. frequency of cyclonic storms).[34] Socio-economic vulnerability is shaped by political, economic and social process within the state of a human system, whereas bio-physical vulnerability refers to the likelihood of occurrence of climatic shocks and severe ecological consequences. Thus vulnerability depends on the system's propensity to be adversely affected by climate change including both exposure and sensitivity, and system's ability to deal with or recover from its adverse impacts.[34] Adger *et al.* have extended such spatially bounded vulnerability by incorporating the idea of 'nested' and 'tele-connected' effects, where vulnerability is concerned with a large scale process of

socio-cultural change and market integration.[35] Adopting such methodology, this paper has analyzed vulnerability of the Kendrapada district, with special focus on the two study villages.

To analyze bio-physical vulnerability status of the Kendrapada district, the present study assessed the monsoon-wise rainfall pattern, impact of cyclones and floods, and susceptibility of houses. Table 1 shows descriptive statistics of monsoon-wise[f] rainfall in the district for more than a century (i.e. 1901–2008). Most rainfall occurs in a short space of time in the monsoon season. The annual mean rainfall was 1472.63 mm, out of which, the monsoon mean rainfall was 1100.91 mm, which constitutes 74.75% of the total. In addition, the coastal regions of the Kendrapada district (e.g. Rajnagar and Mahakalpada blocks) comprises coastal alluvium/ saline inundated soil due to the presence of saline rivers as well as being submerged by the tidal waves.[36] The level of soil's salinity changing from time to time during the year. During monsoon, the salinity level declines due to gravitational flow and percolation of high rainfall, and the soil therefore becomes suitable for agricultural production. Such soil, however, again becomes more saline after the monsoon season due to lack of rainfall (see Table 1), and is thus not suitable for agricultural production (i.e. December to June). The coastal communities are hence only cultivating paddy (mostly traditional variety) in the monsoon season, and the land remains fallow in the rest of the year.[36] Since a large number of coastal people are depending on agriculture (e.g. 67.47% in the Kendrapada district; see Table 4) and derive a major share of their income, such type of soil quality and lack of rainfall in the other seasons have led higher vulnerability to any kind of further risks including climatic shocks (e.g. cyclones and floods). In fact, there is also probability of losing monsoon paddy crops in some years (e.g. 1999, 2006, 2007, 2010 etc) due to major cyclonic events that lead to salinity intrusion as well as water-logging, and lack of monsoon rainfall[g]. In these particular years, the level of vulnerability is much higher as they lost their major share of annual income. In these years, the vulnerable people are following certain ex-post coping measures to smooth consumption, e.g. informal borrowing, out-migration and reduce consumption etc.

Further, Kendrapada district is exposed to frequent cyclones and floods, which have significant impact on livelihood of coastal population (Table 2). There has been a deficiency of monsoon rainfall in the last decade. Most of the rainfall has come due to the cyclonic events. During 1994–2009, the district experienced cyclones and floods 23 times, and out of which more than one million people were affected thrice during 1995, 1999 and 2007. During the FGDs, most of the people in both the study villages explained that they had faced three severe cyclones in

[f]Winter monsoon: January and February; Pre-monsoon: March to May; Monsoon: June to September; and Post-monsoon: October to December.

[g]For example, most of the respondents in the study villages have told that they lost paddy crop in 2010–11 due to lack of monsoon rainfall.

Table 1 Descriptive Statistics of Monsoon wise Rainfall in Kendrapada District (1901–2008)

	Annual	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
Mean	1472.63	33.13	120.19	1100.91	218.39
Median	1462.54	24.62	122.77	1085.58	218.12
Maximum	2211.31	147.09	307.86	1657.24	657.4
Minimum	775.21	0	20	633.28	24.69
Std. Dev.	225.15	30.36	59.05	178.63	110.35
CV[h] (%)	15.29	91.65	49.13	16.23	50.53
Observations			108		

Source:: Analysis of data collected from 'Global CRU 2.1 dataset consisting of interpolated climate grids from the Tyndall Centre for Climate Change Research, Norwich, UK' (1901–2002), and Indian Meteorological Department (IMD) (2003–2008)

Table 2 Impacts of Cyclone and Flood in Kendrapada District, 1994–2009

Year	Cyclone/ Flood	Frequency	No. of Villages Affected	Population Affected (in millions)	Human Causalities	Total Houses Damages	Crop Lands Affected (in ha.)
1994	Flood	1	435	0.39	10	NA	30418
1995	Flood	2	1506	1.17	4	3017	0
1999	Flood	1	359	0.25	4	80	14650
1999	Severe/ Super Cyclone	2	1567	1.65	473	308733	123750
2001	Flood	1	821	0.82	NA	31926	64287
2003	Flood	2	585	0.62	14	7744	22646
2005	Flood	3	378	0.41	3	NA	NA
2006	Flood	4	1021	0.94	2	5444	69940
2007	Flood	4	0	1.23	5	2214	29270
2008	Flood	2	684	0.76	16	58429	64994
2009	Flood	1	47	NA	0	NA	NA
Total (1994–2009)		23	7401	8.24	531	417587	419955

Source:: Data collected from Special Relief Commissioner (SRC), Govt. of Odisha, Bhubaneswar; GoO (1999a, and b); and GoO (2009b)[13,14,37]

the last few decades, that is during 1971, 1982 and 1999, and among them, the 1971 cyclone had more severe effects. All these episodes clearly assert that the district is highly vulnerable to cyclones and floods, which put the coastal people on high risk situation.

In addition, Table 3 outlines the percentage of level of risk, and structure of houses in Kendrapada district. In this district, 100 percent of total area is cyclone prone and 35.5 percent is flood prone. In the context of housing units, 77.3% of house walls are under category 'A', and 87.3% of house roofs are under category 'R1'. Since a major portion of houses are situated at low elevations, there is a high probability of them being destroyed during the cyclones and floods.

[h]Coefficient of variation.

Table 3 Percentage of Level of Risk and Structure of Houses in Kendrapada District.

Wall/ Roof[1]	Percentage of Level of Risk	
	Cyclone 100% No. of houses	Flood 35.5% Percentage
Wall		
Total Category of 'A'	274179	77.3
Total Category of 'B'	66609	18.8
Total Category of 'C'	4446	1.3
Total Category of 'X'	9537	2.7
Total	354771	100
Roof		
Total Category of 'R1'	309796	87.3
Total Category of 'R2'	2666	0.7
Total Category of 'R3'	42309	11.9
Total	354771	100

Note: [1]Category A → Building in field stone, rural structures, un-burnt brick houses, clay houses; Category B → Ordinary building, building of the large block and pre-fabricated type, half timbered structures, building in natural hewn stone; Category C → Reinforced building, well built wooden structures; and Category X → Other materials not covered in A, B, and C - these are generally light and brick; Category R1 → Light weight (grass, thatch, bamboo, wood, mud, plastic, polythene, G1 metal, asbestos sheets, other materials); Category R2 → Heavy weight (tiles, and slate); and Category R3 → Flat roof (brick, stone, and concrete). [2]Percentage of area under risk.
Source: BMTPC (2006)[38]

In the context of socio-economic vulnerability, Tables 4 and 5 show the indicators of Kendrapada district, and particularly the study villages. The district, having 3.54% of Odisha's total population, is considered as the 10th developed in the state as per the overall HDI of 0.626. In this district, 67.47% of people are depending on agriculture for their livelihood, and importantly, 86.16% of people are marginal farmers (Table 4). Likewise, a larger portion of the people are depending on agriculture in the both the study villages, and it is in fact higher than the whole district, e.g. 98.66% in Badakota village and 93.11% in Suniti village respectively (Table 5). This implies that the coastal communities are basically depending on agriculture for their livelihood, and moreover, most of them are marginal farmers. As agriculture is considered as highly vulnerable sector throughout the climate change literature,[39] most of the people seem to be highly susceptible due to erratic rainfall variation, and higher frequency of cyclones and floods. In the context of housing unit, a larger portion of the people live in thatched houses, which are highly susceptible to such events, e.g. 89.8% in Badakota village and 93.11% in Suniti village (Table 5).

Table 4 Socio-Economic Indicators of Kendrapada District

Indicators	Year	Kendrapada
Demographic Profile		
Percentage of Geographical Area	2001	1.63
Total population (in million)	2001	1.302
Percentage of Total Population	2001	3.54
Decadal Growth Rate	1991–2001	13.25
Percentage of Rural Population	2001	94.31
Population Density	2001	492
Sex Ratio	2001	1014
Literacy Rate	2001	76.81
Socio-Economic Profile		
DDP Per Capita (INR at 1993–94 prices)	1998–99	3964
Percentage of Rural Families in BPL	1997	59.89
HDI	2001	0.626
HDI Rank	2001	10
Work Participation Rate	2001	29.83
Percentage of Net Sown Area (NSA)	2006–07	52.27
Percentage of Marginal Farmers (< 2 ha.)	2001	86.16
Occupational Classification		
Total Worker (Percentage of Population)	2001	29.82
Percentage of Main Worker	2001	75.6
Percentage of Marginal Worker	2001	24.4
Percentage of Dependency on Agriculture	2001	67.47

Source:: GoO (2004); GoO (2008a); GoO (2007)[1,4,40]

4.2. *Multiple threats to mangroves in the district*

The recent study on sustainable adaptation[30] emphasizes that the vulnerability context is generated by multiple interacting social, economic, environmental and political processes in addition to the climate change. These processes often interact synergistically to reinforce vulnerability for particular groups. Threats to the mangrove ecosystems in coastal Odisha are outlined in brief below. These threats in combination have lead to a serious loss of mangrove forest, e.g. 50% of the world's mangrove forests are destroyed during the second half of the 20th century.[20] A recent study by Upadhyay and Mishra has shown that more than 80% of the degradation of mangrove forests is due to anthropogenic disturbances which do not allow the regeneration of mangrove species.[32] Earlier studies recorded that mangrove forests have been degraded between 5-30% , and 20-60% respectively in Bhitarkanika and Mahanadi sites of Odisha, both of which fall under Kendrapada district.[33]

Table 5 Socio-Economic Characteristics of two Study Villages

Village Characteristics	Badakota	Suniti
Geographical Location		
Distance from sea	3–4 km	1–2 km
Distance from River	0 km	No
Status of Creeks	Medium	High
Status of Mangroves around the village	Low	High
Probability of Salt water intrusion	High	High
Village Demography and Respondent Details		
Total no. of Households (Census, 2001)	56	962
Total Population (Census, 2001)	275	4106
Percentage of Literacy (Census, 2001)	65.63	65.81
Percentage of Agricultural Dependent People (Census, 2001)	98.66	93.11
Total no. of Sample Respondents	49	108
Occupation of Respondents		
Percentage of Farm Population	98	99.1
Percentage of Non-Farm Population	2	0.9
Type of Dwelling Units of Respondents		
Pucca	4.1	6.5
Semi-Pucca	6.1	0
Thatched	89.8	93.5
BPL/ APL of Respondents		
Percentage of below poverty line (BPL)	85.7	13
Percentage of above poverty line (APL)	14.3	87

Source:: Census (2001)[41]; Field Survey (2010 and 2011)

4.2.1. *Unsustainable economic growth*

There has been continuous conversion of mangrove forest into agricultural land and aquaculture, illegal collection and selling of poles, coastal tourism, and more recently, planning and clearing space for industrial activity.[32,33,42–44] For instance, Reddy *et al.* find that during 1973 to 2004 both dense and open mangroves have declined 16 and 1518 ha respectively, whereas agriculture area has increased 2436 ha in the Bhitarkanika region.[43] Building on the notion of 'nested and tele-connected vulnerability',[35] this study has found that persisting social and economic problems in the southern coastal districts (e.g. Medinpur) of West Bengal state are the cause for the loss of mangroves in the study region. In the Suniti village, we were told that the ancestors of more than 90% of households are migrated from West Bengal since 1960s mainly due to lack of agricultural land to accommodate the growing population. Now most of the agricultural lands are either leased-in from the government of Odisha or encroached into the forest land. This lead to the loss of mangrove eco-systems. Due to the lack of major income opportunity except agriculture for most of the people, there is ongoing illegal cutting of mangroves

in order to survive. Further, the requirement of wood for fuel as well as the reconstruction of thatched house once in two-three years is also the major cause for the destruction on mangrove forests. In addition, a large number of people are still maintaining conventional lifestyle (e.g. high dependency on agriculture and fishing) due to lack of education which leads to continuous pressure on mangrove forests in the form of requirement of more land for agriculture and aquaculture purposes.

4.2.2. *High population density*

The coastal areas of Odisha are fertile, providing agricultural opportunities in the encroached mangrove areas in addition to income opportunities arising from coastal economic activities ranging from rich fisheries in the sea and delta areas and increased tourism activity. As a result of these opportunities, the population density in the coast has increased during the last five decades.[42] Rising from 451 to 492 people per sq. km between 1991 and 2001, it is almost double in the coastal belt as compared to Odisha in general, where figures rose from 203 to 236 people per km^2 during the same decade.[1] This has lead to continued pressure on mangrove forests exerted through the demand for firewood, charcoal, timber (for boats and housing), grazing of domestic animals, as well as increased pollution from the population and economic activity.[32,33,42,44,45] In these study villages context, Table 6 highlights decadal population statistics since 1961 with growth rate. There is a significant increase in population during 1961-71 in Badakota village. One reason for this is that when Khirakota village was washed away in the 1971 cyclone event, most people migrated to Badakota village. In contrast, we can see there is almost stagnant population growth during 1991–2001, as people are at present migrating to other village due to river erosion. In the Suniti village, there is no such village exist in the 1961 census report. However, we find that there were population establishment in the 1971 census report, which is the prominent cause for the mangrove destruction.

Table 6 Population statistics of Study Villages

Year	Badakota	Growth Rate	Suniti	Growth Rate
1961	101	—	N.A.	—
1971	177	75.25	2586	—
1981	211	19.21	2579	−0.27
1991	282	33.65	3089	19.78
2001	275	−2.48	4106	32.92

Note: Source: Census (1961, 1971, 1981, 1991 and 2001)[46–50]

Figure 3 Land erosion of Badakota village by Ansupa River

4.2.3. *Sea level rise and river erosion*

Higher tides as a result of sea level rise have forced people to migrate towards more inland areas, which is combined with encroachment and cutting of mangrove forest to make more land available. In a study by Richard Mohapatra on Satabhaya village of the district, most informants stated that they had already migrated three times and although they did not know how many times more they would have to migrate, it is becoming increasingly difficult to do so as most of the lands are under the Bhitarkanika Mangrove reserve forest.[51]

In addition, during focus group discussions, some farmer informants of both Badakota and Suniti villages stated that most of their agricultural land has become saline due to the regular high tides through a large number of canals/ creeks and tributaries of the rivers, such that they are not able to use their agricultural land for multi crop purposes. They feel that this is due to the loss of coastal mangroves and the salt water coming directly into their land has been cited as an irreversible loss for them. On the other hand, some people particularly in Badakota village have already migrated two-three times during their life cycle due to continuous river erosion; it happens due to the loss of mangrove forests around the village over a time period (see Figure 3).

4.2.4. *Changes in government policy*

A major cause of the deterioration of mangrove forest is also attributed to changes in Government policy since the 1950s. Before independence (i.e. up to 1951), mangroves were protected and preserved. During the '*Anchal Sasan*' (separate revenue division under the local administration) under the Department of Revenue from the year 1951 to 1957, the encroachment and devastation of mangrove

habitats and the growth of human settlement in this region had begun, and this led to indiscriminate cutting of trees and the illegal occupation of forest and non-forest lands.[42]

The Government of Odisha has taken steps to preserve the mangrove forests. Ownership was transferred from Zamindars (feudal land owners) to the state Government in 1952 and several forest areas were created in the protected areas. But, the real scientific management of Bhitarkanika mangrove started with the transfer of its administrative control from '*Anchal Sasan*' to Athagarh forest division, under Development (Forest) Department, Odisha on the 15th November 1957.[42] The forest area of Rajnagar block was declared as Bhitarkanika Wildlife Sanctuary in 1975 and a national park by 1988; the forest area of Mahakalpada was declared a reserve forest in 1978 and brought under the Gahirmatha Marine Wildlife Sanctuary in 1997[27,42] and Bhitarkanika Mangroves were designated a Ramsar Wetland of International Importance in 2002.[52]

However, in contrast to this, the conservation and ecological status of mangrove forests have a actually been declining contributing to undermining of environmental integrity and sustainable adaptation options. For instance, the vast '*Chhada*' jungle was retained by the Revenue Department despite a clear directive to transfer it to the Forest department. The conflicts between these two arms of Government on property rights over the last five decades, have created an opportunity for corruption within the departments and the occupation of the lands by people who have even managed to get the land registered in their names.[42,53] Furthermore, out of the total 672 km^2 of sanctuary area, about 25% is covered with mangrove forest which is managed by the state Forest Department, whereas, the rest, including agricultural lands, homestead lands, government lands and pasture lands, etc in and around the sanctuary are either managed by private land owners or the Revenue Department of Odisha. Having 28 village '*Panchayats*' (local administrative units in rural areas of India) that consist of 400 villages with about two hundred thousand people around the sanctuary, the search for food and firewood by the growing population, the conversion of previous paddy cultivation area into prawn farms for higher returns and the grazing of livestock, exert biotic pressure on natural resources.[42]

Finally, it is a plan of the Government of Odisha to evacuate some of the villages near the sea and resettle them within the mangrove forest reserve. Since some of the villages of the Satabhaya Panchayat have submerged due to high tide and SLR, the Government of Odisha has planned to evacuate entire villages within this Panchayat in order to avoid future loss, and resettle the villages near Bagapatia village. The government is also planning to clear an area suitable for building a port near Barunei delta region in line with industrialization plans for the state.[54] Other large scale industrial activity in the past also resulted in mangrove loss: in 1994 the Department of Fisheries of GoO, in collaboration with the World Bank cut around 2000 acre of mangrove forest for prawn farming.[55]

Focus group discussions with NGO activists revealed that the Satabhaya Panchayat, although not an island, is cut-off from the mainland in the sense that it requires a 10 kilometer walk to reach it from the nearest 'Gupti' Panchayat. People here have cut the mangroves in order to create agricultural land and build their thatched houses. Part of this is due to the lack of income generating opportunities and part is because of the lack of knowledge about the maintenance of their livelihoods through better ecosystem management. Similarly, a recent study by Badola and Hussain found that the loss of mangroves are due to information failures.[26] These include lack of information on the value of conserving mangrove ecosystems; market failures due to excessive access to common resources; intervention failure due to the absence of appropriate integrated resource management policies; and inter-sectoral policy inconsistencies.

The case also illustrates the importance of global-local linkages and how developments in one area may create vulnerability in other areas, as proposed by the sustainable adaptation framework. The mangroves are vulnerable due to tele-connected factors such as degrading income generating opportunities for Bangladeshi fisher communities, who are migrating to the coastal regions of Kendrapada district and establishing livelihoods through the illegal cutting and selling of mangrove poles.

4.3. *Potential for sustainable adaptation*

In Odisha, the current development paths promoted by the Government focusing on industrial growth and large scale commercial development while paying little attention to smaller scale livelihood options of local populations is contributing both to environmental degradation and social inequity. The latter reinforces environmental degradation as mangroves are sourced for livelihood options, increasing climate risk in the long term. These developments together are undermining sustainable adaptation, therefore.

It is important to enhance understanding of how mangrove conservation can contribute to sustainable adaptation not only by mitigating cyclonic and flood risk in terms of death tolls and property damage, but also by enhancing adaptive capacity. Moreover, it is a good source of capturing greenhouse gases (GHGs) from atmosphere. In general, mangrove ecosystems are rich in biodiversity and can provide coastal communities with many valuable goods and services.[23] Apart from livelihood provision for the poor, additional ecosystem services of mangroves include prevention of coastal erosion, barriers against typhoons, cyclones and hurricanes, protection of coral reefs from siltation, soil conservation and natural biological waste water treatment. In the latter case, mangrove ecosystems lower the biological oxygen demand (BOD), perform bioremediation by removing toxic elements, and provide breeding, nursery, and feeding grounds for harvestable marine fauna.[33,44] In sum, most of the people in the coastal areas are depending

on mangroves (fully or partly) for their survival, e.g. 30.6% in Badakota village and 100% in Suniti village.

Protection and rehabilitation of these ecosystems are therefore crucial from livelihood and environmental points of view.[22] In addition, the benefits can be estimated economically. The income generating benefits of mangroves are well articulated: they provide wood for fuel, furniture and construction, green leaves and fruits for fodder and thatch, and they are a source for products as diverse as tannin, paper, dyes, chemicals, honey, incense and medicines.[33] Badola and Hussain have attempted to assign monetary values to the economic benefits of mangroves considering four main parameters: nutrient retention (US$ 350/ acre/ year), land accretion (US$ 983,795.70 over a period of 111 years), storm abatement (US$ 116.28/ per household) and fish and shellfish production as well as seeding (US$ 39.97/ hour for offshore fisheries, US$ 1.9/ house for inshore fisheries, and US$ 0.2/ hour for fish seeding).[26] In the line of mangroves acting as natural barrier, Badola and Hussain have estimated cyclone damage cost avoided due to mangrove conservation in the three selected villages in the Bhitarkanika region.[21] The study found that the loss incurred per households was greatest US$ 153.74 in the village with no mangroves but had an embankment, followed by US$ 44.02 in the village having no mangrove shadow and embankment, and US$ 33.31 in the village that was protected by mangroves. A recent study by Das shows that the benefits of retaining mangroves (INR 27,312/ha/year) are higher than the opportunity cost of protecting mangroves (INR 20,756/ha/year).[56] Mangrove conservation therefore protects poor people through the rehabilitation process after disaster events as mangroves provide basic livelihood options. Further, Hussain and Badola have conservatively estimated that more than 14.5% of total household's income is generated through mangrove forests, and importantly, it is more than 30% for the poor and marginalized households residing near the mangroves.[24]

Further, Badola and Hussain have found that a high percentage of people surveyed (88.6%) in the three study villages of Bhitarkanika mangrove ecosystems recognized the contribution of mangroves in cyclone and flood mitigation.[21,26] Through FGDs, we have observed that most of the vulnerable people in the study villages, especially in Badakota village, are interested to participate in the process of generating mangrove forests around the village to protect them from cyclonic storm and river erosion. In Suniti village, we have found that a larger share of people is depending on catching fish (both offshore and inshore), mud crabs and prawns to maintain their livelihood during the whole year, especially during the off season in addition to agriculture. Thus mangroves provide the crucial ex-post adaptation option for most of the people during the climatic shock years, in addition to act as an ex-ante adaptation option that reduce expected loss due to cyclonic storm.

5. Conclusions

As elsewhere, in Odisha the mangroves drastically reduce the physical impacts of cyclonic events, provide positive economic benefits and also address social equity by providing poor coastal peoples with income generating opportunities. At the same time, there are many threats to their environmental integrity and ability to support livelihoods and adaptive capacity of the poor, especially from competing large scale commercial activities and land uses.

The case of Odisha demonstrates the potential, as well as challenges, of conserving mangroves for supporting sustainable adaptation in coastal regions. Measures that may be required to conserve mangrove forests in a way that supports sustainable adaptation include generating awareness among the people regarding the positive benefits of mangrove conservation, creating long-term ecosystem based employment opportunities for coastal communities that reduce poverty, and improving local governance systems for the management of coastal mangroves.

In areas like Odisha, that are prone to cyclonic related events, the building of coastal resilience, especially through natural resilience, is urgent. The discussion in this paper has shown that conservation of mangroves is economically efficient, increases employment and income opportunities for local people (i.e. poverty reduction – enhancing adaptive capacity), and acts as a buffer for storm abatement (i.e. reducing risk of climate impacts). The findings underscore observations by previous studies in other regions such as Vietnam regarding the benefits of mangrove ecosystems in managing climate related risks.[25] The conservation of mangroves in coastal regions, as clearly demonstrated by the case of Kendrapada, can provide a sustainable adaptation strategy in the context of cyclonic risk.

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