# PREDICTION OF CLIMATE CHANGE-INDUCED SEA LEVEL RISE IN CHILIKA-PURI COAST OF ODISHA, INDIA: WITH SPECIAL PROMINENCE ON ADAPTATION ACTION STRATEGY FRAMEWORK

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**Abstract.** Predictions of changes in coastal habitat boundaries due to expected relative Sea Level Rise (SLR) allow advanced preparation for particular parts of the coastline to mitigate and offset anticipated losses and reduce risks to coastal growth and human safety. Thus, a better understanding of SLR and its impacts are essential to anticipate risks associated with SLR. The first move in such direction will be to project SLR at the local level at various time scales and scenarios formulated by the Intergovernmental Panel on Climate Change (IPCC). This research aims to project SLR using IPCC Representative Concentration Pathway (RCP) scenarios and identify coastal natural resources and their dependent human communities along Chilika-Puri coast in Odisha, India, those in the risk of impacts and vulnerable to projected SLR. This study also aims at exploring suitable adaptation choices for informed decision making. IPCC criteria for assessing the SLR were followed in this research work. Future SLR projections were developed as per IPCC's RCP scenarios using the SimCLIM tool. The observed relative sea level trend is 1.94 ± 0.96 mm/yr. The projected SLR for the Chilika-Puri coast indicated 38.88 to 74.81 cm under high emission scenarios for the year 2100. To combat the potential impacts of SLR in the study area, a comprehensive adaptation strategy framework (both planned and anticipatory adaptation) is proposed, with relevance to the study zone, which will also have global implications.
**Keywords:** *comprehensive adaptation strategy, natural resource, potential impacts, RCP, SimCLIM, SLR projections*

## Introduction

Through the twentieth century, sea levels have increased worldwide. Due to global warming, these rises will almost certainly accelerate throughout the twenty-first century and beyond, though its magnitude is still uncertain. The recent Intergovernmental Panel on Climate Change (IPCC) reports a 0.20 m global mean sea level rise from 1901 to 2018 (IPCC, 2021). The average rate of Sea Level Rise (SLR) was 1.3 mm/yr (1901-1971) and rose by 03.7 mm/yr (2006-2018), and it would continue to rise to 2 m by the end of the century under very high emissions scenario (SSP5-85 low confidence) (IPCC, 2021). Since human-induced global warming first surfaced in the 1980s, SLR has been viewed as a significant threat to low-lying coastal communities worldwide (Barth and Titus, 1984; Milliman et al., 1989; Warrick et al., 1993; Nicholls et al., 2011). The consequences will be very diverse in time and place due to the considerable diversity of coastal environments, regional and local variances in predicted relative sea level and climatic changes, and differences in the resilience and adaptive ability of ecosystems, sectors, and countries.

Predictions of changes in coastal habitat boundaries due to expected relative SLR allow for advanced preparation for particular parts of the coastline to mitigate and offset


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anticipated losses and reduce risks to coastal growth and human safety (Gilman et al., 2007). Thus, a better understanding of SLR and its impacts is needed to anticipate risks associated with it. The first move in such direction will be to project SLR at the local level at various time scales and scenarios formulated by the IPCC (Ramachandran et al., 2017: Khristodas et al., 2022). These projections will facilitate more efficient coastal planning and management of natural resources and develop adaptation strategies for the coastal communities.

The study area Chilika-Puri coast of Odisha is prone to various calamities, including tropical cyclones, storm surges, and tsunamis. With the expanding population, coastal vulnerability to such disasters has increased significantly. The economy of the state has suffered severe setbacks due to catastrophic disasters (Mohanty et al., 2020). Besides, the accelerated SLR will also pose a significant threat to the coastal stretch of Odisha (Kumar et al., 2010; Suganya et al., 2015; Kumar, 2015). The consequences of the SLR in the coastal environment and the sociological aspects of the SLR response have been studied (Doukakis, 2005). There are still considerable gaps in understanding climate change-induced SLR projections and their influence on regional and local levels. It is mainly unexplored on the Chilika-Puri coast. Addressing these gaps through strategic planning, such as establishing a suitable framework to project, assess, and respond to the threat of SLR at the local level, particularly for the Chilika-Puri coast, necessitates immediate action, which forms the primary research motivation of this research work.

Suitable adaptation will depend on environmental and socio-economic factors. As a result, substantial research is required to examine possible consequences and establish appropriate adaptation methods. In this light, this research aims to project SLR using IPCC RCP scenarios and identify coastal natural resources and their dependent social communities along the Chilika-Puri coast in Odisha, India, that may be in danger and vulnerable to SLR projections. Furthermore, this study aims to discover suitable adaptation choices to make informed decisions. The following research questions are generated based on the study's origin of the problem, the identified research gaps, and the need for the study: (i) what are the projections of sea-level changes at the local level, i.e., the Bay of Bengal region of the Chilika-Puri coast, under different IPCC RCPs scenarios? (ii) what are the likely consequences of climate change-induced SLR on natural resources? (iii) who are the coastal natural resource-dependent communities influenced by the rising sea level? (iv) what adaptation measures are required at the cadastral level to safeguard coastal natural resources and their dependent social communities from rising sea levels? what are the responsibilities of the concerned stakeholders, and what policy interventions are required?

The following are the primary objectives of this study, which address the research concerns raised above: (i) to evaluate and observe past sea-level changes, (ii) to predict future SLR at the local level under various RCPs scenarios for the study area (iii) To investigate the impact of SLR on coastal natural resources and the social communities that rely on them and identify vulnerable SLR inundation zones (iv) To evolve a strategic plan for adaptation to SLR as a precautionary/anticipatory response measure.

## Materials and methods

### *Study area*

The study area Chilika-Puri Coast with a coastal length of 100 kms is located between 19° 22'50.15"N, 85° 05'16.40" E and 19° 48' 19.82"N, 85° 51' 53.19" E in the


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Puri district of Odisha, India (*Fig. 1*). The study area is situated on the east coast of India and is a maritime belt with plenty of natural resources. The Study area relishes international importance and attracts people to the famous Chilika lagoon, Lord Jagganath temple, and Rushiklya Olive Ridley rookery. The study area covers a diverse topography, including beach terraces, low cliffs, sandy beaches, dunes, rocky shores, estuaries, wetlands, and forests. More than 300,000 fisher folk communities mainly depend upon the Chilika Lagoon for their livings. The Rushikulya Rookery is India's most significant mass nesting site of the Olive Ridley sea turtle in the southernmost part of the study area. As per the Hindu religious faith, Puri is the holy city of Lord Jagannath, which is located on the Bay of Bengal, Odisha. According to the 2011 census, the city's population is 2.01 lakhs (0.201 million), and the city witnesses more than 40 lakhs (4 million) visitors and pilgrims due to temple tourism. Most of the study area is classified as agricultural land, and livelihoods mainly depend on farming and related activities. However, the local community has started migrating to various cities for better livelihood options (Velan and Mohanty, 2015). The study area has a historical record of severe natural disasters like floods and cyclones, adversely affecting agricultural production. The Chilika-Puri coastal area on the Bay of Bengal coast of India periodically experiences the loss of life and severe damage from tropical cyclones originating in the Bay of Bengal past (Murty et al., 1986; Dube et al., 1994; Das et al., 1983). Severe flooding triggered by storm surges during the 1999 super cyclone massively destroyed thousands of people's lives and property near the coast. Extreme sea levels are significant causes of concern for coastal flooding in the coastal region of Odisha (Kumar et al., 2010; Khristodas et al., 2022).

Due to frequent storm surges, the study area encounters rising sea levels, which cause severe coastal erosion and structural damage (Kar et al., 2021). Many low-lying coastal regions, like the Chilika lagoon area with an altitude of 0-2 m, are only at sea level and are highly vulnerable to the effects of coastal disasters and increasing sea levels (Khristodas et al., 2022). The local communities living in the densely populated northern areas of the Chilika-Puri coast are particularly at risk. These areas are significantly more likely to be exposed to natural disasters like cyclones and floods. As a result, many of the inhabitants (the population of Fishermen and Farmers) living in low-lying coastal areas are highly susceptible to coastal flooding, extreme events, and SLR.

### *Projection of sea level rise and inundation area mapping*

The present research devised qualitative and quantitative methodology in which primary and secondary sources are thoughtfully tapped for information and perspective. Furthermore, IPCC criteria for assessing the SLR were followed in this research work. Many studies estimate past SLR monthly mean sea-level values (Unnikrishnan et al., 2006, 2015; Ramachandran et al., 2017; Khristodas et al., 2022). Paradip tide gauge station is Odisha's only tide gauge station available in the PSMSL archive (Station ID: 1161). The monthly mean sea level observed data (1966 to 2015) of Paradip tide gauge station were downloaded and analyzed to observe the changes in sea level and its trend along the coast of Odisha. Future SLR projections were developed per IPCC's RCP scenarios using the SimCLIM tool for the three different timescales with an interval of 30 years, i.e., for 2040, 2070, and 2100. SimCLIM, a user-friendly tool, includes a scenario generator that uses pattern-scaling approaches at essential scales (Warrick, 2009). Due to future SLR along the coast, the inundation area was estimated using


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inundation mapping in the ArcGIS 10.5 tool (Malik and Abdalla, 2016). The Cartosat-1 (30 resolution) digital elevation model (DEM) from National Remote Sensing Centre (NRSC), Hyderabad, India, was used in this study. The CartoDEM was post-processed for geoid correction, and the null values were removed. The processed DEM was clipped with the study area shape file. The generated DEM has been validated using Differential Global positioning system (DGPS) measurements. Then the inundation area for 0.5 m and 1 m SLR scenarios were calculated and mapped using the Raster Calculator tool in ArcGIS.

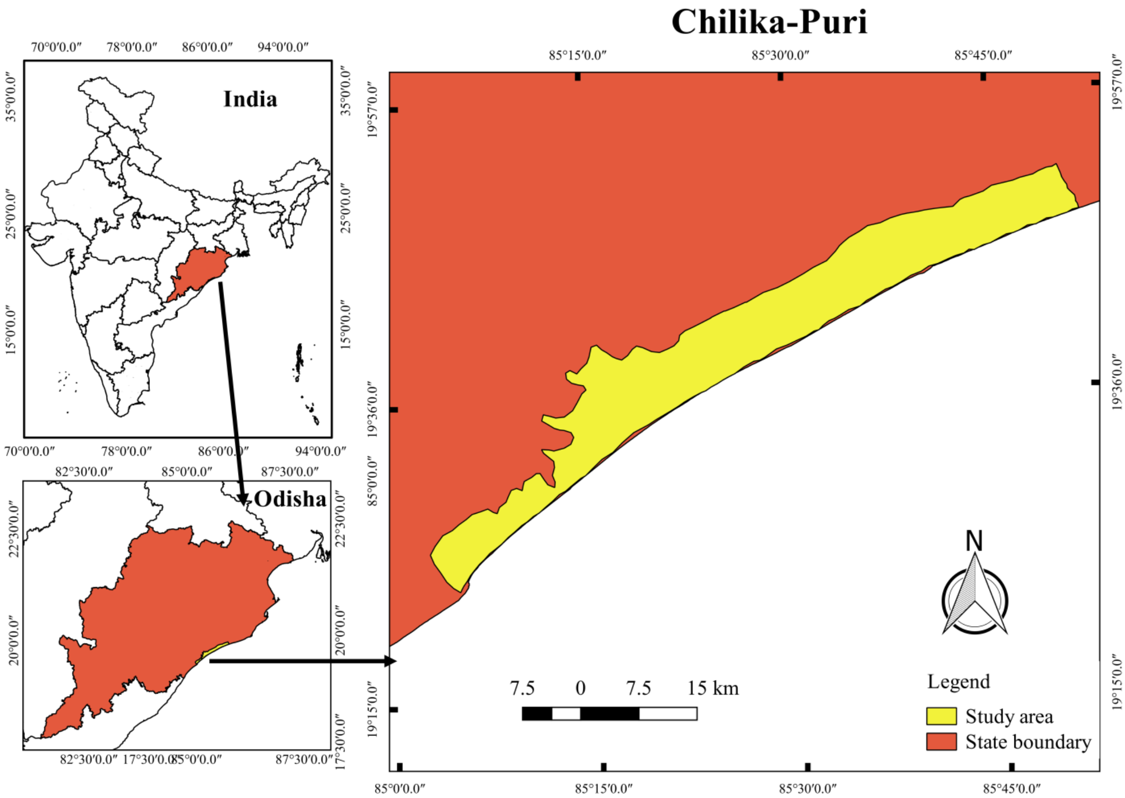


***Figure 1.*** *Study area map of Chilika-Puri coast*

### *SLR adaptation action strategy framework*

Participatory Rural Appraisal (PRA) methodology was used to gather new data and construct a novel hypothesis about SLR in the coastal natural resource-dependent population. To obtain information about audience understanding, attitudes, and perception about SLR risk information, a qualitative approach included document-based evaluations and semi-structured interviews were carried out. It was carried out utilizing techniques such as secondary source evaluation, comprising mapping, (ii) direct observation, foot transects, interaction, and active participation, (iii) key informant interviews and group discussion, (iv) graphical representation, and (v) field report writing. Multiple statistical tools were used to see if there were any significant differences in perceptions about SLR based on the gender and educational level of the respondents. The current study intends to communicate SLR to raise awareness among various stakeholders and prioritize SLR adaptation solutions that have been discovered.


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## Results

The observed sea-level change from 1966 to 2015, the SLR projections for the six coastal districts for four different scenarios at three-time scales, and district-wise inundation areas due to future SLR, perception of residents on climate change induced sea level rise and the framework of adaptation strategies for the Chilika-Puri Coast are presented here.

### *Observed sea-level changes from 1966 to 2015*

The yearly mean sea-level data from 1966 to 2015 were analyzed to see the changes along the coast. This 50-year-long monthly data from Paradip tide gauge station shows that the sea level along Odisha's coast is increasing steadily. The observed relative sea level trend is 1.94 mm/yr with a 95% confidence interval of +/- 0.96 mm/yr, comparable to 0.64 feet in 100 years (*Fig. 2*).

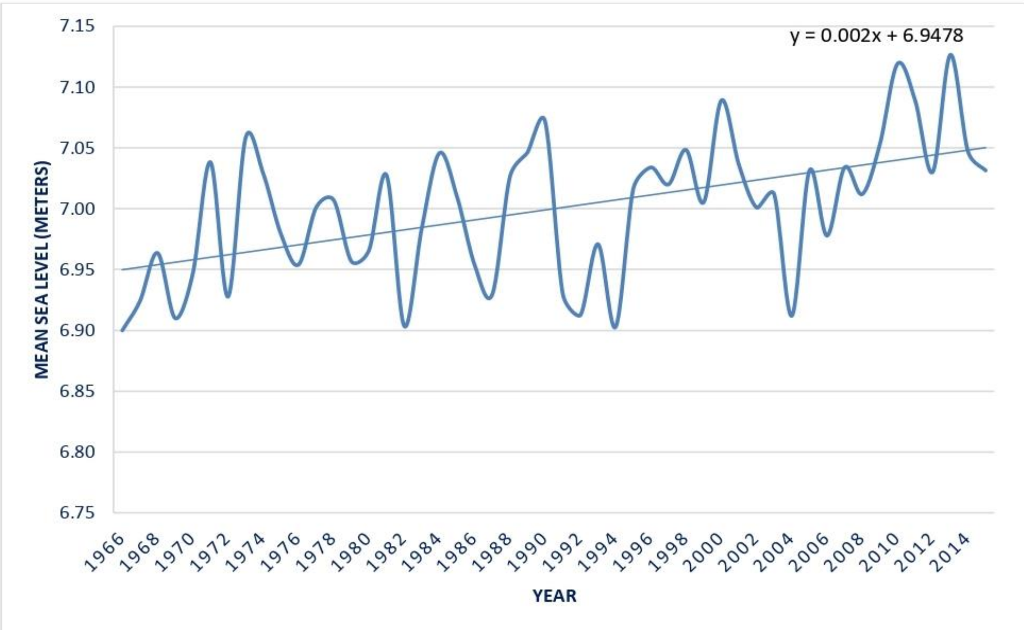


***Figure 2.*** *Observed MSL trend of Paradip tide gauge station, Odisha*

### *Future IPCC scenarios of SLR for Chilika-Puri Coast*

SLR projections (low, medium, and high) of IPCC RCPs 2.6, 4.5, 6.0, and 8.5 were made for four different timescales with an interval of 30 years, i.e. for 2040, 2070 and 2100. The projected SLR for the Chilika-Puri coast indicated 38.88 to 74.81 cm under high emission scenarios for the year 2100. The detailed projections for each timescale are described below:

#### *SLR scenarios for the year 2040*

The SLR projections for 2040 have been estimated at 4.32 to 8.80 cm for the RCP2.6; 4.99 to 8.98 cm for RCP4.5; 5.33 to 10.22 cm under the RCP6.0, and 6.29 to 12.22 cm for the RCP8.5 scenario. The SLR projections under IPCC RCP2.6, RCP4.5, RCP6.0, and RCP8.5 scenarios for all the districts are shown in *Table 1*.


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*SLR scenarios for the year 2070*

The SLR projections for 2070 have been estimated at 13.74 to 28.99 cm for the RCP2.6; 15.76 to 31.52 cm for RCP4.5; 15.04 to 30.30 cm under the RCP6.0, and 19.50 to 36.75 cm for the RCP8.5 scenario. The SLR projections under IPCC RCP2.6, RCP4.5, RCP6.0, and RCP8.5 scenarios for all the districts are shown in *Table 1*.

*SLR scenarios for the year 2100*

The SLR projections for 2100 were estimated as 20.24 to 48.37 cm for the RCP2.6, 25.01 to 55.54 cm for RCP4.5; 26.88 to 56.04 cm under the RCP6.0 and 38.88 to 74.81 cm for the RCP8.5. The SLR projections under RCP2.6, RCP4.5, RCP6.0, and RCP8.5 scenarios are listed in *Table 1*. A graphical representation of the SLR trends are presented in *Figure 3*.

***Table 1.*** *SLR Scenarios for Chilika-Puri Coast (in cm)*

| Scenario | RCP2.6 | | | RCP4.5 | | | RCP6.0 | | | RCP8.5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Range/year | Low | Medium | High | Low | Medium | High | Low | Medium | High | Low | Medium | High |
| 2040 | 4.32 | 6.60 | 8.80 | 4.99 | 7.89 | 8.98 | 5.33 | 8.88 | 10.22 | 6.29 | 10.15 | 12.22 |
| 2070 | 13.74 | 21.64 | 28.99 | 15.76 | 23.58 | 31.52 | 15.04 | 21.99 | 30.30 | 19.50 | 27.86 | 36.75 |
| 2100 | 20.24 | 33.19 | 48.37 | 25.01 | 40.32 | 55.54 | 26.88 | 40.05 | 56.04 | 38.88 | 55.72 | 74.81 |

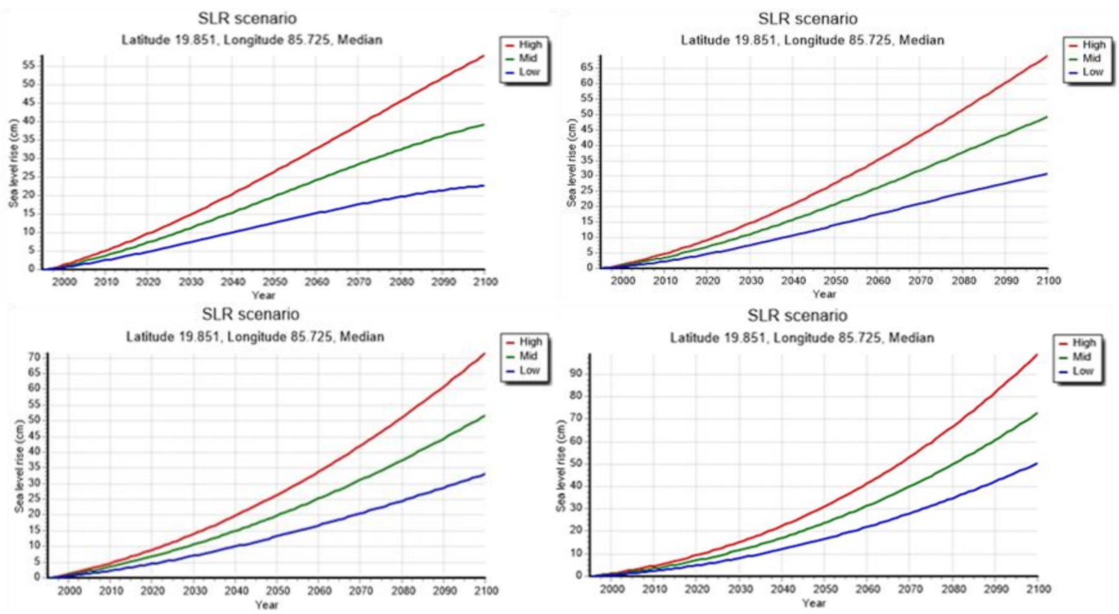


***Figure 3.*** *Trends of SLR Projection for RCP2.6, RCP4.5, RCP6.0, and RCP8.5 for the Chilika-Puri Coast*

### *SLR inundation mapping*

The inundation modelling using ArcGIS has been carried out for appropriate vulnerability assessment and framing suitable adaptation strategies in the Chilika-Puri coast. The inundated area (*Fig. 4*) of the Chilika-Puri coast for 0.5 m and 1 m SLR is listed in *Table 2*. For 0.5 m SLR and 1 m SLR, respectively, 78.70 km$^2$ and 98.61 km$^2$ of


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the 127.97 km$^2$ agricultural area would be submerged. The barren land area is 78.82 km$^2$, out of which 11.57 km$^2$ areas would be inundated for 0.5 m SLR and 21.35 km$^2$ for 1 m SLR. Of the 127.97 km$^2$ total built-up area, 5.84 km$^2$ areas would be inundated for 0.5 m SLR and 12.23 km$^2$ for 1 m SLR. Out of the 134.39 km$^2$ of vegetation area, 68.88 km$^2$ areas would be inundated for 0.5 m SLR and 86.49 km$^2$ for 1 m SLR.

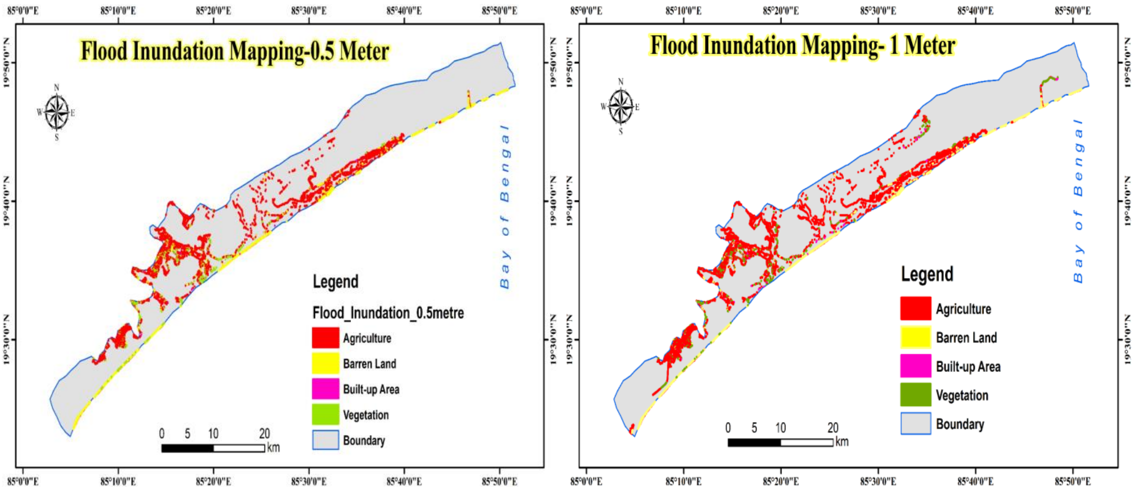


***Figure 4.*** *Area of inundation (0.5 m and 1 m SLR)*

***Table 2.*** *SLR impact analysis*

| Sl. No. | LULC types | Area (km$^2$) as per 2017 classification | Inundation area (km$^2$) 0.5 m SLR | Inundation area (km$^2$) 1 m SLR |
|---|---|---|---|---|
| 1 | Agriculture | 127.97 | 78.70 | 98.61 |
| 2 | Barren land | 78.82 | 11.57 | 21.35 |
| 3 | Built-up area | 60.54 | 5.84 | 12.23 |
| 4 | Vegetation | 134.39 | 68.88 | 86.49 |

### *Coastal adaptation to SLR*

One of the most practical and long-term responses to SLR is regarded to be a coastal adaptation. In this study, the study area’s three primary coastal natural resources—agriculture, aquaculture farms, and forest under Puri Sadar, Brahmagiri, and Krushnaprashad Block—are more significantly impacted by the projected SLR (0.5 and 1 m). IPCC (2001) identified different types of adaptations: anticipatory adaptation, planned adaptation, autonomous adaptation, private adaptation, public adaptation, and reactive adaptation. To combat the potential impacts of SLR in the research area, a combination of planned and anticipatory adaptation is proposed.

#### *Planned anticipatory adaptation*

The following two-track strategy has been suggested to frame planned-anticipatory adaptation for a productive coastal system like the study area (Chilika-Puri Coast): the ecosystem-based adaptation and the other is community-based adaptation to predict the impact of SLR.


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*Ecosystem-based adaptation*

Using biodiversity and ecosystem services to help individuals adapt to the effects of climate change is known as ecosystem-based adaptation (EbA) (CBD, 2009). Community-based adaptation (CBA), which is described as "a community-led approach based on community objectives, needs, knowledge, and skills that should enable people to plan for and cope with the effects of climate change," is closely related to EbA (Hannah Reid, 2009). The EbA strategy is regarded as an adaptable, economic, and widely applicable strategy capable of addressing climate change's scale, velocity, and uncertainty (Jones et al., 2012). An outline for EbA in this study for four primary coastal natural resources, namely, agriculture, forest, aquaculture and eco-sensitive zones (Chilika Lake and Rusikulya Olive Ridley Rookery) recommended below:

*Agriculture*

The agricultural land of the study area is seriously threatened by rising SLR. Significant concerns in this area include stress from flooding, an increase in salinity, and sediment erosion at landward zones. The agriculture area of this region is at risk of inundation to 0.5 m and 1 m SLR. In this context, there is an urgent requirement for adaptive measures, especially with the active involvement of local communities of the study area. The major identified adaptation options are listed in *Table 3*.

***Table 3.*** *Identification of ecosystem (agricultural) based adaptation strategies to SLR*

| Adaptation options | Benefits | Constraints | Locations |
|---|---|---|---|
| Change in farming practices | No dependency on one particular crop, and thus it may ensure food security | Difficulties in identifying alternate crops and practice as it is time consuming | Major portion of agricultural land in Brahmagiri and Krushnaprasad block |
| Saline tolerant varieties | Ability to meet the challenges of SLR and may ensure sustainability | High technological input is needed, expensive, time-consuming | A major portion of agricultural land in Golasahi village, Puri sadar block |
| Building improved defenses, irrigation and drainage | Keeping salinity levels tolerable | The trial and error method to check the suitability of this practice may not apply to all locations | A portion of agricultural land in Alupatana and BhoiSahi, Brahmagiri block |
| Change of agriculture locations | Continuation of agriculture practice but at different locations | Lack of place availability, difficulty in execution | A significant portion of villages Biripadar, Malud, Patapur, Gabakund, Panapadia |

*Aquaculture*

The aquaculture farms in the Brahmagiri Block (Satapada, Alupatana, Panasapada, Gabakunda, and Anandapur) and the Krushnaprasad Block (Talatala, Malud, Rasakudi, and Patharganja) need to pay more attention to the adaptation measures. One possible adaptation strategy for aquaculture farms to deal with SLR is to practice alternative aquaculture farming by introducing salt-tolerant strains. Moreover, combining aquaculture with other farming practices may lower financial loss and livelihood insecurity risk. Site-specific zoning of aquaculture activities will be an essential long-


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term adaptation tool to SLR. A list of adaptation responses to aquaculture farms to SLR is demonstrated in *Table 4*.

***Table 4.*** *Identification of ecosystem (aquaculture) based adaptation strategies to SLR*

| Adaptation options | Benefits | Constraints | Locations |
|---|---|---|---|
| Salt tolerant strains | Ability to cope with increased salinity to face the threat of SLR, limited but commercially high cost | Difficulty in providing a conducive environment for euryhaline species to grow | Major aquaculture farm located at Satapada, Alupatana, Panasapada, Gabakunda, Anandapur (Brahmagiri Block)<br><br>Aquaculture farms located at Talatala, Malud, Rasakudi, Patharganja village (Krushnaprasad block) |
| Maintain optimal conditions | Sustainability of aquaculture farms and developing a practice to adopt changing conditions | High-cost, intensive labor work | |
| Diversified organisms/products | Continuous production of aquaculture products, irrespective of a particular type of products | Difficulty in providing a conducive environment, particularly meeting the health of the farm with multiple organisms | |
| Site-specific zonation | Aquaculture practices can be continued but at different locations and not on choice | Lack of place available to shift, difficulty in shifting and maintain the condition in new zone, high cost | |

### *Forest*

Significant patches of reserved forest located at Krushnaprasad and Brahmagiri block may be permanently inundated to a projected SLR of 0.5 and 1 M SLR. Scattered patches of forest located at Puri Sadar block are also equally under high risk and require appropriate adaptation actions. Coastal communities of the Chilika catchment area have shown their renewed faith in nature by replanting mangroves across 40 hectares of land in the intertidal regions of Arakhuda, the old mouth of lake Chilika. Long-term retreats with relative SLR may be facilitated by site planning for some mangrove-containing coastal portions, particularly in less developed areas (Dixon and Sherman, 1990; Gilman et al., 2008). For the restoration of mangroves in the Arakhuda region, a MoEF approach known as “Canal Bank Planting” and “Fish Bone” design can be used. Enhancing the sedimentation profile of the mangrove soil is regarded a high priority among the adaptation measures for the mangrove ecosystem to SLR in this study, followed by peat construction as a short-term and ongoing response, and the physiographic setting is considered as a long-term strategy.

### *Prioritizing community-based adaptation (CBA) strategies*

Schipper et al. (2014), Karim and Thiel (2017), Khan (2017), Ensor et al. (2018), and Hussein et al. (2020) have covered several aspects of CBA and building the adaptive capability of coastal fishing communities.

CBA aims to empower communities to prepare for and respond to climatic stress by facilitating inclusive, community-driven, and sustainable adaptation. In theory, this is achieved by enabling local peoples to plan for the impacts of climate change and determine the methods and goals of adaptation. The identified CBA strategies are SLR community outreach and education, recognizing indigenous knowledge, stakeholder


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mapping, developing local capacity, building SLR resilient livelihood, developing good health and sanitary system, valuing women's participation in decision-making policies, promoting climate-risk insurance, community-based climate change action, and SLR based risk reduction efforts (*Fig. 5*).


***Figure 5.*** *List of CBA strategies for Chilika-Puri Coast to SLR*

*Community-based non-formal SLR communication and stakeholder participation*

SLR information, communication and education activities are vital to enhancing local communities' adaptive capacity as they necessitate positive changes among individuals, groups and institutions (Sales, 2009); and to prepare appropriate local-level CBA strategies (Khan et al., 2022). A highlighted the importance, urgent awareness, and preparedness of climate change education at the grassroots level. Community-based climate awareness was created using non-formal climate change education and learning approaches to increase climate knowledge and capacity at the local level and empower people to take an active role in developing appropriate adaptation measures. Thus, community participation is key to conservation and sustainable use methods. Local people are significant and direct managers and users of the resources to be conserved, especially in climate change (SLR). In this case study, four intervention techniques were used to raise stakeholder climate knowledge (key, primary, secondary, and tertiary stakeholders) in communities in Satapada Panchayat of Brahmagiri block (Bhoi Community) and Puri Sadar (Telugu fisherman community): (1) Convey information: a one-way transmission of information to provide a basic understanding of climate science, provide missing facts or data on global and local climate, and raise awareness of their current and future state of exposure and sensitivity to change climate, specifically sea-level rise. This strategy used community radio, information campaigns, news articles, posters, and pamphlets to disseminate information. (2) Build understanding: a two-way information transfer that


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enables stakeholders to establish their techniques for grasping climate change and clarifying their doubts. The impact of SLR on natural resources and the level of vulnerability to the dependent community was emphasized through location-specific investigations and presentations with discussions, vulnerability mapping (e.g. mapping various degrees of exposure to natural resources and degree of vulnerability to different stakeholders), and focus group interviews (e.g. direct interviews with different groups, including the fishermen's community, the Bhoi community – a unique indigenous community of the region – along with local NGOs who work on natural resource conservation and community development). Thus, techniques in this category aid in sharing ideas and discourse to develop a sense of place and clarify and deepen awareness and concern about climate change impacts. (3) Improve skills: stakeholders learn to apply or implement a skill or organize and critique information. Programs such as the citizen science, which goals to promote stakeholder engagement with climate research and science, encourage volunteers and network volunteers from the local fishing community to implement and accomplish research-related responsibilities such as indigenous observation and recording of daily weather changes in the study area and periodic measurements of tides; training the trainer's program to develop a network of informed trainers who can set up their initiatives to design and deliver resilience training programs on natural resources and the dependent community; cooperative learning workshops to offer opportunities for stakeholders to share knowledge and experience in technical aspects of natural resources, in particular, to identify climate-vulnerable agricultural crop varieties and introduced capacity building for the agriculture-dependent community to face the risk posed by the SLR. (4) Enable sustainable actions: transform stakeholders through critically addressing the problems. This allows stakeholders to work collectively to define goals and intervention methods and develop organizational leadership in the local community to fight climate change. Previous strategies could be limited to climate change information; this tends to include suitable adaptation options (e.g. grappling with different dimensions of the same problem to redefine it can help bring new solutions). In this case study, stakeholders of the fisheries and agriculture-dependent communities are motivated to design adaptation projects, learn how the decision-making process works for planning suitable adaptation options for their locality; and how they can effectively influence decisions. Stakeholders are then encouraged to cooperate and work with local NGOs, the Forest Department, the Department of Environment and Forests, the Government of Odisha and other agencies in natural resource conservation, management and restoration from the view of climate change.

The socio-economic profile of the study area (*Table 5*) demonstrates that, of the interviewees, 31.41% were in the 36-45 age group, and 30.32% of the fishermen communities had more than 20 years of fishing experience. Among them, 45.85% had received an education below the 10$^{th}$ standard. Among those surveyed, 76.17% have an annual income below 1 Lakh (2056 USD). Furthermore, the results of the perception analysis of the respondents (*Table 6*) of the study area reveal that 86.64% of people think SLR is a danger to their life. According to 2.17% of respondents opined that SLR would increase 1–5 feet by the end of the century. Nevertheless, the Rapid Rural Appraisal (RRA) has revealed that this study area's fishing and farmers' communities are not much aware of climate change and SLR even though they have experienced several coastal disasters from.


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***Table 5**. Socio-economic profile of respondents*

| Categories | Frequencies | % |
|---|---|---|
| *Age* | | |
| 18-25 | 74 | 26.71 |
| 26-35 | 50 | 18.05 |
| 36-45 | 87 | 31.41 |
| 46-55 | 43 | 15.52 |
| 56 and above | 22 | 7.94 |
| *Gender* | | |
| Female | 17 | 6.14 |
| Male | 260 | 93.86 |
| *Education level* | | |
| Below tenth | 127 | 45.85 |
| Tenth | 41 | 14.80 |
| Intermediate | 36 | 13.00 |
| Graduate | 33 | 11.91 |
| Postgraduate | 40 | 14.44 |
| *Family size* | | |
| 2 and 3 | 34 | 12.27 |
| 4 and 5 | 136 | 49.10 |
| 6 and 7 | 60 | 21.66 |
| 8 and 9 | 24 | 8.66 |
| 10 and 11 | 14 | 5.05 |
| 12 and 13 | 3 | 1.08 |
| 14 and 15 | 6 | 2.17 |
| *Occupation* | | |
| Business | 19 | 6.86 |
| Daily labor | 38 | 13.72 |
| Farmer | 34 | 12.27 |
| Fisherman | 84 | 30.32 |
| Government employee | 4 | 1.44 |
| Housewife | 9 | 3.25 |
| Lecturer | 11 | 3.97 |
| Social worker | 20 | 7.22 |
| Student | 37 | 13.36 |
| Teacher | 21 | 7.58 |
| *Income* | | |
| Below 1 lakh (1223.11 USD) | 211 | 76.17 |
| 1-2.5 lakhs (1223.11- 3057.77 USD) | 8 | 2.89 |
| 2.6-5 lakhs (3180.08- 6115.53 USD) | 50 | 18.05 |
| 5-10 lakhs (6115.53-12231.07 USD) | 1 | 0.36 |
| 6-10 lakhs (7338.64-12231.07 USD) | 5 | 1.81 |
| Above 10 lakhs (12231.07 USD) | 2 | 0.72 |
| *Loan access* | | |
| Yes | 166 | 59.93 |
| No | 111 | 40.07 |
| *Insurance for natural disasters* | | |
| Yes | 80 | 28.88 |
| No | 197 | 71.12 |

***Table 6.*** *Perception of the respondents on SLR*

| Question | Answer | Frequencies | % |
|---|---|---|---|
| Do you think Sea level rise danger for life? | No | 240 | 86.64 |
| | Yes | 37 | 13.36 |
| Do you have any idea of shoreline change in your locality? | No | 238 | 85.92 |
| | Yes | 39 | 14.08 |
| How much do you think the sea level has risen in the past 100 years? | Don't know | 271 | 97.83 |
| | Between 1-5 feet | 6 | 2.17 |
| How many feet do you think sea level will rise in the next 50 years? | Don't know | 189 | 68.23 |
| | Under 1 feet | 19 | 6.86 |
| | Between 1-5 feet | 25 | 9.03 |

Super Cyclone 1999 to 2019 Fani, which are highly affected coastal disasters. The difficulty in distinguishing between just hearing and being aware of climate change-induced SLR was evident among the respondents. Similarly, 68.23% of the people opined that they do not know of any change in SLR, whereas about 6.86% of respondents opined that SLR would increase by less than 1 foot in the next 50 years.

### *Actions toward climate change induced SLR*

Most interviewees responded that they were not remarkably assured that climate change adaptation measures could alleviate the impacts. Most believed that for adaptive measures to be effective, the community needs to act together as a whole and that therein lies the main obstacle. The attitudes and mindsets of the citizens elicited the most comments in all of the interviews, with most responding that there is a general apathy amongst individuals about climate change and the environment as a whole. As SLR is one of the most significant effects of climate change, the study area residents expressed their interest in sharing climate change mitigation options (*Fig. 6*) and their suggestions to adapt SLR in their locality (*Fig. 7*). To take a set of steps towards the events that could be caused by climate change, like sea level rise, the most important one was plantation (25% out of total respondents), followed by less use of electricity (22% out of total respondents).

Furthermore, the residents of the study area opined that Govt. should take necessary adaptation measures in their locality to reduce the risk of SLR. About 65% of the residents believe that education programs on SLR can be the best option to make people aware of climate change-induced SLR. 11.6% building sea walls and jetties should be constructed to avoid SLR risk. Whereas 7.6% opined building dunes and protecting wetlands can be the necessary adaption measures.

## Discussion

Climate change-induced SLR projection for Chilika-Puri coast in all four RCPs of IPCCC AR5 has been estimated with an average maximum of 55.72 cm by 2100. Even a small increase in sea level of 3 feet (91 cm) might result in significant beach and coastal wetland erosion, more flooding, and salt water intrusion into rivers, bays, and


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aquifers (Titus, 2008). The observed relative sea level trend is 1.94 mm/yr with a 95% confidence interval of +/- 0.96 mm/yr, comparable to 0.64 feet in 100 years (*Fig. 2*). Tide gauge data estimations along the Indian coast illustrate a rise in sea level of 1 mm/year (Unnikrishnan et al., 2006; Khan et al., 2022). Although SLR in the Indian Ocean is not consistent, the rate of rise in the north Indian Ocean was 0.33 cm/yr from 1993 to 2015 and 0.10 to 0.17 cm/yr from 1874 to 2004 (Swapna et al., 2020). The projected SLR for the Chilika-Puri coast indicated 38.88 to 74.81 cm under high emission scenarios for the year 2100. Based on several scenarios of RCPs generated from CMIP5 climate projections, the IPCC AR5 anticipated a global mean SLR for 2081-2100 of between 55 cm and 82 cm relative to 1986-2004 (Church et al., 2013). However, using SimCLIM climate modelling software, the local SLR prediction for Chennai has been estimated to be between 7.10 cm and 77.88 cm (Ramachandran et al., 2017). As rates of SLR continue to increase due to climate change, land planners require accurate spatial analyses on the extent and timing of coastal flooding and associated hazards (Poulter and Halpin, 2008). For 0.5 m SLR and 1 m SLR, respectively, 78.70 $km^2$ and 98.61 $km^2$ of the 127.97 $km^2$ agricultural area would be submerged. Many floods, increased tidal inundation, rapid erosion, intrusion of saltwater, rising water tables, and several ecological changes are among the effects of accelerated SLR that have drawn more attention (Dolan and Walker, 2006).

The current study suggests a combination of planned and anticipatory adaptation to counteract the possible effects of SLR in the study area. Agriculture, forestry, aquaculture, and eco-sensitive zones (Chilika Lake and Rusikulya Olive Ridley Rookery) are the four main coastal natural resources studied in this study. SLR is already impacting tidal freshwater forests (Doyle et al., 2010), and tidal saltwater forests (mangroves) are expanding landward in sub-tropical coastal reaches taking over the freshwater marsh and forest zones (Di Nitto et al., 2014). The baseline for coastal flooding rises as the sea level rises. This brings further inland daily and monthly tidal flooding, periodic storm surges, and shallow groundwater's fresh/saline transition zone. Over time, the additional inland reach of storm surges results in coastal forest dieback. The CBA process begins with assessing vulnerabilities to climate stress, the factors underlying such vulnerabilities and related capacities to adapt. The assessment process typically combines technical appraisals by external actors with participatory self-assessments. CBA practitioners then seek to partner with local peoples to strengthen their capacity to prepare for and respond to the effects of climate variability and change. CBA practitioners aim to build upon existing adaptive capabilities, consisting of local knowledge, networks, practices, skills, technologies, expertise, norms and institutions, and peoples' intrinsic motivations, aspirations and goals. The CBA process seeks to build the overall capacity of communities regardless of whether or not specific climate change impacts manifest. Various CBA strategies to cope with climate change induce SLR has been identified for the coastal region of the Chilika-Puri coast. To elicit information about audience understanding, attitudes, and perception about SLR risk information, our qualitative approach included document-based evaluations and semi-structured interviews. According to the socioeconomic characteristics of the study area, 30.32% of the communities of fishermen who were interviewed had been fishing for more than 20 years. Correct perception of climatic variability (SLR) positively correlates with age and experience (Rapholo and Makia, 2020). A maximum number of interviewees could be placed in the marginal farming category and practice rain-fed farming. According to Sathyan et al. (2018), millions of rainfed smallholder farmers


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would face immediate hardship and hunger due to climate change. Among those surveyed, majority of farmers are having annual income below 1 Lakh (2056 USD). Poor inhabitants are more likely to be exposed to climate hazards and stresses and have the less adaptive capacity (Leichenko and Silva, 2014).

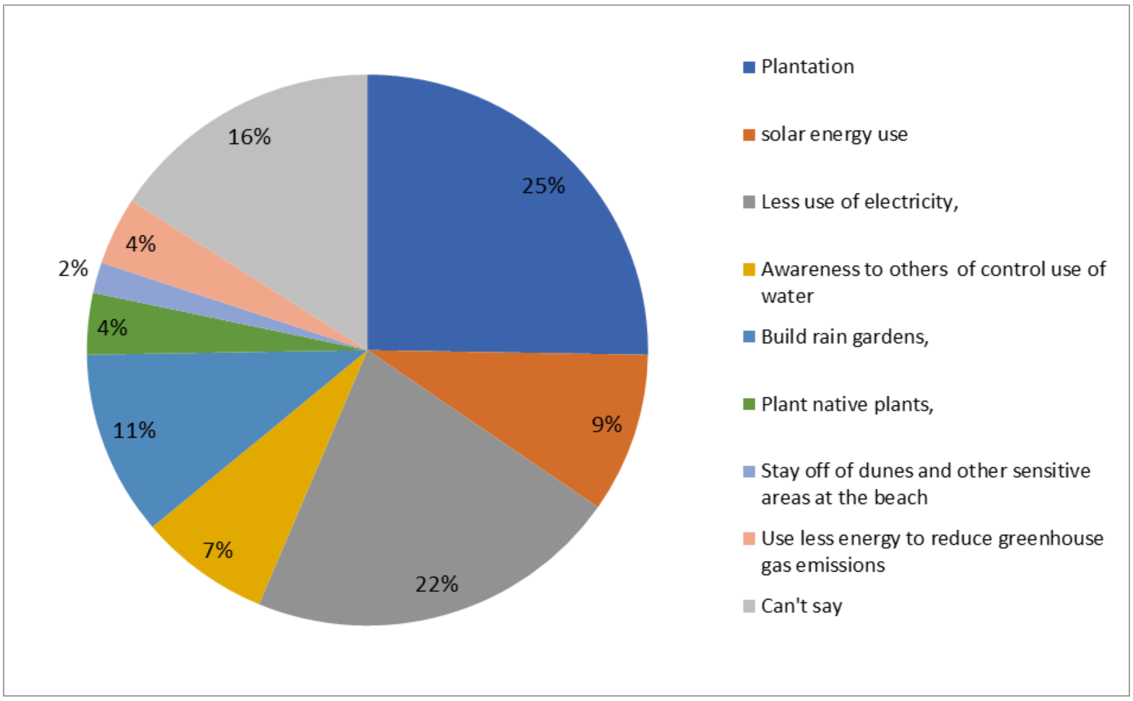


***Figure 6.*** *Steps the respondents would be willing to take to combat the impacts of sea level rise*

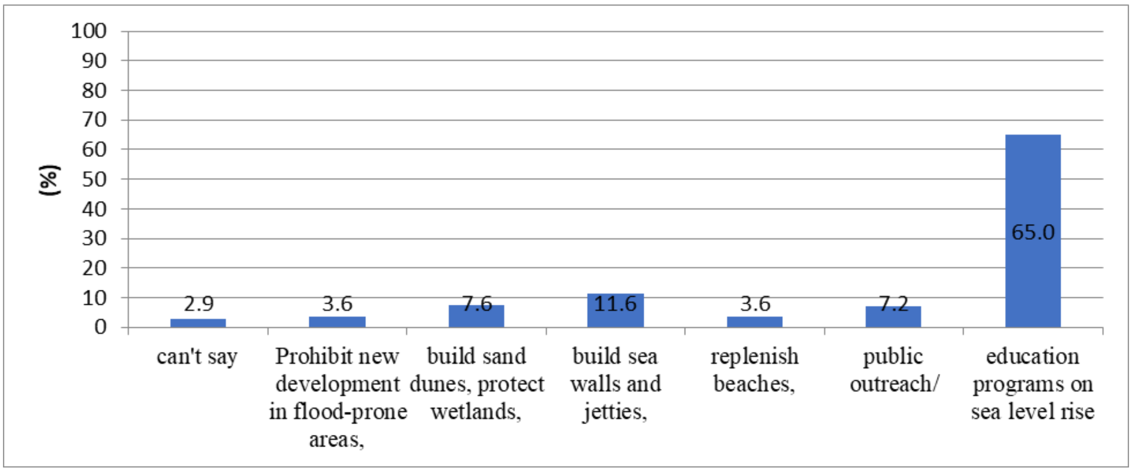


***Figure 7.*** *The actions which the community better prepare for SLR based on respondents' opinion*

The knowledge gained from the findings of this study and lessons learned can be used to develop important CBA participatory techniques for promoting climate adaptation policies through efficient climate services. To help scientists, politicians, and people in the area gain new insights and collaborate more effectively to promote


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community adaptation, adaptive techniques evolved site-specific features. This study examined how the CBA participation process in climate services affected SLR and came to the conclusion that effective participatory group action is the first step in raising local awareness of SLR risk, developing capacity through networking with vulnerable communities, and uniting on a single platform for collective decision-making (Karim and Thiel, 2017). Therefore, the comprehension of the climate service approach used relevant to SLR risk communication and capacity building of fishing and farming communities of Chilika-Puri coast highlighted in this study has the potential to inform policy-relevant recommendations that would advance CBA both in the present and possibly in the future at the local level in accordance with national and state coastal climate adaptation policies.

## Conclusions

The study has estimated general patterns of SLR and provided a holistic approach to understanding SLR and baseline SLR information of the study area. Like many other low-lying coastal regions, small-scale fishing and farming communities are vulnerable to the impacts of SLR. The synthesis of SLR risk information and data in this study revealed that the low-elevated topography of this region is prone to coastal disasters and vulnerable to SLR scenarios. An increasing trend of 0.19 cm/yr SLR was observed along the coast of Odisha from 1966 to 2015. SLR will continue rising until the end of the century under all emission scenarios. The projected SLR for the Chilika-Puri coast indicated 38.88 to 74.81 cm under high emission scenarios for the year 2100. The biological and ecological hotspots of the Chilika-Puri coast, such as Chilika Lagoon, and Rusikulya Olive Ridley rookery, which lies along the coast, would be at risk of rising sea levels. The study urges to frame SLR inclusive planning in coastal zone management in the state. This study recommends a combination of planned and anticipatory adaptation as response action measures to combat the predicted impact of SLR in the study area. To frame planned-anticipatory adaptation for a productive coastal system like the study area, the ecosystem-based adaptation and the other is a community-based adaptation to predict the impact of SLR. Various CBA strategies to cope with climate change induce SLR has been identified for the coastal region of the Chilika-Puri Coast. SLR risk communication and capacity building of artisanal fishing communities to manage and recover from climate change, and SLR is a necessary means to reduce their vulnerability. However, SLR risk awareness among the artisanal fishing communities of the study area is limited. Realizing the importance of communities’ awareness and adaptation to SLR, this study has meticulously adopted the ecosystem and community-based adaptation framework to collect, disseminate and communicate the risk of SLR; and discourse to build consent about the reality of SLR and co-development of climate adaptation action.

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## REFERENCES

[1] Barth, M. C., Titus, J. G. (1984): Greenhouse Effect and Sea Level Rise: A Challenge for This Generation. – Van Nostrand Reinhold, New York. http://epa.gov/climatechange/effects/coastal/SLRChallenge.html (accessed May 24, 2011).
[2] CBD (Convention of Biological Diversity) (2009): Connecting biodiversity and climate change mitigation and adaptation: report of the second ad hoc technical expert group on biodiversity and climate change. – Technical Series No. 41. Secretariat of the CBD, Montreal. http://www.cbd.int/doc/publications/cbd-ts-41-en.pdf.
[3] Church, J. A., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., Merrifield, M. A., Milne, G. A., Nerem, R. S., Nunn, P. D., Payne, A. J., Pfeffer, W. T., Stammer, D., Unnikrishnan, A. S. (2013): Sea Level Change. – In: Stocker, T. F., Qin, D., Plattner, G. K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P. M. (eds.) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.
[4] Das, P. K., Dube, S. K., Mohanty, U. C., Sinha, P. C., Rao, A. D. (1983): Numerical simulation of the surge generated by the June 1982 Orissa cyclone. – Mausam 34(1983): 359-366.
[5] Di Nitto, D., Neukermans, G., Koedam, N., Defever, H., Pattyn, F., Kairo, J. G., Dahdouh-Guebas, F. (2014): Mangroves facing climate change: landward migration potential in response to projected scenarios of sea level rise. – Biogeosciences 11: 857-871.
[6] Dixon, J. A., Sherman, P. B. (1990): Economics of Protected Areas. A New Look at Benefits and Costs. – Island Press, Washington, DC.
[7] Dolan, A. H., Walker, I. J. (2006): Understanding vulnerability of coastal communities to climate change related risks. – Journal of Coastal Research 1316-1323.
[8] Doukakis, E. (2005): Coastal Vulnerability and Sensitivity Parameters. – European Water, 11: 3-7.
[9] Doyle, T. W., Krauss, K. W., Conner, W. H., From, A. S. (2010): Predicting the retreat and migration of tidal forests along the northern Gulf of Mexico under sea-level rise. – Forest Ecology and Management 259(4): 770-777.
[10] Dube, S. K., Rao, A. D., Sinha, P. C., Chittibabu, P. (1994): A real time storm surge prediction system: An application to east coast of India. – Proceedings of the Indian National Science Academy 60(August): 157-170.
[11] Ensor, J. E., Park, S. E., Attwood, S. J., Kaminski, A. M., Johnson, J. E. (2018): Can community-based adaptation increase resilience? – Climate and Development 10(2): 134-151.
[12] Gilman, E., Ellison, J., Coleman, R. (2007): Assessment of mangrove response to projected relative sea-level rise and recent historical reconstruction of shoreline position. – Environmental Monitoring and Assessment 124(1-3): 105-130.
[13] Gilman, E. L., Ellison, J., Duke, N. C., Field, C. (2008): Threats to mangroves from climate change and adaptation options. – Aquatic Botany 89(2): 235-250.
[14] Hussein, I., Alves, M. F., Morgado, F. (2020): Artisanal Fishing and Climate Change: The Case of Pemba, Mozambique. – In: Filho, W. L., Brandli, A. M. A. L., Tony Wall, P. G. O. (eds.) Climate Action. Encyclopedia of the UN Sustainable Development Goals. Springer Nature, Cham, pp. 42-51.
[15] IPCC (2001): Climate Change 2001. The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (TAR-IPCC). – Cambridge University Press, New York.
[16] IPCC (2021): Summary for Policymakers. – In: Masson-Delmotte, V. et al. (eds.) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth


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DOI: http://dx.doi.org/10.15666/aeer/2105_44254444

Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

[17] Kar, P. K., Mohanty, P. K., Pradhan, S., Behera, B., Padhi, S. K., Mishra, P. (2021): Shoreline change along Odisha coast using statistical and geospatial techniques. – Journal of Earth System Science 130: 209.

[18] Karim, M. R., Thiel, A. (2017): Role of community based local institution for climate change adaptation in the Teesta riverine area of Bangladesh. – Climate Risk Management 17: 92-103.

[19] Khan, A. S. (2017): COREDAR for cities: Developing a Capacity-Building Tool for Sea-Level Rise Risk Communication and Urban Community-Based Adaptation. – In: Filho, W. L., Keenan, J. M. (eds.) Climate Change Adaptation in North America: Fostering Resilience and the Regional Capacity to Adapt. Springer Climate Change Management, Berlin, pp. 137-157.

[20] Khan, A. S., Kumar, M. S. R., Chella, R. S. (2022): Risk communication and capacity-building: a case study on framing CBA strategies of artisanal fishing communities to sea-level rise using BASIEC. – Climate Services 26: 100299.

[21] Khristodas, P. M., Palanivelu, K., Ramachandran, A., Anushiya, J., Prusty, B. A. K., Guganesh, S. (2022): Assessment of climate-induced sea-level rise scenarios and its inundation in coastal Odisha, India. – Applied Ecology and Environmental Research 20(4): 3393-3409.

[22] Kumar, M. (2015): Remote sensing and GIS based sea level rise inundation assessment of Bhitarkanika Forest and adjacent eco-fragile area, Odisha. – International Journal of Geomatics and Geosciences 5: 674-686.

[23] Kumar, T., Mahendra, R. S., Nayak, S., Radhakrishnan, K., Sahu, K. (2010): Coastal vulnerability assessment for Orissa State, East Coast of India. – Journal of Coastal Research 26: 523-534.

[24] Leichenko, R., Silva, J. A. (2014): Climate change and poverty: vulnerability, impacts, and alleviation strategies. – Wiley Interdisciplinary Reviews: Climate Change 5(4): 539-556. https://doi.org/10.1002/wcc.287.

[25] Malik, A. and Abdalla, R. (2016): Geospatial modeling of the impact of sea level rise on coastal communities: application of Richmond, British Columbia, Canada. – Modelling Earth System and Environment 2(3): 146. https://doi.org/10.1007/s40808-016-0199-2.

[26] Milliman, J. D., Broadus, J. M., Gable, F. (1989): Environmental and economic implications of rising sea level and subsiding deltas: the Nile and Bengal examples. – Ambio 18: 340-345.

[27] Mohanty, S., Mishra, S., Mohanty, R., Mohapatra, A., Pattanaik, A. (2015): Ichthyofaunal diversity of Chilika Lake, Odisha, India: an inventory, assessment of biodiversity status and comprehensive systematic checklist (1916-2014). – Check List. 11(6): 1-10. DOI: 10.15560/11.6.1817.

[28] Mohanty, S. K., Chatterjee, R., Shaw, R. (2020): Building resilience of critical infrastructure: a case of impacts of cyclones on the power sector in Odisha. – Climate 8(6): 73.

[29] Murty, T. S., Flather, R. A., Henry, R. F. (1986): The storm surge problem in the Bay of Bengal. – Progress in Oceanography 16(4): 195-233.

[30] Nicholls, R. J., Hanson, S. E., Lowe, J. A., Warrick, R. A., Lu, X., Long, A. J. and Carter, T. R. (2011): Constructing sea Level Scenarios for Impact and Adaptation Assessment of Coastal Areas: A Guidance Document. – In: Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA). IPCC, Geneva.

[31] Poulter, B., and Halpin, P. N. (2008): Raster modelling of coastal flooding from sea-level rise. – International Journal of Geographical Information Science 22(2): 167-82.

[32] Ramachandran, A., Khan, A. S., Palanivelu, K., Prasannavenkatesh, R., Jayanthi, N. (2017): Projection of climate change-induced sea-level rise for the coasts of Tamil Nadu

and Puducherry, India using SimCLIM: a first step towards planning adaptation policies. – Journal of Coastal Conservation 21(23): 1-12.
[33] Rapholo, M. T. and Diko Makia, L. (2020): Are smallholder farmers' perceptions of climate variability supported by climatological evidence? Case study of a semi-arid region in South Africa. – International Journal of Climate Change Strategies and Management 12(5): 571-585.
[34] Reid, H., Alam, M., Berger, R., Cannon, T., Huq, S., Milligan, A. (2009): Community based adaptation to climate change: an overview. – Participatory Learning and Action 60: 11-33.
[35] Sales, R. F. M. (2009): Vulnerability and adaptation of coastal communities to climate variability and sea-level rise: their implications for integrated coastal management in Cavite City Philippines. – Ocean & Coastal Management 52(7): 395-404.
[36] Sathyan, A. R., Funk, C., Aenis, T., Breuer, L. (2018): Climate vulnerability in rainfed farming: analysis from Indian watersheds. – Sustainability 10(9): 3357. https://doi.org/10.3390/su10093357.
[37] Schipper, E. L., Ayers, J., Reid, H., Huq, S., Rahman, A. (eds.) (2014): Community-Based Adaptation to Climate Change: Scaling It Up. 1st Ed. – Routledge, Abingdon. https://doi.org/10.4324/9780203105061.
[38] Suganya, R., Sarathy, R. V., Raj, B. J. R., Rajamanickam, M., Anandaraju, K. (2015): Assessing coastal vulnerability to sea-level rise between Gopalpur and Puri, Odisha Coast of India, using remote sensing and GIS. – International Journal of Engineering and Management Research 5(2): 844-851.
[39] Swapna, P., Ravichandran, M., Nidheesh, G., Jyoti, J., Sandeep, N., Deepa, J. S. and Unnikrishnan, A. S. (2020): Sea-Level Rise. Assessment of Climate Change over the Indian Region. – Springer, Singapore, pp. 175-189.
[40] Tol, R., Klein, R. J., Nicholls, R. J. (2008): Towards successful adaptation to sea-level rise along Europe's coasts. – Journal of Coastal Research 242: 432-442. http://doi.org/10.2112/07A-0016.1.
[41] Unnikrishnan, A. S., Shankar, D. (2006): Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates? – Global and Planetary Change 57(3): 301-307.
[42] Unnikrishnan, A., Gangan, N., Lengaigne, M. (2015): Sea-level-rise trends off the Indian coasts during the last two decades. – Current Science 108(5): 966-971.
[43] Velan, N., Mohanty, R. K. (2015): Gender-Wise Rural-To-Urban Migration in Orissa, India: An Adaptation Strategy to Climate Change. – In: Ramos, C. D. (ed.) Inequality and Climate Change: Perspectives from the South. African Book Collective, Oxford, pp. 137-170.
[44] Warrick, R. A. (2009): Using SimCLIM for modeling the impacts of climate extremes in a changing climate: a preliminary case study of household water harvesting in Southeast Queensland. – 18th World IMACS/MODSIM Congress, Cairns, Australia, pp. 2583-2589.
[45] Warrick, R. A., Barrow, E. M., Wigley, T. M. L. (1993): Climate and Sea Level Change: Observations, Projections and Implications. – Cambridge University Press, Cambridge.

## APPENDIX


***Photo 1.*** *Photographs of questionnaire survey and focused group discussion*

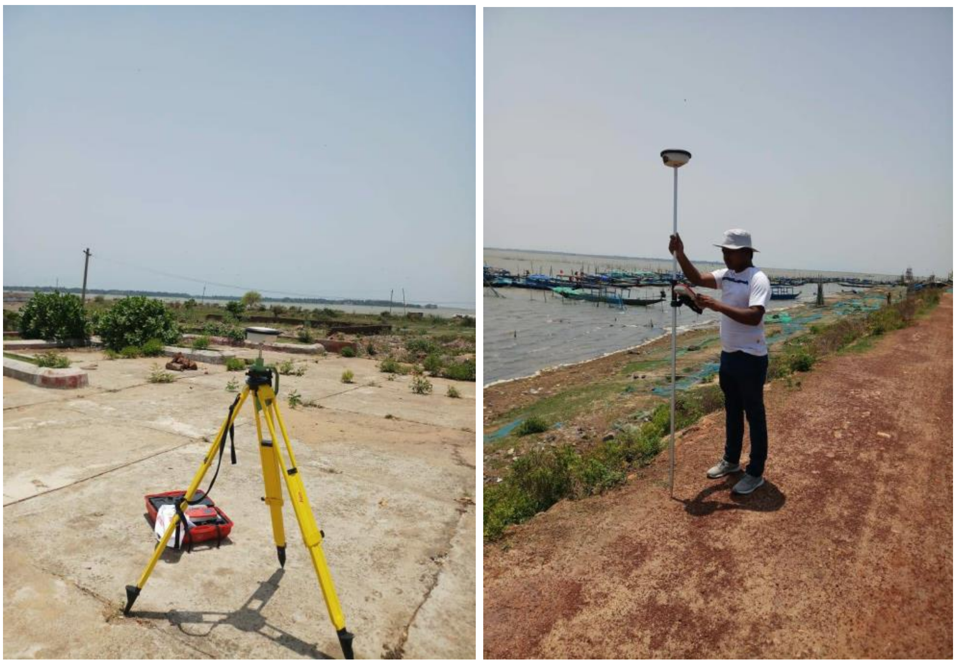

***Photo 2.*** *Ground truth verification using DGPS*


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