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Socio-economic vulnerability due to climate change: Deriving indicators for fishing communities in Mumbai

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ABSTRACT

This paper assessed the socio-economic implications of climate change and vulnerability of fishing communities known as “Koli” living in Mumbai, India. The vulnerability indicators are derived from sustainable livelihood literature and use of multi-criteria analyses and are validated with expert opinions. A survey of two hundred fishermen from five fishing villages in Mumbai was conducted to collect data. The results demonstrate that vulnerability perpetuates due to physical and financial resource constraints among the fishing community. Fishermen from Madh and Worli villages are observed to be more vulnerable and less adaptive due to their inability to use efficient mechanized boats and advanced fishing implements, such as fish finders and GPS (Global Positioning System). The divergence in the vulnerability scores among fishing villages is attributed to the coping strategies, resource availability, knowledge and the benefit derived from the local government. Fishermen have been observing the negative impacts of climate change on their fishing livelihoods. Adaptation strategies to maximize fish catch are observed in such practices as targeting different species and fishing intensively for several days. However, these practices are leading to an imbalance in the common resource pool and biased resource sharing among different groups of fishermen.

1. Introduction

Coastal regions around the world remain the major sources of economic activity. The tremendous increase in the concentration of population near the coasts is threatening the coastal environment [1]. At the same time, sea level rise (SLR), heavy rainfall, floods and cyclones damage the coastal property and infrastructure. These phenomena also affect human lives and place a serious burden on the coastal communities. Many poor countries in such regions as Africa, Asia, and Latin America have a large population living in and around coastal areas that are at a high risk from flooding, storms and SLR. In South Asia alone, 60 million people live in high-risk coastal flooding zones [2]. The coastal areas of developing countries, such as Bangladesh, India, Maldives and SriLanka, are more vulnerable to floods due to the lack of infrastructure and adaptive capacity to address the climate change impacts.

India has an 8000-km-long coastline that is highly productive and densely populated. This coastline is also highly fragile due to the frequently occurring cyclones and storms that lead to the degradation of the local economic environment and further affect the earnings of many people, including the members of coastal fishing communities [3]. Studies observe that climate change has already altered the ocean conditions, particularly the water temperature and biogeochemistry. These observed changes, along with future climate projections, are expected to impact fisheries production, distribution and composition [2,4]. The fisheries sector provides employment opportunities and contributes to local economic development [5]; however, the low-income and poor fishing communities living on the flood plains are especially vulnerable to such changes. In many climate change impact and vulnerability assessment studies, the unit of analysis is considered at the district or state level [6–9]. A community level vulnerability assessment study presents more challenges since different communities tend to respond to climate change differently, depending on their sensitivity and adaptive capacity. This paper addresses these issues by assessing the vulnerability of poor fishing communities, popularly known as Koli communities, in Mumbai, India. The results of this study are useful for policy makers and researchers dealing with climate change vulnerability at the community level.

This paper is arranged into six sections. Section 2 highlights the issue of vulnerability of fishing communities in the coastal regions. Section 3 discusses the measurement of vulnerability and the selection criteria for vulnerability indicators. Section 4 describes the selection of

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the study region and the questionnaire used. Section 5 discusses the results. Section 6 presents the paper's conclusions and its major highlights and findings.

2. Climate change issues and concerns

The livelihoods of coastal fishing communities are heavily impacted by the pollution of coastal waters due to extensive use of coastal resources which leads to health issues, loss of wetlands, loss of mangroves, and loss of corals. Climate change related SLR and flooding will further multiply the worries of fishing communities and enhance their vulnerability by decreasing the availability of fish, fish migration and loss of fishing boats and nets [10,11]. This approach will lead to an inequitable distribution of earnings among the fishing communities and increase the movement and migration of people. In spite of the above adverse effects on fisheries, the number of migrants increase near the coasts for survival opportunities. Studies show that climate change in Nigeria has led to low fish productivity, low incomes, starvation, poor health, and a poor standard of living of the fishermen [12]. Institutional mechanisms are also weak in providing insurance and other financial compensation to fishermen. Furthermore, there are other significant technical, social and economic barriers in their adaptations [13–15]. Therefore, it is pertinent to study how fishing communities exploit and depend on the coastal ecosystem and develop strategies to enhance their resilience against climatic variability [13].

Studies also [16] highlight the need for local area-specific policies to reduce vulnerability and to enhance adaptive capacity within rural communities. A study [16] has derived a social vulnerability index for Ghana, assessed local level impacts, and concluded that vulnerability and adaptation are very critical due to complex combinations of socioeconomic, political and environmental factors that act together to influence vulnerability to climate change. Another study [17] also assesses the vulnerability of fishery-based livelihoods with the impacts of climate variability and change using locally relevant indicators of exposure, sensitivity, and adaptive capacity among two communities in Bangladesh. The key indicator that determines sensitivity of an individual household is the dependence on marine fisheries for livelihoods. The adaptive capacity is undermined by the combination of physical, natural, and financial capital of the community and is also influenced by the diversity of livelihood strategies. The findings of this analysis suggest that to lessen the vulnerability to the impacts of climate changes is to increase resilience through sustainability. The involvement of the communities at the grass root level will serve as the strongest cohesive factor that will ensure the success of any sustainable programme of the government [18].

Since the 1950s, the estimated rate of change in SLR is 2.5 mm per year along the Indian coastline [19]. A mean SLR of 15–38 cm is projected by the middle of the 21st century. Additionally, a 15% projected increase in the intensity of tropical cyclones would significantly enhance the socio-economic vulnerability of coastal communities in India [20]. A study shows that a 1-m SLR will damage 5763 km^2 area of the coastal states in India and will put7.1 million people at risk, which represents 4.6% of the total coastal population in the country [6]. Considering the economic impacts, Mumbai, the financial capital of India, is the most vulnerable district in the country [21]. Mumbai is also expected to observe a rise in the average annual temperature between 1.25 and 1.75 °C under different scenarios [22]. Climate models predict significant changes in annual precipitation (a decrease in rainfall during the first half of the year and an increase in rainfall from September to November), an increase in the intensity of periodic rainfall, and a decrease in the number of rainy days [22–24]. Flooding is a common problem in Mumbai, particularly when a heavy rainfall coincides with a high tide. In July 2005, the city received an unprecedented 944 mm of rainfall in a 24-h period. Until 1989, the average annual rainfall of Mumbai was 2129 mm. In 2005–2006, the average annual rainfall was 3214 mm [25], an increase of 50%, which resulted in the most devastating floods which left more than 500 people dead in mostly slum settlements. The direct economic damage was estimated at more than Rs 50 billion. Many people were rendered homeless and the flood severely affected living conditions particularly in vulnerable and low lying areas [26].

The oldest residents of the city of Mumbai are the Kolis of the fishing communities [27]. According to the Marine Fishery Census of India, there are 30 fishing villages in Mumbai [28]. The total Koli population in Mumbai declined from 50,075 in 2005 to 40,953 in 2010 and the number of fishing families also declined from 10,082 in 2005 to 9,304 in 2010. There are 612 fishermen families living below the poverty line (BPL) in overpopulated villages [28]. The major causes for the fishermen to lose their livelihoods are climate change and depleting fishery resources. The reduction in fish catch, new entry of non-fishery businessmen to the fishing business and modernization of fishing practices are causing a decline in the Koli population. The use of mechanized boats, modern technologies and improved fishing practices benefits only a few large-scale fishermen and creates stiff competition among them [29,30].

3. Measuring vulnerability

The concept of vulnerability and its analysis have been reviewed in the climate change literature and other disciplines, including economics, sociology, and geography. The multidisciplinary nature of vulnerability often makes it difficult to assess and analyse vulnerability [31,32]. Additionally, the issue of vulnerability is location and context specific. This poses challenges for the local governments, researchers and policy makers to analyse, prescribe and decide effective policy [33]. Therefore, the measurement of vulnerability especially in the coastal communities' is more challenging [34].

The indicators for measuring vulnerability are generally derived by combining the indicators of adaptive capacity, sensitivity and exposure [9,35–41]. The construction of these indicators is constrained by many uncertainties because it is data-driven and based on an inductive approach. Additionally, finding an appropriate scale and criteria for aggregating these indicators are other limitations [42]. On the other hand, the deductive approach uses theoretical insights to understand the nature and causes of vulnerability for the purpose of deriving the indicators [43].

This study uses the Sustainable Livelihoods Approach (SLA) and Multi-Criteria Analyses (MCA) to select indicators and to allocate weights to the selected indicators [44–46]. MCA includes a full range of social, environmental, technical, economic, and financial variables and facilitates the evaluation of multiple options against multiple criteria [45,47,48]. The actual measurement of indicators need not be in monetary terms but is often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impacts, categories and criteria. The Analytical Hierarchical Process (AHP) is the most common approach within MCA [49–51]. The effectiveness of AHP depends on its capacity for decomposing the complexity of the ranking into a hierarchal structure, and its ability to use the capacity of human cognition in undertaking paired comparisons to determine the relative importance among a collection of criteria [44]. AHP is widely used to determine the relative importance of different management objectives in the fisheries sector and for coastal management [52,53]. In the case of a climate change vulnerability assessment, the AHP model can be applied for indicators' measurement of individual preferences by comparing the sub-components with each other and assigning weights to these components [44].

3.1. Selection of vulnerability indicators

The vulnerability indicators are derived after reviewing the literature on the relevance of indicators in explaining exposure, sensitivity and adaptive capacity (Fig. 1). These indicators are validated through a