



**SOCIO-ECOLOGICAL RESILIENCE
AS A SUSTAINABLE DEVELOPMENT STRATEGY
FOR REMOTE RURAL SETTLEMENTS
IN DIFFERENT GEO-CLIMATIC ZONES OF INDIA**

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About the Series

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Abstract of this Working Paper

Socio-Ecological Systems (SESs) play a fundamental role in determining the inherent capacities of rural communities located in and around the natural systems like forest areas, as they are intricately linked with the environment. In the wake of climate change, the customary human-nature relationships found in such remote communities are alleged to be perishing as the local SESs are being distorted by the changing environmental conditions. Since a large proportion of rural population in India lives in and around natural systems, the country is increasingly vulnerable to climate impacts. Further, being placed in diverse geo-climatic settings, remote rural communities in India are often side-lined from the mainstream development process. To effectually address the grass-root level concerns in these communities, the study pushes for a community centric approach for establishing a better understanding of risk perceptions and local priorities for risk reduction. With an explicit focus on SESs in remote rural communities, this study has come up with a defined set of indicators in consideration with diverse geo-climate settings in India. These indicators are used to study the existing situation in eight selected rural settlements from four different areas in India viz., Melghat region, Tadoba-Andhari Tiger Reserve, Katrenikona Mandal and Zunheboto region. Using choice based preference method, the community perceptions regarding different indicators of SESs are being assessed and suitable directions for building grass-root level resilience are being recommended, in lines with global policy frameworks on sustainable and resilient urban habitats including Sendai Framework for Disaster Risk Reduction, The New Urban Agenda and Sustainable Development Goals. The study results highlight that the 'Livelihoods' aspect is the foremost priority for all the rural communities irrespective of the climatic zone and the traditional knowledge and customs serve as the support systems for driving these remotely placed rural communities.

Keywords

Socio-Ecological Systems, Rural communities, Geo-climatic zones, India, Choice Experimentation

Indications of contributions to IRDR

Science Plan and UN Agendas

<i>IRDR Sub-objectives</i>	2
<i>SFDRR targets</i>	SFDRR Priority 1, 2
<i>SDGs and/or Climate Goals</i>	SDG Target 11, 13
<i>S/T Roadmap actions</i>	Integrated indigenous local knowledge in DRR

1. How does this study contribute to IRDR research objectives?

The Socio-Ecological systems are complex adaptive systems and correspondingly there is need for a dynamic decision making in changing climate scenarios. The study acknowledges the traditional knowledge systems of the indigenous communities for understanding the persisting risks in the different geo-climatic zones in India from a socio-ecological systems perspective which addresses 'objective 2' of IRDR. The community's traditional knowledge underlines the necessary actions for curbing losses in the native areas with long-term perspective. The study demonstrates community inclusive decision making based on the participatory approach.

2. How does this study contribute to SFDRR targets?

The study results promote a greater awareness at governance level of the importance of traditional local knowledge and indigenous practices to disaster risk reduction (Priority 1), which is in lines with the objectives of Sendai framework. This research can potentially help local governments to mobilise their resources more effectively towards preparing community oriented strategies for disaster risk reductions and climate change adaptation thereby focusing on Priority 2 of SFDRR.

3. How does this study contribute to SDGs and the Climate Goal?

The project highlights on Socio-Ecological Resilience provide a new direction to the discourses on approaching sustainable development. The study strives to formulate integrated strategies to boost resilience in rural settlements by bolstering the socio-ecological aspects and providing a sustainable pathway to strengthen the rural capacities. Thus, the study focuses on SDG 11 (sustainable cities and communities) and SDG 13 climate action in the form of contribution of policy review report with case studies from three different geo-climatic zones in India.

4. How does this study contribute to Science & Technology Roadmap Actions?

The research emphasizes on integrating local knowledge and practices in disaster risk reduction which is also an action for S/T roadmap action. The study underlines the core need for incorporating traditional knowledge into local level disaster risk reduction strategies and pushes for preserving the best practices through proper documentation.

Main recommendations to DRR policy

The study finds three general recommendations that are supposedly applicable for all selected areas and must be considered as a stepping stone to reframe the management of socio-ecological systems in rural settlements across the country namely: 1). Promoting Indigenous Economy, 2). Documenting Traditional Knowledge and 3). Enhancing Social Safety Nets

Main Text

1. INTRODUCTION

The natural climate variability has customarily been a challenge to rural livelihoods, primarily based on climate sensitive sectors. In the recent decades, the human-induced climate change has advanced the complexities of this challenge to another level. IPCC (2007) points out that, the natural climatic variability compounded with human-induced climate change is supposed to adversely affect millions of livelihoods around the world. The growing occurrence of extreme events and the on-going changes in climatic conditions pose significant threats and elements of surprise for rural communities which are highly dependent on the natural environment for their livelihoods (Thomas et al. 2005). **UNFCCC (2009) underlined that the rural communities in the developing countries are expected to be affected more due to their extensive dependence on climate sensitive livelihood options and limited adaptive capacity to adapt to the changes.** While being unpredictable, the emerging changes in climate present serious problems to the development and management perspectives for rural areas (Walker et al. 2004) as they influence their endurance and adaptive capabilities. The imprudent development drift is causing adverse environmental impact for indigenous communities in terms of land use, environmental pollution, biodiversity loss and large economic impact in terms of changing demographics, reduction in agricultural employment and diversification of the rural economy. Apparently, the prolonged intensification of such imperceptible stressors is increasing the spatial differentiation of rural areas in terms of economic, social and environmental outcomes. GIZ (2011) emphasized that the degree of uncertainty associated with climate projections has become a major concern for global communities today. The climate change is expected to further influence the agricultural practices as the growing seasons will be extended and the variability of the climate will increase, which will lead to severe changes in agricultural productivity and will all have significant effects on the natural environment. Further, the projected increase in global precipitation is likely to be spread unevenly across different regions as high latitude and equatorial regions are expected to receive more precipitation.

India's diverse geo-climatic conditions as well as its high degree of socio-economic vulnerability places it in the vanguard of climate change impacts, widely concerning the diverse rural societies. The country faces a major challenge from the changing climatic conditions due to its growing population, rapid urbanization, stressed ecological system and a substantial dependence on natural resources (World Bank 2011). Notably, the rural areas account for a larger part of the geographical area in India. As per Census 2011 reports, there are 0.64 million villages in India, which shelter more than two-third of the country's population. Furthermore, 58% of rural households in India are directly

engaged in agricultural activities (NSSO 2014), and the progressive changes in climate increasingly concern the rural population dependent on agriculture.

Human-nature interactions are demonstrated to be the key factors shaping global sustainability and human well-being, however owing to the increasing frequency and intensity of disasters, many aspects and processes of nature are threatened or have disappeared due to the human action or inaction. The accumulating pressures of economic instability, globalization, booming population growth and climatic challenges are affecting communities around the world irrespective of administrative boundaries. The rural communities located in fragile locations like forest areas, coastal areas etc. are exceedingly vulnerable to the impacts of emerging climate discrepancies as their survival is completely based on the surrounding natural environment. The systemic understanding of human-nature interactions enables revealing effectiveness as well as monitoring implications of various policy decisions on status of ecological resources and human wellbeing, which could be vital from generating regional resilience perspectives. Since, social and ecological systems in such remotely placed rural communities are closely linked, this study addresses the climate related concerns in remote rural communities from a systems perspective with detailed explorations at the finer spatial level. The Socio-Ecological Systems (SESs) thinking considers settlements as coupled human and ecological systems. The study theorizes that the gaps between policy making and community needs could be bridged only when the local concerns are taken into consideration. For this reason, this study attempts to understand the dynamics of SESs based on the perception of local communities residing in eight different settlements in three geo-climatic zones of India. The study establishes a thorough understanding of social and ecological systems in the selected settlements before coming up with a comprehensive indicator set that corresponds to SESs in different climate zones. Based on choice-based preference method, the study evaluates the community priorities for different parameters of SESs and subsequently suggests feasible strategies to enhance their resilience in the changing environment.

Section 2 provides insights to the evolving human-nature interactions and establishes the core need for looking at isolated social and ecological systems from a systems perspective. Section 3 elaborates on the concept of SESs and the complimentary relationship between resilience and sustainability of SESs. Section 4 details out characteristics of all the selected case study areas and the major concerns to SESs in different geo-climatic zones of India. The study methodology is detailed in section 5 wherein the software tool and statistical method used for the research are also explained. Section 6 presents the results and observations of the primary surveys conducted for the study. Also, the method of analysing survey results is being explained as well as the observed results are being contemplated. The study results and feasible strategies to enhance the resilience of SESs are being discussed in section 7 and 8.

2. EVOLVING HUMAN NATURE INTERACTIONS

Humans and nature have patently co-evolved over centuries or millennia, creating unique bio-cultural systems (Bergamini et al. 2013). The social systems abiding in and around the nature profoundly interact with the ecological substrate and their survival is primarily dependent on their interrelations with natural environment. In fragile ecosystems like forests and coastal areas, the environment and its natural resources are conditioned by the actions of indigenous societies and hence the human and natural systems should be seen as overlapping components, together forming a holistic complex adaptive system (Schouten et al. 2009). The patterns, intensity and scale of human-nature interactions considerably fluctuate with respect to the geographical features of any land area, extant geo-traditional practices, local flora and fauna, abiotic components such as soil type, resource availability etc. It is important to note that the threats and vulnerabilities to SESs also differ in levels and impact depending upon the geo-climatic conditions and scale of human-nature interactions. **Dwelling in and around the nature, the social and ecological systems in rural areas are completely entangled and therefore the rural communities experience environmental pressures and disturbances at different scales, from extreme weather events to market shocks.** UNU-IAS et al. (2014) highlighted that the management of these interlocking social and ecological systems requires the capacity to cope with complexities and adapt to emerging scenarios.

Before long, the interactions between human and natural systems have emerged as an unusual concern today because of the hurtling development scenario, whose impacts are demonstrated to be globally connected, both socio-economically and environmentally (Liu et al. 2016). The on-going scenario has markedly changed the environmental settings like forest cover, biogeochemical and hydrological cycles and even the climate systems. The human influence has allegedly become so pervasive that it dramatically alters the evolutionary trajectories of many other species (Liu et al. 2007). Aylward et al. (2005) stressed that the continued recklessness may profoundly modify the ecological dynamics by depleting the available stocks, resulting in the loss of important habitats and the services they offer to society.

Adger (2000) underlined that the rural communities live and operate in social systems that are inextricably linked with the adjoining ecological systems and there is need for understanding the social and ecological systems as one system operating over many linked scales of time and space. The social and ecological processes define and shape the patterns and dynamics of SESs where social outcomes (e.g., socio-institutional processes) remain contingent upon ecological dynamics (e.g., biophysical and environmental processes) and vice versa (Folke et al. 2005; Nayak et al. 2014). Today the need for resilience perspective to manage SESs is augmented by the proven fact that these complex adaptive systems do not change in a predictable, linear, incremental fashion (Pisano 2012) and it becomes very important to keep a track of these dynamic changes. In the brink of progressive degradation of natural resources, the demand for sustainable development together with the need for diversification of the

ecosystem services to effectively confront the on-going change is today greater than at any time.

3. SOCIO-ECOLOGICAL RESILIENCE & SUSTAINABILITY

The term 'Social-Ecological Systems' (SES) evolved when an ecology dominated community used it to differentiate themselves from those who disregard the human footprint in ecosystems (Stojanovic et al. 2016). The mosaic features of SESs have been shaped over generations by a strongly interlinked set of traditional practices that have been adapted and transformed to maintain and improve the community's well-being while absorbing shocks to the system. It has been manifestly substantiated that the study of social and ecological systems in isolation from one another produces trivial results, particularly when these results are used to shape policies. Research (Norgaard, 1994; Dillard 2007) has also pointed that the social and ecological aspects cannot be separated in their cultural and institutional context as these systems are linked in synergistic and co-evolutionary relationships. The resilience of SESs depends on the links between social and ecological components, in which humans adapt to the environment and change the environment in the process, as it does on ecological characteristics (biodiversity, habitat, ecosystem services) and social ones (institutions, networks, education) (Bergamini et al. 2013). There is a strong link between social and ecological resilience, particularly for social groups or communities that are dependent on ecological and environmental resources for their livelihoods (Adger, 2000). **Besides, resilience and sustainability are complementary concepts i.e., sustainability is the measure of system performance, whereas resilience is the means to achieve sustainability during or after a disturbance (Tendall et al. 2015).** While the concept of resilience lays emphasis on adapting with climate change, the notion of sustainable development stresses on the need for collateral existence of social and ecological systems in supporting human life (Sonnino et al. 2006). Hediger (1998) pointed out that for environmental sustainability, it is desirable to integrate social and ecological systems at various geographical scales, ensuring compliance with general system requirements, such as ecological and cultural integrity, economic stability, social equity and economic efficiency. The sustainable approach calls for maintaining the regional assets (social and ecological) alongside the development process and requires that conservation and change be balanced through an adaptive process of optimisation across various system goals.

SESs are inherently complex and interconnected, and the relatively new field of sustainability science focuses on providing holistic approaches that aim to understand the dynamic linkages between nature and society to support sustainable adaptations, environmental management and policy recommendations in the face of uncertainty (Armatas et al. 2017). A variety of new approaches to deal with the on-going changes and uncertainty in SESs are being developed motivated by the pressing challenges faced by the society and informed by a growing body of theoretical and empirical work (Biggs et al. 2015). The resilience of SESs depends as much on the links between human and ecological components, in which humans adapt to the environment and change the

environment in the process, as it does on ecological characteristics (biodiversity, habitat, ecosystem services) and social ones (institutions, networks, education) (Oudenhoven et al. 2010). Kim & Lim (2016) emphasized that the traditional approach to resilience is the one which examines a society's evolutionary process. The idea of evolutionary resilience is rooted in the fact that the seemingly stable state in nature or society can suddenly change and become something radically new, with characteristics that are profoundly different from those of the original (Kinzig et al. 2006). Evolutionary resilience promotes the understanding of places not as units of analysis or neutral containers, but as complex, interconnected socio-spatial systems with extensive and unpredictable feedback processes which operate at multiple scales and timeframes. Further, the knowledge acquisition of SESs is an on-going, dynamic learning process, and often emerges with people's institutions and organisations. The rapid pace at which these complex systems are changing requires governance and management strategies that are robust to uncertainty (Folke 2006).

4. CASE STUDY AREAS

India possesses a large variety of climates ranging from extremely hot desert regions to high altitude locations with severely cold conditions. Within India it is possible to define six regions with distinct climates (Bansal & Minke 1988) and seven regions based on the physiographic characteristics. Since, this study aims to cover diversity of rural settlements from different parts of India, a total of eight settlements have been selected from three different geo-climatic zones (locations shown in figure 1). Two of the selected study areas are Melghat (*1) and Tadoba (*2) which are from peninsular plateau region located in central India. Melghat and Tadoba region are protected forest areas covered under 'Project Tiger' (initiated in 1972) which is one of the largest conservation schemes in the world, aimed at tiger conservation in specially constituted tiger reserves representative of various bio-geographical regions throughout India. These tiger reserves even today are home to many tribal communities spread in hundreds of communities inside the reserve areas. The third study areas is Katrenikona (*3) located the east coastal plains of India. It represents a delta landform which is a sophisticated depositional feature that typically occurs at the mouth of a river. By definition, the mouth of the river is where the river drains into a water body such as lake, ocean or sea, leading to reduction of the rivers capability to transport sediment any farther. The communities residing in Katrenikona are completely dependent on the sea-based occupations like fishing, shell collection, aqua-farms, casuarine plantations etc. The fourth case study areas is Zunheboto (*4) located at North of Satoi Mountain Range, Nagaland. The case study represents hilly settlements located at the peak of mountain forests. The local tribes have allegedly remained isolated from the neighboring states for centuries. The orthodox location of villages on top of the hills poses a huge challenge in establishing physical connectivity between the villages as the roads are often damaged by landslides and subsidence. Moreover, the high altitudes make the region prone to strong wind, hailstorm, landslides, forest fire and drought. The

key concerns pertaining to the resilience of SESs in all the four selected case study areas are as elaborated below:

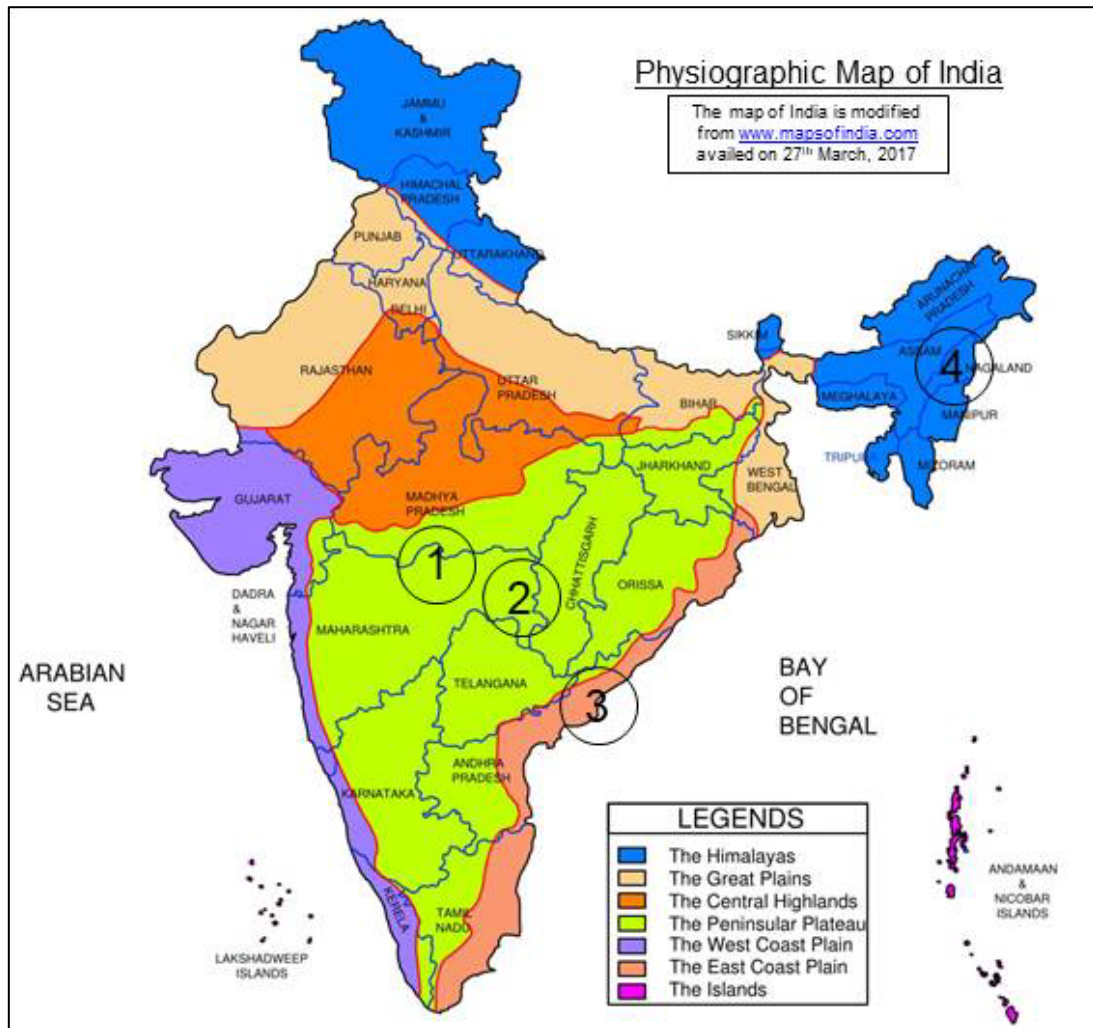


Figure 1: Location map of selected case study areas (Source-Author)

1. Melghat is the prime biodiversity repository of the Maharashtra State (figure 2) and was among the first nine Tiger Reserves notified in 1973-74 under the 'Project Tiger'. Melghat represents predominant forest areas traversed by rivers and its tributaries which make many remote villages inaccessible during rainy season. The local communities have for generations been dependent on forest produce for their sustenance but with the advent of Melghat Tiger Project, the social structures in the region are found to be transforming. **The legal restrictions imposed on the extraction of resources along with the natural discrepancies in climate conditions have drastically impacted the livelihoods of the local communities.** The increasing seasonal migration due to the poor employment scenario in the region has become a major concern for sustaining the traditional knowledge possessed by the indigenous communities of Melghat.

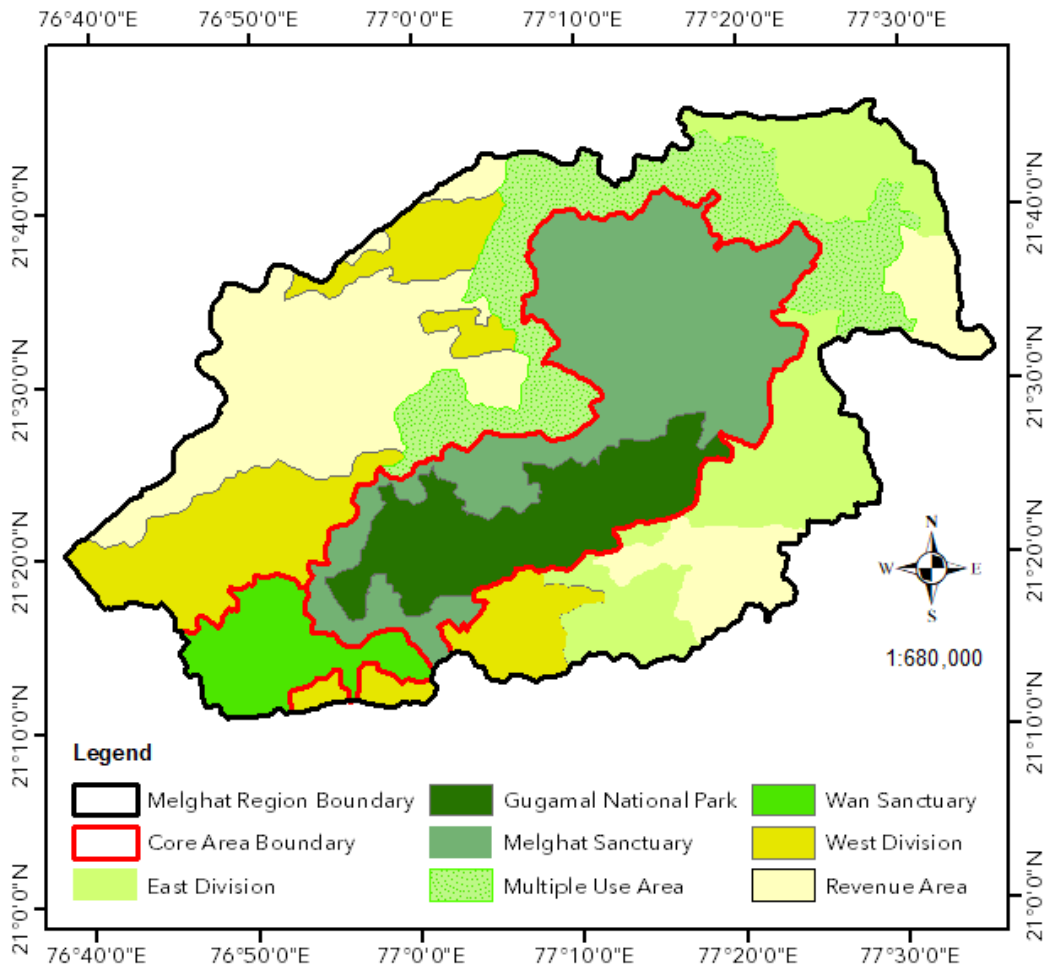


Figure 2: Detailed Map of Melghat region (Source-Author)

2. Tadoba Andhari Tiger Reserve (TATR) is notable as Maharashtra's oldest and largest national park and is one of India's 43 'Project Tiger' reserves. It constitutes a unique ecosystem, comprising, wide variety of flora and fauna with unique natural scenic beauty. The increased tiger sightings have brought TATR on national map as the region is flourished with thousands of tourists every year. The Gond tribes have been residing in these forest areas for generations, however with the advent of Tiger Project (figure 3), the central focus of authorities has been on the relocation of these indigenous communities. The increased wildlife conflicts and the change in climatic conditions force the locals to seasonally migrate for work. **The concept of modernization is degrading the long possessed traditional systems and forcing the local communities to adjust with the alien phenomenon of acculturation.**

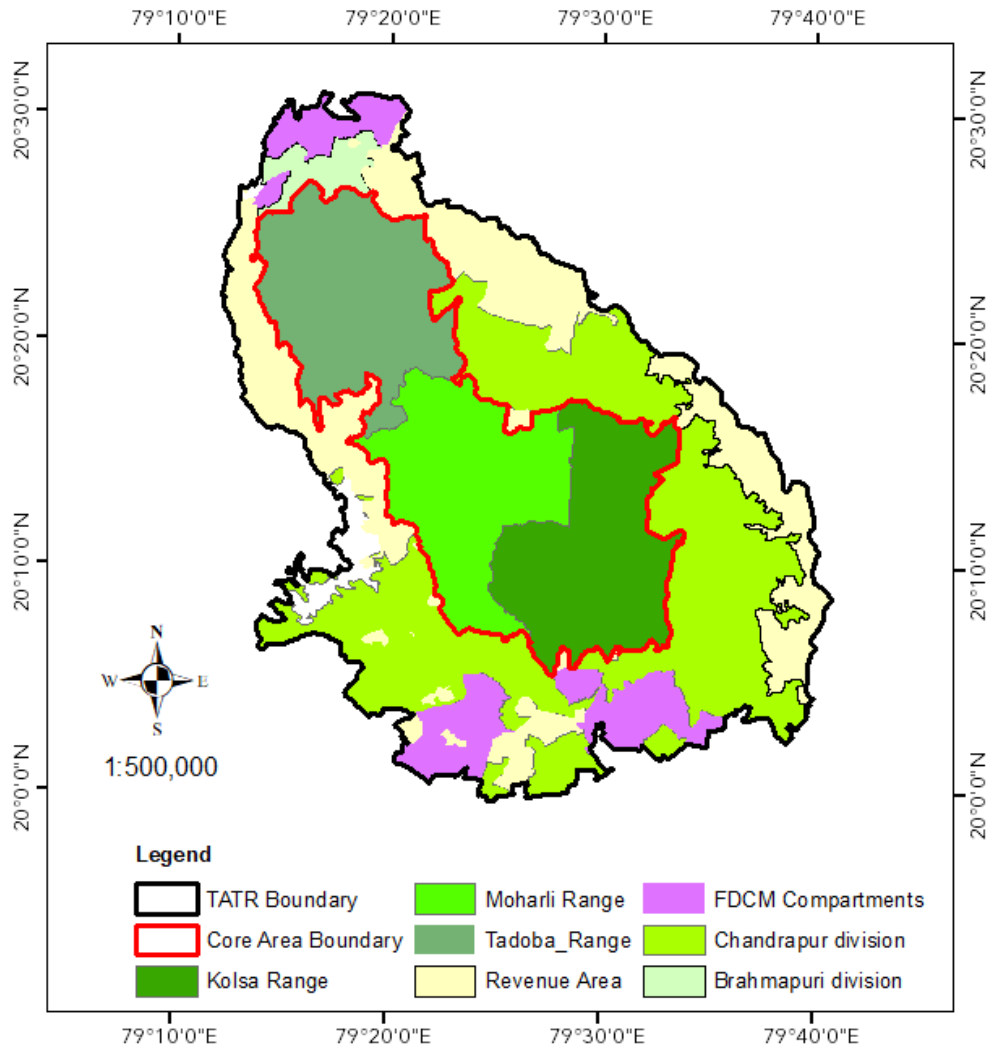


Figure 3: Detailed Map of Tadoba Andhari Tiger Reserve (Source-Author)

- Godavari is the largest river, draining the peninsular India, and has made an extensive delta on the east coast of India (figure 4), protruding into Bay of Bengal. Katrenikona Mandal is situated in the East Godavari River Estuarine Ecosystem (EGREE) which constitutes the second largest area of mangroves along the east coast of India. It provides significant ecological and economic benefits and livelihood services to the coastal communities which mostly practice fishing and their livelihoods are completely based on this sacred river. **The rapid economic changes and emergence of large scale production activities in last few decades have resulted in the degradation of overall ecological integrity of the EGREE particularly the mangrove ecosystems.** The mangrove flora of the coast is very much threatened due to the persistent development activities and so are the local livelihoods of Katrenikona Mandal.

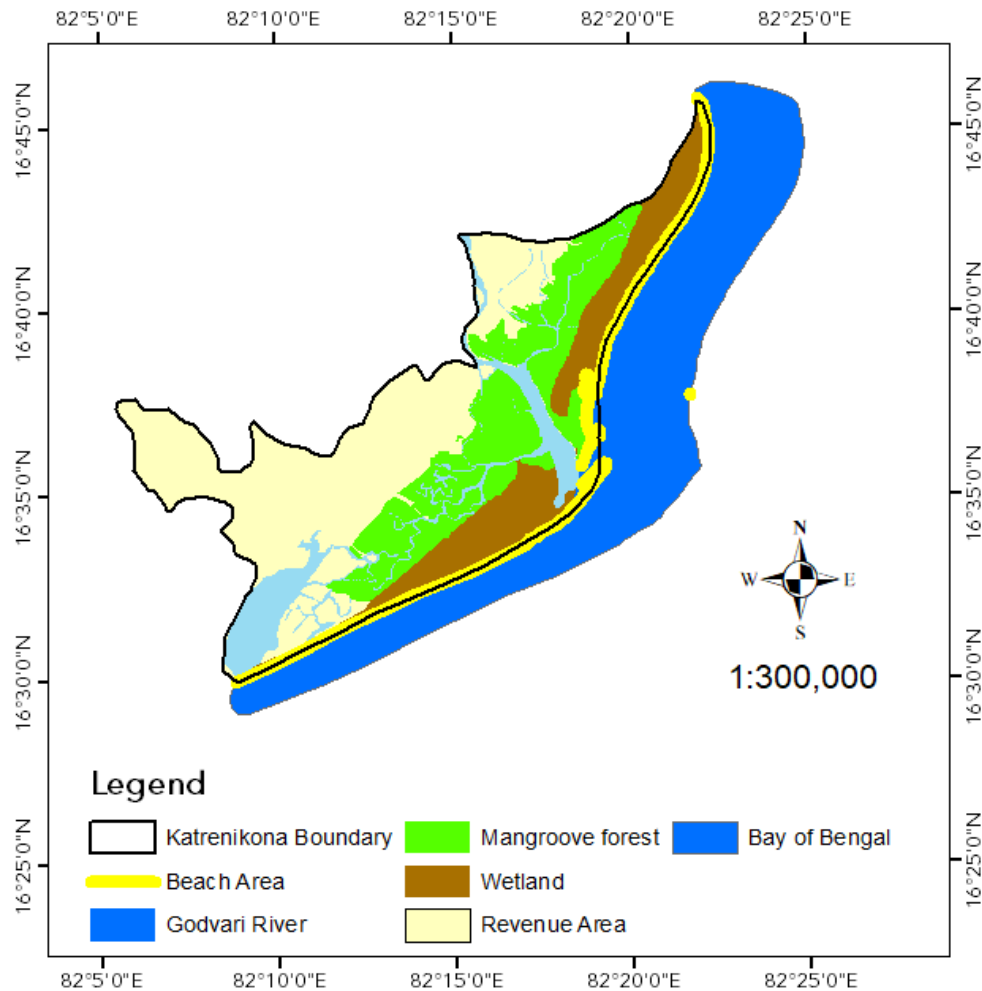


Figure 4: Detailed Map of Katrenikona Mandal (Source-Author)

4. While the rest of India has shared the institutional and social values, the tribal tract of the North-East region has remained isolated from the mainstream of the national consciousness. The region is inhabited by hundreds of groups and communities with different ethnic identities, religious beliefs, social formations, languages, and history of political organizations. Zunheboto is the land of Sumi tribes and the governance is dominated by the traditional tribal culture with the preponderance of semi-autonomous and self-managing indigenous local institutions at different levels. The inadequate socio-economic development of the region is allegedly because of relative isolation, the difficult terrain and inaccessibility (as seen from figure 5). **The predominantly rural region is further exposed, at varied fronts, to the evolving discrepancies of modernization, urbanization, climate change etc., as a result of which the socio-ecological systems are found to be eroding.**

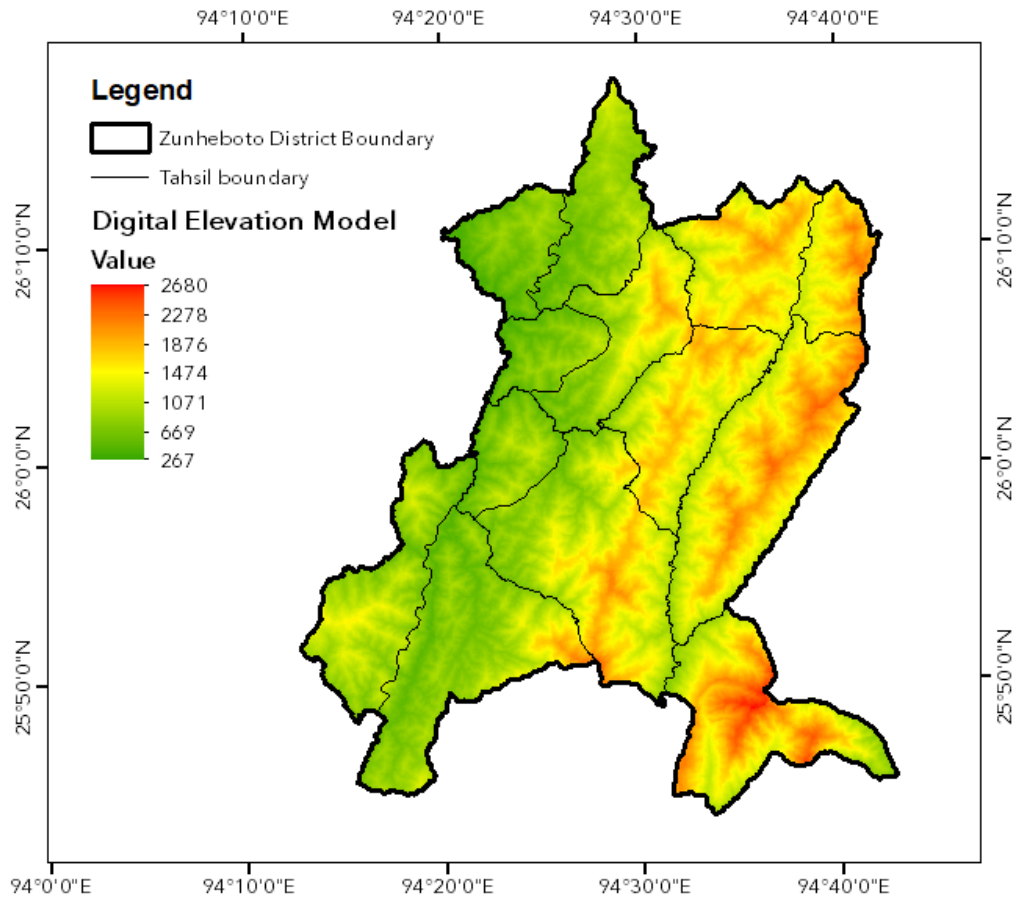


Figure 5: Elevation Map of Zunheboto district (Source-Author)

5. STUDY METHODOLOGY

To effectually bridge the gap between community needs in remote rural areas and policy making, the study theorizes that the consideration of community perceptions is incumbent for development planning especially in the wake of climate discrepancies. Since the variegated environmental threats are perceived differently within the broader patterns of society, it is important to analyse them in close cooperation with the local communities. For that reason, this study has employed method of indicators to meritoriously determine the community priorities in context of changing environment scenario. Globally, there are several established conceptual models to understand resilience, however the variety of frameworks that exist for the study of SESs often lack a comprehensive understanding of the system dynamics and majority of them tend to overlook the systems of traditional ecological knowledge which are practical, attuned to local ecology and embody a complex of socio-cultural interactions pertinent to ecosystem functioning and resilience (Oudenhoven et al. 2010; Bergamini et al. 2013). Research has pointed that the indicators of community disaster resilience are classified mostly in five domains namely: Social, Economic, Institutional, Physical and natural domains (Suarez et al. 2016; Ostadtaghizadeh et al. 2015; Das Gupta & Shaw 2015). However, this study points out that these established indices do not incorporate the vital

parameters of closely linked social and ecological systems, provided they consider the universal development aspects of infrastructure, institutional setup, financial aspect etc. **Subsequently, there is need for rethinking the customary indicators of resilience to adjust in the context of SESs in different geo-climate zones of India. The indicator set defined for the study captures the diverse aspects that are essential for understanding SESs and comprises of five major aspects sub-categorised into twenty indicators (four indicators each for 5 aspects).** These indicators are selected in consideration with the local communities, focusing on their relevance, applicability and significance to the rural communities in three selected climate zones. The defined indicator set (table 1) entails both qualitative and quantifiable parameters. However, they are primarily assessed based on the community perceptions and experiences of the local communities.

Table 1: Defined Indicators and their corresponding abbreviations

ES	ECOSYSTEM SERVICES
ES1	Food Variety
ES2	Forest Produce & Timber
ES3	Landslide & Flood Protection
ES4	Customs & Rituals
EG	ENVIRONMENTAL GOVERNANCE
EG1	Ecosystem Knowledge & Training
EG2	Participatory Governance
EG3	Active engagement in Ecological Conservation
EG4	Monetary provisions for ecological conservation and DRR
SC	SOCIO-CULTURAL
SC1	Ethics & norms for resource conservation
SC2	Continuity of traditional knowledge systems
SC3	Climate Adaptive lifestyle
SC4	Recognition for innovations in adaptation & mitigation
LV	LIVELIHOODS
LV1	Availability of alternative income source
LV2	Distance from livelihood supporting services
LV3	Access to financial institutions
LV4	Training and development
NH	NATURAL HAZARDS
NH1	Early warning systems
NH2	Integration of hazard map in planning
NH3	Adaptive measures and coping mechanisms against natural calamities
NH4	Response mechanism and community capacity

In the contemporary scientific literature, there are numerous statistical approaches that are used to determine how people value different features of a service or scenario. **Choice modelling is found to be one of the widely applied methods in the fields concerning utility maximisation of services based on the preferences of the target groups.** It is fundamentally a stated choice preference method and is based on a simulated future scenario under which people make decisions for selected attributes. The choice experiment helps to determine what combination of number of attributes is most influential on respondent choice or decision making. Since the variables in a stated preference involve a non-linear relationship or uncertainty in their occurrences, this research adopts logistic regression (an approach to prediction) to model binary outcomes where the dependent variable is a dummy variable (coded 0, 1). Logistic regression transforms probability ranging between 0 and 1 to log odds ranging from negative infinity to positive infinity and this transformation is called logit transformation. Notably, the coefficients obtained by logistic regression are challenging to interpret because of the nonlinearity and the complicated algebraic translations. Therefore, this study analyses the community perceptions for different indicators based on the log of odds (odds ratio) scores, which amongst all the choices of transformation, facilitates for easier interpretation of the coefficient values (Deshkar 2013).

In the choice based survey, the respondents face two generic alternatives for each choice set, described by four corresponding indicators. The defined set of indicators under each aspect are shown to respondents and by analysing how they make preferences for choice sets within a particular aspect, the implicit valuation of the individual indicators is determined. These valuations are then used to create models that help determine the best suited development options. The survey data consisted of a set of choices in terms of A and B for all the given permutations and combinations of different variables. The settlement wise choice data is converted into a binomial form and tabulated in the excel sheet. The data in binomial form is then used to construct an excel worksheet saved in '.csv' format that is valid for running a Generalised Linear Model using software R. A logit model constructed in R is run to get the logit regression coefficients which provide the basis for interpreting the statistical significance of each variable. The values so achieved indicate the levels of significance for each component in resiliency. These levels are then analysed based on which the inferences and interpretations are drawn to understand the relationships between components of community resiliency and parameters of rural development. An odd is the ratio of probability of occurrence of an event to the probability of its non-occurrence or $p/(1-p)$. For the variables W, X, Y and Z, the interpretation of the odds ratio can be done as one unit difference in predictor W corresponds to a multiplicative change of e to the power coefficient in the odds of X, Y and Z. Thus, the exponentiated values of the coefficients (odds Ratio) are calculated for all the parameters to ease the analysis of survey results.

6. RESULTS & OBSERVATIONS

Based on the survey results, the study derived odds ratio scores for defined indicators in all the selected rural settlements. To put forward a comparative analysis of four selected areas, the study results for rural settlements within the same zone were merged. Figure 6 depicts the odds ratio scores for rural settlements of Melghat region wherein indicators within different dimensions have been compared based on the Odds Ratio scores and the most critical aspects are identified based on the community perception. The odds ratio scores signify the comparative level of significance of indicators which helps to prioritise the indicators. Based on the odds ratio scores for five key aspects as shown in figure 6(a), it can be interpreted that the change in predictor of Livelihoods aspect by 1 unit, while keeping all other predictors constant, will change the odds (probability of enhancement or reduction) of other parameters of SESs by a factor of 1.03 (Ecosystem Services), 1.17 (Environmental Governance), 1.00 (Socio-cultural) and 1.04 (Natural Hazards) respectively. It is important to note that an odds ratio less than 1 indicates the probability of response to be less than 50%. The change in odds of such parameters could be either positive or negative but it will remain in the ratio to the odds of concerned variable, provided the other variables remain constant. This relationship is unlike one which is explained by linear regression and accommodates the dynamic nature of socio-ecological systems. In case of Socio-Cultural aspect, since the odds ratios are almost near to 1, there is a near probability of 0.5 or a 50:50 chance that it will have an equivalent reciprocating effect on the odds of levels of remaining parameters. Thus, based on the odds ratios, it can be inferred that in the case study of Melghat, 'Livelihoods' and 'Environmental Governance' are comparatively more significant from community perspective. This does not downplay the significance of Ecosystem Services, Socio-Cultural and Natural Hazards, but could mean that these services need to be emphasised more in development planning for the rural communities of Melghat. Similar analysis is been done for all the case study areas. **The five broad aspects of SESs defined for the study namely Ecosystem Services, Socio-Cultural, Environmental Governance, Livelihoods and Natural Hazards have also been prioritized on the basis of their odds ratio scores for all the four case study areas (table 2) and the key observations have been discussed thereafter.** It is important to note that the higher odds ratio score denote higher level of significance in table 2.

1. The results of choice experiments in all the four case study areas unilaterally depict the core importance of 'Livelihoods' (LV) aspect in resilience of SESs. The lack of job opportunities and poor economic conditions have made the survival of the indigenous communities difficult, given the remoteness and the fragile environmental conditions in all the selected case study areas. Further, the changing climatic conditions have distorted their customary occupational structures like forestry, timber collection, bamboo weaving, fishing etc. based on environment. In all the selected areas, there is a genuine need for alternate income sources and there is need to enhance capacity building initiatives as the traditional knowledge systems are gradually fading.

Table 2: Community preferences based on the Prioritized Odds Ratio Scores

ASPECTS	MELGHAT	TADOBA	KATRENIKONA	ZUNHEBOTO	
ES					
EG					
SC					
LV					
NH					
Legend					
Level of Significance	RANK 1	RANK 2	RANK 3	RANK 4	RANK 5

2. The second most critical aspect for all the study areas is found to be 'Environmental Governance' (EG). The major reason behind the preference to 'Environmental Governance' (EG) aspect is alleged to be the intricate human-nature dependencies. The human societies in fragile locations depend on the environment for their survival vis-à-vis livelihoods. However, given the context of progressively increasing population and the reckless utilization of environmental resources, the local communities seek for effectual resource management by means of environmental governance.
3. 3. Notably, the community priorities for the remaining three aspects of 'Ecosystem Services' (ES), 'Socio-Cultural' (SC) and 'Natural Hazards' (NH) are found to be different for land based and sea based communities. The preferences for communities residing in Katrenikona Mandal (sea based communities) are found to be different from other three regions (land based communities). The local communities in Katrenikona give higher priority to 'Ecosystem Services' (ES) and 'Socio-Cultural' (SC) aspect when compared with other case study areas, which prioritized Adaptability to 'Natural Hazards' (NH). The aspects of 'Ecosystem Services' (ES) and 'Socio-Cultural' (SC) parameters are more important to the communities of Katrenikona as they form the basis for adaptability to natural disasters even before the physical measures of adaptability (NH). In contrast to this the landwards settlements are finding the physical measures of adaptability to be primarily important for coping with natural hazards.
4. 4. The results of choice experiments further depict that the 'Socio-Cultural' aspect is placed at the least significance level for most of the case study areas. This observation corroborates the fact that the traditional systems are gradually diminishing as the indigenous communities are pushed into the wave of modernization. The indigenous communities are known for their traditions and culture; however they have given higher priority to other aspects of SESs in comparison to socio-cultural aspect. The study speculates that there could be two reasons behind this; either the communities believe that there is need for strengthening all the other sectors apart from socio-cultural aspect or the importance of socio-cultural systems is slowly fading and the communities are moving towards other aspects of resilience in line with modernization.

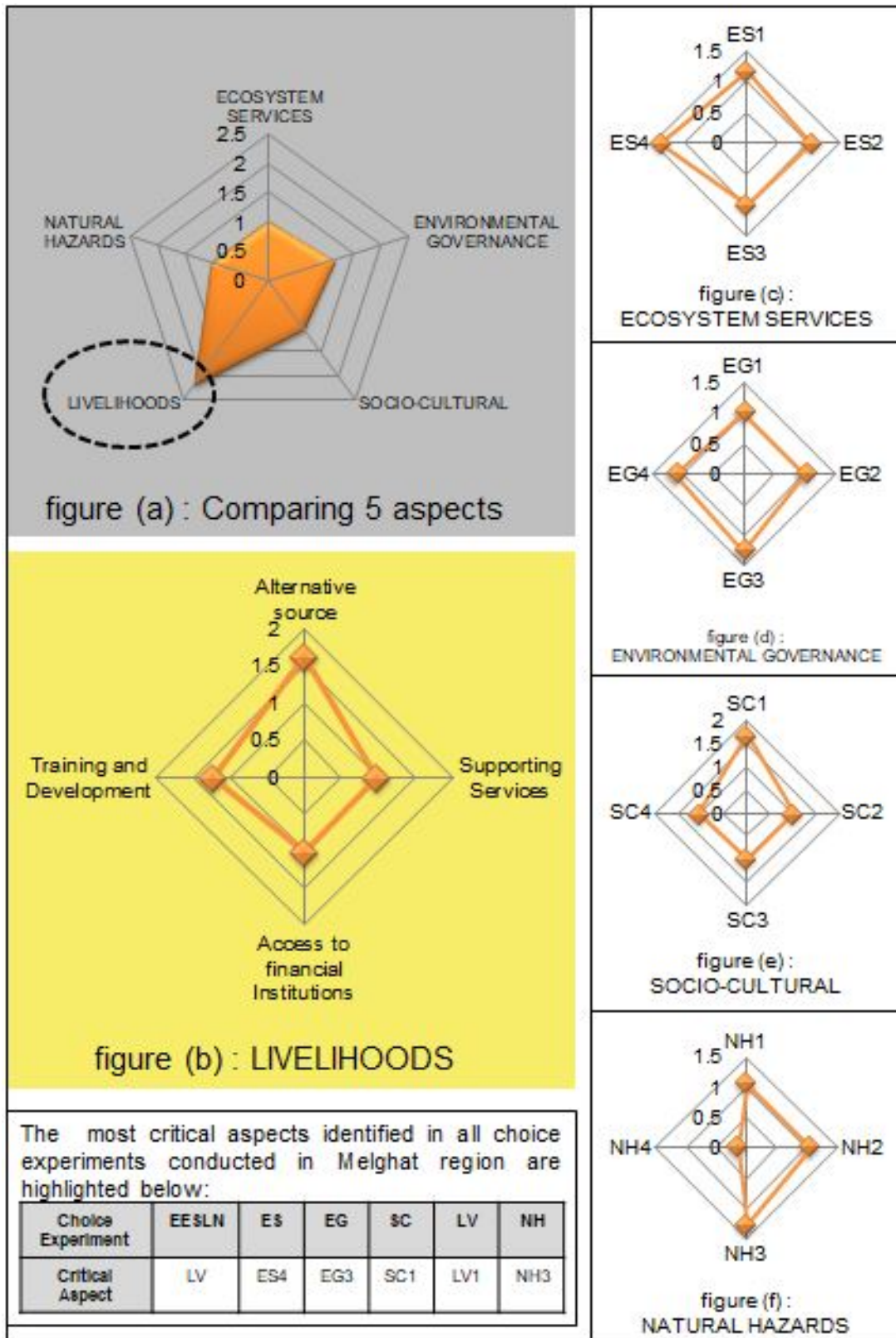


Figure 6: Odds Ratio Scores for defined indicators from 2 selected rural settlements in Melghat

7. DISCUSSION

As highlighted from the study results, the issue of livelihoods is pertinent to all case study areas. The conventional nature based livelihoods practised in remote rural communities like bamboo weaving, fishing, collection of forest produce, animal rearing etc. have become more difficult due to unpredictable weather and seasonal changes. **In the wake of emerging disaster risks, there is genuine need for diversifying traditional livelihoods in order to minimise the susceptibility of indigenous communities to climate related hazards.** Based on the identified priorities for strengthening SESs, this study pushes for revitalising traditional occupations that are based on nature friendly techniques like soil and water-conservation methods, harvesting practices, re-introducing traditional technologies. The indigenous techniques of water harvesting, better construction with the locally available material would substantially contribute in decreasing the loss of property during disasters such as cyclones, floods and earthquakes. Further, the thorough understanding of the complex SESs (differently for land and sea-based communities) and the emerging traps is needed to establish a holistic, people friendly and inter-agency approach that can contribute to environmental security and the well-being of people. The important supposition derived from the study results are that the concerns of environmental management vary based on the geo-climatic conditions. Recognizing that there cannot be readymade win-win options for local governments to make development decisions under risk scenarios, robust risk governance mechanisms should be established at sub-national level and tailored as per the local institutions, practices and made relevant to local communities and stakeholders as emphasized in Sendai Framework for Disaster Risk Reduction. The Socio-Ecological Systems (SES) thinking should be promoted in district, regional and local development planning as it facilitates an integration and updation of indigenous knowledge acquired by local communities and ecological knowledge developed through scientific approaches.

The global fraternity of researchers have undeniably made a long stride forward towards strengthening the institutional mechanisms for disaster management. However, the incompetent response in tackling the gradually evolving disaster situations like recurrent droughts, grimly remind that despite the best preparedness and response standards, disasters still remain a key challenge to policy makers around the world (Miller and Rivera 2015). The precipitously increasing frequency and intensity of disasters flagrantly testify that the nature's fury is yet to be demystified, and at this critical juncture, the major task for policy makers is to strive towards higher levels of understanding, preparedness, mitigation efforts and adaptive mechanisms gathering experience from global communities. In the context of indigenous communities, the efficient transfer of knowledge and experiences is imperative to ensure that the institutional framework and social networks are nested across scales. It is particularly interesting to note that the Intergovernmental Panel on Climate Change (Mclean 2010) has identified traditional and local knowledge as an important missing element in its previous assessments and a focus of its work for its next assessment process. The increasing rural-urban migration rates and the declining significance of socio-cultural aspect further concern the local SESs.

Correspondingly, there is need to bring into mainstream a renewed consciousness that retrieves the traditional lifestyle and socio-cultural heritage. Local communities in fragile locations often develop their own distinct way of addressing disaster risk which can facilitate the process of disaster risk reduction in cost-effective, participatory and sustainable ways. They are also the repositories of local ecosystem knowledge having survived for decades based on prevailing ecological resources. The study drives for retaining the best of ancient traditions while incorporating new practices that enables the communities to maintain cultural integrity while they engage and coexist with the progressing world. The requisite recognition to the traditional knowledge possessed by the indigenous communities could help sustaining the ecosystem friendly customs and beliefs eventually paving way for resilience of SESs at the grass root level.

8. CONCLUSION

The growing frequency and intensity of disasters pose serious concerns for human societies particular those dwelling around the natural systems. While the complex inter-relationships of social and ecological systems in such fragile locations play a key role in their continued existence, it is a matter of increasing concern that the prevailing SESs are being influenced in the wake of emerging climate discrepancies. Correspondingly, the major task for policy makers is to strive towards higher levels of understanding, preparedness, mitigation efforts and adaptive mechanisms. There is increasing need for methodically understanding and exploring the complex interactions between the society and environment. This study presents a brief overview of SESs in eight selected rural settlements from different geo-climatic zones of India and highlights the threatening impacts of climate change on selected communities. While the rural communities located in and around natural systems like forest areas, coastal areas and hilly areas are sidelined from the mainstream development process due to their remote locations, there is need to address the emerging concerns in these areas by duly taking into consideration the local issues. While, Sendai Framework for Disaster Risk Reduction and Paris Agreement duly emphasize on climate change mitigation and adaptation, the study underlines that incorporating community perception in policy making is one of the core needs for inclusive development. Subsequently, the study evaluates the defined indicators of SESs based on community perspective. The study adopted choice based experimentation to determine the community based priorities for climate change planning and conducted community consultation workshops in all the selected rural settlements. The results of the primary surveys are analyzed using R-software. The study employs logistic regression method and the community perceptions are understood through the determined odds ratio scores.

The study results depict that 'Livelihood aspect' is the foremost priority for all the selected rural communities followed by 'Environmental Governance', while the community perception for other aspects of Ecosystem Services, Natural Hazards and Socio-Cultural aspect are found to be varying. The study points out that there is need to bring into mainstream a renewed consciousness for the traditional livelihoods and environmental

governance. **As the climate is becoming more and more variable and unpredictable, indigenous communities essentially need to supplement their subsistence livelihoods with income gathering activities beyond agriculture in order to minimise their susceptibility to climate-related hazards.** The diversification of traditional livelihoods strategies combined with capacity building in non-traditional sectors would effectually allow rural communities to draw on various sources of food and income and in doing so, spreading the risks of vulnerability to climate change. The future scope of the study includes deliberating on the environmental dynamics and trying to understand the applicability level of selected parameters for other areas. Also, there is further work to be done on developing suitable policy measures aligned with the community perceptions for enhancing resilience in SESs. This approach can potentially help the local governments to mobilize their resources more effectively towards preparing community oriented strategies for disaster risk reductions and climate change adaptation.

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10. CONFLICTS OF INTEREST

The author declares no conflicts of Interest.

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