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# Saving a Wetland in Southern India through a Social Ecological Systems Approach, Based on Community Values, Perception and Action

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## Abstract

This paper discusses the impacts of human habitation on the natural ecosystem of a wetland, Pallikaranai, Chennai, India. We have adopted a social-ecological systems approach to define the problem and examine the aspects surrounding it. Through this research we address sociological aspects and gauge community perception, knowledge, attitude and behaviour of the urban society interacting with the marsh and with water bodies in general. Our findings show that, although 88% (178 out of 203) of those who were surveyed were concerned about the environment, such concern and their knowledge and awareness-were not always reflected in their actions, mainly because of external factors including the increasing population density and such aspects of urban lifestyle as water consumption.

The dynamics of this social-ecological system is further explored by examining trends in social, ecological and climate-related parameters and observing the timeline of events which have resulted in the present state of the marsh. International recognition by Ramsar is a landmark event and how the administration and stakeholders will collaborate to promote biodiversity conservation is currently a question. Our research attempts to provide a framework and throw light upon details and issues that, when considered will ameliorate the existing social-ecological system with respect to this case as well as many other wetlands in similar circumstances.

**Keywords:** Community perception of water bodies; Integrated water resources management; Pallikaranai; Social-ecological systems framework; Urban wetland restoration; Water for cities

## Introduction

With the anthropocene trend of settlements increasingly turning urban and many natural areas being attacked by humans, the commitment towards a clean, green, healthy and robust ecosystem seems to be taking a downward turn. Global demand for ecosystem services continues to surpass ecosystem capacity according to Li et al., human-centric activities take precedence over otherwise normal ecosystem-functioning and we are left with our waste products so that, Berger refers to 'waste landscape' as an 'indicator of healthy human growth' and as an essential component of civilization [1,2]. With the increasing population densities, are such civilization practices called for? Aldeia et al., wrote about this society-nature polarity, which emerges from capitalist, colonial and patriarchal dimensions and discuss how we should rethink our approach towards natural sciences, shifting from the focus on humanity towards anthropocentricity-integrated conservation [3].

Meng et al., discuss the relationship between biodiversity and human health and their evidences across various economic sectors [4]. The Social-Ecological Systems (SES) approach is a dynamic framework which encompasses both the social and ecological dimensions of natural landscapes. Ostrom advocates adaptive governance and self-governing principles as the way forward towards resilience, adaptation and transformation of regional landscapes and ecosystems [5]. The porosity and openness of these systems is also a determining factor and discuss the theory of Complex Adaptive Systems (CAS) as a better way to theories and comprehend SES [6]. Cumming deploys the scientific method to predict the outcomes of managerial and policy interventions to make SES more resilient [7]. He classifies the SES framework based on its spatial and temporal attributes into the following hypothesis-oriented SES, assessment-oriented SES, action-oriented SES, problem-oriented SES and theory-oriented or overarching SES frameworks.

According to him, any SES framework should build on earlier frameworks. This hierarchy is also based on increasing complexity of issues and nature of management surrounding the SES and capacity for a framework to lend itself to empirically testable phenomena to add to the scope for governance and thereby resilience and adaptation of the SES. Threats to SES are encountered in the developed countries as well as in the developing countries. India is the world's second most populous country and population pressure, despite the country's rich and varied natural landscape, strains its resources. Population densities tend to be high (averaging about 425 people per square kilometre). The environmental movement may be strong, comprising Non-Governmental Organizations (NGOs), the media, academia and interested individuals, but environmental awareness is scattered, being largely limited to pockets of relative affluence and big cities and ignorance of the environment goes hand in hand with widespread poverty. India has tried to develop eco-cities and simultaneously reclaimed mangroves to construct a sea link in Mumbai [8-10].

India has also enacted several laws to ensure the protection of flora and fauna and forests-although their implementation leaves much to be desired and falls short of the current need to address specific real-world problems. Bruley et al., studied the historical configurations of an SES adapted to economic, policy and climate-related changes in the French alps, focusing on adaptive mechanisms

due to the nature's contribution to people framework, co-production and related drivers of change, whereas Petursdottir et al., studied the stakeholders' attitudes and responses to evaluating the impact of government policies and effectiveness of restoration in a large-scale rangeland restoration programme in Iceland [11,12]. Vallury et al., discuss Ostrom's theory of SES and the effectiveness of design principles in the governance, evaluation and other ways to address SES [5,13]. Their research is based on various irrigation communities and how they manage water as a resource in Andhra Pradesh, India. Middletone Manning et al., have brought to light the case of a land trust, led by indigenous women, which addresses community needs and lack of land [14]. Going beyond conservation, the trust envisions a sustainability initiative led by an eco-cultural community in the San Francisco Bay Area.

Lynch et al., explore issues around wetland conservation and sustainability in three developing countries comprising internationally significant wetlands, namely, Tanzania, Colombia and Papua New Guinea [15]. They examine key aspects of the socio-ecological values associated with the wetlands, stakeholder and governance issues, conservation and management issues and management responses to the same. Quandt et al., discusses how land retired from agriculture can be repurposed to minimize social, economic and environmental harms, while maximizing potential benefits [16]. Hubertus et al., discuss precipitation in the Ethiopian highlands, the cases of perceived *versus* actual, as a factor in regional development [17]. Opedes et al., discuss the land use changes of encroachment on a park area [18]. These various studies support our understanding of SES research and the framing of study sites in order to solve real-world problems that call for an inter-disciplinary approach.

India is home to 75 wetlands recognized by Ramsar along with large numbers of water bodies and rivers. (Ramsar is the name for the convention on wetlands, an international convention, adopted in Ramsar, Iran, in 1971 [19,20]. However, only a few wetlands have been assessed in economic terms and enjoy some degree of protection from the state, many more are neglected and misused and one among them is Pallikaranai, near Chennai, in the state of Tamil Nadu in southern India. That wetland is the focus of the present study. Pallikaranai, along with Pulicat further north, Kazhuveli near Pondicherry and Point Calimere (the southernmost tip of Tamil Nadu) dots the state's natural landscape. Pallikaranai Wetland is located in Chennai, south of the erstwhile corporation boundary, draining into the Bay of Bengal and hence a coastal wetland. Whereas the other landscapes enjoy a more pristine environment, Pallikaranai is close to Chennai, one of the four most important cities in India. Vencatesan et al., maintain that since the 1960s, Pallikaranai has shrunk by 10% and is today limited to only about 600 hectares [21,22]. The forestry department has taken control of the wetland and with the reclamation processes in place, a total of 700 hectares has been earmarked as a protected area. The marshland has suffered because of encroachments, both by the authorities and the public at large.

Influx of population, pollution, establishment of a dumping ground within the marshland and roads and other infrastructure are the main drivers of change and damage. Our research examines the existing problem and the drivers of change leading to the present condition in Pallikaranai by adopting a "problem-oriented" Social-Ecological Systems (SES) framework. The nature and scale of the problem both spatially and temporally and the result of previous 'action' enables us to explore the 'problem' and address the parameters acting upon the 'system'. We explore the gap between physical and chemical (quality-oriented) studies, ecological classification and sociological surveys and integrate the disciplines, linking causative factors with existing phenomena. We identify ecological, functional, social and administrative factors as interdependent actors affecting the ecosystem and thereby address the dynamics of the SES from theoretical as well as empirical perspectives. Our research questions which form the backbone of the research are as follows.

- How do the social and ecological issues relate to each other and what do we derive from a social-ecological framework?
- How do we study the community perception of water bodies in general? What is the nature of community perception of Pallikaranai?
- What are the government policies related to restoration and management of the wetland and how effective are they?
- What are the economics of saving or restoring the wetland, in terms of benefits and costs? How does the economic value of the wetland ecology manifest socially?
- How can one ensure that international recognition by the Ramsar convention is leveraged in such a way as to improve the attention on the marsh and provide protection for the marshland?

The underlying hypothesis on which we frame this research is stated as the very concepts of greening the city and sustainable living are perceived as economically unviable and are neglected because they require capital (financial, human, social, ecological) to be established it as a way of living, particularly in developing nations with a vast socio-economic diversity.

## Materials and Methods

### Study area

Pallikaranai marsh (12.949371°N, 80.218184°E) is among the last existing natural wetlands around Chennai, India. The marsh drains an area of about 250 km² through two outlets, namely the Okkiyam Madavu channel and the Kovalam creek and empties into the Bay of Bengal (Figure 1). This major hydrological basin receives the overflow from 34 tanks on its west; now with intentional hydrological interventions, this number has increased to 65 [23]. Chennai receives its annual rains through the North-East monsoon in October-November. Being on the leeward side of the South-West monsoon, in June, the city receives practically no summer rainfall. Earlier, surface water and groundwater in the region were abundant and water from the lakes was ample to irrigate the fields. Over time, however, the lands associated with the marsh have become highly urbanized as seen in the land use land cover map.

After the 1970s and 1980s, more and more people migrated to this area from villages further away. Initially, they earned their livelihoods through farming but later converted their farm land into land meant for other uses such as for building residential spaces so that they could obtain loans from banks by mortgaging such land. Another factor was the introduction of a road connecting the eastern and western sides of the marsh, which divides the water body-a major intervention in the early 2000s. This triggered a spurt in civil construction and turned large parcels of land into concretized surfaces. Lands that were not only surrounding the marsh but also those contiguous with it or had extended into the water body itself were registered and assigned survey numbers as seen in an overlay of revenue map. This change indicates that people live in large numbers close to the marsh.

Historically a flood plain bearing the soil type, granite gneiss and recent alluvium, this was an area of about 50 sq.km and bore the nomenclature, Pallikaranai marsh [24]. It is the natural habitat to some highly endangered reptiles such as the Russell's viper and birds such as the Glossy ibis, Pheasant tailed Jacana etc., Pallikaranai Marsh supports 349 species of flora and fauna.

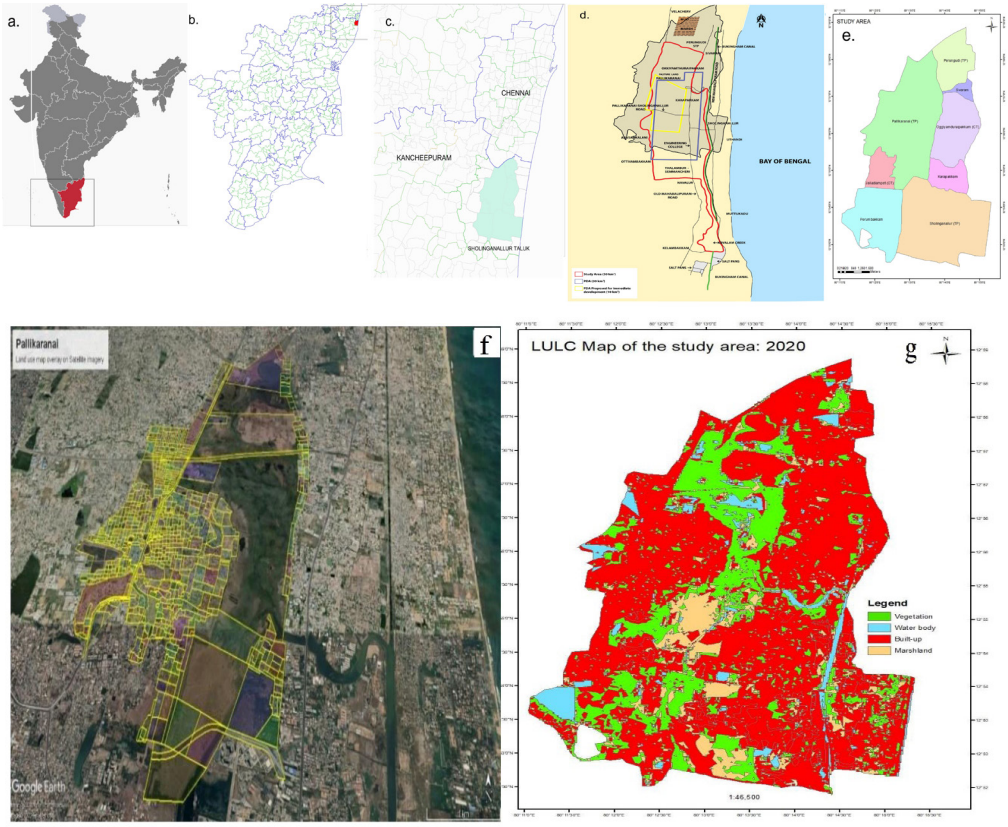


**Figure 1:** The marsh drains through two outlets ensuring the marsh's ecological balance while supporting local biodiversity and acting as a natural barrier during monsoon seasons. **Note:** (a). India (b). Tamil Nadu state (c). Chennai city corporation (d). Regional context: Study area and drainage routes; (e). Study area (f) Land cover map of study area (g). Google earth map with revenue map overlaid as yellow lines.

The Marsh is home to 133 species of birds, 10 species of mammals, 21 species of reptiles, 10 species of amphibians, 50 species of fishes, 9 species of molluscans (snails and clams), 5 species of crustaceans and 7 species of butterflies. About 114 species of plants are found in the wetland including 29 species of grass. Pal et al., have discussed the environmental status of the marshland and the heavy metal contaminants due to the Perungudi dumpyard [25]. Our discussions with key-informants also elucidated the fact that oil deposits contaminated the groundwater in many areas. Recent research by Indian Institute of Technology (IIT), Madras shows that every metre cube of surface water in the marshland contains an average of 1758 microplastics of which 50% are less than 1mm thick and are contaminated with heavy metals such as zinc, iron, nickel and titanium [26].

Sources for our research include field documentation and primary information, secondary information from document analysis and previous research and sociological data collection by ethnographic methods. The research questions cover every relevant aspect of conservation of the marsh, present condition of the marsh, community relations towards water bodies, the economics of protecting it and the measures taken by the government. Document analysis has been an ongoing process for over four years and field data collection was in stages, with the latest sociological data collection having been conducted in April 2023-May 2023, which covered the qualitative aspect. For quantitative assessment, we conducted an online survey (N=203) and have identified relationships between the variables. Therefore, a mixed methods research highlighting the methodological approach shown in Figure 2.

The study focusses on community behaviour and stakeholder's approach and inter-relationships. We covered this part of the data collection in 16 semi-structured interviews (about 40 minutes to 50 minutes each) of various experts, stakeholders and office-bearers and additionally a Focus Group Discussion (FGD) with about ten members discussing their experiences and perspective. We presented to the interviewees, our SES approach and also received feedback and they have reiterated the significant aspects. We went about in the following framework, discussing the uncertainty or complexity of the SES and their relationship with the land. Our multi-pronged exploration resulted in the following learnings.

## Results and Discussion

### Social ecological systems approach

We perceive the existing condition of Pallikaranai as having acquired a problem oriented social ecological system stage in its growth and development. The problems include those related to approaches to maintenance and present condition of the marsh with respect to its pollution status. Also relevant are its functional attributes in terms of conveyance of water or drainage to the sea, sustainability of biodiversity, groundwater recharge and other ecosystem services. The framework in Figure 3 shows the related issues surrounding the marshland site and possibilities for relooking at the status. The drivers of change have mostly been economic and increase in population therefore, we examine design solutions based on the principles of the social-ecological framework outlined by Cumming. Empirical studies based on field data as well as results from resource monitoring can enhance the use of this framework. We have been investigating the marsh in terms of its land cover change and sociological and climate-change related attributes and the trends observed in these aspects as shown in below (Figure 4).

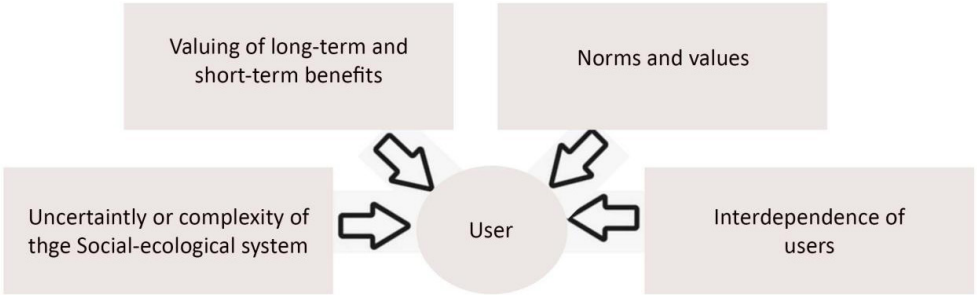


**Figure 2:** The study focusses on community behaviour and stakeholders' approach and inter-relationships.

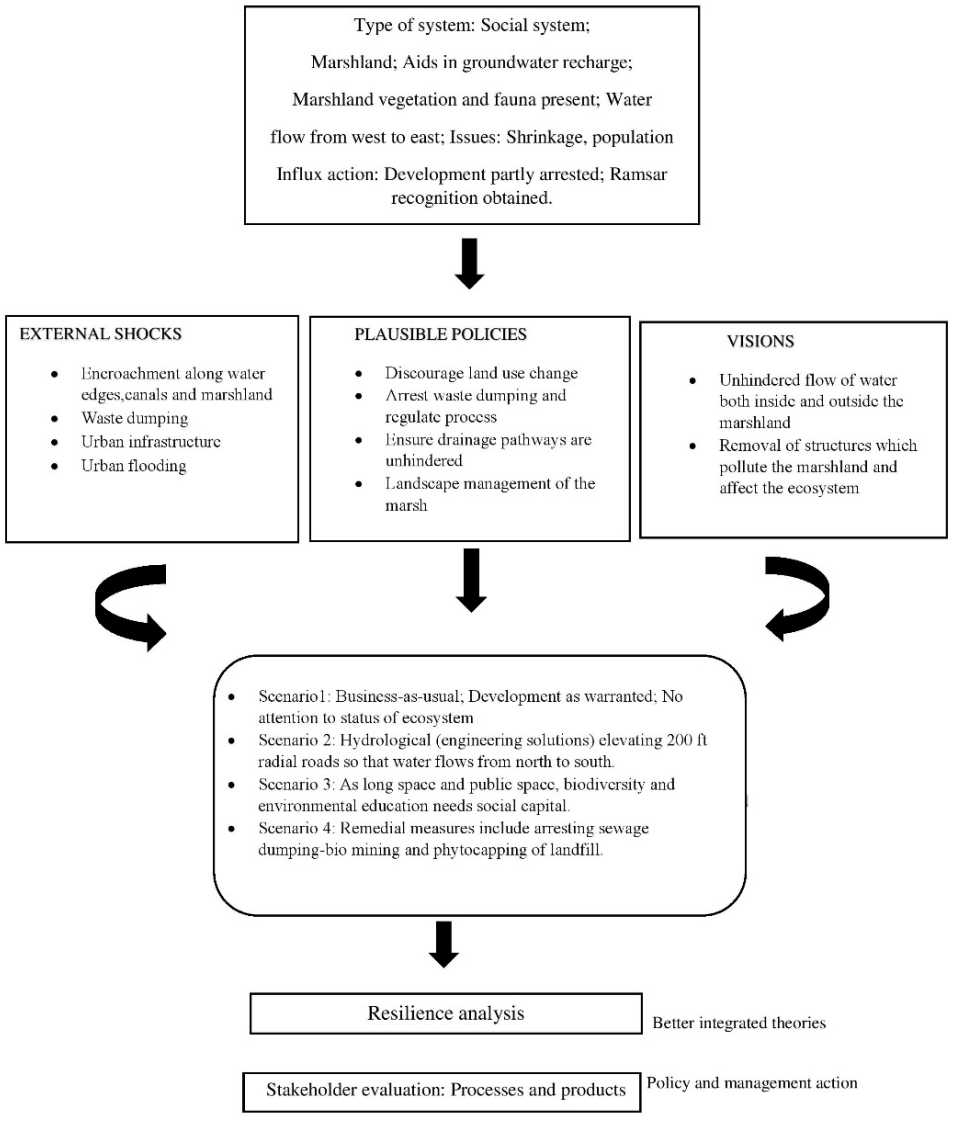


**Figure 3:** Problem-oriented social-ecological systems framework.

Our understanding from these trends as seen in Figure 4 population and built up area are the parameters which exhibit a steady increase while ecological parameters. Madhusudhan et al., show a deteriorating trend [27]. Climate data shows marked changes in recent years though Chennai always went through warm periods of rather high humidity. The weather data is from an online repository by name, Wunderground (Weather underground), which may be showing simulated data for historical periods. The charts are indicative and display correlations between climate trends and simultaneously we have the social and ecological parameters for the same time period to comprehend active social-ecological patterns accounting for impacts on the marsh. Birds visit the marsh through the year and a repository, e-Bird shows the migration patterns. A similar set of observations was explored by Bruley et al., on historical re-configurations of the social-ecological system in the French alps [11].

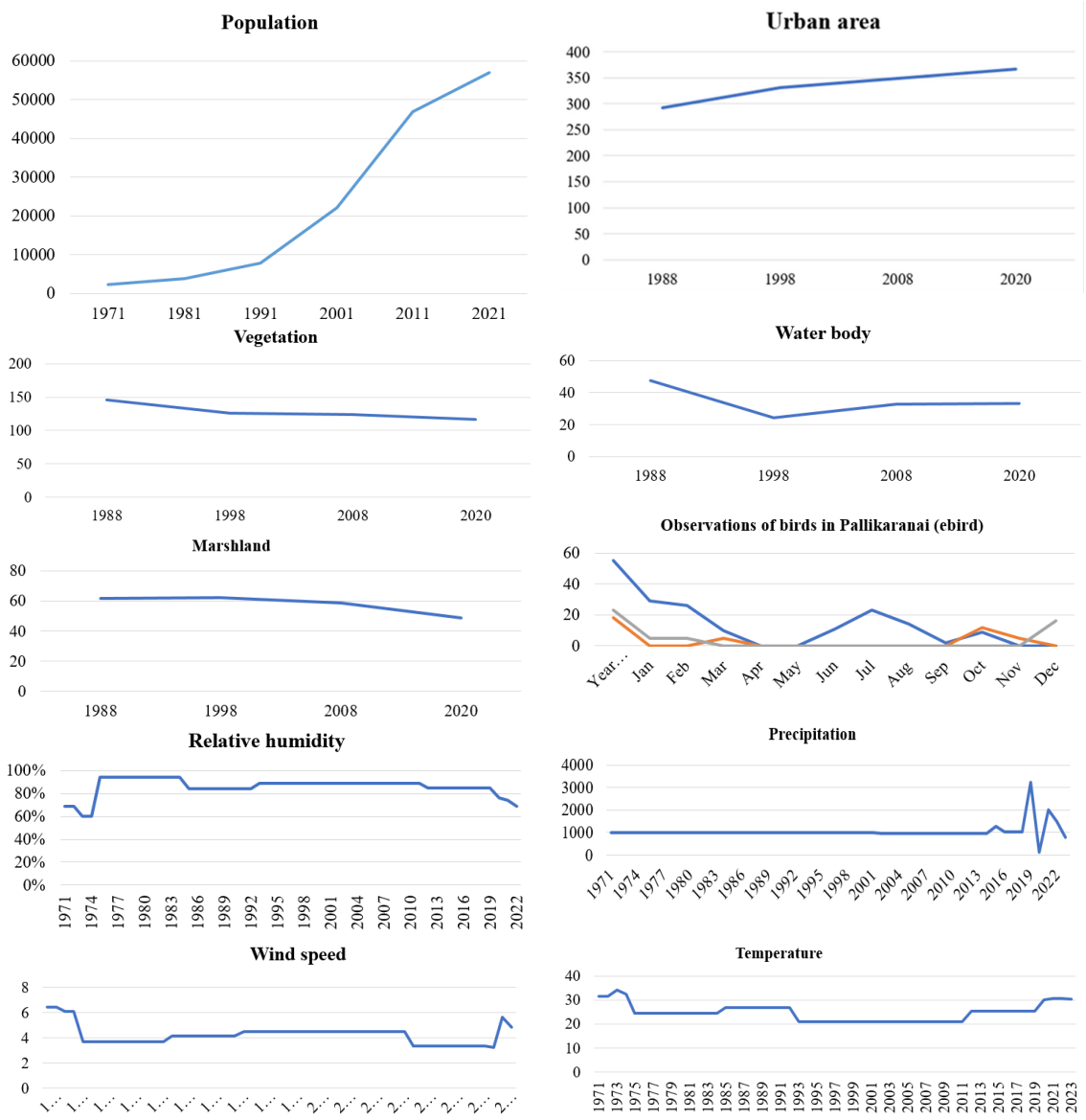


**Figure 4:** Trends in urban, ecological and climate-related parameters. **Note:** Birds-Narayanapuram (); Lotus pond (); Kovilambakkam lake ().

## Community perception of water bodies

Community perception acts as a driving factor in approaches towards water bodies and the research by Scholte et al., on a wetland park in Bulgaria reiterates the same [28]. In our semi-structured interviews, we have learnt that many members of the public view the Pallikaranai marsh as a source of water (referring to groundwater recharge) and as aesthetic and as a climate regulator. Further perceptions of ecosystem services like soil formation, spirituality, source of raw materials and pollution control also exist, not-withstanding negative impressions of mosquito-breeding, garbage dumping and burning which most people lament about. The interviews we conducted were about 16 in number, with a wide spectrum of professionals, academicians, elected representatives, members of Residents' Welfare Associations and other members of the community and government officials. We asked them questions and tried to infer about the flaws in management, reasons for this extent of damage, existing modes of living and future of the marsh as well as that of the citizens who live in close proximity to the marsh.

We also conducted a Focus Group Discussion (FGD) with about ten representatives from the community, incidentally men, with two women from our side. Based on the results from the FGD, we have presented this case in the earlier sections also and in this section we delve deeper into community perception of the marsh and of water bodies in general. Three large lakes, Vadakapattu eri, Anai eri and Sith eri dominate the landscape of Pallikaranai village from earlier times. These lakes among 34 others, are found to drain into the marsh. Of the three, one is fully lost to encroachment and has been built upon and one has shrunk and dried out; however, the third Anai eri, was protected by restoring it and a protective wall was being built around it. In debates on methods of restoration, we were able to examine

public response to building such a wall. For instance, Vencatesan et al., discuss the standard but particularly insensitive restoration method of building walking tracks around water bodies.

In the present case, because the wall was left incomplete, the lake was encroached upon, with serious damage to the lake and the ecosystem. This being one of the last remaining lakes, it garners some attention from the public. Community perception of ecosystem services of wetlands and community engagement in addressing land conflicts are therefore noteworthy in this context [29,30]. Previous research shows that Pallikaranai is a mix of saline and freshwater ecosystems that earlier sustained turtles a variety of fish and a range of marsh plants including reeds and grasses [31]. Later, over time and as human population increased, the wetland also supported a diversity of occupations, which included raising cattle, harvesting grass, fishing and farming. Whereas, today most of the people who followed these occupations have turned to other and more lucrative occupations and have thus achieved a higher socio-economic status.

Development elsewhere seems to have bypassed Pallikaranai, for reasons like the natural landscape being unconducive for urbanization. This may be most appropriate considering the natural ecology of the region nevertheless, the city sought to grow. For instance, widening a stretch in Pallikaranai of the historically existing Velachery–Tambaram road was a much sought-after project. It could have benefited the residents immensely, but the project did not see the light of the day because of the government's inability to acquire sites. Yet, sites or properties denoted as 'poramboke' (commons) exist adjacent to the lands that can be reclassified as for residential use, which appears inconsistent to those at a disadvantage. During the FGD, we realized that because banks did not extend loans against agricultural property, people sought help from the Chennai Metropolitan Development Authority(CMDA) to convert their agricultural lands bordering the marsh into residential lands. This can be seen even in the land-use maps used for the second master plan [32]. Even as such strategies for development are being implemented, greater forces have exploited the situation.

As we learned during the FGD, initially the area had only two factories and they were the players in the local economy. Over time, real-estate developers brought in people from faraway places, who demanded infrastructure and comfortable living and ended up polluting water bodies sometimes wilfully. With various citizens in distress over anti-social elements, we sought to inquire, by means of a survey, on values and means of living, in other words a survey of people's knowledge, behaviour and attitude towards the environment, particularly water bodies. In framing questions for people living near the Pallikaranai marsh, we sought to be familiar with the living conditions and actual situation on the ground. We realized later that this objective was better achievable through semi-structured interviews and focus-group discussions, which we have previously presented. Our generic questions, which were based on previous knowledge, crystallized into concerns related to values which means of living focused on themes related to the environment.

Patton discusses the significance of qualitative interviewing as a means of capturing authentic information and the methods [33]. Such interviewing differs from quantitative surveying in that the results obtained from the interviews are descriptive or qualitative, not easily amenable to quantification. On the other hand, we can ask probing questions in a survey. These considerations and our learning from pilot surveys and preparatory work, led us to deploy a mix of methods to collect data. From our learnings from the FGD, we realise that public behaviour around water bodies follows certain value systems and lead to collective action. Therefore, we conducted a survey among interested people by circulating it online, in a wider geography of the whole of Chennai, India and beyond where applicable. The results of this survey are given below. The sample size was 203. It was an online survey data collection method, which gave prompt responses and the questionnaire was redesigned after a pilot survey. It takes its roots partly from the Rokeach value survey, which questions respondents on terminal values and instrumental values for living.

Our survey was related to water resources, so we focused on knowledge, attitude and behaviour on themes related to consumption, conservation of water, awareness about sustainability, socially conscious behaviour and living practices. The survey fetched reasonably prompt and positive responses probably because the theme resonated with the respondents. In the interviews, a few people expressed their frustration with the situation as they saw it and in despair over the polluted state of our water bodies even asked us what knowledge we hope to gain from this scenario. Water is perceived as a personal commodity and resource and people were ambivalent in supporting our interest in establishing the need to protect water resources. The survey touched upon water conservation, consumption, other sustainable practices and use of resources and ethical values related to water. On each of these topics, we framed a set of questions to certain the respondents' environmental knowledge, attitude and behaviour. The survey obtained responses from 203 individuals: The sample size was therefore 203 and not all of them lived in Chennai. The demographic variables were age, gender, occupation and location (in Chennai or away from it). The questions included the following (the abbreviations in brackets serve as column headings) (Table 1).

- Do they (the respondents) believe in Saving Water (SAV_WATER)? (attitude or values).
- Do they think Over-Extracting Groundwater (OVEREXT_GW) is harmful? (knowledge or values).
- Do they Have a Well-Maintained Rainwater-Harvesting Facility? (HAVE_RWH) (behaviour or actions).
- Are they personally Exploiting Ground-Water (EXPLOIT_GW) either through more than one bore-well or very deep extraction? (behaviour or actions).
- Have they Supported People of Lower Socio-Economic (SUP_LOW_SE) strata with the use of water from their personal source? (knowledge or values or behaviour).

Age as the demographic variable offered five options, namely under 18 years, 18 years-36 years, 37 years-48 years, 49 years-59 years and 60 years and above was significantly correlated to the variable on whether they believed over extraction of groundwater to be harmful and also negatively correlated to the behaviour variable on whether they had a rainwater-harvesting facility. Belief in saving water correlated to being mindful of over extraction and empathy towards the lower socio-economic strata and sharing water with its members. Concern about over-extracting groundwater correlated negatively to having the facility to harvest rainwater. These significant correlations are shown in Table 1.

Other responses reveal the anomalies in behaviour and their correlation with knowledge, attitude and values. For various reasons, which we explored in our personal discussions with people, we found little correlation between behaviour and knowledge, values, or their attitudes, which are shaped by external factors and realities. People also have different priorities depending on who they are, as reported by Tudor et al., who studied a spectrum of citizens in Chennai, India, ranging from the average taxpayer to concerned citizens to environmental activists [34]. Therefore, individual behaviour cannot be predicted from the individual's knowledge or expectations but can be moulded through education and awareness, as can be inferred from the following findings.

| | | Correlations | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Age** | **SAV_ WATER** | **OVEREXT_ GW** | **HAVE_RWH** | **EXPLOIT_ GW** | **SUP_LOW_ SE** |
| Age | Pearson correlation | 1 | 0.131 | .233** | -.271** | -.029 | 0.015 |
| | Sig (2-tailed) | - | 0.062 | <.001 | <.001 | 0.685 | 0.828 |
| SAV_WATER | Pearson correlation | 0.131 | 1 | .142* | -.051 | -.096 | -.162* |
| | Sig (2-tailed) | 0.062 | - | 0.043 | 0.472 | 0.175 | 0.021 |
| OVEREXT_GW | Pearson correlation | .233** | .142* | 1 | -.158* | -.015 | 0.032 |
| | Sig (2-tailed) | <.001 | 0.043 | - | 0.024 | 0.837 | 0.649 |
| HAVE_RWH | Pearson correlation | -.271** | -.051 | -.158* | 1 | 0.061 | 0.091 |
| | Sig (2-tailed) | <.001 | 0.472 | 0.024 | - | 0.385 | 0.198 |
| EXPLOIT_GW | Pearson correlation | -.029 | -.096 | -.015 | 0.061 | 1 | 0.097 |
| | Sig (2-tailed) | 0.685 | 0.175 | 0.837 | 0.385 | - | 0.166 |
| SUP_LOW_SE | Pearson correlation | 0.015 | -.162* | 0.032 | 0.091 | 0.097 | 1 |
| | Sig (2-tailed) | 0.828 | 0.021 | 0.649 | 0.198 | 0.166 | - |
| **Note:** ** Correlation significant at 0.01 level (2-tailed) and *Correlation significant at 0.05 level (2-tailed) | | | | | | | |

**Table 1:** Correlations among age and values, attitudes and actions.

- No. of people who believe in saving water=179, comprising 41 who personally exploited groundwater; 112 who probably exploited groundwater; and 26 who did not exploit groundwater.
- No. of people who agreed or strongly agreed to being against indiscriminate extraction of groundwater=174, comprising 127 who had a well-maintained facility to harvest rainwater; 29 who said they might have such a facility; and 18 who had no such facility. The same 174 respondents also comprised 37 who personally exploited groundwater either through more bore-wells or deeper bore-wells; 113 who might be doing so and 24 who had never exploited groundwater through bore-wells.
- No. of people agreed or strongly agreed that they are socially and environmentally empathetic=182, comprising 121 who supplied water from their own sources to people of lower socio-economic strata; 24 who might have done so and 37 who did not. The same 182 respondents also comprised 141 who segregate their solid waste (garbage) 21 who might do so and 20 who did not.

## Government policies related to restoring the marsh Social-Ecological Systems (SES)

The following timeline shows the events leading to the present state of the SES from pre-colonial times (Table 2). The administrative policy-related events (colored orange) present a picture of what the government action towards the situation has been. According to Vencatesan et al., there is no legal protection for wetlands as far as India is concerned though there have been environmental, biodiversity and forest protection acts and laws in place. Therefore, the action on the part of the government, in terms of implementing a management plan has been due to civic movements and NGOs in more recent times. The marshland has been brought under the protection of the forestry department, but as Panini states, reserved forests strictly ban human uses such as grazing and converting a marshland into a reserve forest conflicts with the general implications of wise-use of wetlands as stipulated by the Ramsar convention.

Our learnings from the FGD showed that government policies

to save the marsh may be ongoing but there are also elements of an anti-social nature in collusion with the authorities for example, cases of commons (not private) and land having acquired registration deed status existing adjacent to each other simultaneously, encroachments occur even on a channel corridor earmarked as a drainage canal. Hence, it is obvious that the efforts to save the marshland are not a wholehearted citizens movement, rather it is certain sections of the citizenship who are fearing, maybe worse climate disasters or loss of resources, or who are ecologically aware, though this section may be a minor percentage.

Pallikaranai, being a coastal wetland, is not immune to hydrological disasters during heavy rainfall and cyclones. The annual North-East Monsoon (NEM) brings forth a downpour resulting in inundation causing damage to lives and property. Two such major recent events were in 2015 and 2023 [35,36]. While the city reeled under the effects of the monsoon, it was furthered by an oil spill in the coast and the structural and functional role of the marsh, which has been inadequately utilized by the community, comes to light. Various options such as providing direct drainage from west to east through man-made canals, even by-passing major roads have been considered, according to the reports by the metropolitan development authority.

## Environmental valuation of the marshland for Social-Ecological Systems (SES) approach

With respect to Pallikaranai we have previously attempted a linear regression model along the lines of Chaudhary et al., discussing relationships between distance from water body and land value (guideline value). We have found a weakly significant negative correlation between these variables, indicating that land value has been higher at greater proximity to the marsh for a certain larger boundary on the western side of the marsh. Our enquiries from the forest department show that an amount of Rs.368.73 million is the net present value of expenditure on the marsh as of the year 2021. Whereas the Total Economic Value (TEV of the marsh, of an area of 694.885 hectares (ha) is much higher inspite of the shrinkage, which could be of much greater value if it were in appropriate level of maintenance.

The case of Pallikaranai differs from Sukhna lake, by not being of the urban center type since it is a coastal wetland and is not connected to numerous surrounding urban centres [37]. Nevertheless, out study of benefits and costs is a learning and the constraint of coastal zone deterring economic in other words, city growth, may be used as a promotive factor for saving the wetland, while keeping a check on urban encroachment.

To do a benefit cost analysis, we must identify the primary benefits and primary costs. Figure 5 depicts a listing of primary benefits, costs and secondary benefits and costs implied by Pallikaranai marsh, with respect to the inhabitant community. The issue that presents itself predominantly is that of urban flooding which poses disastrous threats to the community and can be attributed as a key player in the loss of ecological resources. Okapi et al., have quantified the damage to Chennai, India, by the major flood of 2015 [38]. Rajan et.al., have determined that a loss of over Rs.1,50,000 million impacting 10%-15% of the country's production was suffered by the industry lobby [39].

| | **Status or nature of activity** | **Impacts on public** | **Impacts on ecosystem** |
|---|---|---|---|
| Pre-colonial | Agricultural lands and forests | No organized public, hence no impacts | Virgin land. No human intervention. |
| 1806 | First known intervention: laying of the 420 km long Buckingham canal for navigation | No public, hence no impacts | Adverse impacts on the ecosystem mooted |
| Colonial | Agriculture prevailed, classified as wastelands by the revenue department | Decrease in monetary value of land | Presence of agriculture and native species boded well |
| Early days of independence | St. Thomas Mount as administrative headquarters | First signs of urbanization | Probably unplanned development |
| 1970s | Early migrants into Pallikaranai | Signs of urbanization | Probably unplanned development |
| 1980s | Arrival of migrants; Pallikaranai marsh identified as one of the 94 wetlands in National Wetlands Conservation and Management Programme (NWPC) (1985) | Initial recognition of wetland status; no impact on public | Positive move |
| 1987 | Pallikaranai became a town panchayat | Development | None |
| 1993 | Consultations by Chennai Metropolitan Development Authority (CMDA) and environmental impact analysis towards developing Pallikaranai region as a light-industrial area | Move to marshlands for city development. Positive move for public | Not boding well for the marsh; untouched land would have remained protected |

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| Late 1990s | Part of the water body being used as dumping ground | Increasing population and pollution | Does not bode well for ecology |
| Pre-2002 | Introduction of a road dividing the marsh | Boon for commuters; east and west sides of the marsh connected | Marshland divided into northern and southern halves by the road; impeded flow of water as culverts were insufficient |
| 2005 | Pallikaranai marsh brought under the purview of forest department | Need to conserve marshland first recognized following spurt in urbanization. | Positive impact on ecology. |
| | Establishment of a post office; its postal code changed from 603 102, which placed the post office in Kanchipuram district, to 600 100, making it part of Chennai city | Development and infrastructure | Policy changes supporting migration and population growth; may bode ill for the ecology. |
| 2006 | Plan to widen a 3.5 km stretch of the main Velachery-Tambaram road, but plan ran into difficulties because of encroachments; a road divider and streetlights added | Development and infrastructure | Establishment of settlement and its growth |
| 2007 | Civic body called for protection of marshland; high court hearing on Perungudi sewage treatment plant and the dumping ground; 317 (ha) of marshland declared as a reserve forest under Section 4 of Tamil Nadu Forest Act 1882 | Recognition by government | Positive impact for ecology |
| 2008 | Second Master Plan 2026 for Chennai; Pallikaranai brought under Chennai Municipal Corporation | Continued urban growth; marshland annexed to the city | Probable harmful impacts of development on the ecosystem |
| 2012 | 115 wetlands- including Pallikaranai- identified under National Wetland Conservation Programme; however, dumping of solid waste continues | Recognition by government, while public continues to migrate to the area | Positive recognition |
| 2014 | Comprehensive management plan for Pallikaranai marsh prepared by the Chennai-based NGO Care Earth | Research and development efforts by a few citizens for the government | Positive recognition |
| 2015 | Historic Chennai floods; Pallikaranai roads and impervious areas responsible for inadequate flow of rainwater and inundation; solid waste dump grows to a huge size | Members of the public distressed; awareness of hydrological system begins to grow gradually. | Warning signs from nature |
| 2017 | Beginning of metro rail construction; Medavakkam station 3 km from Pallikaranai village, reinforcing its island status. Further, due to dense settlements, access to west impeded | No use to public; many hurdles remain | Interventions and solutions should be pro-ecosystem; solutions should reflect sensitivity to living conditions |

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| 2018 | State government announces plans to restore 695 hectares of the wetland under National Adaptation Fund for Climate Change over 5 years (2018–2023) | No impacts on public | Positive recognition |
| 2020 | Hydrological interventions such as drainage channels and biomining of dumping ground | To make life more comfortable for public | Focus mostly on repairs; a holistic vision required for the marsh |
| 2021 | Inauguration of Pallikaranai marshland park (about 1 hectare) on the marshland adjacent to other institutions that have encroached on the marsh | Marks the importance of forestry department; some attention from the members of public | Focus mostly on repairs; a holistic vision required for the marsh |
| 2022 | Recognized as a Ramsar site | Most significant event in the history of the marsh; efforts of pro-environment public bear fruit; further action and awareness needed to protect and make Chennai a water-sensitive city | Positive recognition; more efforts needed to maintain the status |
| | Water flow from west to east impeded due to buildings and covered areas; proposed canal project halted because of more encroachments; alternative canal constructed through residential areas | Sad plight of residents due to anti-environmental stand of land-grabbers. | Negative impacts on ecology; drainage may not be as effective as expected |

**Table 2:** Timeline of social and ecological events surrounding the wetland.

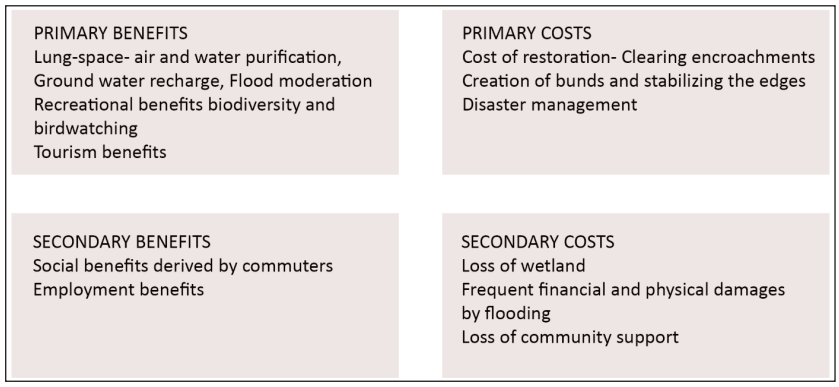


**Figure 5:** Benefits and costs of restoring the Social-Ecological Systems (SES).

Other studies describe Contingent Valuation Method (CVM) and Travel Cost Method (TVM) which have been used to study environmental economics with respect to the landscape of Sikkim, Himalayas by Rai [40]. Community support, local political support, involvement of all stakeholders in the implementation of a management plan include some of the methods previously used in biodiversity improvement programmes in Asia and across the world additionally, this may promote greater socio-economic resilience due to economic diversity, creation of jobs for local public, protection from flooding by technological measures which will satisfy and make the public participate in conservation efforts, generating compensations by enabling the common pool of resources to be utilized by all [41]. Some of the interesting responses to emerge during the discussions were statements blaming the government for its policymaking.

A woman interviewee asked us how we could deny someone the right to build when they have a deed of ownership for their land. If a 'ground' is available everyone will build ('ground' in local parlance indicates a parcel of land measuring 2400 square feet, a unit commonly used in layouts both approved and unofficial). People felt overpowered by a land mafia, which claims ownership of lands at the most lucrative locations. Also at many locations, the residents depend on water supply and sewage collection managed by external service providers (that is other than state agencies) and this, they claim is part of the nexus between the service providers and the authorities for monetary gains. Apparently, the sewage lorries have now been geo-tagged but, according to the activists we interviewed, the government lets private contractors operate them for economic gains. People also complained about the increasing pollution, deterioration of

groundwater in the form of excess salts and oil deposits and the fact that their homes were inaccessible to their domestic help because of poor connectivity.

### International recognition

The recent addition of Pallikaranai to the Ramsar list bodes well for biodiversity and ecological conservation if the right objectives are pursued. Various criteria of flora, fauna and bird species inhabiting the marsh have been found to be present, satisfying relevant criteria as per the Ramsar information sheet and activities already implemented have been described in the same. Greater commitment towards monitoring is called for active research programs need to be established and the information sheet states that this is yet to be implemented. The conservation measures which will justify our attitudes and enhance the biodiversity value of the wetland need to be put in place and this may require active participation of various stakeholders. Pallikaranai is a rather large landscape as it stretches over parts of the city and we have encountered people who claim to be activists who are involved in spreading awareness about water resources associated with other water bodies also. A collective, concerted effort, responding to legible targets and goals is the need of the day.

Wetland evaluation is often constrained by lack of adequate knowledge of local biological diversity, ecosystem functioning and dynamics, the openness of their spatial boundaries to external influences that go beyond management boundaries, difficulties with determining baselines and by past and ongoing loss and degradation. Ostrom discusses adaptive governance and self-governing principles for cases like this with a massive acting and stakeholder community. The nature of responsible behaviour circumstances like this, is believed by the fact that there is not sufficient legal support for the "green agenda". The present nature of agenda is neither a "brown agenda" as the systems in place seem to only be the commercial gains of certain participants [42].

The following are reasons for importance of the Pallikaranai case in the local context and international readership: as a social-ecological system it may work to demonstrate the theories we have discussed, namely by Ostrom, landscape urbanism and is a Ramsar site harbouring a number of ecosystem services, significant in the context of Sustainable Development Goals (SDGs) of the United Nations (UN) and Integrated Water Resources Management (IWRM) principles. Further, it acts as a site for adaptive and self-governance and citizens' participation. It witnesses the dynamics of climate change in interaction with ecology and man-made infrastructure and also acts as a supporting site for biodiversity and environmental education. It may work as a testing ground for dynamics of this nature, but may not withstand high-population intensive uses and responses. Being a coastal ecosystem, despite the high demand for recreation-based uses, which is the ongoing trend in the city, one has to make way for eco-sensitive solutions [43].

The biological importance of the marsh cannot be stressed any further, as it has been recognized internationally for the same reason. We have hypothesised that ecologically friendly solutions for human living have been perceived as escalating living costs and therefore, people allocate basic expenditure for services management. Due to this, they are denying themselves alternative, pleasant, sustainable and contextually significant responses to community and governance problems. The problem becomes all the more pressing with the sensitive nature of coastal ecosystems and local knowledge and ecological sensitivity need to be applied to approach the current situation.

## Conclusion

We examined a social-ecological system in Chennai, India and categorized it by its problem-oriented attributes. This framework can be translated into empirical studies and changes were examined with the historical knowledge that we have compiled. Our data collection and analysis opened our eyes to the many facets of civilization in generic as well as localized and specific terms. Knowledge, attitude and actions are popular modes of evaluation with respect to community studies and we have additionally examined in detail the living conditions and woes of a region that desires to develop and shoulders the responsibility of spearheading an ecological revolution. Future planning should include data on climate projections and ecosystem conditions in addition to demographics. As a policymaker or a local change maker, one has to take cognizance of these principles.

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