# Developing an investment case for Kochi under the Integrated sub-national action for Biodiversity: Supporting implementation of National Biodiversity Strategy and Action Plans (NBSAP) through the mainstreaming of biodiversity objectives across City Regions (INTERACT-Bio) Project

**Draft Final Report for Part II of project:**

**Investment case for selected interventions for Kochi City**

**(Mangrove Management and Integrated Pokkali Rice-Fish/Crustacean farming)**

*Submitted to:* **ICLEI South Asia**

सत्यमेव परमो धर्मः

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December, 2021

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*Supported by BMU through Interact Bio project and ICLEI South Asia*

## ACKNOWLEDGMENTS

We are very grateful for the support received from several individuals and organizations in conducting this study. The field work for this study was mostly conducted after the COVID-19 pandemic took hold in March 2020, in India. There were several delays and challenges that were faced as a consequence. As researchers, we spent long hours in discussions with our advisors, partners and peers, modifying study designs to meet these challenges while ensuring that reliable, contextually accurate, representative and good quality findings were being generated. This task would not have been possible without the active co-operation, time and effort provided by many individuals. A list of experts and key informants whom we consulted is provided in this report. The list is indeed a long one and words are inadequate to express our gratitude to one and all. We express our sincere thanks to our teachers, colleagues, students and friends who supported us in these difficult times.

We would like to thank and sincerely acknowledge Mayor, Adv. M. Anilkumar and officials of Kochi Municipal Corporation who spared their valuable time in interacting and providing valuable feedback on the study. We are extremely grateful to Dr. Rajan, C-Hed for his support and facilitation. Our heartfelt thanks to ICLEI South Asia and especially, Dr. Monalisa Sen, for her active support throughout the study period. We would also like to express our sincere gratitude to the experts who participated at different stages of the study, willingly sharing their precious time and expertise with us, in spite of the many constraints faced during the COVID-19 pandemic. A special mention of sincere gratitude to the key informants, farmers, community leaders, all of whom spared their valuable time in interacting with the study team and explaining the issues. We would also like to place on record our thanks to the support offered by the administrative and financial departments at the Institute of Economic Growth. The authors alone are solely responsible for the views expressed in this report.

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# 1 CHAPTER 1: BRIEF INTRODUCTION AND SUMMARY

**Objective of the study:** To develop an investment case for an intervention that will align socio-economic development and flow of ecological services for Kochi city.

**Expected outcomes:** a) support implementation of the national biodiversity strategy and action plans and b) feed into the Aichi biodiversity targets under the Convention on Biological Diversity; c) incentivise stakeholder/s through creation of biodiversity linked economic options; d) integrate biodiversity management in economic and social plans for the development of the city.

**Approach:** The study is conducted in 2 parts. Phase 1 has been completed and Phase 2 is nearing completion. Phase 1 developed feasibility criteria, conducted a feasibility assessment from among possible interventions and shortlisted interventions for developing the investment case. Phase 2 has examined the shortlisted interventions in greater details to develop the investment options.

**Methods:** Phase 1 and Phase 2 have both involved field work and expert consultations. Quantitative and qualitative methods have been used for the approach and data analysis. Data and information collection has been based on desk review, focus groups, key informant interviews and questionnaire-based surveys for local communities, farmers and experts. Methods have included content analysis, case study, ranking-sorting/correlational analysis and cost-benefit analysis.

## 1.1 Phase 1 Details

The first phase, comprised of several stages including developing the context for possible interventions, identification of a comprehensive list of potential interventions based on the opinion pooling of different stakeholders (scientists, development experts, government officials, civil society groups), developing economic, social and ecological criteria for a feasibility analysis, evolving a set of quantitative and qualitative indicators to assess each criteria and applying these for a feasibility analysis of the potential interventions. Initially 14 possible interventions were identified, which included mangrove management, sacred grove restoration, revival of Pokkali farming, promotion of urban agriculture, developing urban green spaces, biodiversity parks, agro and ecotourism, several interventions for pollution management in water bodies, and waste management for urban, industrial and domestic waste. Based on the feasibility analysis, 6 interventions were shortlisted as making the cut-off in terms of meeting atleast 50% of each criteria category, including being in the top 50% (out of 14 interventions) in agreement across stakeholder groups on the overall relevance of the intervention. These 6 intervention areas were: Conserving traditional system of Pokkali cultivation; Restoration of mangroves; Homesteads/ urban agriculture; Conservation of sacred groves; Creating Urban green spaces; and Pollution management. Feasibility analysis indicated that of these the top 2 interventions scored highly and could be considered from the stand point of feasibility for implementation at scale. These interventions were Pokkali rice-fish integrated farming and Mangrove management.

In terms of the potential for extent of coverage of stakeholders, strong livelihood benefits, biodiversity and other ecological impacts on soil and water, and climate adaptation through climate smart agriculture in a relatively shorter time scale, Pokkali as an intervention scores highest. In terms of the long-term implications, restoration of mangroves provides substantial ecological benefits including carbon sequestration, biodiversity, coastline stability, and protection of habitat, to name a few. It also provides livelihood and commercial benefits in terms of nursery habitats, fisheries, and protection of infrastructure to inland areas, and as linked benefits one could consider educational and ecotourism values associated with mangroves. *It is possible to also integrate these two and some of the other interventions within these two overall interventions, to the extent that these are linked and do not call for substantial additional resources. For instance, biodiversity parks can be set up themed around awareness creation for mangroves and farm tourism can be promoted with Pokkali ecosystems that integrates mangroves, fisheries and agro-biodiversity conservation.*

**Phase 1 findings:** Six interventions were selected (after preliminary research) for a detailed feasibility analysis. These were: Conserving traditional system of Pokkali cultivation; Restoration of mangroves; Homesteads/ urban agriculture; Conservation of sacred groves; Urban green spaces; and Pollution management. Feasibility analysis indicated that 2 interventions scored highly and could be considered from the stand point of feasibility for implementation at scale:

1) Pokkali cultivation
2) Restoration of mangroves

## 1.2 Phase 2 Details

The existing situation presents the classic case of the environment-development challenge context to start with. Interactive sessions conducted as part of our study highlighted the concerns of local residents and farmers who face the disservices from uncontrolled spread of many of the mangrove species. This was in contrast to residents and non-locals who were not in the vicinity of the mangroves and did not face livelihood concerns associated with the mangroves on a daily basis, and highly appreciated the presence of mangroves. The situation thus presents itself for applying economic, social and environmental rationale to convert a potentially competitive mangrove versus cultivation situation into one of sustainable development, encouraging a complementary relationship.

Various aspects of Pokkali farming were looked into including its location and potential for further development, policy regulations and their impact, rice varieties cultivated, changes in status over the years, employment generation, costs of cultivation and profitability. While there is indication that economies of scale are applicable in the region, majority are small holders and incur losses from paddy cultivation. Simulations of scenarios developed with better management indicate that there is scope for increasing the profitability significantly (ratio of returns to costs) from the status quo. Specific economic and institutional measures are feasible to consider in this regard, but would require investment for financial and human resources, including awareness and capacity building, input upgradation, water and pest management, and in marketing support. Pokkali cultivation has significant potential for biodiversity conservation.

Similarly for fish farming, the socio-economic and ecological aspects were considered to the extent possible. Major species in fish farming cycle are shrimps (white/tiger) or fish species ( pearl spot/crab/grey mullet/Thilapia.) which are done either as single species or as polyculture. Water management, labour costs, seed costs and prices are the main economic aspects. The benefit-cost ratio for various species varies substantially between 0.74 and 2.26, unlike rice cultivation, farming with most shrimp/fish species have ratios greater than 1 and is profitable. However, integrating the two as per current practise (infrastructure development), confirms that the existing situation of rice farming followed by fish farming (with any of the species) is economically not justifiable. Only crab farming could compensate fully for the loss in rice farming, though farming with other species does reduce the extent of loss. Economic sustainability can be achieved only by improving the yield from rice farming through use of quality seeds and scientific management. Positive net returns can thereby be ensured.

The case for mangrove management, in terms of restoration and conservation, was examined in some detail with the help of secondary literature and extensive inputs from experts. Mangrove vegetation in Cochin area is seen along the Cochin back waters (lakes which have access to the sea through bar mouth), particularly along the banks of estuarine water bodies, in the form of small patches or narrow continuous belt. Area under mangroves in Kochi Municipal Corporation (KMC) is about 1.19 sq km (ICLEI South Asia, 2020; Kochi Municipal Corporation, 2020). The mangroves are very limited within Kochi, though surrounding areas are also considered to be relevant, due to its social and ecological significance. Mangalavanam which is in the heart of Kochi city is considered as lungs of the city and are inhabited by many bird species. While estimates vary on the exact status at present, there is agreement among experts that the mangroves have been degrading due to various pressures. These drivers for degradation, potential locations for mangrove management, the ecosystem services from mangroves in the area, and the possible interventions to manage these have been extensively examined with the help of secondary information and expert analysis. Given that integrated farming is often practised around mangroves, this is examined in some detail.

Traditional practices of cultivation are found to be complementary with mangrove conservation, although perceptions on the ground can be very different. Mangroves can provide important ecosystem services for fisheries as well as local agriculture. Integrated Pokkali-fish farming would benefit from supporting and regulating services such as wind breaks, erosion prevention, protection from extreme weather events like floods as well as direct services such as providing habitats for fish breeding and nutrients. Biodiversity conservation and lifecycle maintenance are extremely important services from mangroves, apart from the potential for ecotourism and combining it with agrotourism for Kochi.

Overwhelmingly, mangrove conservation (80%) was the preferred intervention for most experts. All experts stressed that ensuring community participation and buy in would be the only way to achieve success. Community development through alternative livelihood generation would have to be the key to mangrove management. There was strong support that traditional farming is to be pursued as part of the agro-ecological system, in a complementary way. In certain cases growing mangroves exclusively would be the right way ahead, in which case alternative income generation is very important, while in other cases the integrated approach may be adopted with some safeguards in place, especially to monitor the long term impacts closely. Urban land use and land conversion, environmental factors and pollution were the three most cited threats to mangroves.

**Phase 2 findings:** Phase 2 further assessed the 2 interventions that came up from the feasibility analysis, namely Pokkali cultivation (integrated paddy, fish farming) and Mangrove management (conservation, restoration). A cost benefit analysis of field-based data indicates that Pokkali requires specific economic schemes and institutional support to become a feasible option, while being important for biodiversity conservation given the need to preserve traditional varieties, and develop new species that are adaptable to changing conditions such as increasing salinity. An expert survey-based analysis indicates that mangrove management is to be pursued in parallel and in complementary manner. Along with the substantial global benefits, there are several local benefits from biodiversity conservation from mangrove management to the Pokkali cultivation itself.

## 1.3 Recommendations

### *1.3.1 Overall*

- There are several options for investment in biodiversity conservation in Kochi
- Integrated Farming (Pokkali) and Mangrove management are significant and complementary interventions
- When pursued jointly, these two can potentially yield multiple pay-offs at different levels
- Benefits include carbon sequestration and biodiversity conservation, sustainable livelihoods with nearer term benefits and adaptation to changes in soil, weather and climate.
- Economic instruments to enhance the implementation of interventions as well as ensuring investment in safeguards are needed; both direct income generation activities as well as benefit transfer mechanisms are needed. Marketing support for Pokkali maybe important. Context specific valuation study can be done to develop mechanisms such as Mangrove tax and Payment for ecosystem services, to reflect the conservation value for Pokkali and ecosystem services from Mangroves.

- Substantial and active community engagement, along with capacity and trust building activities will be important for investing in sustainable solutions.
- Specific recommendations include: suggested pilots, potential geographical locations for interventions, design of economic mechanisms for benefit-sharing, marketing support and capacity building, institutional mechanisms for implementation and performance monitoring indicators to maximise synergies. Investments in social and environmental safeguards where trade-offs may arise have also been flagged.
- In order to ensure that sustainable ecosystem based practices are adopted and pursued, it is important to be able to agree on monitoring and performance indicators. In the context of Kochi, which has scope for a complementary relationship between agriculture and mangroves, while having a high population density, the SDGs are a good starting point in this regard, especially in choosing indicators that expressly encourage the nurturing of the human-nature relationship, rather than those that only emphasise the biodiversity or ecosystems aspects.

### *1.3.2 Pokkali (Integrated rice-fish) cultivation*

- Strategy to invest in rice farming in Pokkali areas can contribute to both economic and ecological sustainability
- Restoring the Pokkali ecosystem in KMC limits demand investments in infrastructure for waste management and water management as well as collective action
- Restoration of the agroecosystem has to ensure varietal diversity, with genetically pure traditional varieties of seeds being provided to farmers
- Long run cost effectiveness will require planned interventions especially for improving efficiency of production and marketing support.
- In the short run, resource allocation has to be made to provide direct compensation to farmers to incentivise them to adopt sustainable cultivation practices.
- Calculations based on our analysis on the differential between efficiently managed scenario and status quo, indicate an average compensation of approx. 1.6 lakh rupees per hectare per annum (at current prices).
- Transfers to farmers for the positive externality values of regulating and supporting services and which are intangible and are not explicitly captured in these market prices would be higher. Some recent evidence from paddy cultivation (traditional and other)

in Kerala indicates regulating and supporting services could be valued at over 6000 USD (or approx. 4,50,000 per hectare).

- Fish/Shrimp farming is profitable under status quo, and in combination with improved management of traditional rice cultivation, can provide a way of balancing ecological and economic sustainability. However it needs to be done with careful planning, to avoid any negative feedbacks on the ecosystem.

### *1.3.3 Mangrove management*

- Mangrove conservation and restoration intervention needs to be supported on a priority basis with meta-analysis revealing that by conservative estimates, the value of ecosystem services from mangroves could range between USD10,000 to 5000 p.a./per hectare.
- Community engagement at all stages of the management plan, with leadership in specific activities is required.
- The impacts of interventions on mangrove management would depend significantly on the exact location as well as the restoration methods used. It is therefore suggested that an impact analysis integrating the location with the stakeholders maybe undertaken as the first step before deciding on the intervention. Investments in pre-intervention activities need to be factored in from impact analysis to conflict resolution and compensatory mechanisms, if required.
- There is a high level of consensus that special mechanisms for financing conservation and restoration are required. These have to be of both kinds: command and control to enforce regulations (such as pollution fines), alongside direct incentives to manage mangroves (PES, Income compensation for bans, alternative livelihood generation) and collaborative models for carbon offsets (claiming carbon credits)
- It calls for investment in two parallel sets of activities: firstly activities to identify areas and enhance mangroves exclusively where this can be pursued (eg through acquisition); and activities that enhance symbiotic relationship with integrated Pokkali farming in areas where these overlap (eg through community reserves).
- Costs would be incurred on different heads:
  1. Mangrove based interventions (planting, fencing, canal digging, transportation, weed removal, trenching, bio shield development, weed control, waste management and treatment, maintenance costs)

2. Capacity building and training across stakeholders (government, community)
3. Income compensation, new forms of income generation, land acquisition (if required)
4. Research based for knowledge generation and dissemination
5. Policy and regulatory developments and implementation

- Resources need to be invested in technical training (optimal land-use, ecosystem services of biodiversity and protection from weather events, ecological feasibility of site selection for restoration, control of invasive species, technical capacity for restoration interventions including conditions for natural regeneration)
- Investing heavily in knowledge gap filling with local community involvement is absolutely essential. Filling information and knowledge gaps and capacity building that includes citizen science, setting up of platforms for knowledge exchange, estimating and disseminating information on values of mangroves is important.
- Stricter enforcement of existing policy/regulatory measures (existing legal provisions, buffer zones, tenure rights) may have to be supplemented by specific ones targeted at private landowners – such as government acquisition for conservation and restoration of mangrove lands at higher than prevailing market prices; regulation to restrict land use conversion
- Investment in infrastructure for pollution and waste management would enable the process

# 2 CHAPTER 2: APPROACH AND METHODOLOGY

In this chapter, we describe the various approaches and methods that could be considered for an in-depth analysis of the identified interventions. Initially, a literature survey was undertaken to identify various approaches and methods used in feasibility studies, for developing an investment case across varying types of interventions or management strategies, based on the context specific feasibility of an intervention.[1] A desk analysis was undertaken to identify potential methods that could be used for data collection and for analysing the data and results. Literature more specific to the two interventions- Traditional agriculture intervention[2] (Pokkali-fish farming) and mangrove conservation and restoration[3] were focussed upon in particular. Intervention related specific information was collected through extensive literature reviews, secondary information and data sources, primary questionnaire-based surveys and stakeholder interactions through focus group discussions and key informant interviews.

Section 2.1 and section 2.2 present insights from the literature on the various criteria and methods, while section 2.3 discusses in detail the criteria and methods for data collection and analysis that were used for our study.

## 2.1 Criteria used in the literature

A desk review is undertaken, and various qualitative and quantitative criteria identified and grouped into these categories- economic, financial, market; ecological; social; operational; technological and others. Table 2.1 provides further comprehensive information on the various criteria and some examples of sub-criteria/indicators used in these studies. These also include some literature specific to the two interventions that were considered for further analysis (traditional Pokkali rice-fish/crustacean agriculture and mangrove restoration). (Literature used in this chapter given in appendix 2.1).

### *2.1.1 Economic, Financial, Market related criteria*

[1] There are strands of literature that use spatial methods to decide conservation priorities for a specific geographical area or to identify potential locations for conservation. This strand of literature has not been considered due to its requirement for using spatial methods for data collection and analysis (for example- distance indicators). Secondly, studies solely focused on ecological indicators to decide conservation priorities have also been ignored since the study is more focused on studying the socio-economic aspects.

[2] For this intervention, literature on organic and sustainable agriculture, traditional agriculture, paddy farming, integrated rice-fish/crustacean farming systems, cultivation of traditional varieties and literature specific to Pokkali rice-fish/crustacean agriculture were all considered

[3] For this intervention, literature based on international experiences in mangrove restoration and conservation, insights from India and Kerala were collected.

Economic, financial and market related criteria are generally used to understand the commercial viability of a particular intervention by considering the private costs and benefits. These are the most common criteria used in the literature in relation to ascertaining feasibility. Within this category, one of the most common criteria found in the literature is the costs of intervention. Costs are a critical indicator since it can help us understand the funding required for varied interventions, or finalise the intervention in case there is a pre-existing budget.

But it is critical to consider other indicators as well, since simply looking for the cheapest solution that minimises costs and not focusing on overall viability, might lead to various other aspects like successful dissemination being at risk (Huba, et al. 2007). Further, it is important to understand if the activity undertaken as part of the intervention is a revenue-generating activity. Since conservation funding is generally limited, self-financing (for example, through enterance fees to a park) provides a higher chance for continued success of conservation programs (Roberts, Cresswell and Hanley 2018). Another important consideration for ascertaining the commercial viability is to understand the overall potential financial performance expected from the intervention.

For the two interventions chosen, various economic, financial and market criteria were noted in the literature. Most of the literature for the traditional agriculture intervention seemed to look mainly at private costs and benefits, accounting for aspects such as input costs of production, various fixed and operating costs related to production, returns from main and by-products from farming. This information can be used to calculate the returns and the financial performance like return-cost ratios, input-output ratios etc. Further, in addition to operating costs, other costs like costs for building capacity (of farmers, of infrastructure etc), and project management costs (coordination, monitoring etc) together can help calculate the funding requirements (CPGD-Kerala n.d.). Some literature (for example- (CPGD-Kerala n.d.)) also looked at the cost of a potential intervention to mitigate some of the problems associated with Pokkali-fish/crustacean farming. One example of how these criteria were used in the literature to understand the economics of traditional rice cultivation- (Krishnankutty, et al. 2021) calculated costs of farming using CACP cost concepts which included a large variety of costs such as costs of labour (including family labour), livestock, seeds, irrigation, machines and equipment, fertilizers, pesticides, insecticides etc, depreciation and taxes, land rent (leased/own), interest on working capital and so on. Revenue from product, crop productivity are some criteria used to look at the economic effects of farming (Krishnankutty, et al. 2021).

Taking these two pieces of information together, one can calculate return/costs (Krishnankutty, et al. 2021) which gives the financial performance of the activity.

For the mangrove conservation and restoration intervention, economic, financial and market costs included costs of production of forestry produce, plantation and restoration costs and related costs, restoration maintenance and other project management costs. Returns can include private or societal benefits due to restoration, for example reduction in property damage (Rahman and Mahmud 2018).

### *2.1.2 Ecological*

Since one major purpose for conducting the intervention is biodiversity conservation, it is of critical importance to understand how to ascertain feasibility of the intervention in terms of ecological indicators. Ecologically relevant and important indicators in order to understand the overall ecological context, and important indicators to understand changes in environmental asset from the intervention are given under this head. First set of criteria involve indicators which help choose between which species to prioritise and these indicators are commonly used as part of conservation planning. Some of these indicators like uniqueness and endemism are commonly stated in conservation planning studies, but opinions seem to vary widely on which indicators are the most important. One indicator that is considered important in relation to prioritising conservation of species is in relation to whether the species has potential for recovery and long-term sustenance (Martı´n, et al. 2010). This is because "if a species is beyond any reasonable recovery effort it is probably not worthwhile to invest disproportionate resources trying to do so" (Martı´n, et al. 2010).

Another ecological aspect that is important to consider when comparing interventions is regarding indicators to evaluate the potential impact that the intervention can have on ecosystems, environmental assets and ecosystem service flows, vegetation, species and so on. This could be in terms of reduction pollution and emissions, change in species population, reduction of invasive species, reduction of people exposed to natural hazards and so on. In terms of the two interventions, ecosystem services and the ecological benefits due to the restoration or intervention from the traditional agricultural ecosystem and the mangrove ecosystem, ecological characteristics of ecosystem and their importance for reducing climate change impacts, ecological improvements were some of the criteria considered.

### *2.1.3 Technological*

Technological criteria could be important to consider when looking at interventions having technological inputs or requiring technical support. This criteria might provide insight into the availability of the relevant technology currently, performance, effectiveness of technology, cost of technology and whether it is the least cost option, maturity of technology and level of global acceptance, ease of implementation of technology and how feasible it is to adapt the technology to the local context. Further, some other criteria that might be helpful to consider in interventions with large reliance on technology is the lifetime of the plant and equipment. Potential effects from the intervention, like energy savings, can also be considered in this regard.

#### *2.1.4 Social and socio-economic*

The other major purpose for conducting the intervention is to ensure that ecological improvements are done hand-in-hand with benefits to various stakeholders. In addition, socio-economic and cultural aspects have also been found to be an important consideration in determining whether biodiversity conservation activities are a success or a failure (As seen in the case of national parks in Africa by (Muhumuza and Balkwill 2013). Further, acceptability of intervention by the citizens and larger public and the willingness to contribute in the process is important. One way that citizen willigness could be important is from the point of view of conservation funding. Since conservation funding is generally limited, self-financing provides a higher chance for continued success of conservation programs (Roberts, Cresswell and Hanley 2018). Self financing is possible through mechanisms like user-fees when users express a willingness to pay (Roberts, Cresswell and Hanley 2018). Since, willingess to pay can be expected to differ across different activities and interventions (Roberts, Cresswell and Hanley 2018), it is important to consider criteria relating to social acceptablity and willigness to compare between interventions. Further, lack of social acceptability might result in oppostion from the public and lead to unexpected delays during implementation (Roberts, Cresswell and Hanley 2018).

Comparing socio-economic effects of the intervention to various stakeholders helps understand the potential beneficiaries, gainers and losers of the intervention. This could be in the form of livelihood generation, education, health outcomes, reduced conflicts, aesthetic values and so on. Considering a mix of various sub-criteria to measure the socio-economic effects is important, since preferences for each sub-criteria might differ for different stakeholders. Weights for sub-criteria, if any, should take this into account.

In terms of literature for the two interventions chosen, literature looks at criteria such as employment, livelihood and income generation due to the intervention (CPGD-Kerala n.d., Jayahari, et al. 2020), improvement of quality of life (CPGD-Kerala n.d.), impacts to disadvantaged communities (CPGD-Kerala n.d.), farmers' satisfaction of undertaking traditional farming (Krishnankutty, et al. 2021), lives saved due to reduction in exposure to natural hazards due to mangrove restoration (Rahman and Mahmud 2018) to name a few.

### *2.1.5 Operational*

Operational criteria help answer the question of who will implement the project, their incentives, already existing support and other required support, and provides early knowledge of potential risks and threats.

Various stakeholders are required to come together to ensure implementation. These can be institutions, experts and community involved, policy, political, legal and regulatory bodies. An understanding of the nature of pre-existing support and further support required is helpful to differentiate between interventions since some interventions might possibly already be widely acceptable or have prior evidence of implementation. This also provides early insight into the marketing, communication, collaborations and the awareness raising that would be required. For example when building a business case for a botanical garden, a press realease could be useful to develop initial interest especially for residents and tourists, while a presentation of the business case could be helpful for buy-in to stakeholders like civil society, public sector, private sector and education sector (MCA Urban and Environmental Planners & I and M Futureneer Advisors Pty Ltd 2020).

Further, existing available knowledge of the importance of the intervention or the value of biodiversity might be important to consider. For example, Martı´n, et al (2010) suggests that lack of available knowledge on a certain species resulted in it not making it into a list of protection priority species in their study, even though it had high conservation interest.

Examination of political will is also critical to ensuring implementation. For instance, in a context that is characterised by a critical constraint in availability of a provisioning ecosystem service that the locals have a large dependence on, local public and political will to support solutions that resolve this issue could be quite strong. An example for this is given in Huba et al., (2007) where the intervention to install a biogas plant was well-aligned with public interest and political will since rural Burkina Faso in West Africa had a supply constraint in relation to adequate availability of household fuel, and alternatives such as charcoal, dried dung and wood were still being used.

Environmental projects are said to generally characterised by certain knowledge gaps and uncertainties that would be important to consider (Pannell, et al. 2012). Risk management is considered an essential aspect of feasibility studies (Otoo, et al. 2016, Wilson, Carwardine and Possingham 2009). Operational criteria should also include a knowledge of the various risks and threats involved in implementation. An evaluation of risks could be an invaluable resource during feasibility analysis since it could provide ways to mitigate expected risks and threats. Martı´n, et al (2010) suggest that a knowledge of threats and how to control and mitigate threats might even be more important than financial means available when it comes to the issue of species prioritisation and conservation. Risks can also be identified by understanding the likelihood of success or failure of a certain project.

Some other important operational criteria to consider include time period required for implementation and to show results, availability and reliability of inputs required, monitoring and accountability required and possible occupational safety concerns.

Links with existing domestic, international policy, alignment with international goals, complementarity with existing initiatives etc can help provide policy entry-points, help in overall policy analysis and might also help leverage funding.

### *2.1.6 Others*

Some other aspects could be considered are given here.

*Stakeholders:* Identifying beneficiaries, gainers/losers is important and might have effects on many other criteria. For example, funding mechanism may differ depending on the stakeholder since they would have varying interests and expectations from the intervention (MCA Urban and Environmental Planners & I and M Futureneer Advisors Pty Ltd 2020). Stakeholder collaboration is also very critical and is considered an important aspect of natural resource management (Knight, Cowling and Campbell 2006). Methods involving various stakeholders like stakeholder surveys, were seen across many feasibility studies. Consultation of stakeholders may also help provide insight on social acceptability of the intervention (Pannell, et al. 2012).

*Potential funding mechanisms:* Potential funding mechanisms differ based on stakeholders, funding source, ease of access and so on and it is important to discuss possible funding mechanisms for each intervention.

*Uncertainty in estimation of values:* In addition to operational risk, the inherent uncertainty involved in estimation of values needs to be recognised. This may help understand how much confidence to place in different estimations.

*Transformational potential of project:* Helps understand if project has potential to be scalable and replicable.

### *2.1.7 Importance of considering various categories of criteria and Inter-relationship between various criteria*

Each category of criteria plays an important role in ascertaining feasibility and building the overall investment case. Economic and financial criteria help ascertain the commercial viability, while ecological or social criteria could provide insights on impacts caused to the environment and people due to the intervention. Allocating funds for biodiversity conservation is a complex exercise and requires the usage and balance between multiple indicators. For example, Martı´n, et al (2010) suggests that solely considering certain ecological indicators may result in spending large amounts of funding in conserving some species with large/medium conservation value, but might end up not making any major change in overall risk of extinction. On the other hand, merely considering financial or management indicators might result in not inclusion of certain species due to high risk or lack of knowledge regarding their conservation (Martı´n, et al. 2010) or high allocation of resources for easy solutions.

Inter-relationship and inter-dependence between various criteria also needs to be accounted for. In applying methods like indexes, there is a lot of aggregation involved. This might be an issue since relationships and interactions between various criteria may be in different directions. Criteria may not have symbiotic or complementary relationships, which would need to be taken into account if indicators were to be aggregated together. For example, in a study by Recanati and Guariso (2018), an optimisation model for agro-ecosystems considering socio-economic and ecological aspects was proposed, using the indicators of income, stability of income, and species diversity respectively. The study found substantial trade-offs between income in the short-term and large species diversity (Recanati and Guariso 2018). Further, information on one criteria might feed into building evidence for another criteria. In a study by Roberts, Cresswell and Hanley (2018), they used ecological indicators like tree biomass, sedimentation rates to understand the impact of an intervention on the health of the vegetation. This information further went on to feed into the information given to stakeholders as part of a choice experiment that they later undertook (Roberts, Cresswell and Hanley 2018), which provided them with information on another indicator of potential funding mechanisms. Various aspects of feasibility and the criteria used to measure it are also dynamically changing over time, space and might interact inter-temporally and across various spatial scales as well (Singh, et al. 2020). Methods, detailed in the next section are diverse in their ability to accommodate multiple criteria and relationships between criteria. We look in more detail at various methods used to compare interventions and criteria in the next section.

Table 2.1: Various criteria used in the literature

| S No | Criteria category | Criteria | Qualitative (Quant) /Quantitative (Qual) | Sub-criteria/Indicators<br>(Some examples from literature) |
|---|---|---|---|---|
| I | Economic, Financial, Market | Costs of intervention<br>[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29] | Quant | For example:<br>- Input costs (Land, raw material, seeds, labour and labour, training) [19, 20, 29, 8, 9, 2, 4, 13, 17, 5, 20]<br>-Production costs [29]<br>-Plantation and restoration costs, eradication costs (for invasive species) [9, 4, 28, 29]<br>-Project management costs (monitoring, coordination, repair, maintenance, care of seedlings, logistics, capacity building costs etc) [24, 6, 5, 4, 16, 20, 8, 3, 22, 28, 29]<br>-Capital costs and capital expenditure (CAPEX) [7, 8, 13, 30, 24], Fixed costs [29], Operating costs and expenditure [27, 31, 30, 22, 24, 26, 32]<br>-Opportunity costs [4, 20]<br>-Financing costs [8] |
| | | Economic sustainability/ To evaluate potential economic effects from intervention<br>[11, 7, 8, 19, 33, 20, 2, 30, 34, 16, 21, 22, 23, 24] | Quant/Qual | -Demand, revenue from intervention related activity, products generated through intervention (for example- sale of agricultural, fishery, forestry produce, tourism etc) [11, 7, 8, 19, 33, 20, 29, 25, 31, 23, 24, 26, 27, 32]<br>-Market segment, size, structure [11] and possibility of reaching new markets [30, 34]<br>-Potential economic harm caused by intervention [2]<br>-Reduction in property damage/loss [29] |
| | | Potential Financial performance of intervention<br>[7, 19, 11, 13, 20, 34, 21, 23] | Quant | -Financial Performance and Bankability of intervention [34] (measured using NPV, operating or net profit/loss, IRR, payback period, cashflow, etc)<br>-Firm performance under risk (calculated using probability analysis) [11] |
| II | Ecological | Characteristics of environmental asset and | Quant/ Qual | -Species uniqueness/distinctiveness/ representativeness [6, 35, 1, 36, 37, 38]<br>-Species richness (Rare species according to spatial area occupied) and rarity [1, 38, 35] |

| | | | | |
|---|---|---|---|---|
| | | ecosystem services [6, 35, 1, 36, 37, 38, 5, 2, 24, 39] | | -Level of endemism [35, 1, 37, 38] (Species exclusive to that area)<br>- Trend of population decline of species [1, 5, 38]<br>-Importance of species for ecological phenomena [35] and ecosystem [1, 36]<br>-Keystone species [1, 5, 37]<br>-Species Intactness [35] and proportion of species existing in protected area [1]<br>-Biological potential of species [1]<br>-Recovery potential of species [1, 37]<br>-Threatened species [38], Species vulnerability and adaptive capacity [37]<br>-Ecosystem services from the ecosystem [24, 39] |
| | | To evaluate potential ecological effects from intervention<br>[10, 15, 34. 9, 12, 40, 8, 21, 35, 3, 37, 11, 1, 5, 38, 18, 14, 6, 36, 41, 5, 4, 30, 34, 2, 17, 16, 24] | Quant/ Qual | -Change in ecosystem service flows, vegetation health, biodiversity, soil and soil quality [34, 9, 12, 10, 40, 8, 12, 34, 21, 15]<br>-Change in environmental and economic value of environmental asset [35, 3, 15, 37, 11]<br>-Impact on other environmental assets not part of intervention [3]<br>-Change in population of species [1, 5, 38, 18] and species abundance [14],<br>-Reduction in invasive species [16]<br>-Probability of species survival [6, 36, 41] or having a viable population long-term [5, 4]<br>-Air, water, noise pollution reduction, GHG emissions reduction potential [30, 8, 11, 34, 21] (Does it meet national environmental standards [34])<br>- Potential ecological harm due to intervention [2] |
| III | Social and socio-economic | Social acceptability of intervention<br>[1, 30, 2, 10, 11, 42, 9, 8, 3, 34, 25] | Qual | -Social acceptance and community support of intervention [1, 30, 2, 10, 11, 42] differentiated by stakeholders [9, 8, 2]<br>-Adoption of actions by community and degree of community involvement [3, 34]<br>-Social value of environmental asset or species [1]<br>-Farmer's satisfaction of undertaking traditional farming [25] |
| | | To evaluate potential social effects from intervention<br>[30, 10, 11, 12, 40, 34, 8, 42, 2, 16, 24, 29, 43] | Quant/Qual | -Livelihood and income generation, Employment creation [30, 10, 11, 12, 40, 34, 24, 43], contributions to food security<br>-Poverty alleviation [34]<br>-Quality of life [24]<br>-Education and Skill development [8, 10, 34]<br>-Time savings to community [8]<br>-Improved health outcomes and savings in health-related expenditures [30, 10, 11, 34, 8]<br>-Reduction in conflicts over resources (For example- due to increased water availability [30])<br>-Reduction of socio-economic and gender inequalities [10, 42]<br>-Betterment intergenerational equity [10]<br>-Potential social harm due to intervention [2], social displacement/ resettlement [30]; Potential loss of jobs [30, 11, 34], income loss [29]<br>-Aesthetic value from changes in environment, existence value of species [12, 16] |

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|---|---|---|---|---|
| | | | | -Reduction of people exposed to natural hazards and lives saved [10, 17, 29] |
| IV | Operational | Existing and required support for implementation- Institutional, Human resource, Policy, political, legal, regulatory, Alignment and links with policy<br>[10, 11, 33, 34, 7, 8, 30, 35, 13, 19, 5, 3, 5] | Qual | Institutional<br>-Institutional capacity and requirement for new institutions [10, 11, 33, 34, 7]<br>-Support from government, public and private sector [8, 30, 11]<br>-Regional partnerships required and existing relationships with donors [35]<br>- Capacity of community and their expertise to implement [5]<br>Human resource<br>-Staff capacity, leadership [35, 10], -Capacity building activities (training, awareness) [24]<br>-Knowledge and skill available (including local knowledge) [13, 19], Availability of experts with prior experience with similar interventions [8]<br>Policy, political, legal, regulatory<br>-Support and acceptability in current Political, legal, regulatory environment [10, 11]<br>-Policy support required to encourage uptake of activities [3, 19]<br>-Awareness of various marketing channels [25]<br>-Already existing budgetary incentives [11]<br>-Current investment climate [11]<br>-Links and alignment with existing domestic and international policy, and international goals [24]<br>-Alignment and Complementarity with existing investments and initiatives [5, 30] |
| | | Assessment of potential risks and threats, Likelihood of Success of intervention<br>[20, 22, 7, 1, 30, 2, 11, 21, 8, 16, 6, 5, 44, 22] | Quant/ Qual | -Risks, Severity of risks, probability of risks, Effect of risks [20, 22]<br>-How to mitigate risk [7, 1, 30, 2, 11, 21, 3, 24] and the costs involved [11, 7, 8, 16]<br>-Knowledge of current and future risks and threats [1, 37, 3] and gaps in knowledge [3]; Quality of information available [3]<br>Examples of some risks:<br>Risk of social acceptability [8], Environmental risks [8], Investment risk [35], Lack of political or social support [30, 3], Lack of institutional capacity [30], Lack of familiarity with activity implementation [30], Rate of spread of invasive species [2], Risk of technical failure [3], Legal barriers and difficulty of getting permissions and approvals [2, 3, 11], Availability and lack of land and space [13, 17], Lack of land availability for intervention [30, 2], Health and environmental risks [11, 16], Occupational risks [11], Stakeholders not buying-in [7], Lower actual demand than expected [7], Inability to acquire funding [7], Vandalism of the site [7]<br>Likelihood of Success of intervention<br>-Ascertained based on past implementation [6]<br>-Probability of intervention effectively controlling threat [5] |
| | | Time period<br>[30, 13] [3] [24] | Quant | -Time period required for implementation [30, 13]<br>-Time lag required to show results [3] |

| | | | | |
|---|---|---|---|---|
| | | Availability and reliability of inputs for intervention [13, 17, 11, 10, 34] | Quant/ Qual | -Availability of land and space [13, 17]<br>-Availability and reliability of supply of raw material and other inputs for intervention [11, 10, 13]<br>-Requirement for creation of infrastructure [34] |
| | | Monitoring and accountability setting required [10, 24] | Qual | -Monitoring and reporting plans and mechanisms and protocols for evaluation [10, 24] |
| | | Occupational Safety concerns<br>[13, 30, 11, 2, 8] | Qual | -Staff safety [13] (For example- workers working in waste management related activities [30, 11, 2] and adherence to safety standards [8] |
| V | Technological | Characteristics, availability and effectiveness of technology<br>[10, 11, 13, 2, 11, 34, 42] | Qual | - Availability of technology to undertake intervention [10, 11, 13]<br>-Performance, Effectiveness of technology, least-cost option [2, 11, 34, 42]<br>-Maturity of technology and level of global recognition (number of projects implemented using this technology) [34]<br>-Ease of implementation of technology [34]<br>-Adaptation of technology to local context [34] |
| | | Lifetime of plant, equipment<br>[8, 11] | Qual | - Number of years of operation time for plant and equipment [8]<br>-Operation and maintenance [11] |
| | | To evaluate potential technological effects from intervention [8] | Quant | -Energy savings from intervention (construction of biogas plant [8] |
| VI | Others | Stakeholders | Qual | (Beneficiaries, Losers/ Gainers) |
| | | Potential funding mechanisms [7, 9, 8, 34, 42, 30] | Quant /Qual | -Differentiated by stakeholders [7, 9, 8, 42]<br>-Differentiated by source [30]<br>-Policy, regulatory, fiscal [34] |
| | | Uncertainty in estimation of values [5, 11] | Quant | -Uncertainty of estimating values estimated using simulation models |
| | | Transformational potential of project - potential for scalability and replicability [34] | | -Measured through how much benefits provided |

Source: List of sources given in appendix

## 2.2 Methods for analysing the investment case

Various methods used for data analysis and data collection in the literature to examine the feasibility of an intervention, to compare between various interventions and literature specific to the two chosen interventions were compiled together. Methods vary in terms of if they can allow for quantitative, qualitative variables or both, and the extent of primary and secondary information required. This exercise was undertaken to identify the various methods that were used in the relevant literature to help identify some potential methods that could be used for this study. Here, it is important to note that the feasibility of practical application of the methods depends on the availability of rigorous context specific data to the extent required in the method. Further, the inherent complexities of implementing methods for environmental projects needs to be acknowledged. Some techniques and methods used in the relevant literature has been discussed in brief below and Table 2.2.

In the following sections, we present an overview of the techniques and methods that have been developed to analyse the case for investing in interventions, especially in the context of environmental projects and proposals.

### *2.2.1 Methods used for data collection and analysis*

1. *Stakeholder consultation and surveys*

Inclusion of various stakeholders and experts in the process of ascertaining feasibility of a project is critical to help accommodate perspectives of various beneficiaries, gainers/losers from the project, and to obtain expert insights. Stakeholder surveys have been widely used across all categories of criteria (economic, financial, market; ecological; social; operational; technological; and others). In the literature surveyed, consultations and surveys have taken various forms- workshops, consultations, semi-structured interviews, surveys, WTP eliciting questionnaires, citizen juries, to name a few. While stakeholder consultations and surveys provided the necessary quantitative and qualitative information required, they were analysed using various scoring, ranking methods and economic valuation methods. Expert consultations also helped in providing probabilities and scores for factors affecting success of projects (Joseph, Maloney and Possingham 2009, Brazill-Boast, et al. 2018). Stakeholder analyses can be used to compare across interventions, generally by providing inputs for various methods (For example- WTP eliciting methods). Stakeholder consultations and interviews also provide input for some qualitative analyses (For example- In SWOT analysis as part of the feasibility analysis on beekeeping by Marc (2014)).

With respect to the two interventions, some methods of primary surveys, focus group discussions, stakeholder consultations, semi-structured interviews were used in the literature to capture the various aspects related to the traditional farming intervention

2. *Delphi method*

Another specific method used for decision making is the Delphi method. There are majorly three types of Delphi- classical Delphi, policy Delphi and decision Delphi (IPBES 2016), and the method is used for various purposes such as elicitation, forecasting and is helpful as a decision- making tool especially when there are strong preferences on the topics (IPBES 2016). Through many rounds of consultations and feedback qualitative inputs and opinions are obtained, and converted into quantitative output (IPBES 2016). The method is also used elicit expert opinion (IPBES 2016). For example, Mukherjee, et al. (2014) undertook an expert-based approach to understand the various mangrove ecosystem services globally and rank them relatively. Another application of the Delphi approach to elicit and obtain expert consensus on ecological knowledge was undertaken by MacMillan and Marshall (2006) in the management and conservation of wildlife, specifically an endangered grouse capercaillie *Tetrao urogallus*.

3. *Financial Techniques/Methods- Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period, Return on investment*

Net present Value (NPV), Internal rate of Return (IRR) are common methods generally used for understanding and comparing between financial viability of investments. NPV is calculated using the difference of cash inflows and outflows that are discounted over a period of time; which in many environmental contexts translates to a difference between benefits and costs discounted over a period of time (Otoo, et al. 2016, Boadway 2020). A net present value of greater than 0 implies a viable investment. The formula for NPV is: $NPV = \sum_{t=1}^{T} \frac{Benefits_{\ t} - Costs_t}{(1+Discount\ rate)^t}$ where T is the total number of years of the project and t is the year for which the value is being estimated. (Boadway 2020).

Discount rates in financial terms are defined as return rates that can be expected from an investment with similar risk in the market. On the other hand, social discount rates in many environmental contexts require more careful consideration since it may not be an accurate representation of societal preferences to take market rates directly. This is because many environmental goods could be characterised by market failures (Hepburn 2006).

Internal rate of return is the discount rate that is obtained when the NPV is set to 0 (Otoo, et al. 2016). While the NPV is an absolute value indicating magnitude, the IRR is a rate. IRR from an investment is compared with returns from other potential investments to decide (Franchetti 2011). The higher the IRR is considered better (Tuan and Tinh 2013).

In the literature analysed, financial and economic criteria like costs, certain benefits and financial performance use these techniques to either directly compare between investments, or to apply it as part of larger comparative methods like cost-benefit analyses. Criteria from other categories might feed in as inputs. For example, operational criteria like time period required for implementation for different interventions are also useful as inputs into the NPV or IRR formula.

Return on investment (ROI) is also used to compare between alternative investments and is typically calculated as $\frac{Net\ Return\ on\ investment}{Investment\ cost}$. Alternatively, in this context it can be calculated as the ratio between a change in value due to the intervention divided by the cost of the intervention.

Payback period is the time required to getting back the initial cash investment and is calculated as: $\frac{Invested\ amount}{net\ cashflows\ or\ savings\ in\ operating\ costs}$ (Franchetti 2011). (Operating costs are costs or expenses incurred in normal day-to-day functioning and activities of the business). Shorter payback periods are considered better.

Costs and especially benefits used as input in all these formulas, can vary from being simple to very complex depending on the environmental asset and the nature of costs and benefits considered. Benefits can be values given to environmental changes, economic changes or social changes, of which monetary values for certain benefits might be complex to ascertain. For example, Goldstein, et al., (2008) used ROI to decide between different alternatives for conservation and quantified benefits as change in species density. Nair et al., (2014) used ROI as part of the analysis to compare between various organic and conventional agricultural systems. All these methods have been used to compare across various interventions, but are more generally used as a part of larger comparative methods.

4. *Financial Techniques/Methods-Financial performance measures*

Financial performance measures are useful to evaluate the financial position of the company or investment. While NPV, IRR etc can be used to compare between investments, financial performance provides information on the profitability of a particular company or investment. Some measures that have been used in the literature on feasibility studies and on the interventions include operating profit/loss and net profit/loss, net cashflow, profitability ratios and breakeven analysis. Partial budgeting and evaluation on the basis of additional costs and benefits has also been used to compare between two farming systems (For example, (Ranjith, Karunakaran and Sekhar, Economic and environmental aspects of Pokkali Rice-Prawn production system in central Kerala 2018).

Financial performance measures provide easy to calculate indicators of financial position. Ratios such as the IRR may not rank alternatives that are mutually exclusive in line with their NPVs (Boadway 2020). Further if time periods of the projects are different, IRR cannot be used to choose between the projects since benefits for different projects can accrue at varying points in time (Boadway 2020)

5. *Garrett ranking*

Garrett's ranking method by Garrett and Woodworth (1967) is a method used as part of analysing qualitative information, especially from primary surveys. It takes each respondents' rankings on a particular issue over many factors, and calculate their mean score using a process involving calculating frequencies, percent position of each rank and factor and finally conversion into a score for each factor from where the mean is calculated (Dhanavandan 2016). It has been used to analyse problems/constraints involved in cultivation of traditional rice varieties (Krishnankutty, et al. 2021), or the Pokkali-fish system in particular (Ranjith, et al. 2019).

6. *Economic valuation methods*

*Market valuation:* Market valuation includes various methods which consider direct market prices to calculate values for ecosystem goods and services that are already traded in markets. Alternatively, if the environmental good or service is not directly traded in markets, prices of other marketed goods related to the environmental good or service are considered to compute shadow price of environmental good or service (The Economics of Ecosystems and Biodiversity 2010). In the literature, benefits from fishing, aquaculture, and similar provisioning services were calculated using market valuation (For example: (Tuan and Tinh 2013)). These methods are generally used to value certain benefits from ecosystem services which act as inputs into larger comparative methods like cost-benefit analysis. Literature for the two chosen interventions uses market price to calculate the revenue from produce, and for various provisioning ecosystem services which are marketed.

For ecosystem services already traded in the market, this method provides a simple way of calculating value (The Economics of Ecosystems and Biodiversity 2010). High legitimacy given to values derived from this method since values are based on actual observed data. Since many environmental goods and services are characterised by lack of markets and market imperfections, this method might have limited use.

*Willingness to pay (WTP) eliciting methods:* These are generally survey-based methods used to understand the stakeholders' willingness to pay(WTP) for a certain environmental good or service. Within the literature surveyed, WTP eliciting methods have been used for valuing ecological effects of the intervention, social acceptability and social effects of the intervention, and potential funding mechanisms. There are some instances of the method having been used to compare and choose across criteria and interventions, although they also contribute as inputs into larger comparative methods like Multi-Criteria methods or Cost-Benefit methods. Some specific WTP eliciting methods used in the literature surveyed include contingent valuation and choice experiment methods. While contingent valuation involves choice between a suggested alternative or remaining at status quo, choice experiments involve choice between many alternatives (including the status quo as one alternative). Both are generally set in a hypothetical market setting. Perception and willingness to pay studies using contingent valuation, choice experiment methods for various ecosystem services, or to evaluate the willingness to pay for conservation or restoration were observed for the two interventions.

This method could be very useful in capturing values and preferences for environmental goods that have limited data and information available, and allows for involving and potentially representing the interests of many different stakeholders. Although, the stakeholders that are part of the exercise may not be aware or clearly understand their motivations and preferences, especially in cases where the natural assets are complex. Further, methods such as contingent valuation and choice experiments are set in hypothetical markets, so it may not be an accurate representation of actual preferences and behaviour.

7. *Cost and benefit analysis, cost-effectiveness analysis, Multi-criteria analysis*

*Cost benefit analysis (CBA):* CBA is one of the most conventional methods to choosing between investments and typically calculates the difference between benefits and costs of an investment over its lifetime (Moran, Pearce and Wendelaar 1997). The difference expressed in present value terms, can be used a basis/measure to compare various projects, with positive values indicating a that is a good option for investment (Moran, Pearce and Wendelaar 1997). Alternatively, we can represent the same information in the form of a benefit-cost ratio (discounted) (Tuan and Tinh 2013).

In the literature surveyed which has applied the CBA method, costs have included input costs, restoration costs, management costs, monitoring costs, opportunity costs; while benefits have included aspects like change in trend of the species population, abundance due to the intervention, tourism benefits, revenue from various provisioning services, to name a few. Examples of qualitative cost-benefit analysis also exist in the literature, which just contain a listing and qualitative discussion of various costs and benefits with a few criteria represented in quantitative terms (Huba, et al. 2007). Financial benefit-cost analysis (in the case of the traditional farming intervention), and financial and social benefit-cost analysis (in case of the mangrove restoration intervention) were predominantly observed in the intervention specific literature in terms of applying this method.

*Cost-effectiveness index (CEI)*: Various different connotations and interpretations exist on how to capture cost effectiveness. One way to look at cost-effectiveness is to ask the question of how to best conserve the maximum biodiversity and maximise conservation returns with limited resources (Bottrill, et al. 2008). Contributions from Metrick and Weitzman (1998) and Weitzman (1998) provide one solution on how to optimally conserve biodiversity with limited resources/ budget constraint using a ranking criterion that can be used to compare and choose between various projects. This rank criteria is calculated using information on four variables: cost of conservation activity, increase in probability of species survival due to conservation activity, Utility/Value of species, Distinctiveness ie- How distinctive the particular species is in comparison to its closest comparable species. Joseph et al., (2009) suggested a modification to the formula that was suggested to be more conducive to operationalization than the former. This formula called the cost-effectiveness index or project prioritisation protocol additionally includes the subjectively determined variable of likelihood of success of the project. The probability of success is assessed quantitatively by experts by looking at past implementations, operational, legal, political and social factors that might contribute to the outcome of the project. This method also provides the option to weigh the species using various other political, ecological, social considerations in addition to distinctiveness and utility. The project-efficiency measure is given by

$$\frac{Species\ weights \times Expected\ biodiversity\ benefit\ of\ project \times Probability\ of\ success\ of\ the\ project}{Expected\ cost\ of\ project}$$

(Joseph, Maloney and Possingham 2009, Wintle 2008). This method, although straight-forward, is said to be lacking since it does not account for complementary interactions between various strategies (Wintle 2008). Other criticisms of this strand of thought of cost-effectiveness in conservation argue that this method may not incentivise saving of highly threatened biodiversity causing ethical concerns (Bottrill, et al. 2008). Variations of the formula exist that incorporate uncertainty (Brazill-Boast, et al. 2018) and allow complementarity between strategies (Carwardine, et al. 2019). Some authors don’t agree with such an economic formulation and suggest a more ecologically modified approach to the formula (Perry 2010, Cullen 2012).

CEI has and can be been used to compare and choose across criteria and interventions (For example- (Joseph, Maloney and Possingham 2009)). Methods and approaches espousing principles of cost-effectiveness in conservation investments have been adopted by the Department of Conservation in New Zealand, and in the NSW office of Environment and Heritage in New South Wales, Australia for management of threatened species (Brazill-Boast, et al. 2018).

CBA and CEI allows for valuing costs and benefits over time. All stakeholders' interests may not get equally represented due to inherent prioritisation of monetizable costs and benefits. Further, CBA requires values to be measured in monetary terms, which limits the nature of criteria and values that can be compared under this method. CBA has been criticised for not allowing for interactions between various criteria (Department for Communities and Local Government 2009) and it also does not allow for qualitative criteria.

*Multi-criteria analysis, Multi-criteria decision analysis:* Multi-criteria analysis (MCA) allows for comparison across multiple criteria and multiple alternatives (Esmail and Geneletti 2018) and can accommodate both quantitative and qualitative variables. MCA allows for more flexibility in comparison to the CBA, and addresses some the criticisms of CBA (Department for Communities and Local Government 2009). It is of particular use when "reducing a multi-objective problem into a single-objective problem is either unfeasible or undesirable, especially in participatory settings involving diverse stakeholders with diverse objectives" (Esmail and Geneletti 2018). There are many variations in how MCA is conceptualised and applied, with the simplest being ranking (ranks assigned to different alternatives and/or criteria), and rating (where scores are assigned to different alternatives and/or criteria) (Mendoza, et al. 1999). Another method called Analytical Hierarchy process uses simple pairwise comparisons to understand the importance of one criterion when considered relative to another (Mendoza, et al. 1999, Department for Communities and Local Government 2009). Some software-based tools and methods also exist. Setting relative weights for criteria is generally done with the intention of scaling or to signify relative importance of certain criteria (Stagl 2004). MCA also allows for inter-relationships between indicators (Otoo, et al. 2016). It is also possible to aggregate across criteria to obtain an index. Multi-criteria decision analysis (MCDA) is a variant of the MCA which is helpful for making resource allocation decisions (Department for

Communities and Local Government 2009). Multi-criteria decision analysis helps compare and contrast between different alternatives towards a specific objective, alternatives' performance across various criteria, and the various trade-offs involved (Esmail and Geneletti 2018, Department for Communities and Local Government 2009).

Due to the inherent uncertainties and limited information which is characteristic of many environmental assets and environmental management processes; and possibilities of pluralistic values, many MCA include participatory methods and conduct interactions with various stakeholders (Stagl 2004). In the literature surveyed on MCA and its variants, various kinds of stakeholder consultations have been conducted, some of them being workshops, discussions, SWOT analysis (Strength-Weakness-Opportunity-Threat) by stakeholders (Janssen, et al. 2014, Hermans, et al. 2007, Grošelj, Hodges and Stirn 2016, Otoo, et al. 2016), expert consultations (Jactel, et al. 2012) and deliberative methods using stakeholder juries and workshops (Proctor and Drechsler 2003, Zia, et al. 2011). MCA has varied in relation to the extent of qualitative and quantitative criteria and analysis method used, with some using both (For example- (Otoo, et al. 2016). MCA methods have also evolved to compare multiple criteria, multiple interventions over multiple periods with one possible ranking method being discussed in Frini and Amor (2019).

This method overcomes some of the limitations of CBA, by allowing for the inclusion of values that are not in monetary terms within its scope. This widens the choice of indicators that could potentially be considered (Stagl 2004). Method facilitates comparison and choice between and across indicators, interventions, and potentially inter-temporally as well. Potential inter-relationships between indicators can be taken into account. The method allows for use of both quantitative and qualitative criteria which is compared under the same framework. Decisions relating to weighing and aggregating across indicators require careful consideration based on desired objectives. Multiple stakeholder perspectives can potentially be considered using the MCA method. Stakeholder involvement, although a critical part of MCA, is expensive and time-consuming.

8. *Risk assessment methods- Risk assessment methods, risk register framework*

Risk assessment is considered an important aspect of evaluating the feasibility of a particular project (MCA Urban and Environmental Planners & I and M Futureneer Advisors Pty Ltd 2020). Various risk assessment and evaluation methods exist with the objective of helping to systematically identify, define and manage risks (Mace, et al. 2015, Savvides 1994). In the literature surveyed, risk assessment methods have been used for the criteria categories of economic, financial, market, ecological, operational (containing also some social and environmental risks) and technological, although it could potentially be used to look at risk in any criteria category. Many risk assessment methods allow for comparing across interventions, but they are generally used in a complementary manner with other analyses in order to provide a comprehensive picture of the feasibility of the interventions.

Sensitivity analysis (how changing one variable affects outcomes), scenario analysis (how simultaneous changes in many variables affects project outcomes) are some tools used in the process of risk analysis (Savvides 1994). Another method called simulation analysis represents the variables in the form of probability distributions and calculate impact of the risk on expected return generally using Monte Carlo or other simulation methods (Savvides 1994). In the literature examined for this study, risk assessments seem to follow various structures, with qualitative or quantitative analysis: expert or simulation provided probabilities, ranking and scorings (Example: (Joseph, Maloney and Possingham 2009, Brazill-Boast, et al. 2018, SMEC International Pty Ltd 2016)) or a matrix style framework (For example: (Otoo, et al. 2016), a risk register scoring matrix (UNEP World Conservation Monitoring Centre 2016, Mace, et al. 2015)). Though quantitative approaches are preferred, qualitative approaches (for example: scores given by experts) could provide valuable information (Mace, et al. 2015).

Another specific method, called the risk register approach as applied to natural capital was described by Mace, et al. (2015). Risk registers consider various information regarding the risk-probability of risk, possible impacts, potential for mitigation, and who is responsible for handling it (Mace, et al. 2015, UNEP World Conservation Monitoring Centre 2016). The method classifies habitats based on their quantity, quality, spatial configuration and maps them to the benefits derived from them in a matrix structure, and these benefits in the matrix are rated based on their level of risk. This method has been used to point out which natural assets are characterised by high risk due to unsustainable usage. (Mace, et al. 2015).

Various risk assessment and analysis methods differ in their abilities to allow for interactions between variables (For example, sensitivity analysis does not allow for interactions between variables, while scenario analysis does (Savvides 1994)). Methods also vary in terms of complexity in application with qualitative listings of risk easier to apply in comparison with quantitative simulation models.

Table 2.2: Methodology across criteria and interventions

| **Method/ technique used for data collection or analysis** | **Method/ Technique** | **For Qualitative (Quant) /Quantitative data? (Qual)/ Mixed method** | **Criteria category and criteria that use this method**<br><br>**(Based on literature + potential applicability)** | **Variables required to apply method** |
|---|---|---|---|---|
| Data collection | Stakeholder consultations and surveys [8,1,2, 16, 33, 19, 3, 34, 9, 6, 5, 7, 24, 25, 26, 32] | Quant/ Qual | I, II, III, IV, V, VI<br><br>Could potentially be used for all categories | |
| Data collection and analysis | Delphi method [45, 46] | Qual | Based on literature: II (Ecosystem services, conservation management) | |
| Data analysis | Net Present Value (NPV), Internal Rate of Return (IRR),<br>Pay-back Period [13, 20, 21, 6, 5, 3, 13, 15, 16, 7, 11, 34, 29] | Quant | Based on literature: I (Financial costs, some financial and economic benefits, financial performance)<br><br>Could be applied in any category as long as monetary values are available | - Benefits and costs of intervention<br>-Discount rate<br>-Total time period of the project |
| Data analysis | Return on Investment (ROI) [18, 31] | Quant | Based on literature: I (costs), II (ecological benefit computed using change in species density [18])<br><br>But can be applied in any category as long as monetary values are available | -Costs<br>-Change in benefits |
| Data analysis | Financial performance measures: Operating and net profit/loss, profitability ratios, Net cashflow, partial budgeting, Break-even analysis<br>[7, 13, 19, 20, 11, 27, 31, 32] | Quant | Based on literature: I (Financial performance) | -Various expenses and revenue, to calculate operating, gross, net profit<br>-Cash inflows and outflows<br>-Additional costs, Additional benefits- For partial budgeting<br>--fixed and variable costs, Selling price- for break-even analysis |
| Data analysis | Garrett ranking [25, 26, 47] | Qualitative | Across categories: Used to categorize problems/constraints<br>Could be applied to any ranked qualitative information | -Ranked opinions over a certain number of factors |

| | | | | |
|---|---|---|---|---|
| Data analysis | Market price and proxy market methods, production function [15, 23, 24, 28] | Quant | Based on literature: I, II (Benefits from aquaculture, fishing etc) | -Price of good or service traded in market or price of related good that is traded in the market<br>-Quantity of ecosystem good or service |
| Data analysis | WTP eliciting methods [11, 15, 16, 28, 9]<br>(For example- Choice experiments: Contingent valuation) | Quant, Qual | Based on literature: II (Ecological effects), III (social acceptability and effects), VI (potential funding mechanisms)<br><br>Generally, uses survey methods, hence can potentially be applicable to any category where value can be ascertained | -Questionnaire<br>-Information on stakeholder preferences for the environmental good or service based on surveys<br>-Information on socio-economic characteristics |
| Data analysis | Cost-Benefit Analysis (CBA) [8, 4, 14, 16, 20, 22, 11, 29, 23, 29, 26, 32] | Quant, Qual | I, II (Quant)<br><br>Quantitative CBA could potentially be used for all categories that can be expressed in monetary terms | -Costs<br>-Benefits<br>-Discount rate<br>-Time period of the project |
| Data analysis | Cost-effectiveness index (CEI)<br>[6, 5, 36, 48, 49] | Quant | I, II, IV<br><br>Could potentially be used for all criteria that can be expressed quantitatively | -Costs<br>-Benefits<br>-Weights<br>-Likelihood or probability of Success of project |
| Data analysis | Multi-criteria analysis, Multi criteria decision analysis<br>[11, 42, 50, 51, 17, 52, 12, 53] | Quant, Qual | I, II, III, IV, V, VI<br><br>Could potentially be used for all categories | -List of indicators<br>-List of interventions<br>-Weights<br>-Stakeholder analysis given values, probabilities etc |
| Data analysis | Risk assessment methods, Risk register framework, scenario analysis [44, 20, 22, 7, 1, 30, 2, 11, 21, 3, 8, 16, 6, 5, [24, 29] | Quant/ Qual | I, II, IV, V<br><br>Can potentially be used to look at risks in other categories as well | -Risks<br>-Severity and effects of risk, probability of risk, rating risk<br>-How to mitigate risks and costs involved in mitigation<br>-Costs involved |

Note: I-Financial, Economic, Market; II- Ecological, III- Social, IV- Operational, V- Technological, VI- Others
Source: List of sources given in appendix

## *2.3* Criteria and methods used as part of our approach

### *2.3.1 Criteria and data collection methods*

*Primary data collection (quantitative and qualitative):* For Pokkali farming and fish/prawn farming interventions, primary data on costs of farming and cultivation, capital costs, returns from farming, various problems/constraints faced, institutional mechanisms, operated area and various socio-economic information (age, occupation, income) were collected from farmers. (More details on the survey locations, sampling in Chapter 3). A total of 87 responses were obtained from Pokkali rice farmers, while 31 responses were collected from fish/prawn farmers.

For the mangrove conservation intervention, expert surveys were designed using a quantitative and qualitative semi-structured questionnaire and many experts from various social sciences and natural science disciplines across India working on natural resource management issues were virtually approached. A total of 23 responses were obtained. Various questions on their recommendations and perceptions regarding relevant ecosystem services, perceived problems and challenges, suggestions and recommendations, costs, opportunities for mangrove conservation/restoration/maintenance were asked. Questionnaires used for all the surveys have been given in the Appendix. All the experts and stakeholders consulted in relation to the study have been given in Appendix 2.2.

*Secondary data collection (quantitative and qualitative):* Secondary quantitative data and qualitative information was collected using extensive literature reviews and desk analyses for various criteria. A more detailed description is given in Table 2.3 which summarizes the various criteria, sub-criteria and data collection methods used as part of our approach.

Table 2.3: Criteria, sub-criteria used in this study and data collection methods

| Criteria category | Criteria | Sub-criteria/ indicators (for each intervention) | Quantitative/ Qualitative | Methods used for data collection (Literature/Survey) |
|---|---|---|---|---|
| Economic, Financial, Market | Costs of activity, intervention | *Pokkali rice- fish farming:*<br>-Detailed costs of production/cultivation from rice farming, fish farming, prawn farming<br>-Comparative costs of various farming alternatives | Quantitative | Primary survey, secondary literature estimates |
| | | *Mangrove conservation and restoration:*<br>-Costs of action and inaction | Qualitative | Expert surveys |

| | | | | |
|---|---|---|---|---|
| | Economic effects from activity, intervention | *Pokkali rice- fish farming:*<br>- Revenue from farming activities and by-products<br>-Comparative economic benefits of various farming alternatives | Quantitative | Primary survey, secondary literature estimates |
| | Financial performance of activity/ intervention | *Pokkali rice- fish farming:*<br>-Net profit/loss from farming<br>-Return-cost ratios<br>-Breakeven analysis<br>-Financial performance under various scenarios | Quantitative | Primary surveys |
| Ecological | Ecological characteristics of ecosystem, species selection; Drivers of degradation; Potential ecological effects | *Pokkali rice- fish farming:*<br>-Ecosystem services provided by Pokkali rice farming systems in Kochi and Kerala<br>-Ecological status of Pokkali farms in Kochi and Kerala<br>-Drivers of degradation of Pokkali farming in Kochi and Kerala | Mostly qualitative, some quantitative estimates | Secondary literature |
| | | *Mangrove conservation and restoration:*<br>-Ecosystem services and benefits provided by mangrove ecosystems in Kochi and Kerala<br>-Ecological status of mangroves in Kochi and Kerala<br>-Drivers of degradation of Kochi and Kerala mangroves | Mostly qualitative, some quantitative estimates | Secondary literature, expert surveys |
| Social and socio-economic | Social acceptability; social effects from activity/ intervention | *Pokkali rice- fish farming:*<br>-Potential income improvements, livelihood generation, health, other socio-economic benefits due to goods and services contributed by ecosystem | Qualitative, some quantitative estimates | secondary literature |
| | | *Mangrove conservation and restoration:*<br>-Ways to encourage community involvement<br>-Monetary valuation of socio-economic benefits contributed by ecosystem services from mangroves (Limited discussion based on literature availability in Kerala, Kochi context) | Qualitative, some quantitative estimates | Expert surveys, secondary literature |
| Operational | Policy, regulatory, institutional support | *Pokkali rice- fish farming:*<br>-Existing laws, policies applicable for activity, synergies with national goals and targets<br>-Institutional support (Padashekarams) | Qualitative | Primary surveys, secondary literature |

| | | | | |
|---|---|---|---|---|
| | | *Mangrove conservation and restoration:*<br>-Existing laws, policies applicable for activity, synergies with international and national goals and targets<br>-Some support mechanisms applied and applicable to address challenges to conservation and restoration in Kerala, Kochi context and India | Qualitative | Secondary literature, expert surveys |
| Others | Stakeholders involved | *Mangrove conservation and restoration:*<br>-Various beneficiaries, gainers, losers from mangrove interventions in India | Qualitative | Expert surveys |
| | Economic incentive and funding mechanisms | *Pokkali rice- fish farming:*<br>-Some mechanisms applied in Kochi and Kerala context (Limited discussion based on literature availability in Kerala, Kochi context) | Qualitative | secondary literature |
| | | *Mangrove conservation and restoration:*<br>-Ease of funding<br>-Some mechanisms applied to address challenges to conservation and restoration in Kerala, Kochi context and India | Qualitative | Expert surveys, secondary literature |
| | Challenges in pursuing activity/problems due to ecosystem presence | *Pokkali rice- fish farming:*<br>-Constraints experienced by farmers in pursuing farming In Kochi, Kerala | Qualitative | Primary surveys |
| | | *Mangrove conservation and restoration:*<br>-Inconveniences due to presence of mangroves in Kochi and Kerala | Qualitative | Secondary literature |
| | Locations for intervention | *Pokkali rice- fish farming, Mangrove conservation and restoration:*<br>-Potential locations for conducting intervention and intervention related activities (Limited discussion based on responses) | Qualitative | Expert surveys and consultations |

### *2.3.2 Methods used for data analysis*

A combination of various quantitative and qualitative methods was used to analyse the data collected. Table 2.4 summarizes the various methods used for analysis and the criteria that were analysed using this method.

Table 2.4: Methods used in analysis, criteria and sub-criteria analysed using method

| Method used for analysis | Criteria/ sub-criteria analysed using this method | Details |
|---|---|---|
| Financial cost-benefit analysis, Measurement of financial performance | *Pokkali rice- fish farming:*<br>-Cost schedules<br>- Revenue details<br>-Financial return/benefit- financial cost ratios<br>- Net profit/loss, break-even analysis | Information on costs, revenue of Pokkali rice farming and fish/prawn farming was collected during the survey. This information was used to calculate net profit/loss and to undertake further analyses like calculating the financial cost benefit ratios, and to understand the break-even points. |
| Scenario analysis | *Pokkali rice- fish farming:*<br>-Costs<br>-Revenue (Financial, market benefits)<br>-Net profit/loss | To understand how the net profits change under different farming scenarios when output quantities are changed. |
| Statistical analysis and graphical representations | *Pokkali rice- fish farming and Mangrove conservation and restoration:*<br>All variables from primary and expert surveys | *Pokkali rice- fish farming:*<br>-Summary statistics, two-way frequency tables, graphical representations, correlations<br>*Mangrove conservation:*<br>-Frequency tables, graphical representations |
| Rating and ranking | *Mangrove conservation:*<br>-Most relevant ecosystem services from mangroves<br>-Choice between interventions<br>-Community involvement in mangrove conservation/ restoration – institutional support and economic incentives<br>-Deciding between various opportunities for encouraging investment | -Understanding experts' preferences over various priorities by ranking various alternative choices |
| Garrett ranking method | | -Garrett scores and overall ranks estimated to identify overall priorities and expert preferences |

***Key takeaways:***

- A literature survey was undertaken to identify various criteria used in feasibility studies which compared and choose between interventions or between management strategies, analysed the feasibility of an intervention, and more specific literature to our two interventions. Similarly, a literature survey was undertaken to identify potential methods that could be used for data collection and for analysing the data and results
- Criteria considered were divided into economic, market, financial (sub-criteria: costs of intervention, potential economic effects of intervention, potential financial performance), ecological (Characteristics of environmental asset and ecosystem services, potential ecological effects from intervention), social and socio-economic (Social acceptability of intervention, potential social effects from intervention), operational (Existing and required support for implementation- Institutional, Human resource, Policy, political, legal, regulatory, risk assessments, time period, Availability and reliability of inputs for intervention, Monitoring and accountability setting required, Occupational Safety concerns), technological (availability and effectiveness of existing technology, lifetime of equipment, potential technological effects from intervention) and others (stakeholders, potential funding mechanisms, uncertainty in estimation of values, transformational potential of project).
- In the current study, the various criteria analysed through primary or secondary information were economic, financial, market (Costs of activity and intervention, Economic effects from activity and intervention, Financial performance of activity/ intervention), ecological (Ecological characteristics of ecosystem, species selection, Drivers of degradation, Potential ecological effects), social and socio-economic (Social acceptability, social effects from activity/ intervention), operational (Policy, regulatory, institutional support) and others (Stakeholders involved, Economic incentive and funding mechanisms, Challenges in pursuing activity/problems due to ecosystem presence, Locations for intervention).
- Each category of criteria plays an important role in ascertaining feasibility and building the overall investment case and it is important to account for the inter-relationship and inter-dependence between various criteria.
- Various methods and techniques for data collection and analysis were also identified from the literature, namely, stakeholder consultations and surveys, Delphi method, NPV, IRR, ROI, pay-back period, various financial performance measures, Garrett ranking, various valuation methods- market price and proxy markets, WTP eliciting methods, CBA, CEI, MCA, risk assessment methods.
- In the current study, some of the methods used for quantitative and qualitative data/information collection and analysis include- data/information collection (primary survey, extensive literature reviews and secondary estimates, expert surveys and consultations), data analysis (financial CBA, financial performance measures, scenario analysis, statistical analysis and graphical representations, rating and ranking, Garrett ranking method.

# 3 CHAPTER 3: FINDINGS FROM A DESK ANALYSIS OF TRADITIONAL AND INTEGRATED AGRICULTURE SYSTEMS FOR RICE-FISH/CRUSTACEAN FARMING SYSTEM

## 3.1 Sustainability in Agriculture and Agrobiodiversity

With expanding area and intensification worldwide, agriculture is typically associated with greenhouse gas emissions and ecological degradation (Pham and Smith 2014). On the other hand, sustainable agriculture or ‘evergreen revolution’ attempts to “increase productivity in perpetuity without associated ecological harm” (Swaminathan 2006).
Sustainable agriculture should be multi-dimensional and address economic, ecological, and social aspects (Pham and Smith 2014, Zhen and Routray 2003). Agricultural sustainability is best understood in context specific terms and has both spatial and temporal considerations (Zhen and Routray 2003, Krishnankutty, et al. 2021). These are important perspectives to consider when building an investment case to understand the feasibility and sustainability of a particular practice/method.

Agricultural biodiversity is very important for current and future food security (Kumar and Kunhamu 2021), healthy ecosystems, to fight ecological stresses and to provide financial protection for farmers (Rasheed, et al. 2021, Thrupp 2000). Traditional agrobiodiversity and folk varieties/landraces are defined as “geographically or ecologically distinctive populations [of plants and animals] which are conspicuously diverse in their genetic composition” (Brown, 1978 as cited in (Thrupp 2000)). Kerala has around 2,000 traditional varieties of rice that have adapted to many different agro-ecological conditions (Kumar and Kunhamu 2021). The advent of HYV seeds is said to have led to the reduction and extinction of traditional varieties in many parts of the world including India (Thrupp 2000, Gopi and Manjula 2018) resulting in genetic erosion (Zhu, et al. 2003). For example, in Wayanad, Kerala many traditional rice varieties (55 out of 160) are now considered extinct (Krishnankutty, et al. 2021).

One way to look at sustainable agriculture in India could be through organic farming and traditional varieties cultivation. Organic farming in India only holds around 0.03% of total area cultivated, although it has historically been practised by many communities (Das, Chatterjee and Pal 2020). In contrast to conventional farming, organic farming is typically characterised as not using any chemical pesticides or fertilizers and not using genetic modifications (Das, Chatterjee and Pal 2020). With respect to cultivation of traditional varieties, it is important to remember that different varieties have different traits (for example- salinity resistant) (Kumar and Kunhamu 2021) and that farmers may prefer traditional varieties which deliver high yield in unfavourable circumstances and have multiple traits (Gopi and Manjula 2018).

### *3.1.1 Integrated rice-fish/crustacean farming:*

Integrated farming of rice is a relatively common practice over the world with the combination differing in various countries. Some combinations practiced are rice-fish, rice-prawn, rice-shrimp, rice-poultry, rice-wheat etc. (Chivenge, et al. 2020). An integrated system of agriculture and aquaculture (rice-fish/prawn/shrimp) is commonly practiced in many parts of the world especially in South East, East and South Asia (Vietnam, Burma, Cambodia, Philippines, Pakistan, Thailand, Bangladesh, China, Indonesia and India) (Chivenge, et al. 2020, Ranjith, Karunakaran and Avudainayagam, et al. 2019). It is also practised in various states in India under various local nomenclatures, for example- Khazan (Goa), Gazani or Khar (Karnataka), Bheries/Bhasabhada (West Bengal), Pokkali (Central Kerala) and Kaipad (North Kerala) and may involve cultivation of traditional paddy varieties and aquaculture using brackish water shrimp/freshwater prawn/fish species cultivated based on traditional capture (CPGD-Kerala n.d., Sathiadhas, Najmudeen and Prathap 2009). These integrated systems can cultivate both crops concurrently or in rotation (Kumar and Kunhamu 2021). Integrated rice-fish/crustacean systems can help improve farming income within the resource constraints and contribute to improving social welfare and alleviation of poverty (Nair, et al. 2014).

### *3.1.2 Integrated Pokkali rice-fish/crustacean farming:*

The saltwater aquifers and the oscillation of tides forms unique ecosystems in coastal areas. The characteristics of this ecosystem are strongly linked to the duration of submergence, oxygen diffusion mechanisms, and salinity levels (Ding et al., 2010; Zuo et al., 2012) (Shinogi, et al. 2019). The saline, coastal, submerged wetlands of Kerala, S. India, popularly known as Pokkali fields are one of the best examples for this phenomenon and is traditionally practised in Ernakulam, Alappuzha and Thrissur districts of Central Kerala (CPGD-Kerala n.d., Deepak 2016, Shamna and Vasantha 2017, Ranjith, Karunakaran and Avudainayagam, et al. 2019, Kumar and Kunhamu 2021). The system in Alappuzha is often known as Kari lands. A similar type of ecosystem in the district of Kannur (N Kerala) is known as the Kaipad lands. Pokkali rice refers to a salt-resistant local rice variety grown in lands called Pokkali lands (CPGD-Kerala n.d.). Ernakulam district seems to have maximum area under cultivation of this variety as it has been considered separately or as one of the districts in many studies for this reason

(Ranjith, Karunakaran and Sekhar 2018, Shamna and Vasantha 2017, CPGD-Kerala n.d., Shamna 2017). For the rural communities in Kochi, traditional Pokkali rice cultivation is an important economic activity, although many have discontinued or altered cultivation practices (Rode and Balasubramanian 2018). Pokkali rice-fish/crustacean systems ensure optimal resource utilisation without ecological harm and represent many years of accumulated knowledge (CPGD-Kerala n.d.)

## 3.2 Some Key Characteristics of Relevance to the Study

### *3.2.1 Geography and Ecological characteristics*

Pokkali lands owe its name from the peculiar traditional rice variety grown in these lands. These varieties were very tall (160-200 cms) with luxuriant growth (12-16 tillers per plant (pokkathil aalunnath in Malayalam which means that grows tall). The Pokkali lands are extension of the Wembanad Kole Ecosystem, located in the Alappuzha, Eranakulam and Thrissur Districts. These are marshy lands situated below mean sea level, near the estuaries of river systems draining to the Arabian sea, West of the state. Due to the tidal action and location specialities water enters the field during high tide and drains off during the low tide. These landmasses remain submerged during most parts of the year ,and is saline due to the entry of sea water . During the monsoon the salts are washed away making the soil less saline.

The Pokkali soils are categorized as saline hydromorphic. It is bluish black in colour with light grey on surface. They develop fissures when dry and sticky when wet. The pH and EC of Pokkali soils are reported as in the range of 3.31 to 6.46 and 0.10 dSm-1 to 9.80 dSm-1. The soils are high organic carbon content (0.45-2.90%), available nitrogen, potassium, and sulphur content but low in available phosphorus and magnesium content (Sreelatha and Shylaraj 2017, Santhi, et al. 2017) (Shinogi, et al. 2019).

Some traditional rice varieties present in the area include Kuruka, Cheruviruppu, Orpandi, Choottupokkali, Bali, Orkayama, Eravapandy, Anakodan and Pokkali (CPGD-Kerala n.d.).

The Pokkali variety, which is the focus of this study, is known for their tolerance of salinity, submergence and acidity (CPGD-Kerala n.d.), although it does have a lower yield. The average yield for this particular rice variety is around 2,000 kg/ha (Shylaraj and Sasidharan 2005). Newer varieties have been evolved which could provide higher yields (Vyttila-1 to Vyttila-9) (Kumar and Kunhamu 2021).

Pokkali farming does not include any chemical fertilizer or insecticides but lime and dolomite is applied to the soil since is acidic and has salinity (CPGD-Kerala n.d.). Otherwise, soil on Pokkali lands is very fertile and has high organic matter content (CPGD-Kerala n.d.). This agricultural system also depends on tidal fluctuations for salinity and water level (CPGD-Kerala n.d.).

The average farm size for Pokkali farmers as suggested by Ranjith, et al. (2019) for North Paravur, Kochi and Kanayannur Taluks (Ernakulam district) is around 1.65 ha with around 70% farmers holding marginal/small landholdings.

Pokkali rice variety has received a geographical indication tag signalling both its geographical and ecological uniqueness, given by the Geographical Indications Registry Office in Chennai in the late 2000s. (Deepak 2016, Ranjith, Karunakaran and Avudainayagam, et al. 2019, Shamna and Vasantha, A Study on Farmers Perception on Problems of Pokkali Rice Farming in the State of Kerala 2017)

Pokkali rice-fish/crustacean farming is an integrated system of rice–fish farming and involves rotational cultivation of rice and fish/crustaceans (Kumar and Kunhamu 2021). The organic remains of rice farms forms an ideal environment for fish farming and the fish farming supports the rice cultivation The system forms a complementary relation that supports the ecosystem stability and sustainability. The fields are demarcated into padasekharamas (continuous stretch of lands with specific boundaries with strengthened bunds with sluices to regulate water entry and exit). The cultivation, especially the water management, is usually done as farmer collectives (Padasekhara Samithy, an elected body of owner farmers within a padasekharam). The farm operations for rice starts by mid-April, by draining the field, and closing the sluice gates to prevent further entry of saline water. The fields are allowed to dry and small raised bunds are taken. With the monsoon, when water washes away excess salts from raised mounds, the germinated paddy seeds are sown on these mounds. Once the seedlings grow to desired level, after a month these mounts, along with the seedlings are spread across the field in an evenly spaced manner, manually. The usual intercultural operations (weeding/ manuring, fertilizer application, plant health management) are not done in most cases. The fields are flooded by this time and the crop grows up to keep the panicles above the water level. Moreover, the biodiversity in the ecosystem provides an ambient environment for the growth of the crop, which itself limits weed growth and pest attack. The harvesting is done (120-160 days crop duration) manually, cutting off only the top portion of the straw above the water level along with panicle, standing in the waist deep muddy water and the harvested part is gathered in country boats and transported to the land mass where it is processed further. A major part of straw which is left behind is allowed to decay naturally which enhances the fertility of the system and support the biodiversity as it forms the food to the life forms. After the harvest of Pokkali Rice, the field is kept idle for the decomposition of the crop residue in the field. The system of prawn filtration, rice – fish culture or rice – shrimp culture is adopted by farmers. Prawn filtration is resorted in locations where tidal amplitude is high. The Pokkali rice-fish/ shrimp integration is the most viable and eco-friendly practice in pokkali fields. In this system, the seed shrimps and fishes are allowed to enter into the Pokkali fields through tidal water, by opening the sluice. In other locations it is the capture fisheries. The general chronology of operations are detailed in Table 3.1.

Major operations involved in fish farming include-

1. Strengthening of the outer bunds: After the harvest of paddy the field outer bunds are strengthened and the maintenance of sluices are ensured. This is very crucial before starting fish farming as it is essential to regulate the water flow. Sizable investment is required for this, either as labour in the case of temporary earthen bunds which is to be incurred annually. The recent practice is to use asbestos sheets or construct permanent concrete bunds.
2. Maintenance /installation of sluice gates: Sluice gates locally known as thoombu is the point through which water is let into the field during high tides and is closed when the flow switches. They act as a gate that allow the entry and exit of fishes. It is to be properly aligned and strong to prevent the escape of fish from the field. The average life span of a wooden sluice gate is up to 6-9years with occasional maintenance works. Recently concrete sluices are constructed with subsidy support.
3. Widening of side canals and removal of weeds and silt deposits and pegging: Removal of weeds and desilting of canals, wherever necessary, are carried out for facilitating easy water flow and water holding potential. Proper widening and desilting facilitate better flow through the channels thereby ensuring more water and fish/shrimp to the field.
4. Water Management: Regulating the water inflow and outflow through sluice gate management and the supervision and upkeep of the field is usually entrusted to men on contract basis
5. Seeding the fishes: The fish species generally selected for rice cum fish culture have characteristics to adapt to the rice ecosystem. The candidate species for rice cum fish culture is generally chosen considering the capacity to grow fast in the anoxic condition in field owing to the decay of rice stubbles. Major species grown are discussed later in this subsection. The choice of species is mainly based on suitability of the field as well as entrepreneurial and financial capacity of the farmer.

6. Feeding: Under scientific management the fishes are supplemented with artificial feed, apart from the natural food available in the ecosystem. The shrimps are fed with a pelleted feed containing 35-40% protein and 3-5% lipid and having water stability for 3-4 hours. In case of fishes like pearlspot, they are fed in the morning and evening with a formulated floating pelleted feed or conventional feed having groundnut oil cake, rice bran and fish meal with vitamin-mineral mix as ingredients. The feed contains 24-34% protein and 5% fat.
7. Harvesting: The harvesting is done once the species attain desired size and most of them are exported

Table 3.1: Management schedule of Pokkali Farms

| S. No | Period | Management practice |
|---|---|---|
| 01 | April (from mid april- upto last week of april) | • Draining out of water after fish harvest and letting it dry under sun<br>• Strengthening of field bunds for pokkali cultivation<br>• As the fields dry up to form clayish with cracks soil is turned up to form mounds(towards last week of april) |
| 02 | June (within the first fortnight ) | • The mounds are flattened/levelled up for sowing<br>• Sowing (dates depends on the monsoon rains) |
| 03 | July (After 28 to 30 Days) | • Transplanting trough dismantling and spreading of mounds(locally known as *kothivedhakka*l) |
| 04 | August | • Weeding activities are carried out (this activity is limited only to areas with severity of weeds under normal context pokkali requires minimal weeding as compared to normal paddy) |
| 05 | October / November | • Harvesting (based on maturity)<br>• Certain fish farmers introduce fishes for their upcoming fish culture |
| 06 | 2nd fortnight of October to 1st fortnight of November | • The major bunds are strengthened and holes if any on the bunds are sealed so as to prevent escaping of fish/shrimp from the field<br>• Maintenance works of sluices if any are done (the sawn timbers used in sluice gates are to be dried for a period of 2-3 weeks before installation into the field |
| 07 | November 15 th onwards | • Shrimp filtration activities are started |
| 08 | Last week of November | • Shrimp seeds from the hatcheries are introduced into the field |
| 09 | After 70-90 days after stocking of shrimp fries | • Harvest of white shrimp can be started (70 days after stocking)and tiger shrimp (90 days after stocking)<br>• Harvest is carried out in varied phases based on demands in the market |
| 10 | After 100-120 days after stocking of fishes | • Harvest of fishes are initiated. They are also harvested based on market demands. (Harvest is at its peak during mid February -march) |
| 11 | April 14 | • Final harvest date for fisheries |
| 12 | April 15 | • New cycle of pokkali farming initiates |

Presently, it is legally binding to follow the schedule as shown in table 3.1, wherein the fisheries operations are to be completed and field be ready latest by April 16 to facilitate paddy cultivation and the paddy farming to be completed latest by November 15 for the fisheries culture to begin. Further it is also mandatory that the paddy cultivation needs to be done, for the permission for fisheries farming to be undertaken. This specification is to ensure the sustainability of the system. Many farmers go for short term gains confining to fisheries alone, which is curtailed by this regulation. There is a growing tendency among the farmers to initiate the cultivation and then leave the field unattended or with limited management. This is to comply with the legal directives to ensure permission for fisheries crop. These farmers also enjoy the subsidy support from department of Agriculture. There are some informal reports of the harvested area only as 50% and 28.4 % of cultivated area, in 2017 and 2018 respectively.

Pokkali farming is labour-intensive and requires about 207 man-days/hectare (with various processes such as raising and channelling of bunds, mount raising, soaking of seeds and soil, payal removal, weeding, transplanting, preparation of ground for threshing and shed fabrication, harvesting and post harvesting, measurement and storage); while prawn cultivation requires around 246 man-days/hectare (with processes such as sluice gate installing, raising dikes and canal excavation, weed eradication, work shed, shelter, screen fabrication, basket, net setting, nursery and feeding, operation of sluice gates, fishing operations, terminal operations, categorising and cleaning output, icing, deveining and peeling, weighing, packing, marketing and transportation) and the tall height of mud and water may also make it difficult to mechanise (CPGD-Kerala n.d., Shyna and Joseph n.d.). In terms of the gender composition of the labourers, the requirement for women in Pokkali farming is more (around 84 men, 123 women), and the requirement is lesser for prawn cultivation (around 181 men, 65 women) (CPGD-Kerala n.d., Shyna and Joseph n.d.).

### *3.2.2 Various major fish/crustacean species cultured in Pokkali-fish/crusteacean system*

1. Pearlspot (karimeen):

Pearlspot, which is considered as the statefish is a high valued fish endemic to peninsular India and Sri Lanka. *Etroplus suratensis* colloquially known as 'Karimeen' is also known as state fish of Kerala (2010). It has an elevated laterally compressed body and a small cleft mouth. In the natural habitat, the fish is light green in colour with eight vertical bands. It is an omnivorous detritus feeder which feeds mainly on plankton, small worms, prawns and algae. It is considered as one of the potential candidate species for aquaculture, because of its high market demand, hardy nature, non-predatory habits and ability to breed naturally in confined waters. Pearlspot is a euryhaline fish, thriving well in brackish waters and has the ability to live both in fresh and saline waters.

Pearlspot fishlings of size 4-5 cm are stocked in the farm/pond. The cost of seeds range from Rs.6-10 per kg. based on size. It get acclimatized to salinity of 5ppt (parts per thousand) level in 30 minutes. The Water quality requirements include a temperature of 25- 32 °C, salinity of 0-30 ppt, pH of 7.0- 8.5, transparency of 25-40 cm, dissolved oxygen >4.5 ppm, Alkalinity of 200-300 ppm. After properly acclimatizing the seeds to farm situations, seeds having a size of 4-5 cm are stocked in cage, *happa* or pen installed in the same pond to ensure maximum survival. Afterwards they are let free in the fields. Pearl spot fishlings has an ability to hide within the stubbles of pokkali rice crop and hence farmers introduce them 1-1.5 months prior to pokkali harvest. As the growth rate is relatively poor in pond, seeds are stocked @ 30,000 nos./ha for monoculture. Under poly culture, stocking density is reduced @ 15,000 nos./ha along with milkfish or mullet at 5000 nos./ha. Even though the recommended polyculture stocking density of pearlspot is in the range of 15000/ha normally under the field situations farmers stock them in a range of 4000-7000/ha. Apart from the left over grains and other feeds in the field, feed supplements are also given. Conventional practice is to provide feeds made of groundnut cake, rice bran, fish meal and vitamin mineral mixes. Commercially produced floating pelleted feeds are also extensively used. The feed contain 24-34% protein and 5%fat. Water is maintained at a depth of 1-2 m and 20-30% water is exchanged fortnightly. The pH level is maintained by applying agricultural lime @250 kg/ha. Use of aerators (with efficiency about 2hp / ha) is installed to balance the dissolved oxygen level to regulate the growth rate of fishes. The pearlspot attains marketable size of 250 g over a period of 10-12 months with a survival rate of 80%. A production of 6 t/ha is realized under ideal conditions, when managed as monoculture. However, under real field situations the realized yield is around 1 t/ha and survival rate is below 75%. The harvesting is done on attaining a weight of 200gm for domestic market and export grades usually weigh from 250-400gm per fish. This is one among the most valued fishes and the price in local market ranges from Rs 600 per Kg to Rs 800 per Kg. This is in great demand in the international market and mainly exported to the Middle East and South Asian countries. After harvest they are marketed based on size. Superior sizes are often exported and others are sold at the local markets.

2. Milkfish (Chanos chanos):

Milkfish is one of the most ideal finfishes for farming in coastal areas. They show a wide range of tolerance to temperature (15-40°C) and salinity (0-145 ppt parts per thousand). They feed mostly on filamentous algae from the bottom of the pond and are free from major diseases and parasites. They are widely taken up in coastal regions of Kerala and Tamil Nadu. Milkfish has a higher growth rate in its first year in brackish water. It grows to a marketable size of 30-45 cm long and 300-800 gm in weight, with a survival rate ranging from 80-85%. Usually fingerlings of 7 to 15 cm length are stocked at a rate of 2,000 to 10,000 per ha.

It has a symmetric streamlined body with a large caudal fin. The fry stages feed on lab lab and achieve a growth of around 1 mm per day. The seeds attain a size of 4-5 cms after 30-45 days of spawning. During conditioning, the seed is acclimatized to the salinity in the field. Some farmers stock the seeds in fingerling stages of 7-15 cm so as to ensure a higher survival rate of 80-85%. The water quality requirements include a salinity of 10-30 ppt, Temperature of 26-30°C, transparency of 25-40 cm, pH of 7.5-8.5, Dissolved Oxygen >4.5 ppm. In case of seeds 4-5 cm they are to be raised in happa/pen to attain better size and survival in the nursery pond before transferring to field. Mostly in the field farmers stock fingerling staged fishes. The cost of seeds range from Rs 2. 5-4.5 per kg. In the field fingerlings are stocked at a density of 7,500 no./ha for monoculture. In polyculture, stocking density is reduced to 5,000 no./ha along with pearlspot at 15,000 no./ha. Generally they thrive on natural foods available in the field. In order to achieve quick growth supplementary feeds are given in the form of formulated pellets. They are fed twice daily in the evening and morning. The protein requirements range between 20-32% in the various stages. Even though they are free of diseases periodic liming at 250 kg /ha helps in Ph balance to the required levels. 20-30% water recycling with a depth of 1-2 m is also preferred. Whenever the density of lab lab in the pond decreases, subsequent doses of cow dung are added at 500-1000 kg per hectare. They are harvested after 8-10 months and the attained sizes vary from 700g- 1 kg. The fish is caught with drag net. Under proper conditions they c yield up to 6t/h but in general field conditions they yield between 1-2 t/ha. They have a high demand. They are usually marketed in the local markets and the rates per kg vary between Rs.180-350 per kg based on seasons and sizes. They are not preferred frozen and hence are not exported. (Milkfish has demand in fresh raw form hence they are sold in local markets rather than exporting wherein all fishes are frozen and transported).

3. Grey mullet:

The grey mullet, is one of the important brackish water cultivable species. *Mughil cephalus* is an important brackish water cultivable eurythermal (wide range of temperature tolerance), euryhaline (wide salinity tolerance) fish. The fish is notable with greyish green colour on the dorsal surface and silver-white on the ventral side, an elongated body, broad and flattened head with a small, inferior mouth. It is cultured in seawater and brackish water. Their eyes are usually covered in a layer of adipose tissue. They feed at low trophic levels, consuming microorganisms, decaying organic matter, algae, insect larvae and small molluscs from the bottom. Due to its benthic feeding behaviour, the species is considered as an efficient bio-remediator. Natural breeding of grey mullet occurs in the sea, and the fry drifts back towards estuaries.

The pond is fertilized with poultry droppings at 500 kg/ha or cow dung at 2000 kg/ha. Water is maintained at a level of 25-30 cm for 7-10 days to develop natural feed(planktons). Then the water level is increased to above 1 m before stocking of fingerlings. The cost of seeds vary between Rs.10-12 per kg. The water quality requirements include a salinity of 5-30 ppt, temperature of 26-30°C, transparency of 30-40cm, pH of 7.5-8.5, dissolved Oxygen of >4ppm. Fingerlings of 8-10 cm are stocked directly in the field or if they are of 4-5 cms in size they are grown in nursery pond and transferred from nursery pond after attaining required sizes (8-10 cm). Stocking density is at the rate of 10,000 no./ha (for monoculture). Being a peaceful herbivore, grey-mullet is also stocked (5000/ha) along with pearlspot (15,000/ha) in the polyculture system. Generally they live on natural feed. As a supplement, rice bran or wheat bran is provided. Their protein requirements vary between 20-32%. Periodic liming at 250 kg/ha is done to regulate the pH in the field. Whenever the density of plankton in the pond decreases, required quantity of cow dung is applied at an average rate of 500-1000 kg/ha. The fish attain a marketable size of 700-1000gm within a period of 8-12 months. The harvesting is done with drag net. Though the potential yield is 5t/ha, practically the realized yield range between 1-2 t/ha. Generally these are sold in the local market at a price of Rs. 350-500 per kg.

4. Mangrove crab:

The mangrove crab, *Scylla serrata* which has huge demand in both domestic and international markets, is commonly found in mudflats and mangrove areas. It has flat and broad body covered with a fan shaped carapace. Adult crab migrates to the sea for spawning and the larval stages are completed in seawater. The instar migrates back to the brackish water for further growth and development.

Mostly the farmers obtain seeds from fisherman who gather it from the wetland ecosystems. Even though hatchery seed production technique is available crab farming still depends on wild seed collection. The costs of wild seeds vary from 6-10 Rs/crab. The water quality requirements include a pH of 7.5-8.5, salinity of 15-30 ppt, temperature of 28-32°C, Dissolved oxygen of >4ppm. The survival rate of crabs are relatively low at 66%. They are polycultured with shrimps and milkfish. Young ones are stocked at an average rate of 5000/ha along with 10000-20000 shrimp/ha. The crab is fed with chopped fish twice daily (40% in the morning and 60% in the evening) @ 10% of the body weight initially till it attains a carapace (dorsal section of exoskeleton in crab/crustaceans) width of 6 cm and later it is reduced to 8% for the carapace width in between 6-15 cm and thereafter reduced to 6%. They also do get natural feeds. Care is to be taken in younger stages of life. Water quality is to be ensured fortnightly. pH, salinity, temperature and dissolved oxygen is to be properly monitored. The tendency of cannibalism has a serious impact on its survival rate so they are provided hide out spaces either using pvc pipes or other structures. During the culture period, cull harvesting with lift net or scoop net is done to remove the shooters and to allow smaller crab to grow faster. After the culture period of 8-9 months, the field is drained for complete harvesting by lift net or scoop net and by hand picking. The expected size at harvest is more than 500 g with survival rate between 40% to 50%. A production of 2 t/ha can be achieved annually. The export quality grade crabs fetches Rs 1200-1800 per kg in the local market. They have great demand overseas and more than 60% of produce is exported. The exportable grades range in size from 400-600 grams and the realized price is around Rs.1800-2100 per kg. Smaller ones (200-300grams) are sold in local market at an average price range of Rs 650-900 per kg.

5. Tiger shrimp:

*Penaeus monodon* is one of the fastest growing species among cultured shrimps. The species is euryhaline and can even tolerate near freshwater conditions. Prawn and shrimp culture activities of Kerala has been in practice since ages. However, suitable scientific intervention has been incorporated from the 1990s and the scaled-up exports have made it a profitable business. They are usually practiced in tidal flats. The steady demand in the global market and high economic return has attracted farmers to adopt tiger shrimp culture.

The seeds are obtained from hatcheries from 23-28 days after hatching. Currently both quality checked (tested)and quality unchecked (non-tested) seeds are available in the market and they have variations in price from Rs. 0.1 to Rs.0.8 based on days after hatching and survival rates.

Water quality requirements include a temperature of 28-32ºC, pH of 7-8.5, transparency of 25-45 cm, salinity of 10-35 ppt, alkalinity >200 ppm, hardness of 100-150 ppm, dissolved Oxygen >5 ppm, Total Ammonia Nitrogen <0.1ppm, NO2-Nitrogen <0.1ppm, NO3-Nitrogen <10 ppm, H2S <0.1ppm, Iron <1 ppm. Two weeks before stocking the pond is disinfected with calcium hypochlorite. Later on, 10-12 days before stocking, inorganic fertilizers containing nitrogen and phosphorous @ 40-50 kg/ha is applied to stimulate the growth of diatoms. The stocking density depends on the system of intensification. In intensive culture systems stocking of up to 1 lakh/ha is possible. There is daily recycling of water in pokkali-shrimp culture. So daily monitoring of water quality is not often done. Normally in rice shrimp cultures farmers stock between 15000-50000 nos/ha. Artificial feed supplements are usually provided as formulations of sinking pelleted feed containing 35-40% protein and 3-5% lipid and having water stability for 3-4 hours. Shrimp culture demands constant monitoring of farms. The incidence of viral disease (White spot syndrome virus) is very common and results in high mortality of shrimp which is managed through proper medication to control and prevent the spread. Tiger shrimp attains 30-40 g size within 105-120 days. They are harvested in a regularly over a period of time using a conical net at the sluice gates during low tide when water exgress. The remaining shrimp is harvested by cast netting and hand picking after draining the field. The final harvest is done at night normally and the collected shrimp are chill killed so as to prevent discoloration. An average production of 1.4-1.9 t/ha is realized with survival rate of about 80%. They are mostly exported and are graded based on numbers that make it to a kilogram and are known as counts. 16 counts and 18 counts usually find an international market and the prices vary from Rs. 850-1000 per kg. Counts from 20 onwards reach local markets which fetches Rs. 500-700 per kg.

6. The Indian white shrimp:

*Penaeus indicus* a native of India and South East Asia, is one of the suitable species for brackish water aquaculture. In natural conditions, the adult is seen up to 90 m depth over muddy or sandy sea bottom while the post-larva and juvenile inhabit shallow estuarine waters. It fetches good price in local markets even at small sizes. The exoskeleton is relatively thin, which provides more edible meat per unit weight of the shrimp. The Indian white shrimp attain 20-25 g size within 90-110 days. Production of 1.6-2 t/ha can be realized with a survival rate of 80%. This species is locally known as Naran and has high export market prospects. Its price in the local markets ranges from Rs.400-550 per kg.

Seeds that are brought from hatcheries are 25-35 days after hatching. The seeds are provided both from govt and private hatcheries and seed is priced from Rs. 0.1 -0.6. The water quality requirements include a temperature of 26-32ºC, pH of 7.5-8.5, transparency of 25-45 cm, salinity of 25-35 ppt, dissolved Oxygen >4 ppm, alkalinity of ~200 ppm, Tot. Ammonia nitrogen <0.1ppm, NO2-N <0.1 ppm, NO3-N <10 ppm, H2S <0.1 ppm, Iron <1 ppm, hardness of 50-150 ppm. They are stocked at almost the same ranges as of tiger shrimp. Under intensive system they are stocked at 1 lakh /ha. Under pokkali -shrimp cultivation they are stocked from 20000-50000 nos/ha. Aspects of feeding are similar to tiger shrimp. They are given sinking pelleted feeds four times daily. Some farmers also provide groundnut cakes. Liming and manuring are optional based on the water quality. The Indian white shrimp attain 20-25 g size within 90-110 days. Production of 1.6-2 t/ha is realized with a survival rate of 80%. Initial harvests are made with conical nets. Final harvests are done after draining the water. They fetch Rs.600-750 per kg for exportable grade and local markets, the price range from Rs. 280-500 per kg.

7. Brown shrimp:

*Metapenaeus monoceros* is a species of shrimp in the family Penaeidae. It is also known as speckled shrimp, brown shrimp and pink shrimp in English and choodan chemmeen in Malayalam. They prefer sandy or sandy mud bottoms. They live in brackish water or marine ecosystem. Adults are pale grey with dark brown spots giving them the name brown shrimp or speckled shrimp. Their body is covered with short hairs. They have red–orange antennae. They are medium-sized shrimp with males growing up to 15 centimeters (5.9 in) and females growing up to 20 cm (7.9 in). They are of relatively low significance when compared to tiger shrimp and Indian white shrimp. They come into the field while ingress of water during high tide and grow in the field. They are not raised in hatcheries and occur naturally in costal aquaculture.

### *3.2.3 Pokkali ecosystems and their relationship with climate change and climate change action (mitigation and adaption)*

Paddy and filtration fields in coastal areas in Kerala are prone to sea level rise, with projections suggesting that a rise in sea level by one metre will inundate around 169 sq. km of coastal areas around Kochi (Department of Environment and Climate Change- Government of Kerala 2014). Additionally, rice fields of around 26,400 ha in Ernakulam, Alappuzha and Kannur are affected by perennial saltwater intrusion (Gopi and Manjula 2018). Uncertainties regarding rainfall, unexpected temperature increase, salination and intrusion of salt water land are some expected regional impacts of climate change in paddy lands with projections suggesting a decrease in rice productivity by 4% (but with some gain in north Kerala) (Department of Environment and Climate Change- Government of Kerala 2014).

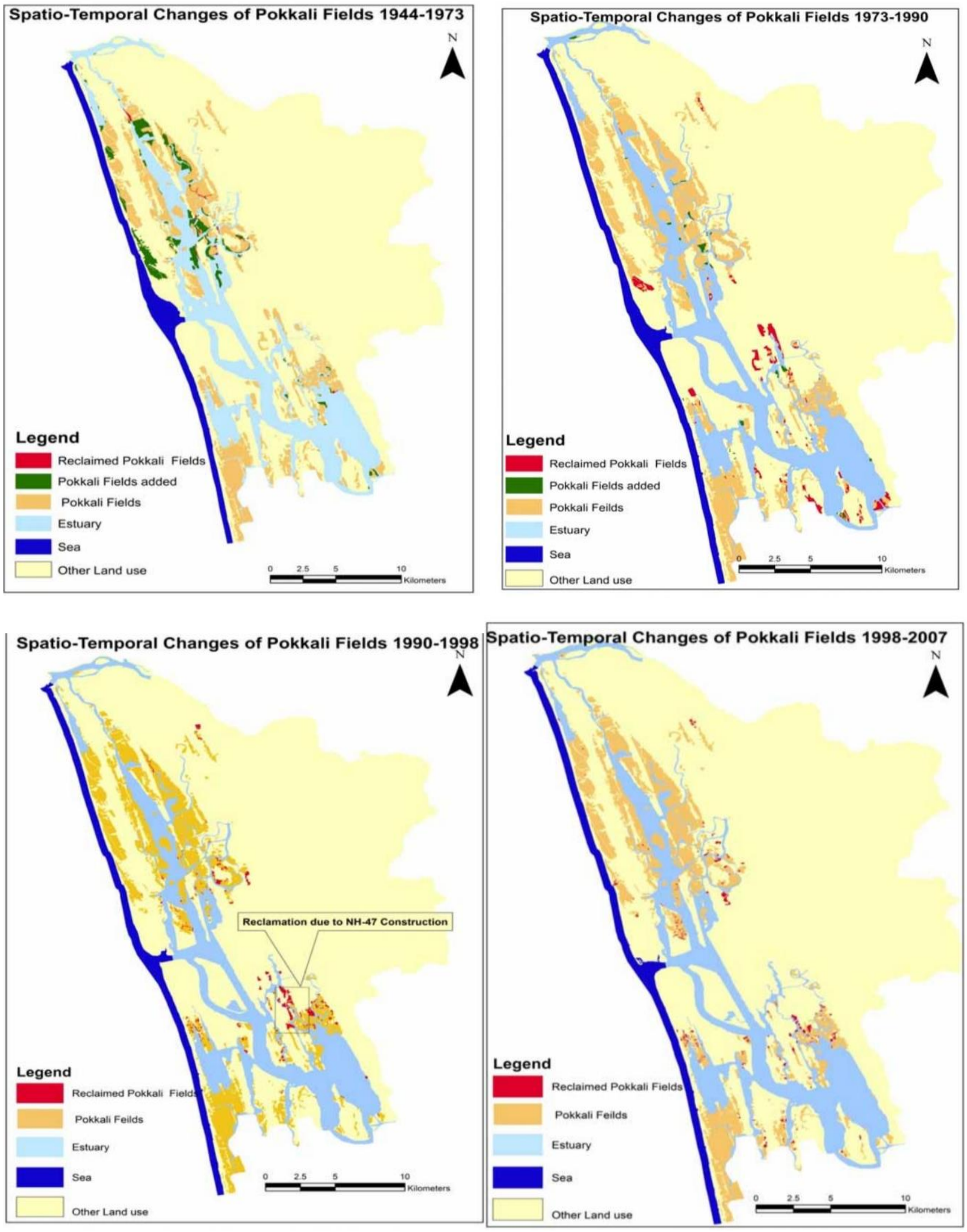
Cultivation of Pokkali rice could help in moving towards climate resilient agriculture (Gopi and Manjula 2018), and further practicing integrated farming by including shrimp that can tolerate salinity could further help improve farmers' income and resilience (CPGD-Kerala n.d.). In terms of climate change mitigation, Pokkali fields are said to have higher efficiency than paddy in carbon sequestration since the paddy residue remains in the field after harvest (CPGD-Kerala n.d.). In terms of contributing to climate change, they (integrated Pokkali rice-fish/crustacean system) contribute lesser to methane gas emissions than conventional paddy due to reduced water stagnation (Ranjith, Karunakaran and Avudainayagam, et al. 2019).

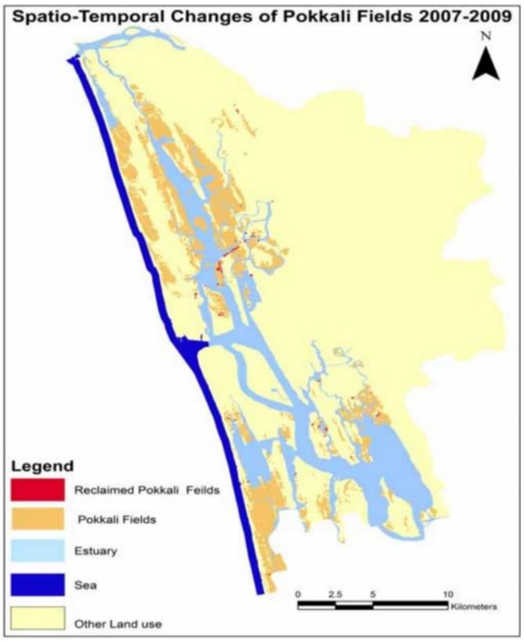
### 3.3 Area under Pokkali agriculture ecosystem and drivers of ecosystem degradation

The area under Pokkali farming is said to have decreased from 25,000 ha around three decades ago (CPGD-Kerala n.d., Ranjith, Karunakaran and Sekhar 2018, Shamna and Vasantha, A Study on Farmers Perception on Problems of Pokkali Rice Farming in the State of Kerala 2017) to around 8,200-8,500 ha (which is available), and only 5,000-5,500 ha under cultivation (Ranjith, Karunakaran and Sekhar 2018, Shamna and Vasantha 2017, Shamna 2017, Vijayan 2016, Shyna and Joseph n.d.). The remaining area is either unutilized or partially utilized under prawn farming and is suggested to have potential for conversion into Pokkali farmlands (CPGD-Kerala n.d.). Further, in terms of the overall area under rice cultivation in Kerala, Pokkali agriculture is said to hold less than 1% (Gopi and Manjula 2018), and around 11,605 farmers are said to be involved in Pokkali cultivation (CPGD-Kerala n.d., Shyna and Joseph n.d.).

Spectro spatial variations in Pokkali based wetlands in Kochi over the period 1944 to 2009 has been outlined in figure 3.1. Changes in area over 1944-2011 in Kochi city has been given in Table 3.2.

Figure 3.1: Spectro spatial variations in pokkali based wetlands in Kochi (1944-2009)






Source:

Table 3.2: Changes in area under pokkali over the years in Kochi city

| Period | Area change km$^2$ | Reduction rate km$^2$/year |
|---|---|---|
| 1944-1973 | 11.224 | +0.387 |
| 1973-1990 | 4.056 | -0.238 |
| 1990-1998 | 3.792 | -0.542 |
| 1998-2007 | 2.445 | -0.245 |
| 2007-2009 | 0.604 | -0.302 |
| 2009-2011 | 0.003 | |

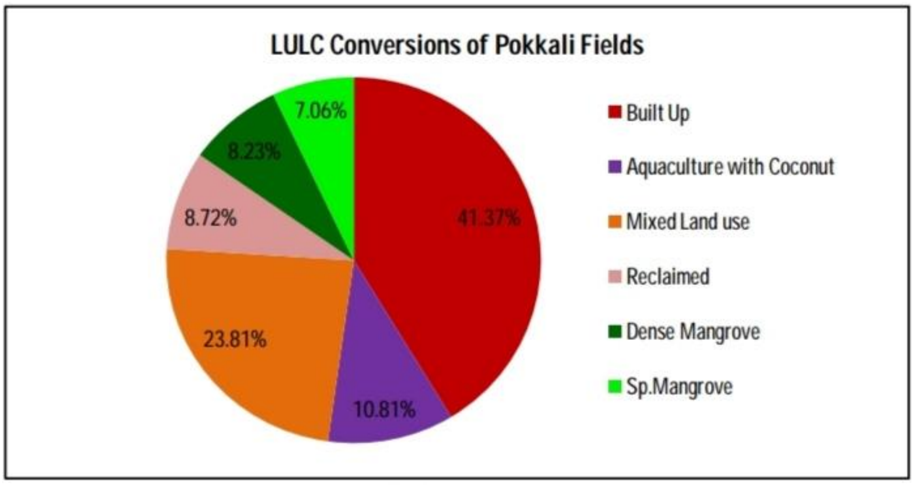
Source:

*The potential for Pokkali cultivation in Kochi* can be derived from secondary sources, such as a project report on 'Promotion of integrated farming system of Kaipad and Pokkali in coastal wetlands of Kerala 2015-16 to 2018-19' by CPGD-Kerala for the National Adaptation Fund (to be executed by the agency for development of aquaculture, Kerala). For instance, one estimate indicates that for Kochi the (potentially total) area under Pokkali/prawn could be about 69 hectares, of which 21 approx. hectares is farmed, implying that about 49 hectares may possibly be revived (CPGD-Kerala n.d.)

***Drivers of agricultural ecosystem changes*** can be many- natural factors (for example, population growth and urbanization), socio-economic factors (for example, income and food consumption per capita) or institutional (for example, governance, policies, investment) (Pham and Smith 2014). The major drivers for changes in Kochi include construction activity (eg highways), conversion of wetlands into residential plots, real estate pressures for waterfront flats and villas and the lack of availability of labours resulting in leaving the lands fallow ending up in encroachment by mangroves.

In order to understand the trend of declining area under Pokkali agriculture, we need to understand the drivers of degradation and the potential impacts they have. Since independence, till the last decades pokkali lands have undergone conversions to a very high extent. Across the literature one driver is most frequently mentioned as the reason for degradation- Conversion of Pokkali rice fields close to Kochi city for other developmental purposes (residential properties, tourism properties, other developmental purposes, plantations etc). In terms of conversion for other agricultural crops, coconut plantations or permanently using Pokkali lands for prawn cultivation seems to be the preference (Deepak 2016, Krishnankutty, et al. 2021, SCMS Water Institute 2016, Kochi Municipal Corporation 2020, CPGD-Kerala n.d., ICLEI South Asia 2020, Rode and Balasubramanian 2018, Vijayan 2016). Some of the major reasons for conversion are also mentioned in Figure 3.2. Most of the lands under pokkali farming had been lost through population pressures resulting in its conversion to built- up areas (41.37%). Few of the cultivated areas have been reclaimed they constitute around 8.7%. Natural encroachment by mangroves is a serious reason behind the loss of pokkali lands and it accounts for 15.29%. Much of the old pokkali fields are nowadays used for aquaculture alone with crops like coconut along its length or width.

Figure 3.2: Reasons for conversion of Pokkali fields




Source:

The agricultural lands closer to the city seem to be the most vulnerable to conversion (Deepak 2016) and are also further affected by the negative externalities of developmental actions around them. For example, construction of an International Container Trans-shipment

Terminal/Vallarpadam Terminal in Kerala and building connective roadways and waterways is said to have resulted in stoppage of water flows and natural marine water flows which were essential for Pokkali-prawn farming (Ranjith, Karunakaran and Sekhar 2018). The terminal and other developmental activities could have caused real estate prices to increase in these areas, which (Ranjith, Karunakaran and Sekhar, Economic and environmental aspects of Pokkali Rice-Prawn production system in central Kerala 2018) suggests could have incentivised many farmers to sell the land. This, although, does not seem to an opinion held by many farmers, as a perception survey by (Shamna and Vasantha, A Study on Farmers Perception on Problems of Pokkali Rice Farming in the State of Kerala 2017) seems to suggest. They undertook a perception survey with the Pokkali farmers in Ernakulam district to identify the problems in Pokkali farming and reported that majority of the respondents disagreed with this statement "Real estate agents have been persuading farmers to sell their farm lands for very attractive prices" (Shamna and Vasantha, 2017). Selling the land could bring a further set of negative externalities to the fields around due to water logging and water pollution which may further cause public health concerns (Ranjith, Karunakaran and Sekhar 2018).

Other possible impacts due to development activities was highlighted in Kochi's LBSAP (ICLEI South Asia 2020) which suggests that Pokkali cultivation within the Kochi city region could have been abandoned due to development of infrastructure like buildings. These developments also seem to have a negative impact in terms of disturbing the ecological balance of these agricultural wetlands (Ranjith, Karunakaran and Sekhar 2018). Further, conversion to other lands may impede the carbon sequestration abilities of Pokkali lands, and may also lead to increased GHG emissions, since Pokkali-prawn systems have reduced methane emissions in comparison to other paddy systems (Ranjith, Karunakaran and Avudainayagam, et al. 2019, CPGD-Kerala n.d.).

The siltation and the stagnancy in Thevara- Perandoor canal in Kochi also seems to have negatively impacted the Pokkali fields, since it used to assist in emptying out the extra water in the fields (SCMS Water Institute 2016). For instance, the Kerala Conservation of Paddy Land and Wetland Act, 2008 (Government of Kerala 2008) states that it is "An Act to conserve the paddy land and wetland and to restrict the conversion or reclamation thereof, in order to promote growth in the agricultural sector and to sustain the ecological system, in the State of Kerala." Deepak (2016) points out that under CRZ rules there are restrictions for reclamation of water bodies but with unclear boundaries and water bodies and Pokkali fields nearby to each other, private encroachment continues to create pressures.

Another possible driver suggested in the literature is the construction of barriers and regulators for preventing tidal variations and saline intrusion, which negatively affects the agricultural fields (CPGD-Kerala n.d.). A lack of water run-off causes weeds and invasive species growth due to increase in sulphur content and acidity and these are said to be difficult to remove (CPGD-Kerala n.d.). Table 3.3 summarizes these major drivers and their impacts.

Some other possible drivers mentioned in the literature but not detailed is displaced labourers leaving agricultural land in a fallow state (CPGD-Kerala n.d.) and the general preference of farmers to monohybrid crops over traditional rice varieties (Krishnankutty, et al. 2021).

Table 3.3: Major drivers of degradation and impacts

| Location (As mentioned in literature) | Drivers/Reasons for degradation | Impacts due to the degradation | | |
|---|---|---|---|---|
| | | Ecological | Economic | Social |
| Villages in Ernakulam, Alappuzha (CPGD-Kerala n.d., Ranjith, Karunakaran and Sekhar, Economic and environmental aspects of Pokkali Rice-Prawn production system in central Kerala 2018), Thrissur districts (CPGD-Kerala n.d.) Kadamakudy Panchayat, Kochi (Deepak 2016) | Land use conversion of Pokkali-fish farms for developmental, or other agricultural purposes; Resulting negative externalities caused in neighbouring fields | -Stoppage of water flows and natural marine water flows for Pokkali-fish fields<br>-Disturbs ecological balance<br>-Adversely impacts carbon sequestration ability of Pokkali lands, and may cause increase in GHG emissions | -Increasing land prices near developed areas incentivising farmers sell land | -Water logging, water pollution causing public health concerns |
| Villages in Ernakulam, Alappuzha, Thrissur districts (CPGD-Kerala n.d.) | Construction of barriers and regulators for preventing tidal variations and saline intrusion | -Growth of weeds and invasive species | | |

## 3.4 Identification and Resolution of Problems/constraints in traditional rice farming, and integrated Pokkali-fish/crustacean farming

In general, organic farming in general is said to be plagued by many problems- for example, high input costs, lack of government support and polices, lack of awareness, infrastructure, financing, low yield (Das, Chatterjee and Pal 2020). Problems have been classified into infrastructural, input related (labour, capital), environmental, output related (pricing, quality, product) and long-term problems.

We summarize below some of the problems specifically faced in traditional rice farming and Pokkali-fish/crustacean farming. Some of these have been well studied (Figure 3.3 plots the number of research articles/report that mention the listed problem). Input related problems, specifically labour shortage and labour costs are among the most frequently mentioned problems, both in the literature and in our survey (as discussed in the next chapter).

#### ***3.4.1 Infrastructure related (physical and institutional):***

1. **Broken Bunds:**

Many Pokkali fields are said to be non-operational due to broken bunds or bunds of inadequate height (Based on stakeholder consultations with farmers by CPGD-Kerala (n.d.) in Thrissur, Ernakulam and Alappuzha districts). According to CPGD-Kerala (n.d.) it could have been broken due to seasonal high tides.

Broken bunds hamper the agricultural process due to

- Fish/ shrimp escaping
- Spread of shrimp disease to nearby farms
- Saltwater intrusion and coastal erosion
- Seepage into fresh water areas
- These may result let the agricultural land lay fallow (CPGD-Kerala n.d.).

2. **Transportation and allied supply chain issues:**

Krishnankutty, et al. (2021) found from a primary survey of rice farmers engaged in traditional rice cultivation in Palakkad, Malappuram and Wayanad, that, lack of transportation was a concern.

Ranjith et al. (2018) conducted a primary survey with Pokkali farmers in integrated Pokkali-prawn farming in villages in Ernakulam district (including Kochi) for the year 2016 and reported that the distance between harvest and processing zone was considered a constraint. The rice is wet after harvest and needs to immediately by transported to processing centres to be cleaned and dried. Further, Ranjith et al. (2018) stated that sometimes farmers needed to bring the harvest in lots of small sizes to the centre. Timely labour requirement for this process was also considered an issue.

3. **Infrastructural mismanagement:**

One further problem in Pokkali rice farming seems to be the lack of timely draining of salt water from agricultural fields which is an activity that needs to be done by the Padashekharam which delays the rest of the production cycle [4] (N. Joseph 2021).

### *3.4.2 Input related*

**4. Shortage of labour:**

Shortage of labour and skilled labour seems to be a highly suggested issue by farmers cultivating traditional rice varieties in Kerala and cultivating Pokkali rice (Shamna and Vasantha 2017, Ranjith, Karunakaran and Sekhar 2018, Krishnankutty, et al. 2021, Ranjith, Karunakaran and Avudainayagam, et al. 2019, Vijayan 2016). A perception based survey by Shamna and Vasantha (2017) of Pokkali farmers in Ernakulam district and the primary survey by Ranjith et al. (2018) with Pokkali farmers in Ernakulam district (including Kochi) both found that around 85% of farmers agreed/stated labour shortage being a concern.

In parallel, a decline in land under Pokkali cultivation seems to be causing displacement of labourers, especially women (CPGD-Kerala n.d., Shyna and Joseph n.d.).

As suggested by these authors, a reason for this problem could be that labourers find the work very strenuous. Harvesting part of Pokkali rice cultivation faces an acute shortage of skilled labours. Unlike normal paddy harvesting Pokkali has to be harvested in muddy water high up to the chest level. There has been many incidents of farmers suffering crop loss as they couldn't get labours for timely harvesting. Deepak (2016) opines that this could be one potential reason for farmers shifting from production of pokkali and shrimp in rotation to just shrimp cultivation.

**5. High labour costs and wage rates:**

High labour costs are a problem for paddy in general (Gogoi, et al. 2020), Pokkali rice cultivation and extensive farming of shrimp (Sathiadhas, Najmudeen and Prathap 2009). Looking at production cost estimates by (CPGD-Kerala n.d.) seem to suggest that within the two inputs used in Pokkali rice farming (seeds, labour), the labour costs constitute about 93% of the total costs. Ranjith, et al. (2019) studying the integrated Pokkali-prawn system suggests that farmers mention high labour wage rates as production constraints. The perishability of prawns is also a concern while low labour productivity has also been flagged by researchers (Krishnankutty, et al. 2021)

[4] https://www.thenewsminute.com/article/pokkali-rice-farming-ernakulam-under-threat-due-mismanaged-infrastructure-147771

6. **Difficulties in mechanising production operations:**

Pokkali farmers expressed difficulties in mechanisation as a constraint to farming (Ranjith et al., 2019, Shamna and Vasantha, 2017). Water logging could make it difficult to use heavy machinery. All the operations in Pokkali rice farming are managed manually and the efforts to mechanize have thus far not shown success.

### *3.4.3 Natural and Environment related:*

7. **Shortage, Absence and unpredictability of seasonal rain:**

Some problems related to biophysical or environmental aspects have also been flagged of which the variability and seasonality of rainfall have been a major concern.

8. **Attack by animals** has also been flagged.
9. **Deteriorating soil and water quality**
10. **Lodging of rice:**

Lodging of Pokkali rice or the bending over of the stems might contribute to reducing yield (Shamna and Vasantha, 2017). Research has been undergoing to develop varieties that could be resistant to lodging (Kumar and Kunhamu 2021).

11. **Pollution in Pokkali fields:**

Pollution could be due to the development around the fields, factories, boats, waste from the city. Some of these may have caused water logging and water pollution in the fields creating a constraint for farming.

### *3.4.4 Output related problems (Pricing, Quality, Product)*

12. **No price premium for traditional rice:**

Many traditional rice varieties in Kerala do not receive price premiums and rice ends up being sold without their identification to wholesalers as a mix with other varieties (Krishnankutty, et al. 2021). This causes farmers to earn less income from the sale (Krishnankutty, et al. 2021). Further, it is suggested that subsidies are more targeted towards HYV than traditional varieties, hence disincentivising farmers (Gopi and Manjula 2018).

Further, it is mandatory that Pokkali cultivation needs to be done for the permission for fisheries farming to be undertaken. Hence, there is a growing tendency among the farmers to initiate cultivation and then leave the field unattended or with limited management to comply with the legal directives to ensure permission for fisheries crop. These farmers also enjoy the subsidy support from department of Agriculture and Panchayat and block levels, although the availed subsidies vary from place to place. There is also some evidence of subsidies being given to Pokkali farmers under a NABARD project by the Agency for development of Aquaculture Kerala[5] (Priyadershini 2020). Recently, Special Agricultural Zones seem to have been setup for Pokkali ( Department of Agriculture Development and Farmers' Welfare-Government of Kerala n.d.)

13. **Poor quality of Pokkali rice:**

Quality of Pokkali rice has been mentioned as a problem for farmers that happens due to a lack of timely labour availability during harvesting (Shamna and Vasantha, 2017). This results in farmers having to sell produce at Rs. 8 to 10/kg to private mill owners, which might further reduce the returns they obtain.

14. **Delays in payments** (Krishnankutty, et al. 2021) and **Fluctuation of price in the market** (Ranjith, Karunakaran and Avudainayagam, et al. 2019) have also been flagged as issues.
15. **Low yield of local Pokkali varieties:**

Although all traditional rice varieties are not low-yielding, the traditional Pokkali variety was thought to yield lesser by farmers in a perception survey by Shamna and Vasantha (2017). Further, when listing various traditional rice varieties in Kerala, Gopi and Manjula (2018) did not mention Pokkali under the list of high yielding varieties. An improved Pokkali variety Vytilla (VTL-1 to VTL -8) seems to a high yielding variety of Pokkali (CPGD-Kerala n.d.).

16. **Milling of traditional rice:**

Milling of traditional rice is a relatively complex issue since the shape of grain is said to affect the ease with which it can be broken during milling, which further affects the rice recovery and quality (Krishnankutty, et al. 2021). In comparison to modern varieties, traditional varieties are said to have more issues in terms of breakage and low hulling percentages during milling which reduces their saleability and commercial value and is hence not preferred by wholesalers (Krishnankutty, et al. 2021). Krishnankutty, et al. (2021) notes that most farmers sell traditional rice milled rather than raw, and also have trouble marketing them (Krishnankutty, et al. 2021). Another problem in this regard is the unavailability of milling infrastructure for traditional varieties (Krishnankutty, et al. 2021).

### *3.4.5 Long-term problems*

[5] Now pitched as climate adaptive food, Kerala's heritage Pokkali rice cultivation needs support - The Hindu

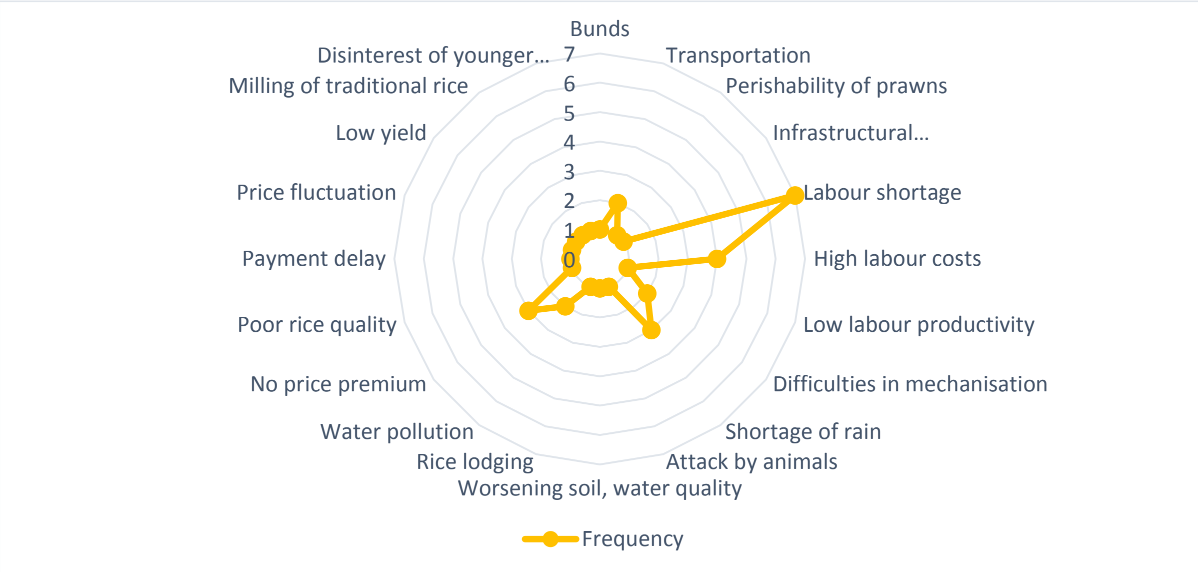
**17. Lack of interest of the younger generation in Pokkali farming:**

Most farmers pursuing traditional agriculture seem to be older in age. For example, in a primary survey by Krishnankutty, et al. (2021) with traditional rice farmers in Palakkad, Malappuram and Wayanad, they found most of the respondents to be in the 40-70 age bracket, with more than 30 years of farming experience. For Pokkali, the age group of labourers was noted to be around 55 years old (Shyna and Joseph n.d.). This, coupled with the seeming disinterest of the younger generation towards this practice, raises concerns about the long term survival of this indigenous practice.

### *3.4.6 Others*

**18. Conflict between Pokkali paddy and fish farmers:** In general, there has also been continuing conflicts between paddy farmers and fisheries farmers, over the control over the production system. The relative economics of the two enterprises and the resource status of the owner farmers make the situation in favour of fisheries culture. There were several instances when the paddy farming is skipped and the fish culture alone is resorted to. Often the fisheries farming operations are not completed and it becomes impossible for the paddy operations to begin which leads to direct conflicts between these two groups.

Figure 3.3: Number of research articles/report that state each problem



## 3.5 Ecosystem services, disservices and benefits provided by paddy, traditional ecosystems and Pokkali ecosystems

This section specifically focuses on the ecosystem services that the literature identified for paddy ecosystems, traditional rice ecosystems and Pokkali rice ecosystems. Table 3.4 contains details on the various ecosystem services from paddy agricultural landscapes, traditional rice landscapes, and the ecosystem services given in green colour are those that the literature specifically attributes to Pokkali-fish/crustacean systems.

Table 3.4: Ecosystem services from paddy, traditional rice and Pokkali ecosystems (ecosystem services given in green colour are those that the literature specifically attributes to Pokkali-fish/crustacean systems)

| Provisioning services | Regulating services |
|---|---|
| **-Food and nutrients** (Chivenge, et al. 2020, Rasheed, et al. 2021, Huang, et al. 2006, Kumar and Kunhamu 2021, CPGD-Kerala n.d., Deepak 2016)<br>-Fiber and fuel (Chivenge, et al. 2020)<br>-**Medicine** (CPGD-Kerala n.d., Gopi and Manjula 2018)<br>-**Fodder** (Chivenge, et al. 2020, Rasheed, et al. 2021, CPGD-Kerala n.d., Kumar and Kunhamu 2021)<br>-Raw materials for agriculture and industry (Chivenge, et al. 2020)<br>-**Genetic material** (Deepak 2016, Rasheed, et al. 2021, Krishnankutty, et al. 2021) | - Water regulation and maintenance (Chivenge, et al. 2020, Kumar and Kunhamu 2021),Maintenance of water tables (Ramsar Convention Secretariat 2016, Gopi and Manjula 2018)<br>-Water purification and Maintenance of water quality (CPGD-Kerala n.d., Rasheed, et al. 2021, Huang, et al. 2006, Kumar and Kunhamu 2021)<br>-Ground water recharge (Rasheed, et al. 2021, Huang, et al. 2006, Kumar and Kunhamu 2021)<br>-Reducing land subsidence and saltwater intrusion (Huang, et al. 2006), Shoreline protection (CPGD-Kerala n.d.)<br>-Soil erosion control and prevention (Rasheed, et al. 2021, Huang, et al. 2006, CPGD-Kerala n.d., Kumar and Kunhamu 2021)<br>**-Flood mitigation and control** (CPGD-Kerala n.d., Rasheed, et al. 2021, Huang, et al. 2006, Kumar and Kunhamu 2021, CPGD-Kerala n.d., Gopi and Manjula 2018)<br>-**Pest and disease control** (CPGD-Kerala n.d., Shamna and Vasantha 2017, Gopi and Manjula 2018, Chivenge, et al. 2020) |

| | |
|---|---|
| | -Climate regulation (Rasheed, et al. 2021):<br>a. **Carbon storage and sequestration** (Chivenge, et al. 2020, CPGD-Kerala n.d.)<br>b. Temperature regulation and maintenance (Huang, et al. 2006)<br>c. Air purification (Huang, et al. 2006) |
| **Cultural services** | **Supporting services** |
| -Spiritual, religious, inspirational (Chivenge, et al. 2020, Gopi and Manjula 2018, Krishnankutty, et al. 2021, Kumar and Kunhamu 2021), Aesthetic appreciation (Chivenge, et al. 2020, Rasheed, et al. 2021)<br>-Cultural heritage, culinary importance (Rasheed, et al. 2021, CPGD-Kerala n.d., Krishnankutty, et al. 2021)<br>-Recreation and ecotourism (Chivenge, et al. 2020, Huang, et al. 2006)<br>-**Local knowledge and education** (Rasheed, et al. 2021) | -Nutrient cycling, retention, regulation and maintenance (Ramsar Convention Secretariat 2016, CPGD-Kerala n.d., Chivenge, et al. 2020), **Nitrogen fixation and soil fertility** (Gopi and Manjula 2018, CPGD-Kerala n.d., Shamna 2017, Kumar and Kunhamu 2021)<br>**-Biodiversity habitat and maintenance** (CPGD-Kerala n.d., Chivenge, et al. 2020, Rasheed, et al. 2021, Gopi and Manjula 2018, Kumar and Kunhamu 2021) |

Note: The ecosystem services noted in the literature to be applicable to Pokkali rice systems have been given in bond and green coloured font.

### *3.5.1 Provisioning ecosystem services:*

Provisioning ecosystem services are goods provided by the ecosystems like fuel, food, medicine, fodder and raw materials for industry (Gopi and Manjula 2018).

***Food and nutrients:*** Rice is a staple food for human consumption in many countries (Chivenge, et al. 2020), and consumption of fish and crustaceans grown in the field (Kumar and Kunhamu 2021) can help bring some further diversity to the diet. Plants grown around the fields in some places is also used for consumption. For example, in Thailand, red water lilies and water mimosas that grow in and around paddy fields are used for consumption as food (Chivenge, et al. 2020).

In comparison to these modern rice varieties, traditional rice varieties are said to provide a larger amount of energy per unit (Gopi and Manjula 2018) and decline in traditional varieties could have a negative impact on nutrition (Thrupp 2000). Traditional rice varieties could help supplement and meet nutritional requirements (for example, zinc and iron micronutrients) (Gopi and Manjula 2018, Rasheed, et al. 2021).

In terms of consumer preferences specifically for Pokkali rice, the evidence is not very clear in the literature. For instance, comparing Wayanad farmers' consumption preferences within the traditional rice varieties in Kerala, Gopi and Manjula (2018) did not include Pokkali rice in this list. Nevertheless, Pokkali rice is an accessible source of nutrition (Deepak 2016) and is said to be used for making breakfast items (CPGD-Kerala n.d.)

***Fiber and fuel:*** Paddy and its by- products (rice straw and husk), could act as energy sources and can also be used to produce biogas/biomass (Chivenge, et al. 2020).

***Medicine:*** Pokkali is suggested to be helpful to treat vomiting and diarrhoea (Gopi and Manjula 2018), rich in antioxidants like tocopherol, oryzanol, tocotrienol (CPGD-Kerala n.d., Shamna and Vasantha, A Study on Farmers Perception on Problems of Pokkali Rice Farming in the State of Kerala 2017), and is good for diabetics due to its amylase content (CPGD-Kerala n.d.). Although, another traditional rice variety in Kerala (Njvara) known for its medicinal value (Ashraf and Lokanadan 2017) finds more common mention in the literature.

***Fodder****:* In addition to being used as fiber or fuel, straw or fodder from rice can be used for food or bedding for livestock (Chivenge, et al. 2020). Fodder from Pokkali rice agricultural systems is also used for cattle (CPGD-Kerala n.d.)

***Raw materials:*** Rice products like husks can be used as inputs in various agricultural processes and in industries. For example, rice husk can be used in vermiculture/mushroom culture to absorb wastewater (Chivenge, et al. 2020). Rice husk is also suggested to be useful in industry for making paint, nanosilica, medium-density fiberboard, low-roll resistance tires, organic plastics and, composite plastics (Chivenge, et al. 2020).

***Genetic material:*** Wetlands store important plant genetic material (Deepak 2016). Traditional rice varieties have a rich gene pool that could help in adapting to climate change (Krishnankutty, et al. 2021, Gopi and Manjula 2018). Reduction of area under traditional rice cultivation could cause useful traits from their gene pools to be lost (Krishnankutty, et al. 2021). Pokkali, being a saline tolerant variety of rice holds genetic material that could be important for adaptation to climate change (CPGD-Kerala n.d.).

#### *3.5.2 Regulating ecosystem services:*

Regulating ecosystem services typically include "benefits obtained from regulation of ecosystem processes" (Alcamo, et al. 2003).

***Water regulation and maintenance:*** Paddy systems and their water run-offs water contribute ecosystem services of water filtration, water regulation, water reuse and water purification (Chivenge, et al. 2020).

***Water purification and Maintenance of water quality:*** The soils in paddy fields perform the service of water purification by removing/absorbing many water pollutants (Huang, et al. 2006). Further, water draining from paddy ecosystems could have improved water quality due to their retention of nutrients from upstream soil in paddy fields, and the nutrients in the run-off water can contribute to eutrophication (Chivenge, et al. 2020).

***Groundwater recharge:*** Although rice production uses a lot of water, paddy soils have large capacities for water storage and groundwater recharge (Chivenge, et al. 2020, Huang, et al. 2006). One reasoning is for their groundwater recharge service is that the water is stored in the field for a long-time causing infiltration (Rasheed, et al. 2021).

***Soil erosion control and prevention:*** Paddy fields, through percolation of water and retention of eroded upstream soils can also help in minimising soil erosion (Chivenge, et al. 2020, Huang, et al. 2006).

***Reducing Land subsidence and saltwater intrusion:*** Paddy fields, due to their groundwater recharge service can help reduce saltwater intrusion and land subsidence (Huang, et al. 2006).

***Flood mitigation and control:*** Water stored in paddy fields hold rainwater and prevent floods and reduce the peak flow of water (Huang, et al. 2006). Further, the bunds around the fields act like barriers to water flows thereby helping mitigate floods (Rasheed, et al. 2021). Pokkali paddy specifically helps in better tolerance to floods since this variety is said to be flood-tolerant (Gopi and Manjula 2018). Secondly, cultivation of shrimp on rice lands has the potential to reduce effects of floods due to the availability of large surface area (CPGD-Kerala n.d.).

***Pest and disease control:*** Arthropods in irrigated rice fields and their enemies (rodents, birds etc) together form a food web that contributes to the natural pest regulation service of paddy ecosystems (Chivenge, et al. 2020). Chivenge, et al. (2020) suggests that this service is obstructed due to the excessive pesticide use and could also lead to pesticide resistance.

Many traditional rice varieties in Kerala, including Pokkali are pest-resistant varieties and could provide consistent yield in these hostile circumstances (Gopi and Manjula 2018).

***Climate regulation:***

- ***Carbon storage and sequestration:*** Due to continuous soil submergence in paddy fields, soil organic carbon builds up (Chivenge, et al. 2020). Pokkali fields in particular are expected to sequester more soil organic carbon with greater efficiency due to the vegetative residue remaining in the field (CPGD-Kerala n.d.).

- ***Temperature regulation and maintenance:*** Water evaporating from paddy fields is expected to cause temperatures to reduce (Huang, et al. 2006).
- ***Air purification:*** Air purification service of paddy lands is expected to happen due to the photosynthesis process (Huang, et al. 2006)

### *3.5.3 Cultural ecosystem services:*

Cultural values are predominantly non-material and intangible but are important to consider while managing ecosystems (Tekken, et al. 2017).

***Spiritual, religious, inspirational and aesthetic appreciation:*** Rice holds an integral place in many cultures, forming part of many cultural identities and holding historical value. In some communities, rice is considered God (Chivenge, et al. 2020) like in Kerala (Kumar and Kunhamu 2021). Kerala as well has historical cultural relationships with rice farming and rice and paddy farming is supposed to signify affluence and following of lineage (Krishnankutty, et al. 2021). Onam, Vishu, Illam-nira, Puttari are some festivals said to revolve around agricultural seasons and processes (Kumar and Kunhamu 2021), Some traditional rice varieties are also said to form a part of rituals, auspicious events and as divine offerings (Gopi and Manjula 2018).

***Cultural heritage and culinary importance:*** Those practicing traditional agriculture and land use management strategies seem to value cultural and heritage values more than those practising more intensive strategies of land use (As evidenced by a perception survey based study by Tekken et al. (2017) with rice farmers in Vietnam and Philippines). A similar example for Kerala was given by Krishnankutty, et al (2021) who remarked that those cultivating traditional rice varieties in Kerala focused more on the cultural and heritages value rather than the economics (Krishnankutty, et al. 2021).

***Recreation and Ecotourism:*** Rice fields can be tourist destinations, with some rice fields classified as UNESCO world heritage sites (For example, the Ifugao rice terraces in Philippines, and Tanada rice terraces in Japan (Chivenge, et al. 2020)). Rice fields could also provide a relaxing atmosphere (Huang, et al. 2006).

***Local knowledge and education:*** Traditional rice varieties and their farming helps prevent the loss of farmers’ historical local knowledge (Rasheed, et al. 2021). Pokkali farming could help protect indigenous farming practices (CPGD-Kerala n.d.)

### *3.5.4 Supporting ecosystem services:*

Supporting ecosystem services include services essential for functioning of other ecosystem services (Alcamo, et al. 2003).

***Soil fertility, nutrient cycling, retention, regulation and maintenance:*** The moist conditions of the soil in paddy ecosystems contribute to nutrient recycling due to a build-up of microbial biomass (Chivenge, et al. 2020). Residue management typically involves burning of straw that recycles soil nutrients which although rich in potassium causes air pollution (Chivenge, et al. 2020). Instead, straw can be retained on fields which will help in potassium absorption, even though it may not have much effect phosphorous and nitrogen cycling (Chivenge, et al. 2020). Chivenge, et al. (2020) suggests the straw contains around 70% of the Pottassium that the rice takes up. Further Chivenge, et al. (2020) suggests nutrient cycling could be improved by diversifying crops through rotations.

Pokkali agriculture could improve soil quality and fertility (CPGD-Kerala n.d., Kumar and Kunhamu 2021) and nitrogen fixation (Kumar and Kunhamu 2021).

***Biodiversity habitat and maintenance:*** Rice farms provide food, shelter, conditions for habitat for many flora and fauna, especially invertebrates (Chivenge, et al. 2020). Many water birds, fish, frogs which face survival threats find a habitat in rice fields (Kumar and Kunhamu 2021). Water run-offs from paddy fields contribute to landscape diversity (Chivenge, et al. 2020).

Traditional rice varieties are said to have gene diversity and characteristics of adapting to unfavourable climate and weather conditions (Rasheed, et al. 2021). This diversity could be critical for ensuring food security in the future (Gopi and Manjula 2018). Further, Pokkali farming would ensure that the local traditional rice varieties are protected (CPGD-Kerala n.d.).

### *3.5.5 Potential disservices*

Some potential disservices for paddy ecosystems and how the Pokkali-fish/crustacean system fares on those disservices have been discussed. It has been summarized in table 3.5.

Table 3.5: Potential disservices of paddy ecosystems and their applicability for Pokkali-fish/crustacean systems

| Potential disservices<br>(Normal paddy ecosystems) | Pokkali-fish/crustacean ecosystems |
|---|---|
| ***Emissions of greenhouse gases (GHG)**:* (Chivenge, et al. 2020, Ranjith, Karunakaran and Avudainayagam, et al. 2019) | There are some ecological differences between cultivating Pokkali rice-prawn system and normal paddy since water moving in and out of the fields for the |

| | |
|---|---|
| Paddy ecosystems contribute to air pollution and GHG emissions due to stubble burning and submerged decomposing organic matter releasing methane (Chivenge, et al. 2020). Methane is said to typically be produced due to organic manure and inputs, soil submergence and water regimes (Kumar and Kunhamu 2021). | Pokkali rice-prawn system prevents continuous water stagnation (Ranjith, Karunakaran and Avudainayagam, et al. 2019).<br>This is important, since this reduced stagnation and draining of water mid-season could contribute to reducing methane gas emission potential (Ranjith, Karunakaran and Avudainayagam, et al. 2019, Kumar and Kunhamu 2021). |
| ***Health costs due to stagnant water***<br>Stagnant water in paddy fields could spread vector-borne diseases (Chivenge, et al. 2020). | Reduced stagnation and tidal fluctuations under Pokkali rice-fish/crustacean farming may potentially reduce these negative impacts, although literature on these linkages could not be identified. |
| ***Negative impacts of chemical fertilizers, pesticides on water quality, purification, and waste treatment***<br>Chemical fertilizers, pesticides used excessively in agricultural systems can affect water quality and potentially other ecosystem services (Millennium Ecosystem Assessment 2005, Chivenge, et al. 2020). | Pokkali fish-crustacean farming is organic and does not use chemical pesticides, chemical fertilizer or insecticides (CPGD-Kerala n.d., Vijayan 2016), hence there may be possible arguments that can be made on the reduced impacts on health, or on water quality by moving to more organic farming methods, but literature could not be identified to validate these linkages. |
| ***Negative impacts of chemical fertilizers, pesticides on health:***<br>Paddy farming in Kerala uses pesticides (P. Devi, Pesticides in Agriculture - A Boon or a Curse? A Case Study of Kerala 2010), which has been found to have adverse health effects on the farm labourers and pesticide applicators (P. Devi 2007). A SANDEE report by Devi (2007) conducted primary surveys amongst farm labourers and pesticide applicators on rice farms in Kuttanad, Kerala in 2004-05 and found short-term health costs of pesticide exposure to be around Rs. 38 (US $ 0.86) per day, which translated to a "quarter of the average daily earnings of the applicator." (P. Devi, 2007) | |

## 3.6 Costs and benefits (Marketed and non-marketed costs and benefits)

Economics of traditional rice cultivation has typically been evaluated in the literature through a comparison of marketed and monetised costs and benefits. There is very limited evidence on monetized values of non-marketed benefits, and none that could be identified on social costs.

### *3.6.1 Possible financial costs and marketed economic benefits*

This limited analysis based on the literature highlights the benefits of an integrated system, but also finds price premiums and price fluctuations to potentially be an important factor in determining profitability. Examples from the literature and insights based on literature to convey this point are discussed below.

The economics and costs of traditional rice cultivation in Kerala varies depending on the traditional variety in question, but a common trend often reported in studies looking at cultivation of traditional varieties or those specifically at Pokkali systems is that many traditional rice farming systems may be operating at losses. For example, studying the costs of traditional rice cultivation in Kerala (Palakkad, Malappuram and Wayanad) calculated using CACP classifications (A1, A2, B1, B2, C1, C2, C3) and further examining the benefit cost ratio and net income (Income– Costs C3), Krishnankutty, et al. (2021) remarked that traditional farming was operating at a loss in 2 out of 3 locations but that it the value could become a profit if the costs of own land or imputed value of personal labour were not considered (Krishnankutty, et al. 2021). The profit in the one location was explained by the price premium for those particular traditional rice varieties due to their medicinal and aromatic values (Krishnankutty, et al. 2021).

Integrated farming of Pokkali-fish/crustacean could be better from the financial perspective in comparison to sole Pokkali cultivation. An analysis by Ranjith, et al. (2019) in North Paravur, Kochi and Kanayannur Taluks (Ernakulam district) notes that simply cultivating Pokkali rice results in a loss of Rs. 62864 /ha; although, integration of rotational prawn as part of the cycle does convert this loss into an overall net benefit (Rs. 5,20,521/ ha) with a benefit-cost ratio of 2.17. Another older estimate by CPGD-Kerala (n.d.) suggests a net benefit (income minus costs) of Rs. 8,48,040 for 5 ha which translates into an average of Rs. 1,69,608/ha from Pokkali-fish/crustacean farming based on information collected from villages in Ernakulam, Alappuzha, Thrissur districts (Data from 2012-2015). The data provided indicates that the benefit-cost ratio (gross income/cost) for this integrated system would be about 2.2, which is similar to the value obtained by Ranjith, et al. (2019). Similar calculations based on the information provided suggests that the ratio of revenue to costs from only Pokkali rice cultivation yields a value of 1.6

(CPGD-Kerala (n.d.)) and 0.51 for the estimates by Ranjith, et al. (2019). This limited evidence confirms the benefits of an integrated system. However, it also brings to light confusion on the profitability of Pokkali cultivation (as seen by the benefit-cost ratio) which although lesser, is still profitable according to the CPGD-Kerala (n.d.) estimates, but not according to the Ranjith, et al. (2019) estimates. Considering that the ratio accounts for the difference in data collection periods, one plausible reasoning for this could be the variation in prices obtained for the produce or inherent price fluctuations in the market which has been mentioned as a problem. Another reason for the difference could be that since CPGD-Kerala (n.d.) considers 5 ha as 1 unit, the cost structures may vary between the two estimates.

### *3.6.2 Possible socio-economic benefits associated with traditional rice/Pokkali paddy/Pokkali-fish or crustacean ecosystems*

In general, *integrated farming of rice and fish/shrimp* could improve land use efficiencies and reduce land degradation. Integrated rice-shrimp/fish farming system could also minimise weed and pest problems, resulting in a reduction in pesticides, inorganic fertilizers etc (CPGD-Kerala n.d.). Secondly, an integrated rotational rice-shrimp/fish system ensures that the field is being used all-year and could reduce the chance of land being used for other purposes like waste disposal (CPGD-Kerala n.d.).

On the other hand, *decline in rice production* could have many negative impacts (for example- for food security) (Ranjith, Karunakaran and Sekhar 2018). Decline in area under traditional rice cultivation could lead to lessening diversity, especially since Padashekarams are said to be similar in that they only hold only 2-3 varieties to ensure efficient and easier management (Krishnankutty, et al. 2021). Decline in area under Pokkali fields could result in a decrease in income and employment. This is true especially for women who may not be in a position to explore further job opportunities due to social and geographical constraints (CPGD-Kerala n.d.)

Some benefits directly deriving from the ecosystem services of Pokkali farming have been listed in table 3.6 below.

Table 3.6: Benefits from ecosystem services provided by Pokkali farms

| Flow of ecosystem services | Benefits (Socio-economic, ecological) |
|---|---|
| Food supply | **Socio-economic:**<br>-Accessible source of nutrition (Deepak 2016)<br>-Used for making breakfast items (CPGD-Kerala n.d.) |
| Medicine | **Socio-economic:**<br>- To treat vomiting, diarrhoea (Gopi and Manjula 2018),<br>-Rich in antioxidants (tocopherol, oryzanol, tocotrienol) (CPGD-Kerala n.d., Shamna and Vasantha, A Study on Farmers Perception on Problems of Pokkali Rice Farming in the State of Kerala 2017)<br>-Good for diabetics due to amylase content (CPGD-Kerala n.d.) |
| Fodder | **Socio-economic:**<br>-Provides additional income, especially for women (CPGD-Kerala n.d.) |
| Genetic material | **Ecological:**<br>-Using salinity resistant varieties or developing varieties using the gene pool of these varieties could help in climate change adaptation from sea level rise and climate resilient agriculture (Gopi and Manjula 2018, CPGD-Kerala n.d.) |
| Flood mitigation and control | **Ecological:**<br>- Helps in tolerance to floods since Pokkali variety is said to be flood-tolerant (Gopi and Manjula 2018)<br>-Effects of floods could possibly be reduced due to shrimp cultivation on rice fields due to the availability of large surface area (CPGD-Kerala n.d.) |
| Pest and disease control | **Socio-economic:**<br>-Has pest resistance, could provide consistent yield in hostile circumstances (Gopi and Manjula 2018) |
| Carbon storage and sequestration | **Ecological:**<br>-Due to vegetative residue remaining in field, Pokkali fields may sequester more soil organic carbon than paddy (CPGD-Kerala n.d.). |
| Local knowledge and education | **Socio-economic:**<br>Pokkali farming could help protect indigenous farming practices (CPGD-Kerala n.d.) |
| Soil quality and fertility, nitrogen fixation | **Ecological:**<br>-Pokkali agriculture could improve soil quality and fertility (CPGD-Kerala n.d., Kumar and Kunhamu 2021) and nitrogen fixation (Kumar and Kunhamu 2021)<br>-For example, retaining straw on paddy fields helps in potassium absorption, even though it may not have much effect on phosphorous and nitrogen cycling (Chivenge, et al. 2020), and |

| | |
|---|---|
| | this could be true for rotational Pokkali-fish/crustacean ecosystems since the paddy remains are left on field which provides nutritional benefits for fish/crustaceans (CPGD-Kerala n.d.), although literature could be identified to substantiate the statement.<br>**Socio-economic:**<br>-Improvements in soil quality could help in obtaining better yields (CPGD-Kerala n.d.) |
| Biodiversity habitat and maintenance | **Ecological:**<br>-Pokkali farming would ensure protection of local traditional rice varieties, local biodiversity (CPGD-Kerala n.d.) |

### *3.6.3 Economic values and valuation of benefits from ecosystem services provided by traditional rice ecosystems*

Various economic values can be associated with the genetic material and resources especially of traditional rice ecosystems- direct and indirect use values, option and quasi-option values, bequest and existence values. Directly, these can be used for fodder, food, breeding and so on, although they farmers may substitute them for more beneficial varieties (Gopi and Manjula 2018). Option values or the value attributed to keeping the option of direct and indirect use open for the future could be a reason to conserve genetic material of traditional varieties, although it may not incentivise farmers due to the minimal private returns (Gopi and Manjula 2018). Traditional varieties could be important from the perspective of adaptation to climate change. Alternatively, these resources may find value in their availability for future generations or just for their existence (Gopi and Manjula 2018).

Very few attempts seem to have been made to value the ecosystem services provided by paddy ecosystems in India and the traditional rice ecosystems. For instance, Nayak, et al. (2019) calculated the values of ecosystem services from paddy ecosystems in Eastern India to be around US$1,238/ha/yr to US$ 1,688 ha/yr. They included values from various provisioning, regulating and support services such as food, by-products, pest control, flow of carbon, nutrient cycling, soil fertility, nitrogen fixation, hydrological flows, soil erosion and soil formation (Nayak, et al. 2019).

Specifically on valuation of ecosystem services provided by traditional paddy ecosystems in Kerala, only one study was found. Rasheed, et al. (2021) calculated values of grain, straw (market price method), iron and zinc nutrients (replacement costs and benefit transfer method), flood mitigation, groundwater recharge (replacement costs and benefit transfer method), nitrogen fixation, soil erosion prevention (benefit transfer method) and the value of disservice due to GHG emissions in Vythiri, Sulthan Bathery and Mananthavady taluks in Wayanad in 2020. They found that US$8,391/ha annually was the value of the Wayanad paddy ecosystem, and that the net ecosystem service value after accounting for the emissions from greenhouse gases was around US$8,375/ ha (Rasheed, et al. 2021).

Calculations by Rasheed, et al. (2021) provide helpful insight on the substantial ecosystem service values provided by paddy ecosystem in general even when accounting for the disservices. Comparing between values of provisioning services provided by traditional and other varieties also highlights the higher values of provisioning services provided by traditional paddy varieties for food and nutrition. While provisioning services were given separately for traditional paddy varieties and other paddy varieties, all other service values were given for the paddy ecosystem as a whole.

In terms of perception of ecosystem services by farmers, Rasheed, et al. (2021) suggests that most paddy farmers recognized the groundwater recharge ecosystem service, followed by water purification and prevention of soil erosion based on their primary survey of farmers growing traditional or other paddy varieties in Vythiri, Sulthan Bathery and Mananthavady taluks in Wayanad in 2020.

### *3.6.4 Comparative costs and benefits of various alternatives*

In terms of comparative costs and benefits between various alternative farming systems and varieties, table 3.7 highlights what could be ascertained from the literature.

1. ***Comparing single and multiple crop systems:***

Organic rice cultivation often is not independently profitable, but an integrated system and addition of other crops could possibly improve the situation (Ranjith, Karunakaran and Avudainayagam, et al. 2019, CPGD-Kerala n.d., Chivenge, et al. 2020). Further, Nair et al. (2014) analysing various agricultural systems in Kuttanad, Kerala found that rotational production of organic rice and organic freshwater prawn contributes 20% more net revenue in comparison to conventional rice and conventional prawn production (Nair, et al. 2014, Ranjith, Karunakaran and Avudainayagam, et al. 2019).

Moving from shrimp to integrated rice-shrimp farming could result in reduced chemical fertilizer use and reduction in risk for disease outbreak for shrimp by 30% in comparison to mono-cropping shrimp (CPGD-Kerala n.d.).

There could also be economic benefits from moving from cultivating only Pokkali paddy to an integrated Pokkali- crustacean system. For example, Ranjith et al. (2018) undertook partial budgeting analysis to compare the incremental/reduced costs and benefits between only Pokkali paddy cultivation and the Pokkali-prawn system for North Paravur, Kanayannur and Kochi Taluks (Ernakulam district) for the year 2016. Comparing the Pokkali-prawn system against only Pokkali rice cultivation suggests added costs of prawn seeds and additional labour (amounting to Rs. 43,000/ha) and added return of Rs. 4,18,000/ha from both prawn and manurial by-product value. The net additional return is positive (Rs. 3,75,000/ha). This, coupled with the fact that Pokkali rice cultivation alone is a loss-making activity in many instances suggests an economic benefit to adding Pokkali rice and prawn cultivation (Ranjith, et al 2018).

Similarly, comparing incremental costs and benefits between semi-intensive prawn production and an integrated Pokkali-prawn system seems to point towards the latter. Ranjith et al. (2018) comparing cost and benefit estimates from North Paravur, Kanayannur, Kochi Taluks in Ernakulam district (for Pokkali-prawn cultivation) and Aluva and Cherthala Taluks in Ernakulam and Alappuzha districts (for prawn cultivation) in 2016 found merit in moving to the integrated system. Semi-intensive prawn cultivation was characterised by high initial investment, is capital intensive and requires more decisions and control on farm preparation, location, density of stocking, fertilization, feeding, seeds etc in comparison to more extensive farming systems (Ranjith et al., 2018). Comparing the semi-intensive prawn system and the Pokkali-prawn system (extensive) suggests added seed and labour costs of Rs. 1,05,000/ha and added Pokkali yield of Rs. 65,000/ha in moving from the semi-intensive system. On the other hand, the reduced costs of moving from the semi-intensive system are many- reduced costs of pond aeration, lime application, prawn feed, organic fertilizer (Rs.1,39,000/ha), and the reduced returns are of only Rs.6,000/ha that is attributable to reduction in prawn yield. The net result of this is that the Pokkali-prawn system has a net gain of Rs. 93,000/ha over semi-intensive prawn production (Ranjith et al., 2018).

Comparing more broadly between extensive, improved extensive and semi-intensive systems of shrimp cultivation in some Indian states in 2006-07 by Sathiadhas et al. (2009) suggests that operating costs and capital investment are lesser for improved extensive shrimp farming in comparison to semi-intensive. Extensive shrimp farming is said to be characterised by high feed and labour costs, with suggestions that production can be increased with better management of feeds (Sathiadhas, Najmudeen and Prathap 2009). This could possibly be interpreted as a point for an integrated Pokkali rice-fish/crustacean system since the feed costs for prawns are maybe lower in this system due to the use of paddy residue as feed.

Table 3.7:Costs and benefits of transitioning from one crop to multiple crops

<table>
<tr><td>Transition from one crop (down)/ to multiple crops (across)</td><td>Rotational organic/ Pokkali rice and organic freshwater prawn</td><td>Integrated conventional rice-fish/crustacean farming</td></tr>
<tr><td>Conventional rice production</td><td rowspan="2">-Rotational organic rice + organic freshwater prawn contributes 20% more net revenue than conventional rice, conventional prawn production<br><br>-Semi-intensive prawn cultivation to Pokkali-prawn system (extensive)<br>Additional costs (seed and labour)- Rs. 1,05,000/ha<br>Incremental return (Pokkali rice) - Rs. 65,000/ha<br>Reduced costs (pond aeration, lime application, prawn feed, organic fertilizer)- Rs.1,39,000/ha<br>Reduced returns (loss of additional prawn production)- Rs.6,000/ha<br>Net return (gain)- Rs. 93,000/ha<br>(Data for year 2016)</td><td>Conventional rice to integrated rice-fish farming could potentially increase farmers' incomes</td></tr>
<tr><td>Conventional/ Semi-intensive crustacean production</td><td>Conventional shrimp to integrated rice-shrimp farming could possibly reduce use of chemical fertilizers and<br>reduce risk of disease outbreak for shrimp by 30%</td></tr>
<tr><td>Pokkali rice production</td><td>Only Pokkali paddy to Pokkali-prawn system<br>Incremental costs (prawn seeds, labour)- Rs. 43,000/ha<br>Incremental return (prawn and manure by-product) – Rs 4,18,000/ha<br>Net return (gain) - Rs. 3,75,000/ha<br>(Data for year 2016)</td><td></td></tr>
</table>

On the other hand, transitioning from integrated Pokkali-prawn farming to prawn farming could lead to reduction in nutrition and supplements that prawns obtain from the paddy residue and also increase the possibility of them getting diseases (Ranjith et al., 2019, Ranjith et al., 2018). This transition could potentially cause loss of livelihoods and also cause a reduction in yield and income in the longer term due to monoculture (Ranjith et al., 2019, Ranjith et al., 2018, Shamna and Vasantha, 2017) (Information summarized in Table 3.8). Although ecological benefits seem to exist, Shamna (2017) suggested that farmers felt that monoculture of shrimp would improve their economic condition based on a primary survey with Pokkali farmers in Ernakulam district.

Table 3.8: Costs and benefits of transitioning from multiple crops to one crop

| Transition from multiple crops (down)to /monocropping (across) | Conventional crustacean production |
|---|---|
| Integrated Pokkali rice-fish/crustacean farming | Pokkali rice+ prawn to prawn farming could<br>-*Reduces nutrition for prawn obtained from paddy residue*<br>-Could increase *possibility of diseases for prawn*<br>-*Potential loss of livelihoods*<br>-*Reduction in income and yield from prawn farming in long term* |

2. ***Comparing traditional and hybrid farming systems, traditional and High Yielding Varieties, and yield differences***

Comparing traditional rice and hybrid rice farming systems could provide some insights on the complex interplays between yield, cost components and pricing that could influence production decisions. Typically, the number of cost components is expected to be lesser for traditional farming since there is minimal usage of chemical fertilizers, and other additional inputs. On the other hand, hybrid varieties may have a yield advantage, although it is not necessarily true that all traditional varieties provide low yields. Although literature specifically on Pokkali or Pokkali-fish/crustacean farming does not seem to be available on the topic, an example from Gogoi, et al. (2020) highlights these concerns.

Gogoi, et al. (2020) compared a hybrid rice farming setup and traditional rice farming system in Assam and advised choosing hybrid farming based on their economic market assessment. Using costs of cultivation information, they found that although increased production costs caused hybrid rice cultivation costs to be higher than traditional rice cultivation by 29.43% on average, hybrids provided substantially higher yield differing by 53.08% and return over costs (2.3 HYV versus 1.66 traditional) (Data from the year 2017) (Gogoi, et al. 2020). Hybrid rice's price/quintal was lower than traditional rice (Rs.1400/quintal versus Rs. 1500/quintal traditional) (Gogoi, et al. 2020). Costs differences between the hybrid and traditional rice farming came from costs incurred for plant protection chemicals, irrigation costs, and seed costs in that order; as traditional farming is expected to use lesser/no chemical inputs (Gogoi, et al. 2020).

A further discussion on the yields could help bring more nuance to the argument. One point to note on yields of traditional varieties is that many traditional varieties are characterised by an ability to withstand various circumstances and hence could be more resilient and reliable in terms of yield in unfavourable circumstance (Krishnankutty, et al. 2021). Secondly, farming in an organic and non-organic (conventional) manner could also influence yield as a study by Nair, et al. (2014) notes based on a comparison of organic rice-organic prawn farming and conventional rice and prawn farming. They found that in the yield of organically farmed rice was 23% lesser in comparison to conventional farms, while mean yield of organically cultivated prawns registered an increase of 10% in comparison to those in conventional farms (Nair, et al. 2014).

Further, comparing the grain and straw yield from traditional paddy varieties with other paddy varieties provides some insights on further variations, although it must be noted that this need not be true of all traditional varieties. Rasheed, et al. (2021) provides this information based on primary surveys in Vythiri, Sulthan Bathery and Mananthavady taluks in Wayanad in 2020. They note a higher yield for traditional paddy varieties in comparison to other paddy varieties for grain (4,170.07 kg/ha versus 3,641.44 kg/ha), but a lower yield for straw from traditional varieties in comparison to other varieties (4,562.04 kg/ha versus 5,098.01 kg/ha) (Rasheed, et al. 2021).

Nevertheless, Krishnankutty, et al. (2021) based on primary surveys in Palakkad, Malappuram and Wayanad notes that the varieties with lower productivity have lesser chances of being chosen for cultivation.

Although quantitative cost or benefit estimates were not available for Pokkali, some insights on the yield and policy context of traditional and HYV varieties of Pokkali have been discussed below. The traditional saline tolerant varieties like (cheruvirippu, chettivirippu, pokkali) were the major ones in the early periods. Later on, Kerala Agricultural University released High Yielding Varieties (Vyttila series) with improved yield and specific attributes. The average yield of Traditional Varieties are 1-1.5T per Ha while that of HYVs yield up to 5-5.5 T per ha. (Details given in Table 3.9). The policy support in general and higher yield realization have promoted the widespread adoption of HYVs of rice in Kerala, which is reported to the tune of 96% of the area under rice farming. Analysing the conservation behavior (of traditional varieties) of farmers in Pokkali area, Devi et al (2017) reports the case of a few Small and Marginal Farmers as confining to the cultivation of Traditional Varieties (TV). High Yielding Varieties (HYVs) has a significant positive influence on the crop yield which is estimated to be to the tune of 1.38 per cent higher, at field level. However, the risks are on the higher side, as revealed by the coefficient of variation at 7.08 per cent and 6.12 per cent respectively for the state as a whole, and 45.93 per cent for Vyttila Varieties and 33.19 per cent for Traditional Pokkali varieties (Devi et al, 2017). The low risk level and taste factors prompt some of the farmers to continue the cultivation of TVs. Generally the farm saved seeds are used by farmers cultivating traditional varieties. Department of Agriculture (DoA) supplies the seeds of HYVs which are fully subsidized. This support is not extended to farmers who use farm saved seeds in the case of TVs. Thus there is the need for extending the policy support for the conservation of TVs.

Table 3.9: Rice Varieties in Pokkali

| Sl. No | Name of the Variety | Traditional/ HYV | Special Features | Average Yield* Kg/Ha |
|---|---|---|---|---|
| 1 | Vytila 1 | HYV | Derived fron chuttupokkali, Tall, Medium maturity, Lodging, long bold grains | 1500 |
| 2 | Vytila 2 | HYV | Selection from cheruviruppu, Tall, medium mature variety, long bold grains | 1750 |
| 3 | Vytila 3 | HYV | Cross between VTL -1and TN-1, Tall, Lodging, Red bold grains | 2000-2500 |
| 4 | Vytila 4 | HYV | Cross between cheruviruppu and IR 4630 - 22 - 2 - 17, Tall, lodging | 3250 |
| 5 | Vytila 5 | HYV | Derived from mutation breeding from Mashuri, Tall, lodging type, medium maturity, unique organic paddy variety, medium round white rice | 3250-4000 |
| 6 | Vytila 6 | HYV | Cross between Cheruviruppu, IR 5, Jaya, Duration 105-110 days, Dwarf, Non lodging organic rice variety | 3500-4000 |
| 7 | Vytila 7 | HYV | Cross between IR -8 and Patnay 23, 115-120 days duration, Non lodging organic rice variety | 4000-4200 |
| 8 | Vytila 8 | HYV | 115- 120days duration, Medium tall, Non lodging organic rice variety, Resi | 4100-4200 |
| 9 | Vytila 9 | HYV | Derived by mutation breeding from chetivirippu, Dwarf, Non lodging organic rice variety | 4025-4300 |
| 10 | Vytila 10 | HYV | Derived by mutation breeding from VTL-3, 115-120days maturity, Dwarf, Non lodging | 4200-4300 |
| 11 | Vytila 11 | HYV | Salt resistant, Dwarf, Non lodging | 5000-5500 |
| 12 | Pokkali | Traditional | Tall, lodging, medium maturity, salt tolerant | 1000 |
| 13 | Cheruvirippu | Traditional | Tall, lodging type | 800-1000 |

| | | | | |
|---|---|---|---|---|
| 14 | Vellapokkali | Traditional | Tall, lodging, long bold grains | 1000 |
| 15 | Choottupokkali | Traditional | Tall, lodging type, salt tolerant | 1000-1500 |

Note: *Average Yield under good management conditions

### 3. *Comparison with some of the other crops grown in the area*

Another factor that is important to consider is how integrated Pokkali-fish/crustacean farming compares to some of the other alternatives in the area. Preliminary evidence from Ranjith et al. (2018) seems to point at the Pokkali-prawn system as better option in comparison to some of the other combinations grown in the area (villages and taluks within Ernakulam and Alappuzha districts). They analysed 3 systems- Pokkali-prawn, semi-intensive prawn and non-pokkali (other crops)- cowpea system with data collected from villages in North Paravur, Kanayannur, Kochi Taluks in Ernakulam district (for Pokkali-prawn cultivation) and Aluva and Cherthala Taluks in Ernakulam and Alappuzha districts (for non-pokkali and prawn cultivation) in the year 2016 (Ranjith et al., 2018).

Comparing the costs, returns and net returns between Pokkali-prawn system, semi-intensive prawn system and non-pokkali-cowpea system pints towards Pokkali-rice prawn system as being the most profitable (Rs. 2,81,000/ha as against Rs. 69,000-1,55,000/ha). Although the costs of Pokkali-prawn system are higher than the non-Pokkali-cowpea system (Rs. 2,40,000/ha versus Rs. 1,51,000/ha), the costs of semi-intensive prawn system are substantially higher (Rs. 4,94,000/ha). In terms of gross return realised, there is a bit of difference between the Pokkali-prawn and the semi-intensive system (Rs. 5,21,000/ha versus Rs. 6,49,000/ha), but the non-Pokkali-cowpea system registers the lowest at Rs. 69,000/ha. The output input ratio is also skewed in favour of the Pokkali rice-prawn system (2.17) as against the other systems (1.31-1.46) (Ranjith et al., 2018).

## *3.7* Solutions/suggestions from literature

Based on the literature, we list some solutions and suggestions to resolve problems, constraints and to improve economic viability.

### *3.7.1 Economic and financial improvements*

Ensuring sufficient financial and economic incentives and keeping a focus on the long term benefits could encourage farmers to make the transition to organic farming (Koesling, Flaten and Lien 2008), and to farm traditional varieties.

1. **Intercropping:** One possible way to provide a financial incentive is through inter-cropping between hybrid and traditional crop varieties (Zhu, et al. 2003). These could have various benefits in terms of potentially improving yield, reducing inputs and fertilizers, reducing possibility of diseases and improving genetic diversity (Zhu, et al. 2003). An application of this approach in Yunnan province, China was suggested to have improved yields, reduced disease incidence, pesticide requirements and bring back into production certain endangered and extinct varieties (Zhu, et al. 2003).

2. **Compensation or payment for providing ecosystem services:** One way to encourage farmers to retain their agricultural lands and pursue traditional agriculture could be to provide compensation for their provisioning of ecosystem services (Rasheed, et al. 2021). In a valuation study, Rasheed, et al. (2021) conducted a primary survey with paddy farmers in Wayanad to understand the willingness of farmers to accept compensation to cultivate traditional paddy varieties and found the mean willingness to accept was US$106/ha which they stated as being lesser than what was offered by the state currently. Kerala seems to have enacted something similar through the provision of Rs. 2,000/hectare as royalty to paddy farmers, as long as land is not kept fallow or being used for other activities [6] (Manjula and Devi 2020).
3. **Agro tourism and recreational activities:** According to Yu, et al. (2018), recreational agriculture activities could include agro tourism (Ex- fee fishing, camping, bird watching), educational and scientific activities, accommodations (Ex- hotels, resorts) or exhibitions of sustainable agricultural practices (Ex-paddy-fish/shrimp/prawn/duck). It is important to highlight the historical and cultural traditions to be an attractive tourist destination (Yu, et al. 2018). Some agro tourism related interventions seem to have been initiated for Pokkali farming under a 'responsible tourism program' with the Palliyakkal Service Co-operative Bank and other partners[7], to conduct immersive walking tours, cycling, kayaking, local cuisine experiences, marketing of the rice to hotels and consumers and farming tours (Responsible Tourism n.d.) for example in

[6] The ecological significance of Kerala's move to pay royalty to paddy farmers | The News Minute
[7] Responsible Tourism | pokkali.in

Ezhikkara Grama Panchayat in Ernakulam (M. Joseph 2019, Priyadershini 2020) and in Kadamkkudy panchayats[8] (Priyadershini 2020).

In terms of locations in and around Kochi, one suggestion could be to consider Pokkali farms in Pambaayimoola, Edakkochi where traditional rice-fish rotation farming can be encouraged and additionally could potentially be developed as an agritourism site. Further details on the possibility and potential for agrotourism in the area and some suggested locations have been outlined in Appendix 3.1.

### *3.7.2 Building Infrastructure*

4. **Construction of bunds:** Broken bunds could cause various problems and increase costs and hence construction of earthen bunds along river or backwater margins and along the edges of each Pokkali field could be helpful to alleviate some of the negative impacts (CPGD-Kerala n.d.). Further, the report by CPGD-Kerala (n.d.) suggests that mangroves can be planted along the bunds to reduce costs of maintenance and to protect bunds from tidal and rainfall fluctuations, although they note that farmers preferred coconut plantations due to animal and bird pest concerns with mangroves (CPGD-Kerala n.d.).

   This intervention could help improve income and employment opportunities for farmers, provide better access to drinking water due to reduced saltwater seepage, protect and defend from sea surges and tidal fluctuations, and could also possibly reduce coastal erosion (CPGD-Kerala n.d.). The mangroves could also have some additional benefits such as improving biodiversity, provide medicines, or poultry feed (CPGD-Kerala n.d.). One important point to note is that planting mangroves also runs the risk of mangroves spreading into the fields (CPGD-Kerala n.d.).

   Costs of intervention are calculated by adding together costs of building bunds, sluice gates, farm equipment and infrastructure required, and the cost of planting of mangroves. For a 5-hectare area, the costs based on the data provided, seem to be about Rs.13,67,099.5 (Rates as of 2014/2015).

### *3.7.3 Community involved solutions*

5. **Self-help groups and cooperative banking:** Joseph (2019) outlined a case study about the Palliyakkal Service Co-operative Bank in Ezhikkara Grama Panchayat in Ernakulam which encouraged Pokkali farming in the area through many activities. One

[8] Now pitched as climate adaptive food, Kerala's heritage Pokkali rice cultivation needs support - The Hindu

such activity was to provide interest free loans for farming of Pokkali rice (M. Joseph 2019). They also set up and organised self-help groups in the area and lent them institutional support. The SHG was said to have around 130 members (M. Joseph 2019). The bank assured farmers of good prices and also ran a centre to provide the various inputs and machines required (M. Joseph 2019). They also improved on the marketing and branded the Pokkali rice for sale in the markets locally (M. Joseph 2019). They have now got support to set up a processing mill for this purpose (M. Joseph 2019).

6. **Building awareness about various channels for selling traditional varieties:** For farmers' older in age, awareness of the many channels to sell their produce (Krishnankutty, et al. 2021) could be one step towards realising better prices. Many farmers may also not be aware of the Geographical Indication tag on crops (Krishnankutty, et al. 2021). Some of the government and non-government channels for selling traditional rice varieties in Kerala were outlined by Krishnankutty, et al. (2021) using examples from Wayanad, Palakkad, and Malappuram. In Wayanad, the government channel is called Supplyco which was said to have standard rates applicable irrespective of variety, except for some unique varieties that sold at a premium (Krishnankutty, et al. 2021). In Malappuram, an additional channel noted was contract farming (Krishnankutty, et al. 2021). Alternatively, it was also possible to sell produce to millers (Krishnankutty, et al. 2021).

## 3.8 Some other operational considerations

### *3.8.1 Existing institutional support and potential synergies*

Under the NAPCC, this intervention could possibly fall under the National Mission for Sustainable Agriculture (CPGD-Kerala n.d.). Alternatively, when looking at the Kochi's LBSAP (ICLEI South Asia 2020), Goal 1.3 ("Conversion to organic farming"), Goal 1.4 ("Promotion of traditional seeds for cultivation"), Goal 1.6 ("Conservation and maintenance of paddy fields (ecosystem services and poverty alleviation") and Goal 1.7("Policy support for protection of paddy fields and promotion of agriculture") under biodiversity goals of focus area 1 (agriculture) could be relevant for this intervention.

Recently, Special Agricultural Zones seem to have been setup for Pokkali (Department of Fisheries Kerala n.d.). Awareness of many measures with farmers seems to be a concern, since

Krishnankutty, et al. (2021) based on a primary survey amongst traditional rice farmers opined that many farmers are not aware of the legal status like on the GI tag of crops.

### *3.8.2 Risk assessment*

Based on information from a risk assessment for integrated Pokkali rice-fish/crustacean farming conducted by CPGD-Kerala (n.d.), some possible risks, their rating and some potential mitigation measures have been discussed.

The risks they discussed include- unavailability of markets for selling output, high salinity levels affecting rice cultivation, low rainfall, rainfall causing infrastructural damage, unexpected jump in seed prices, community buy-in to the intervention being low and viral shrimp diseases (CPGD-Kerala n.d.).

While most of the other risks mentioned above were ranked ‘low’ risk, they found only the risk of price fluctuations for seeds and shrimp diseases to be a ‘medium risk’ concern. For the risk of price fluctuations for seeds the mitigation measure outlined was to use previous harvests' paddy seeds, while for the risk of shrimp diseases the mitigation measure suggested was to use seeds that were PCR tested and quality assured (CPGD-Kerala n.d.).

## 3.9 Some possible literature gaps

- **Requirement for comprehensive cost schedules:** Economics of Pokkali and Pokkali-fish/crustacean cultivation as given in the literature predominantly seems to take into account only operational costs like seeds, wages, fertilizers etc but not the other types of costs like on land, depreciation etc. Some studies discussing various traditional varieties and organic farming do have more comprehensive estimates (For example- study by Krishnankutty et al. (2021) looking at the economics of traditional rice cultivation in Kerala calculates a list of costs (A1, A2, B1, B2, C1, C2, C3) using CACP method), but this type of analysis has not been observed in the literature collected for Pokkali and Pokkali-fish/crustacean cultivation. It was also observed that the inclusion and exclusion of some categories of costs could change the profitability of the crop, and hence a comprehensive cost schedule could be a very important aspect.
- **Non-marketed costs and benefits and Lack of economic valuation studies for the study context:** Within the literature in English, studies valuing marketed goods from the ecosystem and the private costs and benefits associated (i.e.-production costs of Pokkali-fish farming; revenue from sale etc.,) are relatively available. Studies that qualitatively discuss the various economic, ecological and social benefits of Pokkali-

fish farming are also available. In terms of valuing non-marketed goods and services from the ecosystem and the social costs and benefits, quantitative Information on non-marketed costs and benefits seems to very scarce for both traditional rice and Pokkali ecosystems, and an understanding of these values could provide a more comprehensive picture and help in comparison. Valuation could also help in further setting up arguments for why and where investments could be made.

- **Computing funding requirements:** The costs provided in the literature for Pokkali and Pokkali-fish/crustacean cultivation limited to comparison of operational requirements, while in order to compute funding requirements, additional costs may need to be taken into account to get the full picture. Other costs could include building capacity of farmers, of infrastructure etc), and project management costs (coordination, monitoring etc) (CPGD-Kerala n.d.). Building the capacity of farmers could include aspects like awareness programmes, training on farming processes, while capacity building for infrastructure includes maintenance costs (CPGD-Kerala n.d.).
- **Temporal studies:** Studies that track the economics of traditional agricultural systems over longer periods (for example- integrated Pokkali rice-fish systems) could not be identified. Comparing these studies with the long-term effects of other systems like monoculture could help in understanding the longer-term economic viability of pursuing Pokkali cultivation.

***Key takeaways:***

Some trends that seem to emerge from the literature are-

- Cultivation of Pokkali rice could help in moving towards climate resilient agriculture
- Area under Pokkali farming has been on the decline and some of the major drivers of for decline and degradation have been land use conversion of Pokkali-fish farms for developmental or other agricultural purposes and due to construction of barriers and regulators for preventing tidal variations and saline intrusion
- Many problems and constraints exist in pursuing Pokkali-fish/crustacean farming: Lack of infrastructure (Broken bunds, transportation and supply chain issues, perishability of prawn, infrastructural mismanagement), input related problems (Shortage of labour, high labour costs, low labour productivity, difficulties in mechanisation), natural environment related problems (shortage or absence of rainfall, animal attacks, deteriorating soil and water quality, lodging of rice, pollution in Pokkali fields), output related problems (no price premium, poor quality of Pokkali rice, payment delays, price fluctuations, low yield, milling), Conflict between Pokkali paddy and fish farmers and long term problems (disinterest of youth). The problem that has been mentioned in the maximum number of literature has been the labour related problem, specifically on labour shortages
- Pokkali ecosystems provide many ecosystem services, of which those that have been identified in the literature include- provisioning (food and nutrients, medicine, fodder, genetic material), regulating (flood mitigation and control, pest and disease control, carbon storage and sequestration), cultural (local knowledge and education) and supporting (nitrogen fixation, soil fertility, biodiversity habitat and maintenance). In comparison to conventional paddy ecosystems, Pokkali ecosystems also potentially have reduced ecosystem disservices due to GHG emissions and health costs although much literature could not be identified
- Purely from the financial and economics angles, sole cultivation of many traditional varieties, including Pokkali rice seems to be a loss-making affair. Inclusion of prawn/shrimp and pursuing a rotational integrated system seems to be profitable.
- Pokkali farming and integrated farming of rice-fish/crustaceans seems to have a lot of potential ecological and social benefits and are also economically preferable when compared with some of the other alternative farming options in the area. Further, transitioning from production of one crop (conventional rice, Pokkali rice, conventional prawn) to integrated systems could have economic and ecological benefits.
- Paddy ecosystem services in Kerala have substantial values, and some traditional paddy varieties provide higher values of provisioning services (food and nutrition) in comparison to other paddy varieties, although it is unclear how much this would be applicable for the particular traditional variety of Pokkali.
- Discussion of yields, cost components and prices are very important as part of understanding production decisions and choice of traditional varieties. All traditional varieties are not similar in terms of yields.

***Key takeaways:***

- Some suggestions as listed in the literature to resolve problems, constraints and to improve economic viability include inter-cropping, compensation or payment for providing ecosystem services, agro-tourism and recreational activities, construction of bunds, community involved solutions like SHGs and cooperative banks and building awareness on various channels to sell produce.
- Some agro tourism related interventions seem to have been initiated for Pokkali farming under a 'responsible tourism program' with the Palliyakkal Service Co-operative Bank and other partners to conduct immersive walking tours, cycling, kayaking, local cuisine experiences, marketing of the rice to hotels and consumers and farming tours for example in Ezhikkara Grama Panchayat in Ernakulam and in Kadamkkudy panchayats. In terms of locations in and around Kochi, one suggestion could be to consider Pokkali farms in Pambaayimoola, Edakkochi where traditional rice-fish rotation farming can be encouraged and additionally could potentially be developed as an agritourism site.

# 4 CHAPTER 4 – FINDINGS FROM THE ANALYSIS OF FIELD SURVEY DATA ON POKKALI RICE AND FISH FARMING

This chapter presents the findings form the analysis of the quantitative and qualitative data gathered through the field surveys that were conducted with both Pokkali rice and fish/ shrimp farmers. Section 4.1 discusses some details related to the sampling. Section 4.2 discusses insights from Pokkali farming and Section 4.3 discusses insights from fish and shrimp farming.

## 4.1 Details on data collection

### *4.1.1 Sampling*

For Pokkali farming, information was collected from various panchayats such as Kuzhupilly, Edavanakkad, Nayarambalam, Pallipuram, Njarackal, Cheranelloor, Kadamakkudy, Varapuzha, while for fish/shrimp cultivation information was collected from Nayarambalam¸ Edavanakkad and Njarackal panchayats. Convenience sampling method was used to identify respondent farmer owing to the COVID-19 pandemic and resultant movement restrictions. Table 4.1 and Table 4.2 furnishes the list of panchayats and the locations from which the respondents were selected for the study. Telephonic, personal interviews were used to conduct the interviews. A total of 87 responses were obtained from Pokkali rice farmers, while 31 responses were collected from fish/shrimp farmers.

Table 4.1: Locations of respondent farms - Pokkali rice farming

| Sl. No | Panchayat | Locations surveyed under the specific panchayat | Total number of farmers surveyed |
|---|---|---|---|
| 1 | Kuzhupilly | Kuzhupilly beach road,Pallathamkulamkara, | 05 |
| 2 | Edavanakkad | Pazhangad,Aniyal,Vachakkal, Illathupadi | 26 |
| 3 | Nayarambalam | Nedungad, Nayarambalam | 04 |
| 4 | Pallipuram | West of convent junction,Karuthala,cherayi | 06 |
| 5 | Njarackal | Manjanakkad ,valiyavattom side | 09 |
| 6 | Cheranelloor | Cheranelloor | 03 |
| 7 | Kadamakkudy | Moolampilly,Pizhala,Valiya kadamakkudy, Kadamakkudy, | 10 |
| 8 | Varapuzha | Devasompadam, | 27 |

Table 4.2: Locations of respondent farms: Pokkali-fish farming

| Sl. No | Panchayat | Locations surveyed under the specific panchayat | Total number of farmers surveyed |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | Nayarambalam | Aniyal, Nedungad,Beach road,Mangalya west | 12 |
| 2 | Edavanakkad | Pazhangad,Illathupadi,Vachakkal | 14 |
| 3 | Njarackal | Hospital jn -East,Manjanakkad | 03 |

### *4.1.2 Approaches and methods used in data collection*

Various approaches and concepts were used when collecting information on the different variables. The questionnaire used has been reproduced in Appendix 4.1.

For inputs, the actual quantity of seed used for the sowing was gathered from the respondent and the cost of seed was imputed as the actual cost at which it was purchased by the farmer and the same was imputed in the case of farm saved seeds. The employment of men and women labour for various operations were noted and the prevailing wage rate for the respective operation and gender was imputed. Whenever there were family labour use, the existing wage rate for the specific farm operation was imputed. The costs calculations were made based on the concept of paid out costs by the farmers.

The harvested output was valued at the prevailing price at which the farmer sold (not including the portion taken for own consumption/use). The net income thus, is the actual amount received by the farmer.

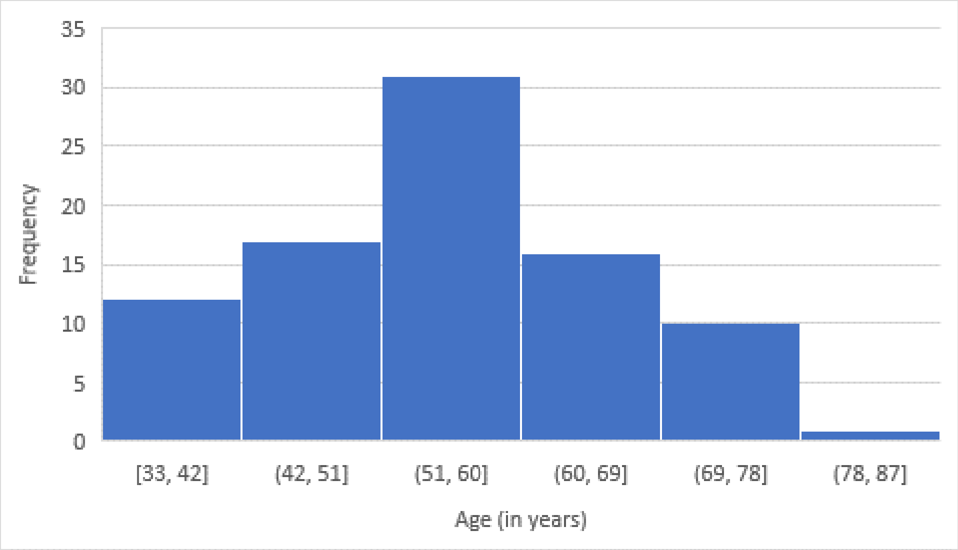
Respondents were also asked questions on the problems from Pokkali rice, fish or shrimp farming. To obtain a listing of the potential problems a literature survey and some informal discussions with farmers and officials of agricultural departments were conducted.

## 4.2 Data analysis- Pokkali rice farming

### *4.2.1 Socio-economic information of respondents- Pokkali rice farming*

*Age:* From the data and Figure 4.1, there seems to be a trend of older farmers being involved in traditional agriculture, with most Pokkali farmers being above 51 years of age. Out of a total of 87 respondents, a substantial number of respondents (67%) were between above 51 years of age, with the average age being 56. The youngest respondent was 33 years old. In Kerala, the farming is done mainly by aged farmers.

Figure 4.1: Age of respondents (Frequency)




*Occupation and Income:* Income from both agriculture and non-agricultural occupations for most respondents fall within the less than Rs. 50,000 range. Most respondents (98%) also worked part-time as Pokkali farmers (Figure 4.2), with income from agriculture for most (96%) below Rs. 50,000 (Figure 4.3- Panel A). Income from non-agriculture for most (81%) was also below Rs. 50,000 while around 19% of the respondents earned in the range of Rs. 50,000 to Rs. 2 lakh (Figure 4.3- Panel B). Non agriculture occupations included a wide range of occupations in the government/public and private sector.

Comparing the mix of agricultural income and non-agricultural income for each respondent suggests that the income from agriculture and non-agriculture for most respondents (84%) fall in the same range (below 50,000), while another 16% of the respondents have agricultural incomes less than non-agricultural incomes. (A snapshot comparing agricultural income against non-agricultural income for some respondents has been given in Figure 4.3- Panel C). It is important to note that previous evidence from literature indicates that in general, farmers underreport income and over report expenditure with the expectation that they will get more government support.

Figure 4.2: Occupation- Part time or full time

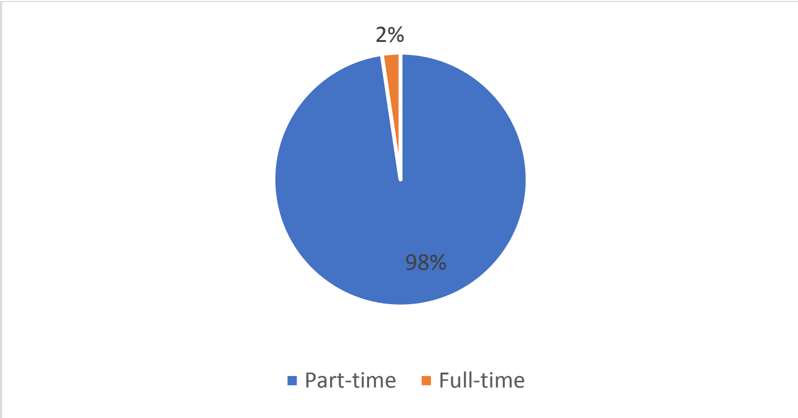
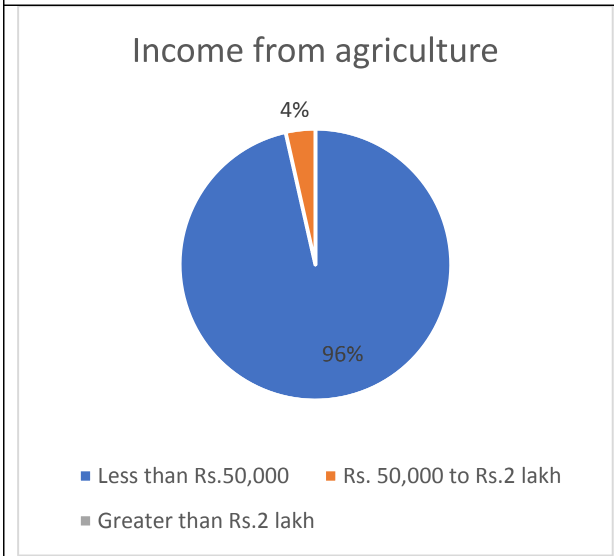
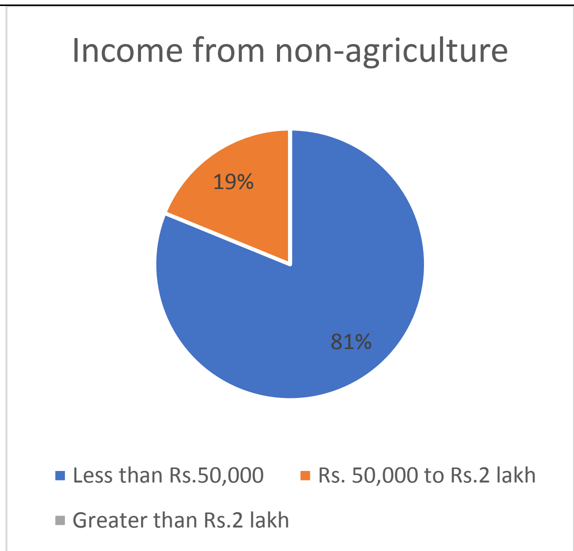
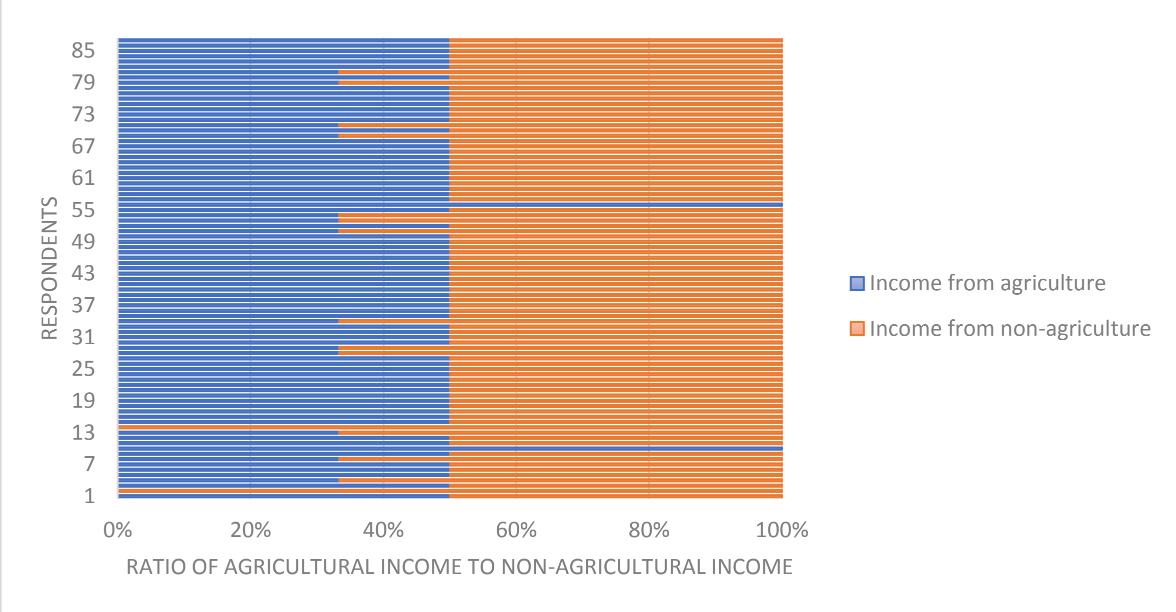



Figure 4.3: Income from various sources (agriculture, non-agriculture)

| Panel A: Income from agriculture | Panel B: Income from non-agriculture |
|---|---|
|   |   |
| Panel C: Comparing income from agriculture and non-agriculture (Snapshot) | |




### *4.2.2 Economics of Pokkali rice farming*

1. Seeds and varieties:

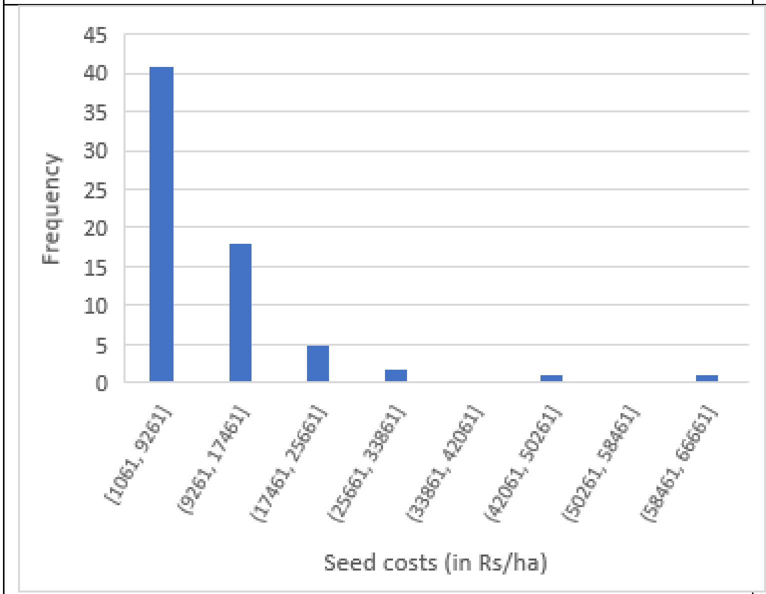
The scientific recommendation of seed rate in Pokkali system is 80-100 kg/ha. However, the farmer practice generally is not as per the recommendation, and is found to be at 130 kg per ha with average price of Rs.77/kg.

There is a wide range of seed costs reported between Rs. 1061/ ha to Rs. 64286/ha, although most respondents (87%) report costs between Rs. 1061/ ha - Rs.17461/ha (Figure 4.4, Panel A). A few respondents (20%) also reported getting their seeds free from Krishi Bhavan (Figure 4.4, Panel B). Seeds are supplied by Department of Agriculture, which are HYVs, and are fully subsidised.

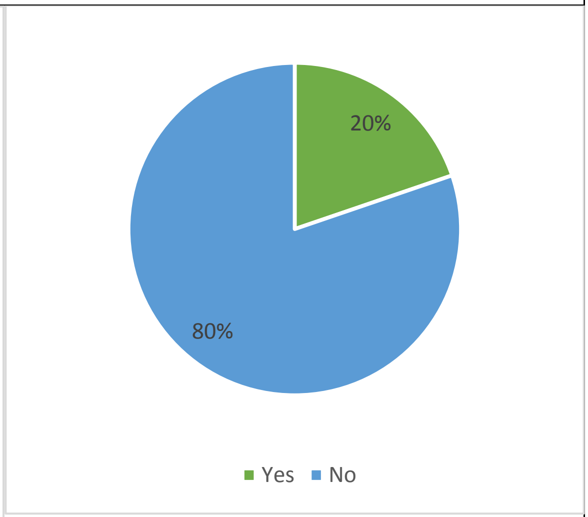
In terms of the varieties cultivated, most respondents (79%) reported cultivating traditional varieties (pokkali, vellapokkali, virippu, Cherunellu), while around 16% reported that they were cultivating HYV varieties (Vytilla varieties, Ezhom). Ezhome is a variety recommended for the saline tracts of Northern area (Kannur) and is not formally recommended for Pokkali tract. A few respondents mentioned both (5%) (Figure 4.4, Panel C).

Figure 4.4: Seed costs and varieties cultivated

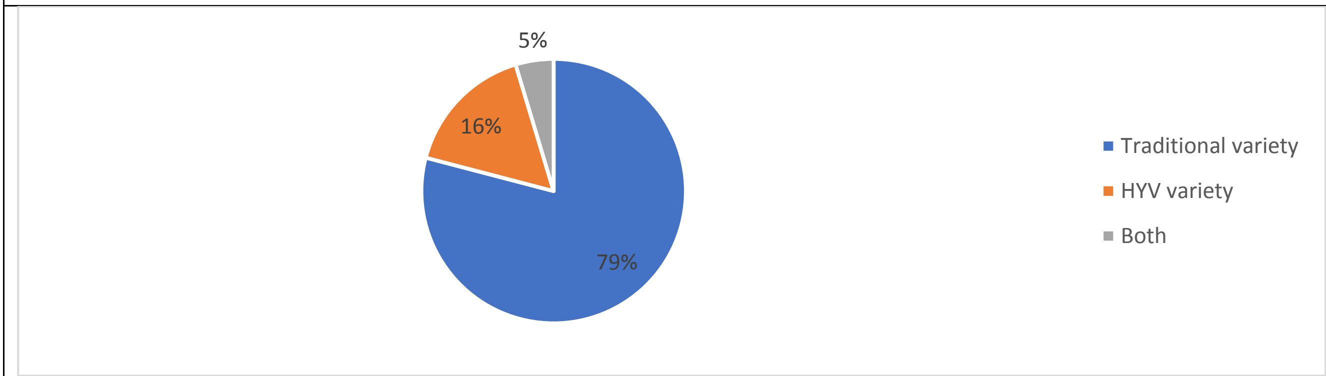
Panel A: Frequency distribution of respondents incurring seed costs (Rs.per hectare)




Panel B: Proportion of Respondents who got seeds for free from Krishi Bhavan




Panel C: Varieties cultivated




2. Labour Use:

Pokkali rice farming employs only human labour, as mechanisation efforts are not successful. Going by the existing male wage rates and working hours, the person days required for cultivating one hectare is estimated at 103.68, which comprises of 49.7 male workers and 53.98 female workers per ha.

Average wage rate for men (Rs. 864.94/day) are almost twice that of women (Rs. 431.72/day). Conventionally, in paddy cultivation more strenuous operations like land preparation, construction of bunds etc are undertaken by men, while operations like weeding, harvesting and post-harvest operations are done by women.

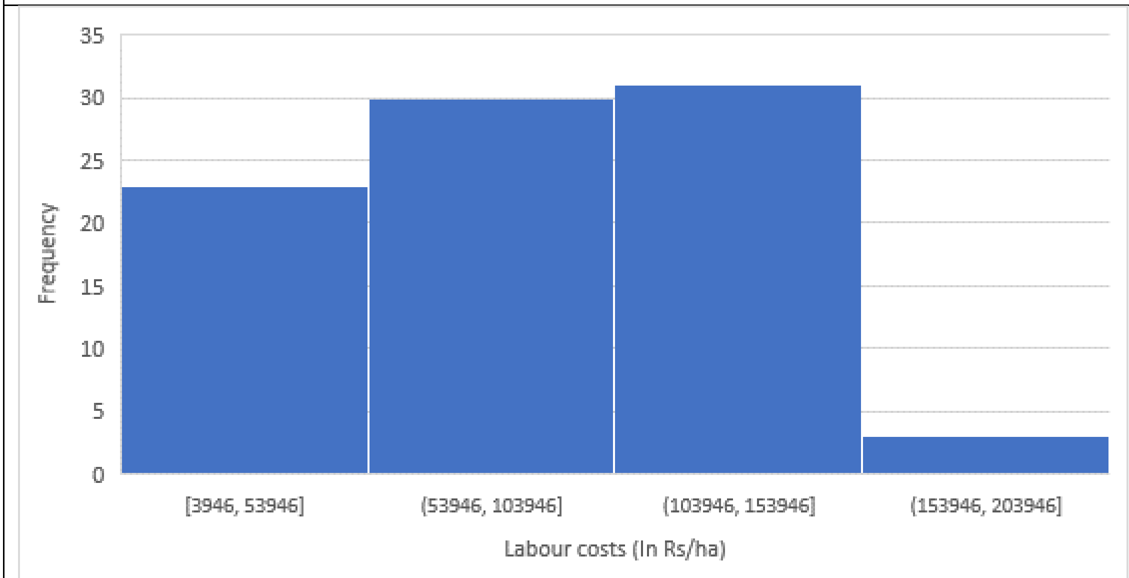
The average labour required for each process varies (as given in chapter appendix 4.2 with summary statistics), with maximum number of labourers required (on average) during land preparation and harvesting. Water management operations which involve sluice management as per the tidal flow is an important operation which is mainly entrusted with men ,on contractual basis for four months .

On average, per hectare labour costs were reported by most respondents (70%) to be in the range of Rs. 53946/ha to Rs. 153946/ha, followed by around 26% of respondents reporting per hectare labour costs in the range of Rs. 3946/Ha to Rs. 53946/ha per hectare. (Figure 4.5-Panel A).

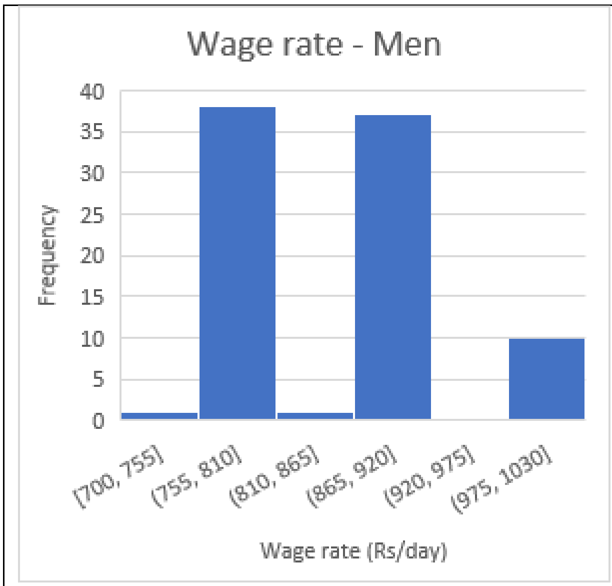
Most respondents (86%) reported wage rates for men between Rs.755-Rs.810/day and Rs. 865-Rs.920/day for men (Figure 4.5-Panel B) and 60% reported between Rs. 428- 467/day for women (Figure 4.5-Panel C). In their respective ranges, more men's wages (11%) were reported to be in the highest bracket (Rs. 975-Rs.1030/day), while only 1% of women's wage rates was reported in the highest bracket of Rs. 584-623/day.

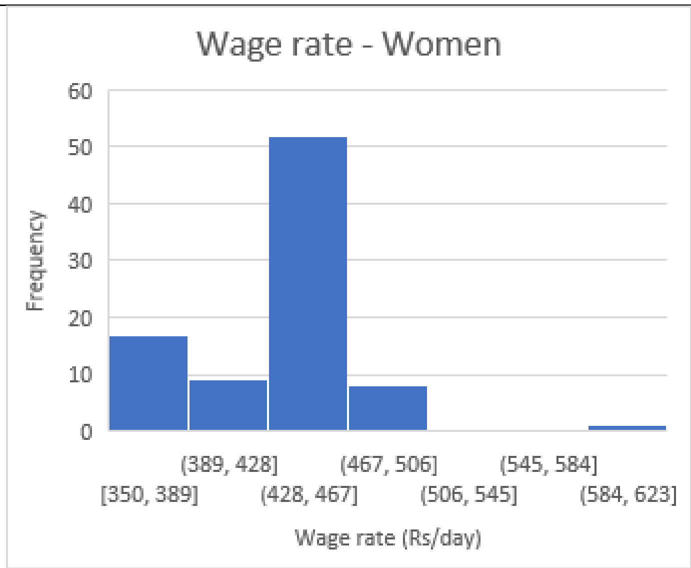
Figure 4.5: Labour details

Panel A: Labour costs per hectare




| Panel B: Wage rates- Men | Panel C: Wage rates - Women |
|---|---|

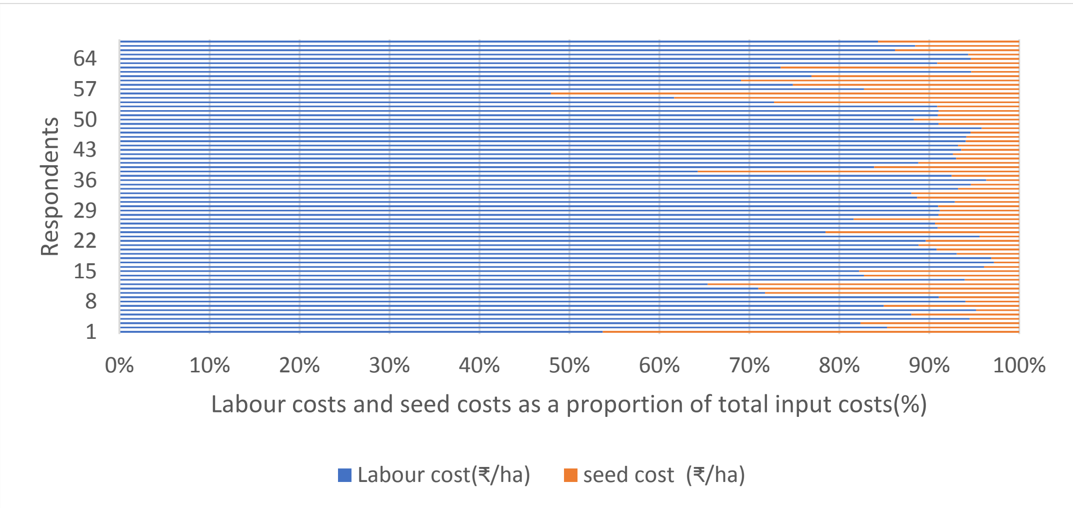



3. Total cost of cultivation

The average cost of cultivation of one hectare of pokkali rice amounts to Rs.76327/ ha. Labour cost alone accounts for 87% of the total costs and the rest accounted for seed. As already mentioned the pokali cultivation is organic by default and no chemicals are applied. Input costs (seed + labour) per ha range widely between Rs. 8232/ha and Rs. 185714/ha. A snapshot of the comparison of the seed costs and labour costs as a proportion of total input costs has been given in Figure 4.6.

Figure 4.6: Comparing contribution of seed and labour costs per hectare to input costs per hectare (Snapshot)



4. Output, returns and income from Pokkali farming:

Though the average potential yield of pokkali varieties commonly cultivated are above one tonne per hectare , the reported yield by the respondents in this study averages to a low 345 kg per ha. The average quantity of output also shows some differences depending on the variety. The average output of traditional varieties was 233.46 kg per ha ,which was lower than that of HYV varieties ( 2487.5kg per ha ).

This low realised yield may be due to poor management, lack of availability of labour on time (which got further worsened during COVID situation) and lack of adoption of HYVs. The harvested produce is mainly stored as seeds, and the remaining taken for home consumption or sold. Around 27% of the harvested produce is sold and 58% is retained as seed, while 12% is used for own consumption and 1% given as wages (Figure 4.7).

The price received for the produce sold ranges from Rs. 30- Rs.100/kg with an average price of Rs. 56.09/kg. Most respondents (91%) report prices on the lower end, between Rs. 30-70/kg (Figure 4.8).

Table 4.3 contains details on the economics of Pokkali rice farming.

Figure 4.7: Quantity of output per hectare, taken for seed (farm-saved seeds), wages, sold and for own consumption

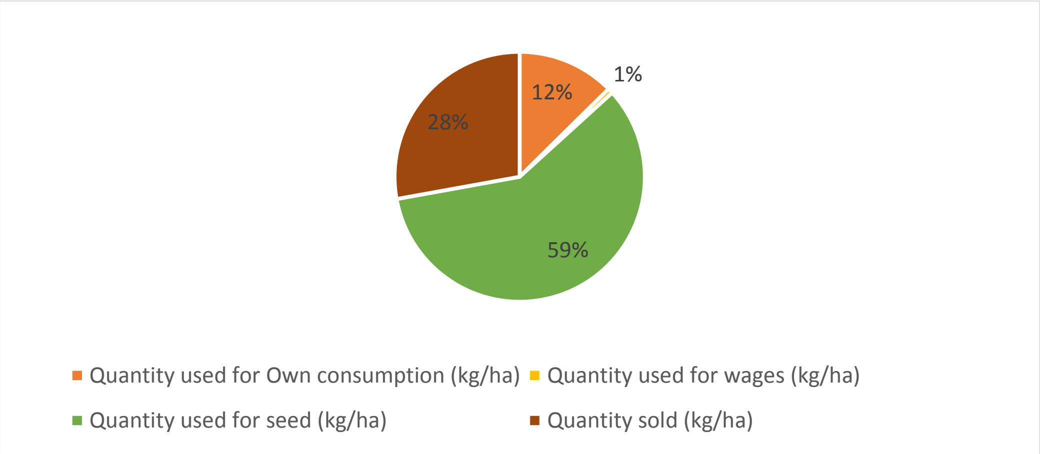



Figure 4.8: Price received for produce sold

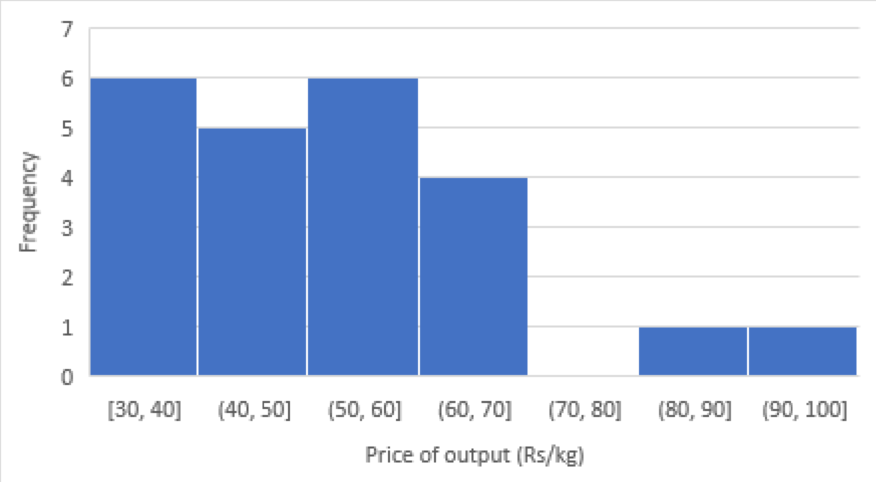



Table 4.3: Cost and returns from Pokkali rice farming (Rs/ha)

| Sl.no | Inputs/ Operations | Quantity of input (kg/ha) | | Value (Rs/ha) |
|---|---|---|---|---|
| 1 | Seeds | 130 | | 10010 |
| 2 | Labour | Men (mandays) (nos/ha) | Women (womendays) (nos/ha) | Value (Rs/ha) |
| | Strengthening outer bunds and fixing sluices | 32.36 | | 27989 |
| | Sowing | | 8.87 | 3829 |
| | Transplanting | | 14.25 | 6152 |
| | Intercultural operations (weeding) | | 1.8 | 777 |
| | Water management | 17.34 | | 15000 |
| | Harvesting | | 27.54 | 11890 |
| | Threshing and postharvest management | | 1.52 | 656 |
| 3 | Total labour cost | 49.7 | 53.98 | 66292 |
| 4 | Total input costs | | | 76303 |
| | Output | Yield (kg/ha) | Price (Rs/kg) | Value (Rs/ha) |
| 5 | Total Returns | 345 | 56.09 | 19351 |
| | **Net Returns (with other adjustments)** | | | **-45180** |

The returns realized for the produce is only Rs.19351 per ha, thus incurring a loss of Rs. 45180. The results confirm the earlier reports by Vijesh et al, 2001 and Renjith et al,2019 wherein the net income was found to be negative. The high negative net income reported by the respondents ,may be partly attributed to the COVID situation . Apart from the persistent decline in paddy cultivation in Pokkali ecosystem, there is a growing tendency among the farmers to initiate the cultivation and then leave the field unattended or with limited management . This is to comply with the legal directives to ensure permission for fisheries crop. These farmers also enjoy the subsidy support from department of Agriculture. There are some informal reports of the harvested area only as 50% and 28.4 % of cultivated area, in 2017 and 2018 respectively. The major constraints reported by the respondents are:

- Climate Changes impacts affect the traditional cycle of cultivation to a very high extent and many farmers end up in loses
- Pokkali paddy seeds availability is a major constraint for farmers in Njarackal, Nayarambalam, Edavanakkad and Kuzhupilly regions
- High Yielding pokkali varieties find it very hard to strive through harsh weather conditions (easily rotten under submerged conditions) unlike traditional pokkali varieties
- There are reports of conflict between paddy and fish farming resulting in loss of the paddy crop
- The loss due to attack of birds (Neelakkozhi in local parlance) is reported as a major problem. The existing recommendations for control is ineffective. The management of this bird is constrained by its status as a protected species
- Some farmers had sighted the inadequacy of motorable roads that make them forced to employ more labours on the day of harvesting so as to take it to threshing locations
- Many farmers realized higher yields highlighted the difficulty in marketing the produce and they also face difficulty in seed storage as they lack sufficient infrastructure
- Some fields which were cultivated over the last ten years has now turned unsuitable for farming as the water can't be drained out completely.
- Pokkali paddy farming sector is under crisis. Most of the farmers take up the crop only to retain their license for fish farming (which is a profitable deal), to be done in rotation after the paddy. As per the govt guidelines only those who take up the crop are given the license for fish farming. Most of the farmers we surveyed pointed out that its from the profit they make in fish farming that they manage to cope up with the loss they face in pokkali paddy farming. Ten years back the average yield from a pokkali paddy was around 700-800 kg per acre. Presently they could produce only for the seed reserve for the next crop season.
- Mechanisation Pokkali rice farming is rather absent. Severe shortage of labour is reported by all farmers. The efforts towards developing the machineries for rice farming in Pokkali has not been fully successful.

- The growth of tourism sector and development pressures have facilitated the conversion of pokkali lands to other purposes. Growth of aquatic plants like water hyacinth in the fallow wetlands also act as hurdle for this wetland rice cultivation.
- The spread aquatic weed, water hyacinth, has made cultivation impossible in several stretches

### *4.2.3 Farm Size Productivity and Profitability*

The farmer profile in the state of Kerala is highly skewed towards Marginal Farmers,who account for nearly 96 % . In agreement to this pattern the operated area for majority of sample farmers (47%) was below one ha followed by 40% farmers with area between 1-3 ha (including 1 and 3 ha), and 13% with area above 3 ha. The average operational holding size was 0.45 ha, 1.73 ha and 6.7 ha for the three groups respectively. Around 5% respondents report leased in area, while all respondents report cultivation in own land.

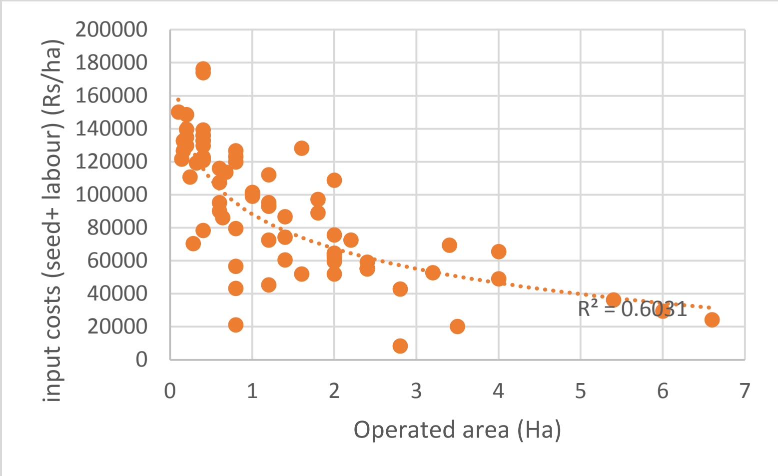
To understand the impact of operating area on possible economies of size and scale, scatterplots were drawn and correlations were estimated (Figure 4.9, Panels A to C). Overall, there seems to be some evidence towards larger operated areas being associated with lower costs/hectare, which could potentially point towards a potential economies of size argument. This is further encouraged by higher unit output (kg/ha) being associated with lower costs of cultivation . Per hectare cost values (Rs per ha) suggested a highly negative and significant correlation between costs and operated area (correlation coefficient: (-)0.71, significant at 1% (p-value: 0.00)) implying that larger operating areas were associated with unit costs. (Panel A).

Looking at the association between productivity (output per ha) and per ha costs of cultivation (Panel B) a positive significant correlation between the two could be observed (Correlation coefficient (0.39, p-value: 0.0005). This suggests that higher output quantities were associated with lower costs, per hectare.

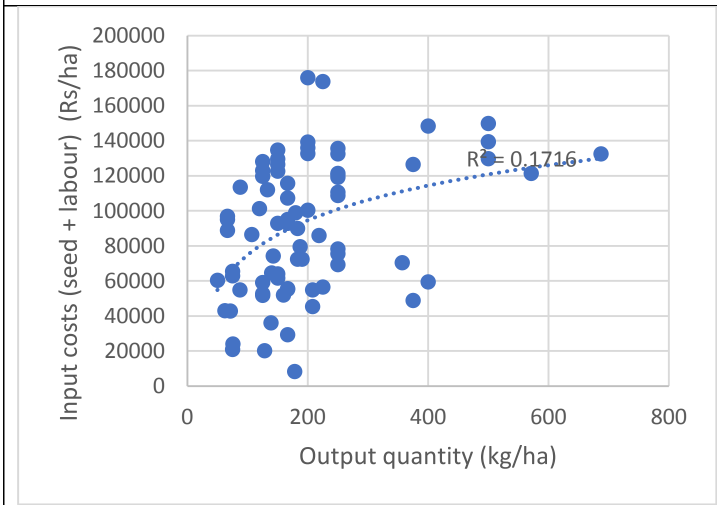
Further, looking at how per unit costs (Unit Cost of production Rs per kg of produce)) differ according to operated area (Panel C) we could observe a negative significant association (correlation coefficient: (-)0.22, significant at 10% (p-value: 0.0532)) suggesting that larger operated areas were associated with lower costs of production. Although the coefficients were significant, it is important to note that the correlation coefficients for Panel B and Panel C were on the lower side, and that most data points were concentrated on the left of the graph due to many respondents having less operated area. Hence further analyses may be required to corroborate the economies of size and scale arguments.

Figure 4.9: Relationship between operated area, costs and output

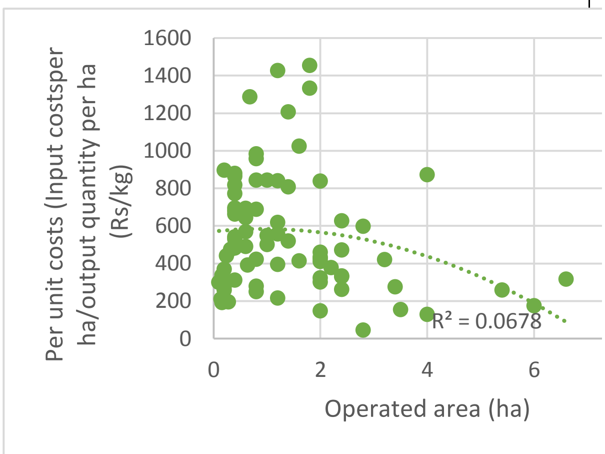
Panel A: Relationship between input costs per ha and operated area




Panel B: Relationship between output quantity per ha and input costs per ha




Panel C: Relationship between operated area and per unit costs (input costs per ha divided by output quantity per ha)




Note: Outliers identified based on Mean+/-2SD rule for all the variables of for operated area, input costs/ha, quantity of output/ha, cost/qty was removed for this graph

Examining the magnitude of these values for various sizes of operating areas (<1ha, 1-3 ha, >3 ha) suggests similar insights (Table 4.4). Comparing between these three size classifications, input costs per hectare and input costs per unit output are the lowest for farms with size greater than 3ha. The average area held by the category (>3 ha) is around 4.51 ha as against 0.45-1.78 ha in the other two categories.

Table 4.4: Summary statistics differentiated by operating area

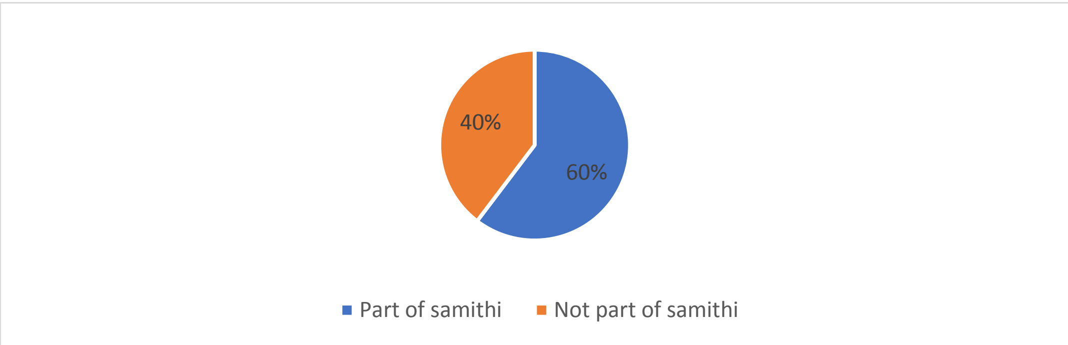
| Variable | Average | | |
|---|---|---|---|
| | Less than 1ha | More than/equal to 1 ha and less than/equal to 3 ha | Greater than 3ha |
| Number of observations | 36 | 32 | 8 |
| Operated area (ha) (Mean) | 0.45 | 1.78 | 4.51 |
| Input costs (Rs/ha) (Mean) | 115547 | 73471 | 43243 |
| Output quantity (kg/ha) (Mean) | 251.57 | 151.93 | 166.86 |
| Input cost per unit output (Rs/kg) (input costs per ha divided by output quantity per ha) (Mean) | 561 | 597 | 327 |

Note: Outliers identified based on Mean+/-2SD rule for all the variables of for operated area, input costs/ha, quantity of output/ha, cost/qty was removed for this table

### *4.2.4 Institutional support*

A majority of farmers (60%) are part of the Padashekara Samithi (Figure 4.10). Names of padashekara committees for rice farming ranged from Kuruppamthodi krishi samajam, Thamaravattam krishi samrakshaka samiti, Thollayiram, Varapuzha pokkali karashaka kshema samiti, Edavanakkad edeath, Ponmaninellulpadhaka Pdasekhara Samiti, Vdakkepadangi, Koottungaladapp padasekhara samiti, kallumadam, vadakkepallambilly, Mullarakkal kumbalathadi samajam, Punchayil padasekharam, Thekkanathuthod karshaka samajam, Kizhakke aniyan krishi samajam, Valiyavattam nel krishi samajam, Padinjare paadam cherukida karshaka samajam, Paadinjare kandam karshaka sangham, Naalpathkettu, Varapuzha padasekhara samiti, kollathalap krishi samajam, Puthanpadam krishi samajam, Thamaravattam krishi samajam, Cheriyanaalpath padasekhara samiti, Aanachanketu.

Figure 4.10: Percentage of respondents who are members/non-members of padashekara Samithi



Comparing some variables for the two categories (part/not part of the Samithi) provides some insights. Comparing the averages between those that were and were not part of the Samithi, we note that those who were part of the Samithi had an average operated area of 2.07 ha while those not part of the Samithi had around 1.59 ha. Quantity of output produced for those part of the Samithi was higher than those not part of the Samithi. (Table 4.5)

Table 4.5: Difference in some variable values between those part and not part of the Padashekara Samithi

| Variable | Mean | Mean |
|---|---|---|
| | Part of Padasekhara samiti | Not part of Padasekhara samiti |
| Number of observations | 38 | 24 |
| Operated area (Ha) | 2.07 | 1.59 |
| Number of labourers - Women(nos/ha) | 90.31 | 85.04 |
| Number of labourers - Men(nos/ha) | 49.98 | 51.26 |
| Labour cost(₹/ha) | 82966 | 77728 |
| Input costs (seed+ labour) (Rs/ha) | 92861 | 83788 |
| Quantity of output(kg/ha) | 298.01 | 137.43 |

### *4.2.5 Problems/Constraints in Pokkali farming*

Various problems in Pokkali farming were compiled together in Table 4.6 by calculating the frequency response for each problem. A majority of respondents (between 92% to 100%) stated that problems such as marketing concerns, interest rate concerns, repayment issues, loan disbursement, corruption, distance and transportation issues and problems of weeds were ‘not severe’. Problems that were classified ‘severe’ by majority of respondents (around 67% to 97% of respondents) included the adequacy of credit supply, lack of marketing facilities, problems in getting reasonable prices and lack of government support. Problems in marketing mainly correspond to cases where there is a marketing mechanism but there are constraints (for example, delayed payment, disputes with respect to quality (moisture content), milling quality, marketing costs etc), while lack of marketing facilities correspond to an absence of regular buyers, difficulties in transportation to market and so on.

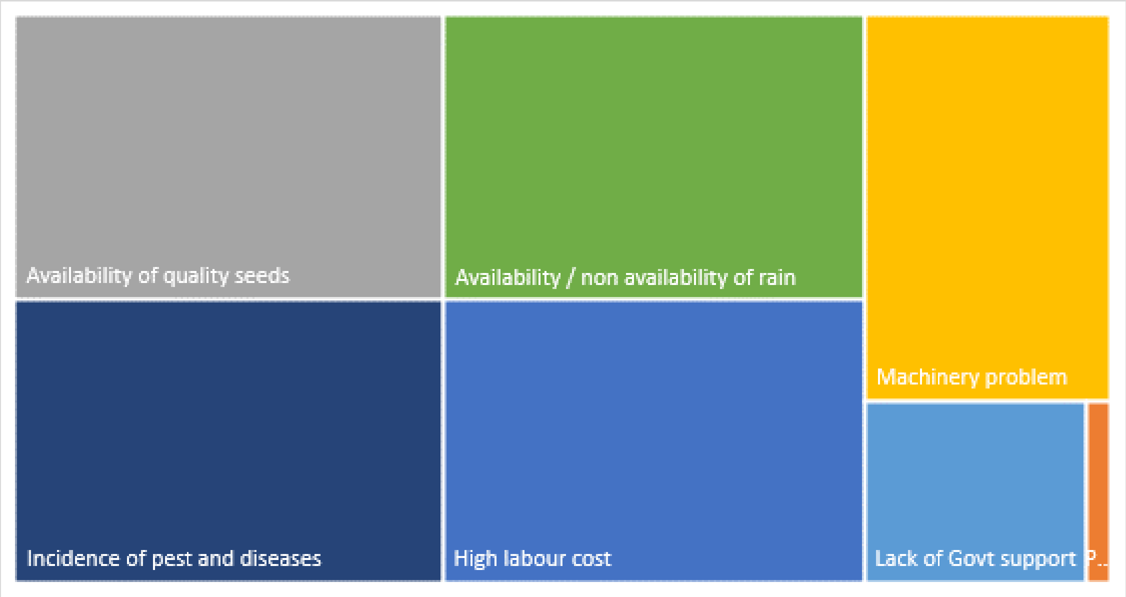
The most severe problems (categorised ‘very severe’) were availability of quality seeds, incidence of pest and diseases, presence/absence of rainfall, high labour costs and machinery problem as suggested by a large number of respondents (around 78% to 100% of respondents). The lack of support from the government and problems in getting reasonable prices were mentioned as 'very severe' problems by few respondents (33% and 3% respondents respectively) (Table 4.6, Figure 4.11).

The loss due to attack of birds (swamphen /purple moorhen) is reported as a major problem. The existing recommendations for control is ineffective. The management of this bird is constrained by its status as a protected species under the Wild Life Protection Act. The aquatic weed water hyacinth is also posing hurdles in the cultivation. Popular chemical weed control measures are not possible under the aquatic system due to ecological reasons.

Table 4.6: Various problems and rating of problems associated with Pokkali farming (Percentage of responses)

| Problems | Responses (in %) | | |
|---|---|---|---|
| | Not severe | Severe | Very severe |
| Problems in marketing | 98 | 2 | 0 |
| High labour costs | 0 | 2 | 98 |
| Credit supply sufficient (or not) | 10 | 90 | 0 |
| Interest rate | 99 | 0 | 0 |
| Repayment problem | 92 | 8 | 0 |
| Delay in disbursement of loan | 100 | 0 | 0 |
| Corruption | 100 | 0 | 0 |
| Lack of marketing facilities | 8 | 92 | 0 |
| Distance & transportation problem | 100 | 0 | 0 |
| Problem of getting reasonable prices | 0 | 97 | 3 |
| Availability of quality seeds | 0 | 0 | 100 |
| Machinery problem | 0 | 22 | 78 |
| Lack of govt support | 0 | 67 | 33 |
| Availability/non-availability of rain | 0 | 1 | 99 |
| Incidence of pest and diseases | 0 | 0 | 100 |
| Problem of weeds | 100 | 0 | 0 |

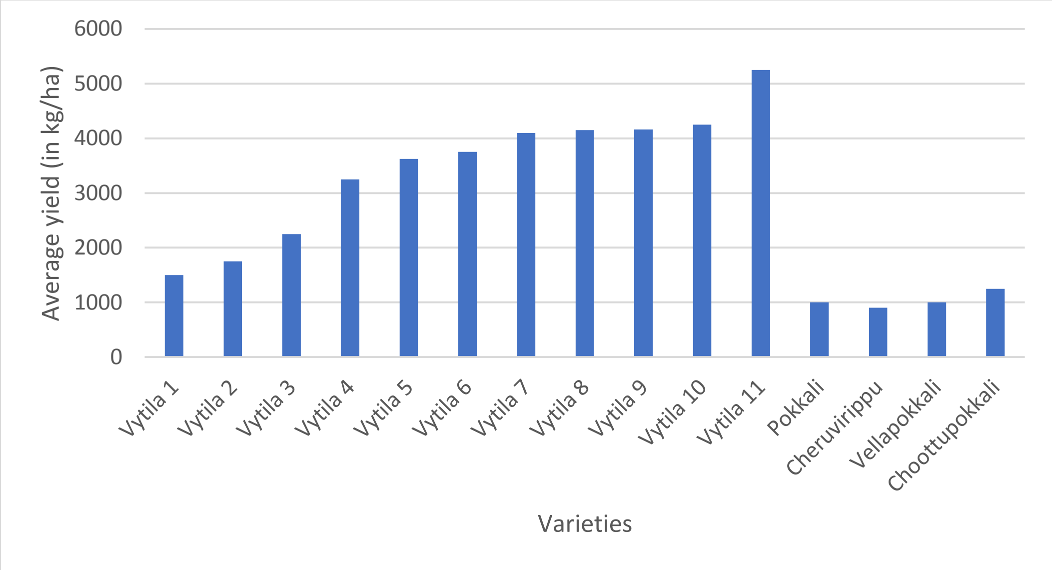
Figure 4.11: Very severe problems in Pokkali farming as mentioned by majority respondents




### *4.2.6 Improving the Productivity: Scenario Analysis*

As noted in Table 4.3, the status quo situation for Pokkali farming yields losses of Rs. (-) 45180/ha. One possible reason for this loss could be the choice of variety and lack of good management practices. In order to examine this hypothesis further, we compare the grain yield in the status quo with the potential yield from different varieties under good management conditions and analyse how that would impact the profits. Due to lack of adequate data on various varieties, an assumption is made that other costs remain constant despite a change in variety, which may not be true practically. There exist many varieties of Pokkali (traditional and HYV) with varying yields under good management conditions as outlined in as discussed in the previous chapter (Table 3.9) and reproduced in figure 4.12.

Figure 4.12: Yield of various Pokkali rice varieties under good management conditions




In the status quo situation, most respondents in the study area for Pokkali farming had mentioned cultivating traditional varieties, with a lesser percentage cultivating HYV varieties (Figure 4.4, Panel C). This status quo scenario is compared with three other scenarios- (i) monoculture scenario with only traditional varieties, (ii) monoculture scenario with only HYV varieties and (iii) diversified scenario with a mix of both traditional and HYV varieties. The yield values are obtained based on Table 3.9 in the previous chapter and figure 4.12, although some adjustments are made. Since the yields in Table 3.9 represent ideal yields under good management conditions, a potentially attainable yield is defined as 80% of the yield given. Further details on the various scenarios-

Status quo: Values as given in Table 4.3 (Yield: 345 kg/ha)

Scenario 1: Cultivation with traditional varieties.

Wherever the yield values are given in a range, the average is first obtained. Then, 80% of these yields are calculated as potentially realizable yields. To get the yield across the various traditional varieties mentioned (Pokkali, Cheruvirippu, Vellapokkali, Choottupokkali), the averages across these varieties are obtained. This value comes to 830 kg/ha.

Scenario 2: Cultivation with HYV varieties

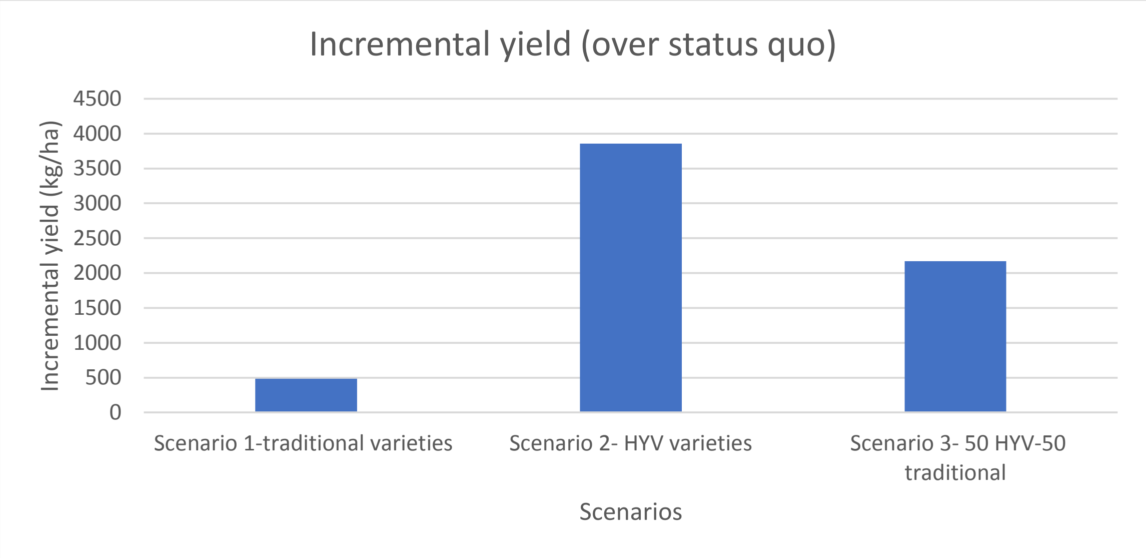
Wherever the yield values are given in a range, the average is first obtained. The most recent HYV Pokkali variety (Vytilla 11) is considered and its potentially realizable yield obtained (ie- 80% of given yield under ideal management conditions). This value comes to 4,200 kg/ha.

Scenario 3: - 50% HYV and 50% traditional

In order to calculate the yield for this diversified scenario, 50% of the yield value from scenario 1 and 50% of the yield value from scenario 2 is obtained and aggregated (ie- 50%(830)+50%(4200)). This comes to 2,515 kg/ha.

Figure 4.13 compares the yields under the various scenarios and displays the difference of the yield in the respective scenario in comparison to the status quo.

Figure 4.13: Incremental yield under various scenarios (as compared to yield under status quo)




Note: Incremental yield is calculated as the difference between yield under the respective scenario and the yield under status quo

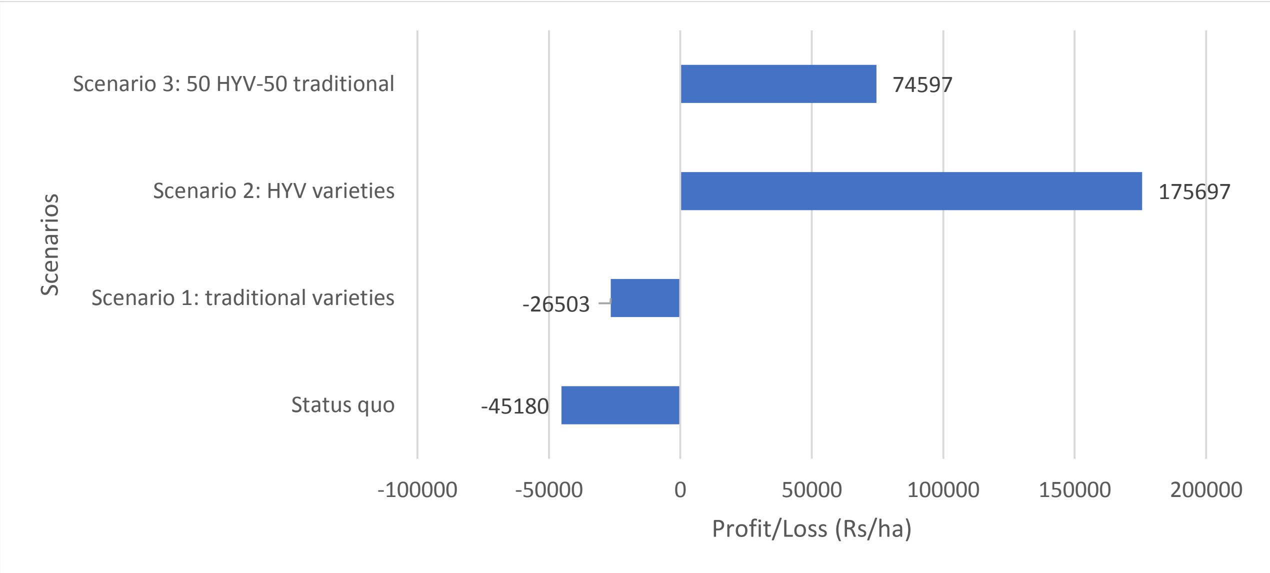
Comparing the profit values across the three scenarios (Table 4.7, Figure 4.14) suggests that scenario 2 (HYV varieties) shows the highest profits (Rs. 175697/ha) followed by scenario 3 (diversified) (Rs. 74597 ha). Scenario 1 with traditional varieties reported a loss, although the loss was lesser than in the status quo (Rs. (-)26503/ha). Calculating ratio of returns to cost also provided similar results with scenario 2 being the highest at 3.30 and scenario 1 being the lowest at 0.65 (except for the status quo which was even lower at 0.25).

The general preference for the farmers to go for traditional varieties was felt during the survey, which was mainly on account of their relatively hardy nature .There were some instances where the NGOs /registered organisations facilitated the sale of these varieties procuring at a higher price of Rs .80 per kg These organisations tapped the urban markets selling the rice as organic rice, highlighting the GI tag as well. However their operations do not cover the entire pokkali belt .

Table 4.7: Economics of Pokkali rice farming under various scenarios

| S No | Variable | Status quo | Scenario 1: traditional varieties | Scenario 2: HYV varieties | Scenario 3: 50 HYV-50 traditional |
|---|---|---|---|---|---|
| 1 | Total costs (Rs/ha) | 76303 | 76303 | 76303 | 76303 |
| 2 | Output quantity-grain (kg/ha) | 345 | 830 | 4,200 | 2,515 |
| 3 | Output- grain - price (Rs/kg) | 60 | 60 | 60 | 60 |
| 4 | Total Returns (Rs/ha)) | 19351 | 49800 | 252000 | 1,50,900 |
| 5 | Profit/loss (Rs/ha) | (-) 45180 | (-)26503 | 175697 | 74597 |
| 6 | Return cost ratio | 0.25 | 0.65 | 3.30 | 1.98 |

Figure 4.14: Profit/loss of Pokkali rice farming under various scenarios




### *4.2.7 Ensuring Agrobiodiversity in Pokkali Ecosystems–Strategies*

*For operationalizing the biodiversity conservation, it is important that locations are identified and demarcated for raising traditional and HYVs, based on locational characteristics and farmer preferences.*

*Establishing a seed scientific seed production programme (Registered Seed Growers programme) for traditional varieties:*

Genetically pure samples of traditional varieties from Pokkali areas are conserved (ex situ conservation) in National Bearau of Plant Genetic Resources, Thrissur (it is reliably learnt that 10 varieties are conserved) (Latha, 2013) furnishes the details of land races collected from across Kerala and their special characteristics) On request they supply 20 nos. of seed material which is to be multiplied. These are to availed and multiplied and distributed to the farmers. It is to be noted that only 3 traditional varieties are presently available in farmers' fields (as per our survey). Vyttila 1 and Vyttila 2 varieties released by Kerala Agricultural University, are selection from traditional varieties (choottupokkali and cheruvirippu respectively) and hence contain all the essential characteristics of the respective traditional varieties and ensure a higher yield of more than 1000 kg per ha. (1 -1.5 t/ha).

*Procurement and Marketing Support*

The procurement and marketing support is to be extended to the farmers for them to dispose the produce after harvest. Efforts to tap the organic consumer market, both domestic and export, needs to be strengthened.

*Payment for Ecosystem Services- Conservation value:*

Those farmers who are ready to cultivate traditional varieties are to be effected with a payment for conservation efforts, which is enough to compensate for the shortfall in returns. Assuming good management practices which demand a 10% higher cost leading to a yield realisation of 1000 kg per ha ,and produce price at Rs 80 per kg ,the net returns from traditional pokkali varieties can be to the tune of Rs 3933 per ha. Comparing the same with the net returns from HYVs(Rs.1,75,697),there is a short fall of Rs .171764.

The Pokkali varieties are known for its attributes of salinity tolerance and submergence tolerance. Modern research on salinity/submergence tolerance rely on these varieties ,especially in the background of climate change induced sea level rise and salinity intrusion. The Pokkali system also aids in carbon sequestration and the methane emission is also reportedly low . Assessment Devi et al 2017 reports the biodiversity value of cultivated land agroecosystems as Rs.52472 per ha (2016 prices) based on the assessments in TEEB studies. It is suggested to form an organisational mechanism (FPC/NGO/Farmer Collective) to undertake the identified activities in the selected location.

### 4.3 Data analysis- Fisheries in Pokkali Ecosystem

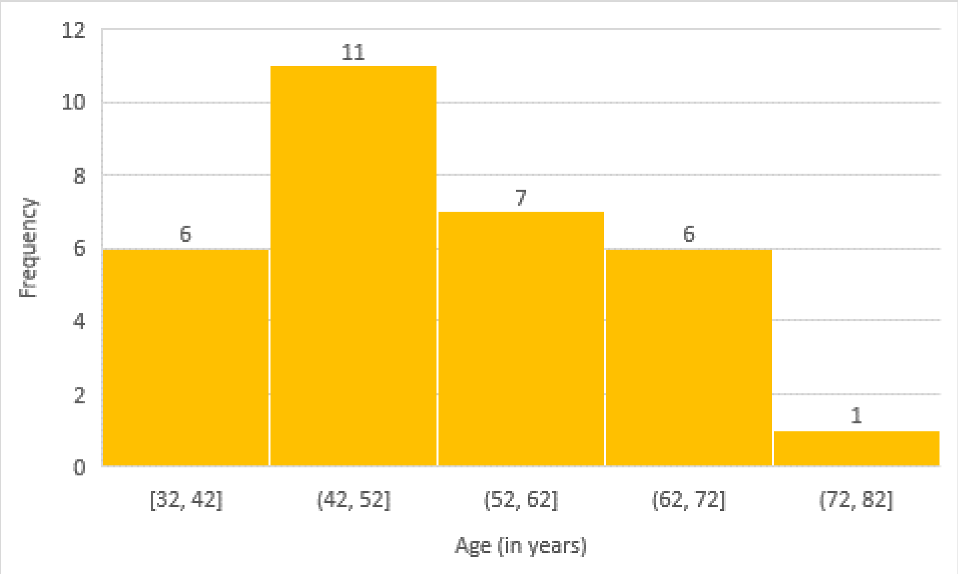
The fish farming is undertaken by individuals or group of farmers both in own lands as well as leased in lands. Even though the farming operations are initiated by the month of November usually the lease auctions start by June -July. The potential famers hold meetings to make decisions on the conditions of lease agreements, policies and lease amounts. The lease agreement is formalized specifying the tenure, amount and area under the lease. The agreement is signed by all the land owners in the padasekharam and the lessee. The agreement along with land tax has to be submitted to the fisheries office so as to avail license for fish farming (Nov 15-Apr 14). In this section we present findings on some key aspects of fish farming from our field survey.

### *4.3.1 Socio-economic information of the fish farmers*

Detailed summary statistics have been given in chapter appendix 4.3.

***Age:*** Most respondents pursuing fish and shrimp farming (58%) fall within 42-62 years of age, with the youngest being 32 years old and the oldest being 73 years old. The average age is 52.42. (Figure 4.15)

Figure 4.15: Age of respondents (Frequency)




***Occupation and income:*** Many respondents (61%) have been engaged in fish/shrimp farming full-time with the remaining (39%) working part-time (Figure 4.16), and this seems to reflect in terms of the incomes as well with 64% of the respondents reporting an income between 1 lakh to 5 lakhs from fish and shrimp farming followed by 26% who report incomes from fish and shrimp farming of greater than 5 lakhs (Figure 4.17, Panel A). Other sources of income forms only a smaller share for most respondents, with many respondents (58%) reporting income of less than 1 lakh from other sources (Figure 4.17, Panel B).

Comparing the mix of income from fish, shrimp farming and income from other sources for each respondent suggests that income from fish and shrimp farming for 94 % respondents is either greater than or in the same range (1 lakh to 5 lakh) as income from other sources. (A snapshot comparing income from fish and shrimp farming with income from other sources for some respondents has been given in Figure 4.17- Panel C).

Figure 4.16: Occupation- part time or full-time

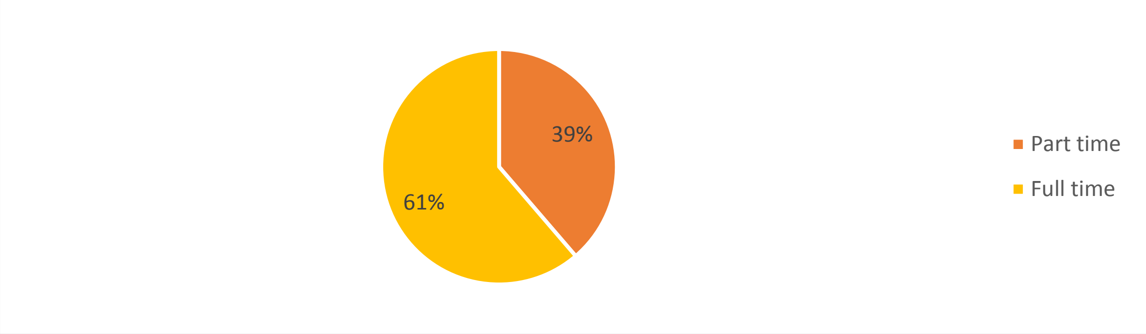
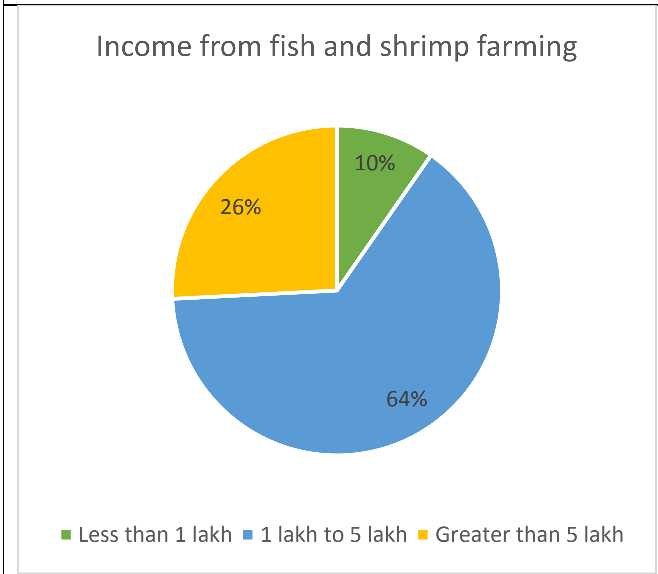
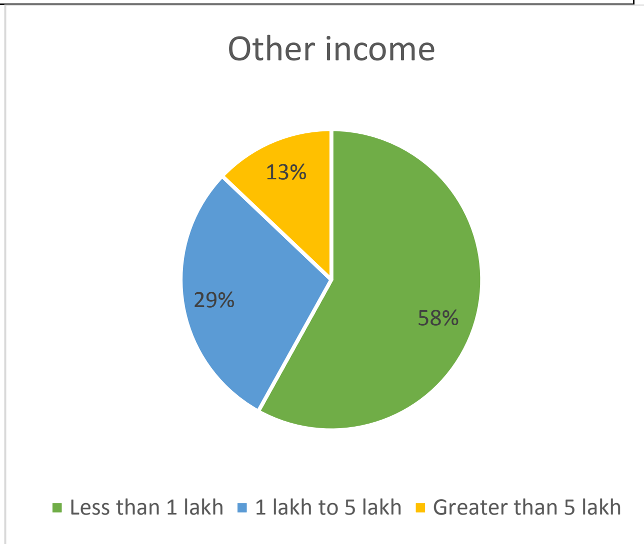


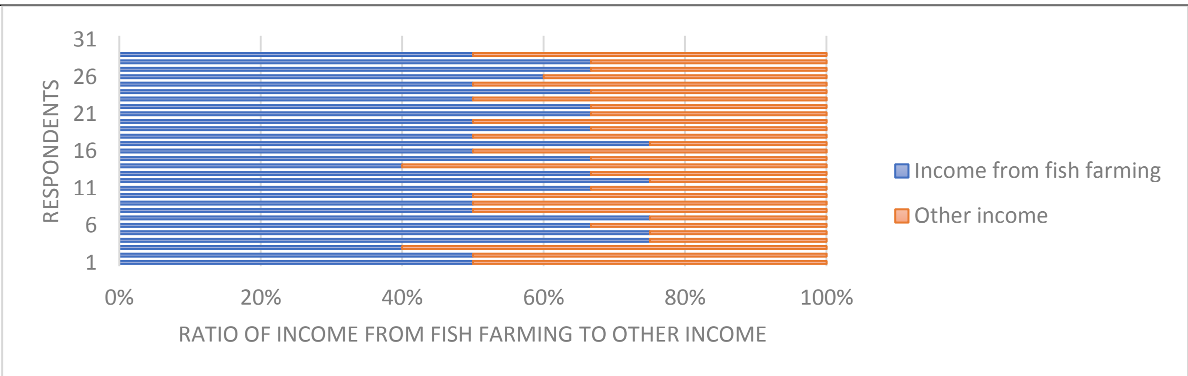

Figure 4.17: Income from various sources (fish, shrimp farming, other sources)

| Panel A: Income from fish and shrimp farming | Panel B: Income from other sources |
|---|---|
|  |  |





Panel C: Comparing income from fish farming and other sources (Snapshot)



Fish farming is mainly undertaken by the resource rich individuals who has been doing it for a long time. 58% of the farmers in the sample operate on leased land, 13 % do the farming in own land as well as lease in and the rest 29 % only are doing the activity in own farms (Table 4.8)

Table 4.8: Lease status of farms in fish cultivation

| Holding type | Number of farmers | Average holding size |
|---|---|---|
| Leased | 18 | 14.35 |
| Owned | 4 | 2.78 |
| Leased+owned | 9 | 8.17 |

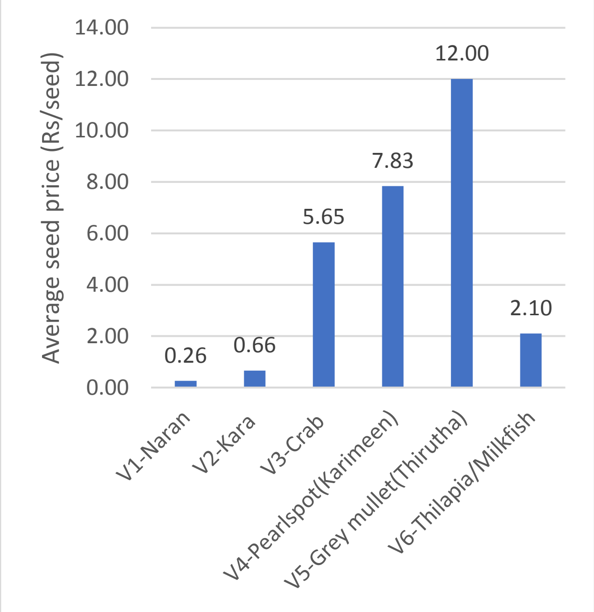
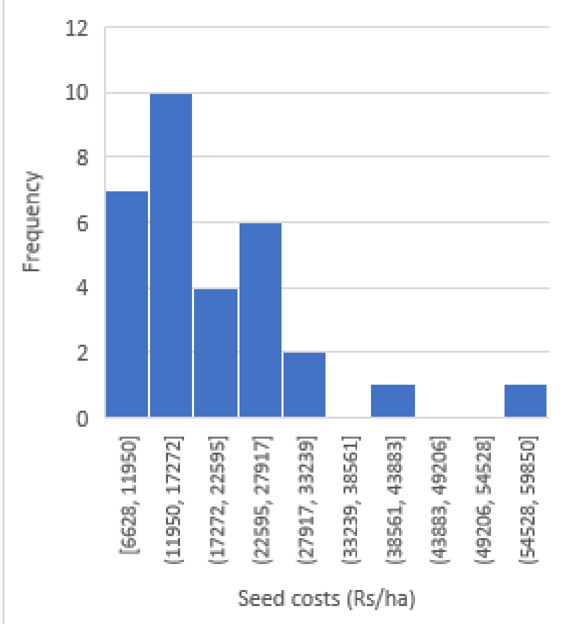
### *4.3.2 Cost of Cultivation*

The details of costs and returns are presented in Table 4.9 (Rice, Shrimp and fish culture). Some of the estimates are derived from situations of polyculture where different species are grown together.

1. Seeds:

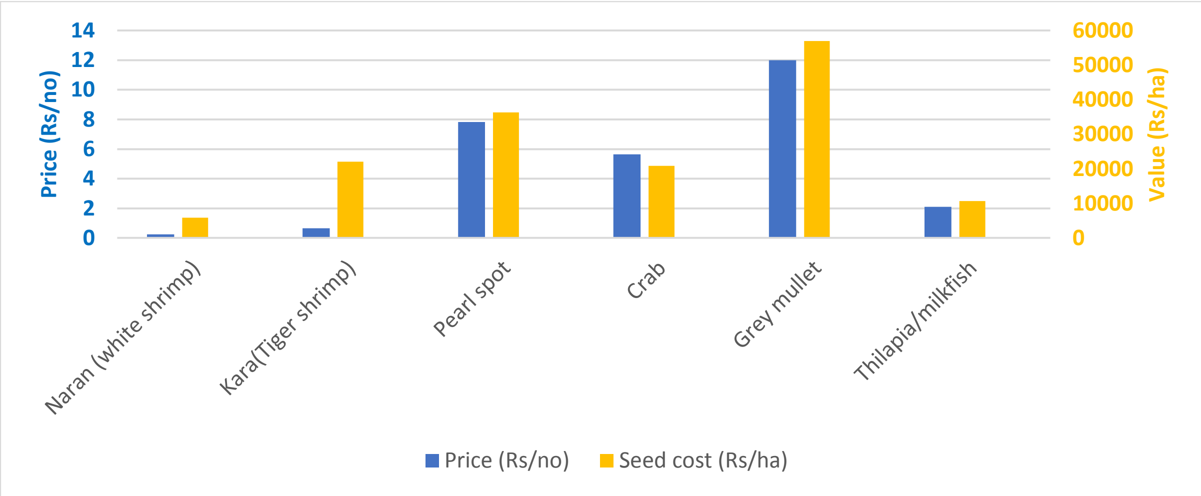
Nearly two third of sample respondents reported following rice –shrimp culture {White Shrimp (Naran ) and Tiger Shrimp ( Kara), one third followed rice fish rotation . The average price of seeds varies from Rs. 0.26/no. for white shrimp to Rs.12/no for grey mullet (Figure 4.18, Panel A). Seed costs per hectare vary according to the species and combination there of (Rs.6628/ha to Rs. 59850/ha), although most respondents1 (87%) report values on the lower end between (Rs.6628/ha to Rs.27917/ha) (Figure 4.18, Panel B).

Figure 4.18: Seed prices and seed costs

| Panel A: Average seed prices for various fish and shrimp species | Panel B: Seed costs per hectare (Frequency) |
|---|---|
|   |   |

Comparing across the various species suggests that the seed costs per hectare and the seed prices for grey mullet are reported to be the highest, followed by pearlspot. White shrimp has the lowest seed costs per hectare relatively (Figure 4.19)

Figure 4.19: Seed prices and seed costs per hectare across the various species




**2.** Labour use and cost

The fish farming part of pokkali cultivation is mainly managed by men and 27.80 mandays are estimated to be required for one ha.of farming ,irrespective of fish species (This is estimated based on existing average wage rates).The wage rates for different operations vary and the total labour cost is reported as Rs. 26896 per ha . The labour use do not vary substantially between the species because the major operations remain the same.

**3.** Other costs

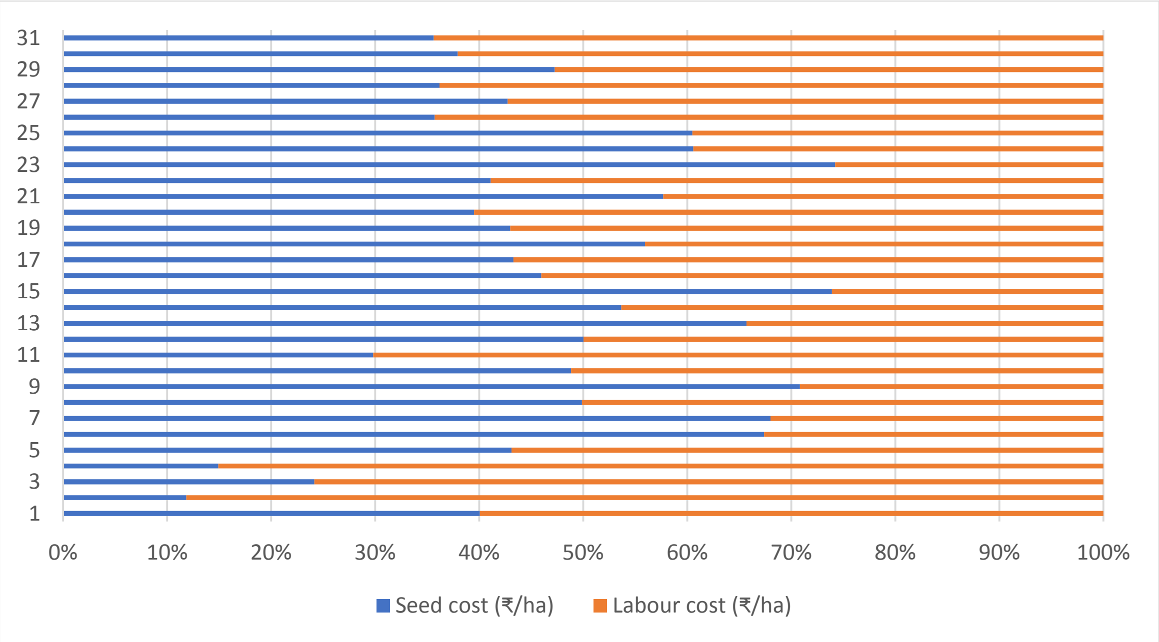
Lease amount forms a sizable share of total cost ,that averages at Rs. 26034 per ha that ranges from Rs.18500-Rs.40000 per ha. depending upon the fertility status of the field, locational advantages and infrastructural aspects .

Liming is done to regulate soil pH to make it ideal for fish survival and growth.(Rs.798 /ha.) and the artificial feed supplements costs Rs.684/ha. The field is lighted throughout the night period and electricity charges amounts to Rs.70 /ha.

Total costs excluding the seed cost amounts to Rs. 54482.

In terms of the contribution of the various inputs to total costs, seed cost contributions range between 12% to 74% of the total costs, while labour costs contribute between 26% to 88% of the total costs (Figure 4.20).

Figure 4.20: Comparing contribution of seed and labour costs per hectare to overall input costs per hectare (Snapshot)

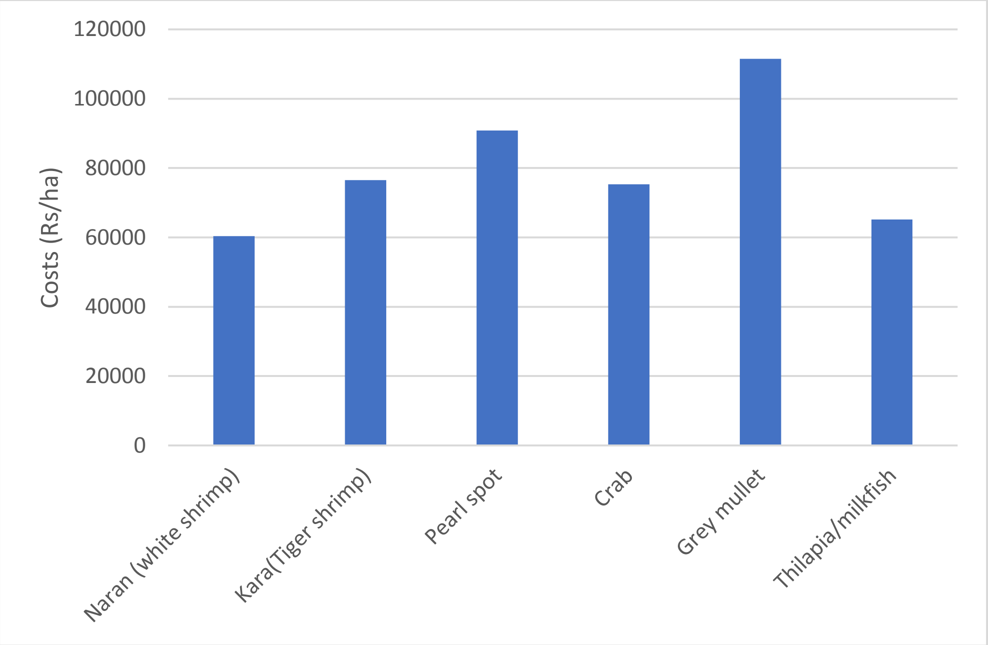



4. Total Cost of Cultivation:

The cost of cultivation differ across species mainly on account of the difference in seed prices, as the labour and other management costs remain the same. The total costs thus is estimated at

Rs. 60352 for white shrimp and that for tiger shrimp, is higher at Rs. 76566, due to the higher seed cost. Total cost of cultivation for grey mullet remain the highest at Rs.1,11,482 ,followed by pearl spot (Rs.90,829), crab(Rs.75,350) and thilapia /milk fish(Rs.65,192) (Figure 4.21)

Figure 4.21: Total cost of cultivation for various species




5. Output, returns and income

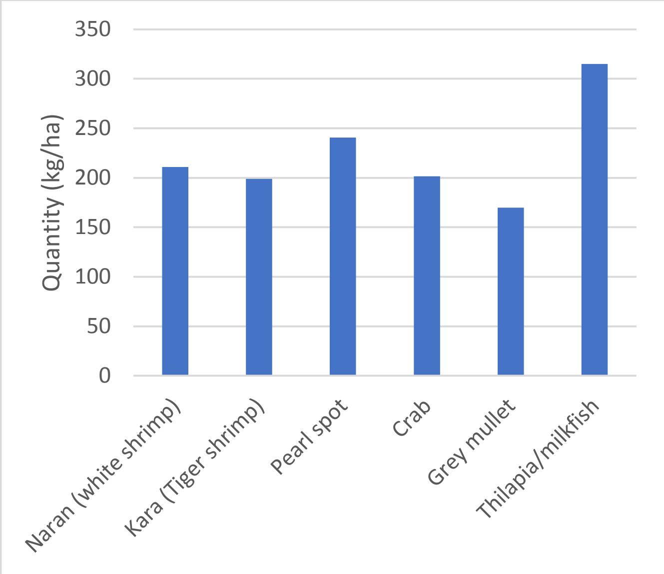
The quantity of output produced, and output price vary across the different fish and shrimp species. The output quantities per ha for the various species range widely depending on the species (Range: 140kg/ha to 375kg/ha for white shrimp, 14.29kg/ha to 200kg/ha for tiger shrimp, 5kg/ha to 108.33kg/ha for crab, 15kg/ha to 115kg/ha for Pearlspot, 6.5kg/ha to 10kg/ha for grey mullet and 17.86kg/ha to 80kg/ha for Thilapia/milkfish). Per hectare output quantities for the various species has been detailed in figure 4.22 (Panel A).

The sale price of crab prices are typically much higher than the other species (Figure 4.22, Panel B).A substantial share (98%) of the harvested fishes are sold, while the rest was either set aside for home consumption (1%) . For exported species the sale in local market is minimum. (Figure 4.22, Panel C).

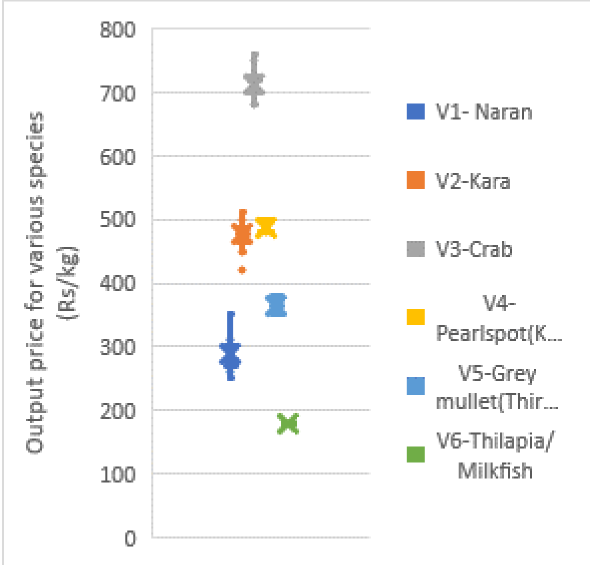
The net profit/loss from various species (including income from miscellaneous species) has been given in Figure 4.22 (Panel D). While greymullet registers a net loss even after including income from the other miscellaneous species, the other fish and prawn species record profits with the highest profit from crab.

Figure 4.22: Sale price of different fish species and shrimps

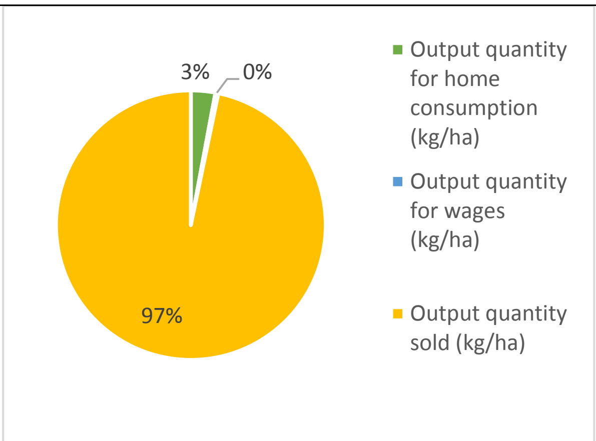
Panel A: Output quantity per hectare for the various species




Panel B: Range of output prices for the various fish and shrimp species




Panel C: Quantity of produce per hectare used for own consumption, wages and sold




Panel D: Net Returns including income from miscellaneous species

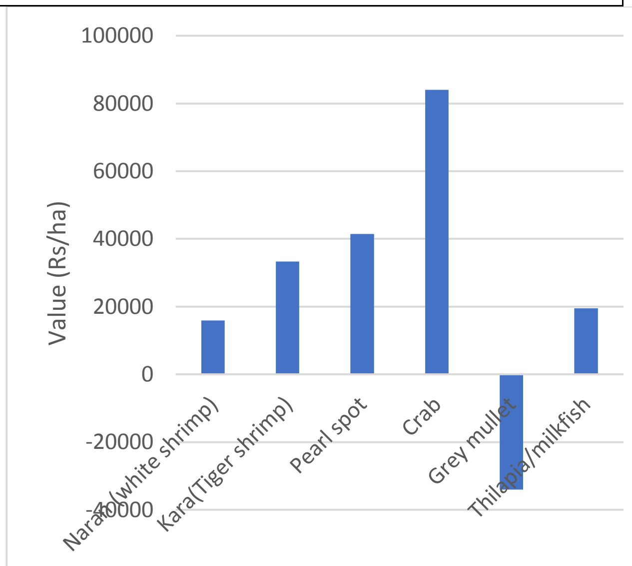


Table 4.9: Economics of Shrimp and fish farming in Pokkali lands

| Variable | Quantity (Nos/ha) | Price (Rs/no) | Value (Rs/ha) |
|---|---|---|---|
| Input details-Seed | | | |
| Naran (white shrimp) | 22928 | 0.25 | 5870 |
| Kara(Tiger shrimp) | 33460 | 0.66 | 22084 |
| Pearl spot | 4642.8 | 7.83 | 36347 |
| Crab | 3693.5 | 5.65 | 20868 |
| Grey mullet | 4750 | 12.0 | 57000 |
| Thilapia/milkfish | 5100 | 2.10 | 10710 |
| Input details- Labour | | | |
| Strengthening of outer bunds | 3.47 | 948.38 | 3292 |
| Fixing of sluice gate | 1.67 | 1934 | 3222 |
| Bund hole patching | 1.08 | 1433.38 | 1548 |
| Widening of side channel | 1.53 | 852.7 | 1304 |
| Pegging(fixing poles) | 1.91 | 826 | 1578 |
| Water management | 15.19 | - | 14250 |
| Harvesting | 2.96 | 575 | 1702 |
| Other expenses | | | |
| Lease amount /ha | | | 26034 |
| Field liming cost | | | 798 |
| Electricity charges | | | 70 |
| Fish feed cost | | | 684 |
| Total Cost (labour + material costs) | | | 54482 |
| Total cost of cultivation for each species | | | |
| Naran (white shrimp) | | | 60352 |
| Kara(Tiger shrimp) | | | 76566 |
| Pearl spot | | | 90829 |
| Crab | | | 75350 |
| Grey mullet | | | 111482 |
| Thilapia/milkfish | | | 65192 |
| Output details | | | |
| Variable | Quantity (kg/ha) | Price (Rs/kg) | Value (Rs/ha) |
| Naran (white shrimp) | 211 | 288.5 | 60874 |
| Kara (Tiger shrimp) | 198.8 | 475.6 | 94549 |
| Pearl spot | 240.71 | 486.67 | 117130 |
| Crab | 201.7 | 713.85 | 143984 |

| | | | |
|---|---|---|---|
| Grey mullet | 170 | 365 | 62050 |
| Thilapia/milkfish | 315 | 220 | 69300 |
| Quantity for consumption | | | |
| Naran (white shrimp) | 5.42 | | |
| Kara(Tiger shrimp) | 5.42 | | |
| Net returns | | | |
| Naran (white shrimp) | | | 522 |
| Kara (Tiger shrimp) | | | 17983 |
| Pearl spot | | | 26301 |
| Crab | | | 68634 |
| Grey mullet | | | (-) 49432 |
| Thilapia/milkfish | | | 4108 |
| Miscellaneous fishes obtained through water infiltration during tidal variations | | | |
| Choodan (shrimp) | 50 | 150 | 7500 |
| Thelly (shrimp) | 45 | 125 | 5625 |
| Other fishes | 15 | 150 | 2250 |
| Total income from miscellaneous species | | | 15375 |
| Net Returns including income from miscellaneous species | | | |
| Naran (white shrimp) | | | 15897 |
| Kara(Tiger shrimp) | | | 33358 |
| Pearl spot | | | 41476 |
| Crab | | | 84009 |
| Grey mullet | | | (-) 34057 |
| Thilapia/milkfish | | | 19483 |
| Benefit cost ratio (Gross returns/Input costs) (Return includes income from miscellaneous species) | | | |
| White shrimp | 1.26 | | |
| Tiger shrimp | 1.44 | | |
| Crab | 1.75 | | |
| Pearlspot | 1.76 | | |
| Grey mullet | 0.69 | | |
| Thilapia/Milkfish | 1.30 | | |

Notes The Cost of cultivation towards labour and other management aspects are same irrespective of fish species

### *4.3.3 Problems/Constraints in fish, shrimp farming*

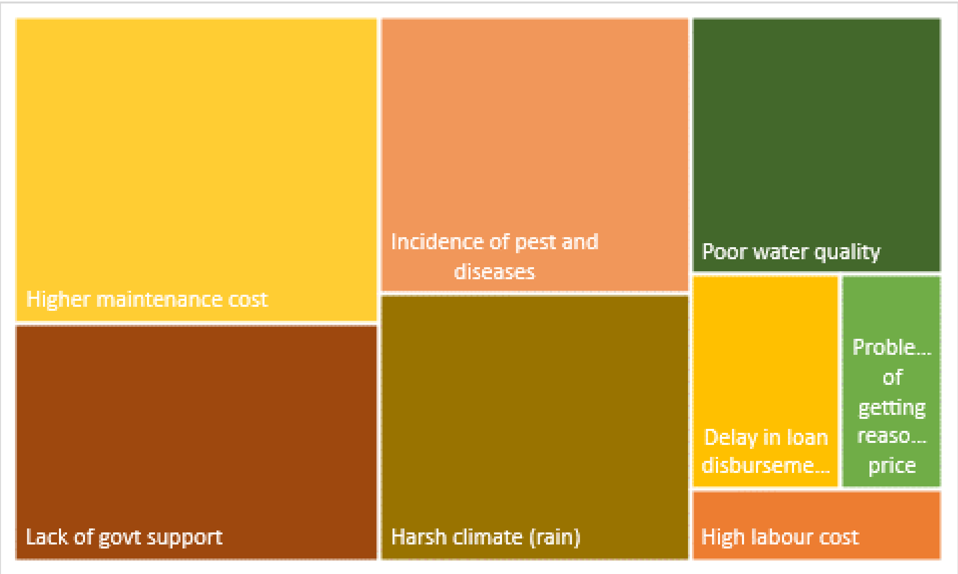
Various problems in fish/shrimp farming based on the primary surveys were compiled together in Table 4.10 by calculating the frequency response for each problem. A majority of respondents (81% to 100%) stated that problems such as insufficiencies in credit supply and weed problems were ‘not severe’. Problems that were classified ‘slightly severe’ by majority of respondents (58% to 100%) included the problems of high labour costs, loan disbursement delays and interest rates, corruption, problems in getting reasonable prices, and availability of quality seeds.

The most severe problems (categorised 'very severe') were lack of government support, harsh climate and rain, poor water quality, incidence of pest and diseases higher maintenance costs, as suggested by a large number of respondents (58% to 100%) (Figure 4.23).

Table 4.10: Various problems and rating of problems associated with fish/shrimp farming

| Problems | Responses (in %) | | |
|---|---|---|---|
| | Not severe | Slightly Severe | Very severe |
| High labour costs | 0 | 84 | 16 |
| Insufficiencies in credit supply | 100 | 0 | 0 |
| Interest rates | 42 | 58 | 0 |
| Delay in loan disbursement | 13 | 58 | 29 |
| Corruption | 0 | 100 | 0 |
| Problem of getting reasonable price | 0 | 81 | 19 |
| Availability of quality seeds | 32 | 68 | 0 |
| Lack of govt support | 0 | 23 | 77 |
| Harsh climate (rain) | 0 | 26 | 74 |
| Poor water quality | 0 | 42 | 58 |
| Incidence of pest and diseases | 0 | 23 | 77 |
| Weed problems | 81 | 19 | 0 |
| Higher maintenance cost | 0 | 0 | 100 |

Figure 4.23: Very severe problems in fish/shrimp farming as mentioned by majority respondents



### 4.4 Integrated Rice-fish farming in Pokkali lands –Scenario Analysis

Combining fish/shrimp farming and Pokkali rice farming estimates also lends some interesting insights on the various possibilities. Different potential combinations are considered, namely estimates from-

(i) Pokkali rice farming (status quo/scenario 1/scenario 2/scenario 3) + V1
(ii) Pokkali rice farming (status quo/scenario 1/scenario 2/scenario 3) + V2
(iii) Pokkali rice farming (status quo/scenario 1/scenario 2/scenario 3) + V3
(iv) Pokkali rice farming (status quo/scenario 1/scenario 2/scenario 3) + V4
(v) Pokkali rice farming (status quo/scenario 1/scenario 2/scenario 3) + V5
(vi) Pokkali rice farming (status quo/scenario 1/scenario 2/scenario 3) + V6

Scenarios have been described earlier in the previous section. Profit and loss of the various combinations have been given in Table 4.11 and Figure 4.24 (Panel A) below. Figure 4.24 (Panel B) graphically represents the incremental profit/loss for the various combinations under the different scenarios as compared to the profit/loss for the respective combination in status quo.

Comparing the different scenarios suggests that the scenario with HYV varieties (scenario 2) provides the highest profits amongst all combinations, followed by the 50 HYV- 50 traditional scenario (Scenario 3). Only these two combinations could ensure a positive net returns under all scenarios.

The existing situation of rice farming followed by the fish farming (with each of the species) was economically not justifiable. Only crab farming could compensate fully for the loss in rice farming ,though farming with other species could reduce the extent of loss. If the realised yield under farming with traditional varieties could be improved through use of quality seeds and scientific management, positive net returns can be ensured, except in the case of rice-grey mullet rotation. This scenario supports the in-situ conservation of traditional varieties of pokklali ecosystem as well.

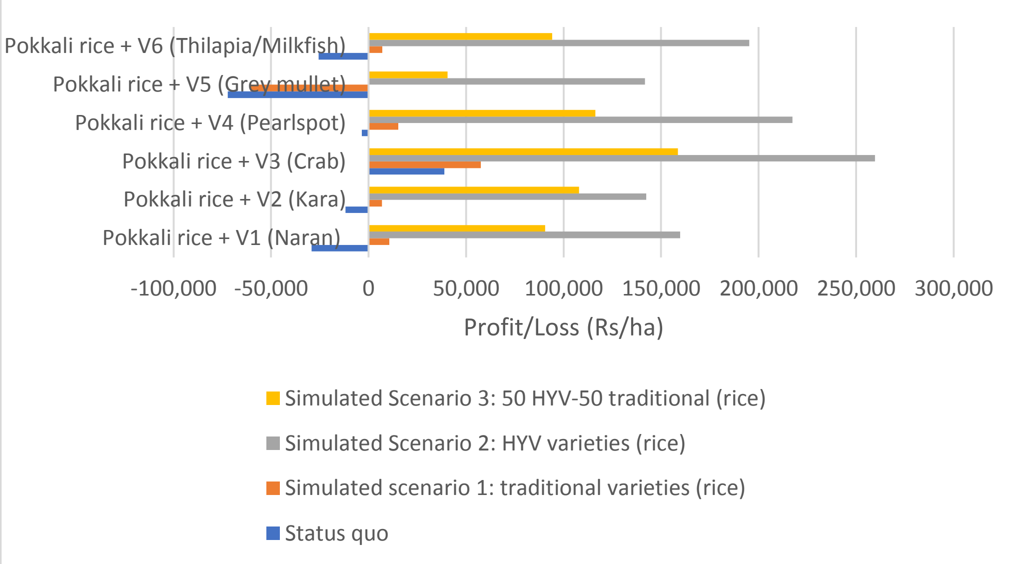
Introduction of HYVs improves the profit level through higher yield and the hypothetical situation of full area under HYVs provides the best system in terms of economic returns, while it is constrained by sustainability aspects as well as conservation of traditional genetic wealth. Coverage of 50% of the total pokkali belt can be a feasible option ,while the rest of the locations can be under traditional varieties. However, the choice of the locations suited for each of the suggested/improved farming practices that ensure sustainability, conservation, social acceptance and economic viability is to decided based on technical dimensions and social preference.

Table 4.11: Relative Economics Integrated Rice Fish culture in Pokkali farms under various scenarios

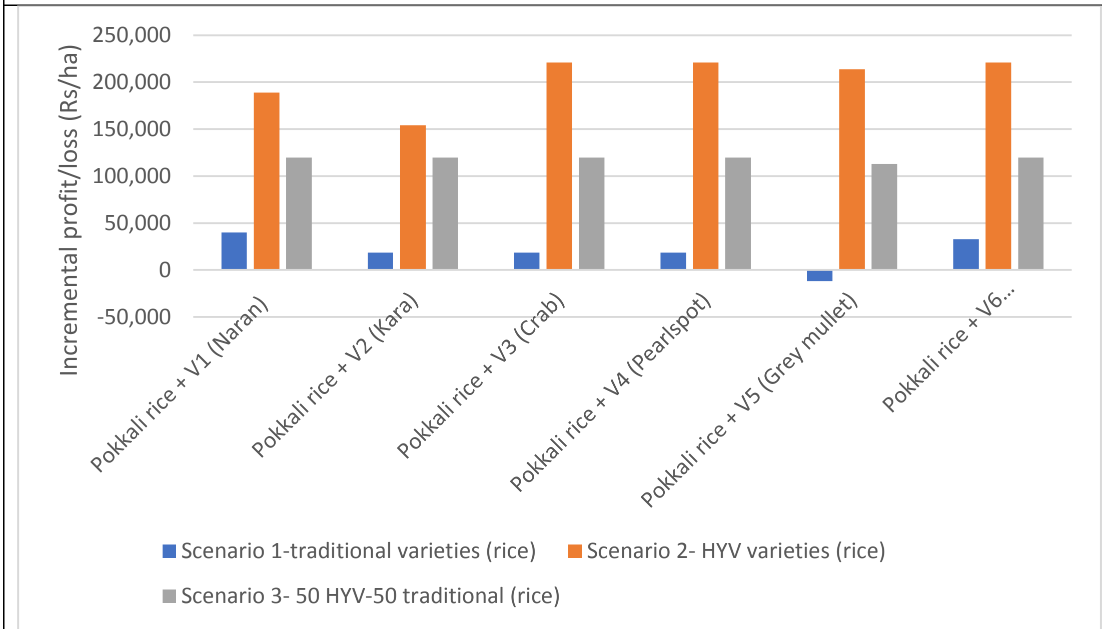
| Variable- Profit/loss (in Rs/ha) from - | Status quo | Simulated scenario 1: traditional varieties | Simulated Scenario 2: HYV varieties | Simulated Scenario 3: 50 HYV-50 traditional |
|---|---|---|---|---|
| Net Returns from Pokkali rice farming | (-) 45180 | (-)26503 | 1,75,697 | 74597 |
| Net Income from fisheries | (Rs/ha) | | | |
| V1- Naran | 15897 | | | |
| V2- Kara | 33358 | | | |
| V3- Crab | 84009 | | | |
| V4- Pearlspot | 41676 | | | |
| V5- Grey mullet | (-) 34057 | | | |
| V6- Thilapia/ Milkfish | 19483 | | | |
| Profit/loss from various combinations | Status quo | Simulated scenario 1: traditional varieties (rice) | Simulated Scenario 2: HYV varieties (rice) | Simulated Scenario 3: 50 HYV-50 traditional (rice) |
| Pokkali rice + V1 (Naran) | (-) 29,283 | 10606 | 1,59,800 | 90,494 |
| Pokkali rice + V2 (Kara) | (-) 11822 | 6855 | 1,42,339 | 1,07,955 |
| Pokkali rice + V3 (Crab) | 38829 | 57506 | 2,59,706 | 1,58,606 |
| Pokkali rice + V4 (Pearlspot) | (-)3504 | 15173 | 2,17,373 | 1,16,273 |
| Pokkali rice + V5 (Grey mullet) | (-)72,237 | (-) 60560 | 1,41,640 | 40540 |
| Pokkali rice + V6 (Thilapia/Milkfish) | (-) 25697 | 7020 | 1,95,180 | 94,080 |

Figure 4.24: Profit/loss and incremental profit/loss of various combinations under scenarios

Panel A: Profit/loss from combinations of Pokkali rice, fish, shrimp estimates under various scenarios




Panel B: Incremental profit/loss from combinations of Pokkali rice, fish, shrimp estimates under various scenarios




Note: Incremental profit/loss is calculated as the difference between profit/loss in the respective scenario (Scenario 1/2/3) and the profit/loss under status quo. For grey mullet, scenario 1 represents a reduced loss in scenario 1 as compared to the status quo.

***Key takeaways***

- Most farmers (Pokkali, fish and shrimp) were above 40 years of age. While most Pokkali rice farmers were above 51 years of age, those respondents pursuing fish and shrimp farming were comparatively young (42-62 years of age).
- Income from agriculture and non-agriculture for most Pokkali farmers fall in the same range (below 50,000), while for most of the fish and shrimp farmers, income from fish and shrimp farming is either greater than or in the same range (1 lakh to 5 lakh) as income from other sources.
- Pokkali rice farming engages 49.7 male workers and 53.98 women workers per hectare, mainly on account of the absence of mechanisation. On average, more women are required. But, men`s average wage rates are almost twice as much as women. Labour costs predominantly form the major component of the costs. Fish and shrimp farming engages 27.80 men and rarely employs women
- The sample respondents in rice farming preferred traditional varieties (pokkali, vellapokkali, cheru virippu, white pokkali, Cherunellu etc.), mainly owing to the hardy nature. A few farmers cultivate HYV varieties released by KAU (vytilla series, Ezhom).
- The marketed surplus from production was very high in rice as well as fisheries farming
- The operational farm size of rice cultivation was below 1ha. In most cases, there seems to be some evidence towards larger operated areas being associated with lower input costs/hectare and lower per unit costs, which could potentially point towards a economies of size argument. Fisheries enterprises operate with higher farm sizes between 2ha-10ha. Comparing operating area for fish and shrimp farming with variables like costs and output does not suggest much possibility of economies of size and scale, although further analysis may be required.
- The locational peculiarities of rice ecosystems generally necessitates collective decision making and action , especially in water management .Hence continuous paddy stretches within a specific boundary known as a padasekharam is operated in a collective decision making mode by padasekhara samithis which are a collective of representatives of owner farmers within the padasekharam. Generally rice farmers are part of respective Padashekara Samithi,on account of the comparative advantges in management,availing of subsidies and other supports from Government .It was observed that rice farmers with slightly higher holding size were members of samithi and the output quantity of the produce was also higher.
- Rice farmers report lack of adequate and timely availability of quality seeds, incidence of pest and diseases, uncertain rainfall and high labour costs as major constraints. Major problems in fish and shrimp farming are lack of government support, harsh climate and rain, poor water quality, incidence of pest and diseases higher maintenance costs
- While the Benefit cost-ratio for Pokkali farming works out to 0.25, for various species of fish and shrimp farming it ranged between 0.69 – 1.76 (Shrimp- V1 (Naran): 1.26, Shrimp - V2 (Kara): 1.44, Fish- V3 (crab): 1.75, Fish- V4 (Pearlspot): 1.76, Fish- V5 (Grey mullet): 0.69, Fish- V6 (Thilapia): 1.30). This suggests that while Pokkali and grey mullet values are below 1 and may be unprofitable, farming with other shrimp/fish species have ratios greater than 1 and are profitable.

- Comparing the profit values across the three scenarios (traditional varieties, HYV varieties, 50 traditional- 50 HYV) suggests that scenario 2 (HYV varieties) shows the highest profits followed by scenario 3 (mixed). Scenario 1 with improved management of traditional varieties reported a loss, although the loss was lesser than in the status quo. Benefit Cost ratio also indicated similar results with scenario 2 as the financially the best ,followed by scenario 3.
- The analysis integrating the profits through fish farming with different species also reconfirms the results that the scenario with HYV varieties (scenario 2) provides the highest profits amongst all combinations, followed by the 50 HYV- 50 traditional scenario (Scenario 3). Only these two combinations could ensure a positive net returns under all scenarios . The existing situation of rice farming followed by the fish farming (with each of the species) was economically not justifiable. Only crab farming could compensate fully for the loss in rice farming ,though farming with other species could reduce the extent of loss. If the realised yield under farming with traditional varieties could be improved through use of quality seeds and scientific management, positive net returns can be ensured ,except in the case of rice-grey mullet rotation. This scenario supports the in situ conservation of traditional varieties of pokkali ecosystem as well.
- Introduction of HYVs improves the profit level through higher yield and the hypothetical situation of full area under HYVs provides the best system in terms of economic returns ,while it is constrained by sustainability aspects as well as conservation of traditional genetic wealth .Coverage of 50% of the total pokkali belt can be a feasible option which is ecologically safe, economically viable and socially acceptable.

# 5 CHAPTER 5: FINDINGS FROM THE DESK ANALYSIS ON MANGROVE CONSERVATION AND RESTORATION

Mangrove ecosystems are a type of coastal wetland containing vegetation that have adapted to marine and estuarine contexts (United Nations Environment Programme, 2014; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). The term mangrove is generally used to refer to both the ecosystem and the various species of plants (Barbier, et al., 2011; United Nations Environment Programme, 2014). Mangrove ecosystems generally and in Kerala, are characterised as being highly biologically diverse (Government of India, 2016; Muraleedharan, Swarupanandan, & Anitha, 2009; Hema & Devi, Factors of mangrove destruction and management of mangrove ecosystem of Kerala, India, 2014). Mangroves can be of different types (for example- on coastlines, overwash, basin, hammock, dwarf/stunted, riverine) (UNEP-Nairobi Convention/USAID/WIOMSA, 2020). In the following sections, we look at some of the key aspects of relevance for the current study, placing the learnings from literature and global experiences specifically in the Kerala and Kochi context.

## 5.1 Relationship between mangroves and agriculture, aquaculture, fisheries and integrated agricultural systems

***Land use and Agriculture:*** Relationship between mangroves and agricultural systems could be multi-dimensional and complex. Overall, there seems to be a threat of conversion into alternative land uses for mangroves. While there is evidence on mangroves providing ecosystem services that positively contribute to fish farming and rice farming with various benefits (for example, in yields, fertility), mangroves and their soil quality may be negatively affected due to these agricultural/aquacultural activities. Traditional agricultural systems may affect mangroves relatively less adversely.

In Kerala and in other Indian states, agricultural activities especially integrated farming systems are undertaken around mangroves (Muraleedharan, Swarupanandan, & Anitha, 2009; Ministry of Environment and Forests, 2011) with protections extended for mangroves on the land in some states (Ministry of Environment and Forests, 2011).

***Conversion of mangrove lands for other uses:*** Conversion of mangrove lands for paddy agriculture and aquaculture poses a threat to mangroves (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). Further, it may not be possible to reverse conversion back to mangroves after moving to shrimp cultivation without careful restoration (Barbier, Mangrove Dependency and Livelihoods of Coastal Communities, 2006).

Conversion of mangroves to alternative land uses, especially aquaculture, is suggested to negatively affect long-term yields and economic gains of fish/crustaceans even if there are some short-term gains (Rahman & Mahmud, 2018), and may also not be justifiable if all the values of the mangrove ecosystem are accounted for. Maintenance of land under mangroves is further important for fisheries, with Truong & Do (2018) finding that mangrove coverage, more than mangrove density affects the profitability and productivity of shrimp farming in Mekong river delta, Vietnam.

Accounting for costs of mangrove restoration and the negative externalities due to shrimp cultivation (for example, water pollution) within the economics of shrimp farming resulted in negative economic returns from shrimp cultivation (Sathirathai & Barbier, 2001; Barbier, Natural barriers to natural disasters: replanting mangroves after the tsunami, 2006). Perverse subsidies further encourage this conversion into aquaculture and shrimp cultivation (Barbier, Mangrove Dependency and Livelihoods of Coastal Communities, 2006).

***Agricultural systems and Traditional Agriculture:*** There is limited evidence on agricultural systems having a negative impact on mangroves with Tripathi, et al., (2016) finding that the mangrove ecosystems' soil quality changes and deteriorates with continuous cultivation of rice in surrounding areas. Although adverse associations between mangroves and agriculture/aquaculture may apply more for commercialisation of agriculture (Muraleedharan, Swarupanandan, & Anitha, 2009) and semi and intensive shrimp farming (Rahman & Mahmud, 2018), it may or may not apply to the same extent for traditional farming practices. Jayahari et al., (2020) based on an analysis on mangroves in KMC and surrounding areas noted that moving away from traditional practices (many of which are inherently sustainable), could have caused negative impacts on the ability of the mangroves to provide certain ecosystem services. For example, traditional fish farmers are said to typically fish when the high tide is withdrawing thereby allowing the entry of various species, while many other farmers (especially non-local) are said to fish during the high tide which is said to potentially affect ecosystem service provisioning by the mangroves (Jayahari, Varghese, Sebastian, & Arun, 2020). Further, in comparison to more modern fishermen who got affected by human-wildlife conflicts, those engaged in traditional fishing were not affected by human-wildlife conflicts (Jayahari, Varghese, Sebastian, & Arun, 2020).

Although traditional agricultural systems may not affect mangroves as adversely as commercial agriculture, perceptions on ground are influenced based on agricultural interests. Pokkali paddy lands in Ernakulam are often surrounded by mangroves (Hema and Devi 2020) and perceived trade-offs between paddy and mangrove ecosystems may have resulted in many paddy farmers not willing to pay for mangrove conservation (Hema and Devi 2015).

## 5.2 Ecosystem services provided by mangroves for agriculture/aquaculture/ fisheries/integrated agricultural systems

Mangroves play an important role in fish and crustacean production by providing them with a space to live, habitat, feed, nutritional requirements, area for nursery, reproduction and increase the technical efficiency of fish production. Further, the nutrient retention service of mangroves seems to have a relationship with the fertility of agricultural areas (Hussain and Badola 2008). Mangroves may also provide ecosystem services to local agriculture like integrated Pokkali-fish farming by acting as wind breaks, erosion prevention, protection from extreme weather events like floods and provide habitats for fish breeding (Rode & Balasubramanian, 2018). We discuss these in greater detail in the following sections.

***Ecosystem services provided by mangrove ecosystems:*** Ecosystem services can be defined as the direct and indirect contributions made by various ecosystems to the well-being of humans (Millennium Ecosystem Assessment, 2005; The Economics of Ecosystems and Biodiversity, 2010; Barbier, et al., 2011; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012). Contributions from ecosystems can range from goods, services and cultural benefits (Barbier, et al., 2011) which can be consumed, used or appreciated (Vo, Kuenzer, Vo, Moder, & Oppelt, 2012). There are majorly four categories of ecosystem services[9]: Provisioning, Regulating, Cultural and Supporting and Habitat services. According to Mitra (2020), the major research focus for mangroves has centred around the ecosystem services of carbon storage and sequestration, nursery services, stabilization of shorelines and contribution of fodder, fuel and wood products. The ecosystem services provided by mangroves has been given in the Table 5.1 below. The ones that have already been identified and specifically mentioned in literature on mangroves in Kochi and Kerala are highlighted in the table in orange.

[9] Based on classifications given in the Millennium Ecosystem Assessment (2005) and The Economics of Ecosystems and Biodiversity (2010) report

Table 5.1: Ecosystem services provided by mangroves

| **Provisioning services:** | **Regulating services:** |
|---|---|
| -**Food, fish consumption**<br>-**Maintenance of fisheries and aquaculture**<br>- **Raw materials-** Wood and **non-wood, fodder**, **Energy resources**<br>- Biochemical products<br>- Ornamental resources/species<br>- Genetic materials | - Local and Global climate regulation- air quality regulation, **carbon storage and sequestration**<br>- Biological regulation and control, pest and disease control<br>-Water flow regulation (groundwater recharge/discharge)<br>-Control of water pollution and waste, water purification and detoxification<br>- Shoreline stabilisation, **Erosion control** and regulation, Sediment retention<br>- **Moderation of extreme weather events like storms, floods, tsunamis**[10]<br>-Pollination |
| **Cultural services:** | **Supporting services:** |
| - Cultural identity, diversity and heritage<br>- Spiritual, religious experiences<br>- Inspiration<br>- **Opportunities for recreation and tourism**<br>- Aesthetic appreciation<br>- Information for Cognitive development- Education, research, local knowledge | - **Biodiversity and lifecycle maintenance**<br>- Soil formation<br>- Nutrient cycling and soil fertility |

### *5.2.1 Provisioning services*

Provisioning services refer to the various goods and services obtained from the mangrove ecosystems for human use and consumption.

- ***Food***

  Many food products are obtained from mangroves like fruits, sugar, vinegar, alcohol, fish, crustaceans, honey, algae, crops, nuts (Millennium Ecosystem Assessment, 2005; Barbier, et al., 2011; Mitra, 2020; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Sandilyan & Kathiresan, 2012; Rode & Balasubramanian, 2018; Government of India, 2016; Muraleedharan, Swarupanandan, & Anitha, 2009; Himes-Cornell, Grose, & Pendleton, 2018; Russi, et al., 2013) (Vo, Kuenzer, Vo, Moder, & Oppelt, 2012) (Clarkson, Ausseil, & Gerbeaux, 2014; Queiroz, et al., 2017) (Kathiresan, 10, 2012; Sinclair, Sagar, Knudsen, Sabu, & Ghermandi, 2021)

- ***Maintenance of fisheries and aquaculture (subsistence and commercial)***

[10] Some of these studies use local data in Kerala/Kochi and are perception based

Mangroves contribute to maintenance of fisheries and aquaculture (Danone Fund for Nature 2009, Barbier, Acreman and Knowler 1997, Sandilyan and Kathiresan 2012) (Barbier, Marine ecosystem services, 2017; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006; van Oudenhoven, et al., 2015; Government of India, 2016)and play an important role in fish and crustacean production by providing them with a space to live, habitat, feed, area for nursery, reproduction (Barbier, et al., 2011; Kathiresan, 10, 2012; Anneboina & Kumar, 2017; Muraleedharan, Swarupanandan, & Anitha, 2009; Brander, et al., 2012). The various litter from mangroves could contribute to satisfying the nutritional requirements of the fishes/crustaceans (Mitra, 2020). This specific provisioning ecosystem service deals with subsistence and commercial fishing (Salem & Mercer, 2012; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; Pascal & Bulu, 2014).

The existence of mangroves is beneficial to fish/crustacean cultivation. Anneboina & Kumar (2017) find that mangroves contribute to increasing the technical efficiency of fish production (calculated using stochastic frontier production functions and further regressions). Further, Muraleedharan et al., (2009) and Hema & Devi (2013) opine that a linear or positive relationship exists between shrimp production and the area under mangroves.

*In Kerala, many local livelihoods are dependent on the mangroves indirectly through their engagement in agriculture and aquaculture (fish, shrimp, seafood, mussel, crab farming)* (Muraleedharan, Swarupanandan and Anitha 2009, Hema and Devi 2013). *Fishery service of mangroves was also perceived and valued as important by many of the locals in KMC and surrounding areas (based on a primary survey conducted by Jayahari et al. (2020)).*

- ***Raw materials- wood, non-wood, energy resources***

Mangrove ecosystems provide various raw materials for human use and consumption (Millennium Ecosystem Assessment, 2005; Barbier, et al., 2011; Clarkson, Ausseil, & Gerbeaux, 2014; Costanza, et al., 1997; Queiroz, et al., 2017) (Kathiresan, 10, 2012; Barbier, Marine ecosystem services, 2017; Brander, Florax, & Vermaat, 2006; van Oudenhoven, et al., 2015; Rode & Balasubramanian, 2018; Himes-Cornell, Grose, & Pendleton, 2018) in addition to food and fish. These could be wood related like timber, fuel wood, other forest products (Barbier, Acreman and Knowler 1997, Ashokkumar and Irfan 2018, Barbier, Hacker, et al. 2011, Mitra 2020) or non-wood products like wax, resins, dyes, tannins, charcoal, glue, fodder (mangrove leaves), bio-fertilizer, insecticides, fiber, coir, construction material (Ashokkumar & Irfan, 2018; Mitra, 2020; United Nations Environment Programme, 2014; Government of India, 2016; The Economics of Ecosystems and Biodiversity, 2010; Danone Fund for Nature, 2009; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Russi, et al., 2013). Mangrove

ecosystems could also provide raw material for construction of houses, roofing, boats, fishing material (poles, stems, roots), household objects and inputs to industry (for example- to make paper) (United Nations Environment Programme, 2014; Sandilyan & Kathiresan, 2012).
Energy resources from mangroves could include timber, fuelwood (Vo, Kuenzer, Vo, Moder, & Oppelt, 2012; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; United Nations Environment Programme, 2014; Brander, et al., 2012; Salem & Mercer, 2012; Mitra, 2020; Sinclair, Sagar, Knudsen, Sabu, & Ghermandi, 2021). *Fuelwood is an important product from mangroves in Kerala , in addition to provision of fodder, coir, and shells from the mangroves. (Muraleedharan, Swarupanandan, & Anitha, 2009).*

- ***Biochemical products***

Mangroves can provide humans with medicinal extracts, medicines and pharmaceuticals (Mitra, 2020; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; United Nations Environment Programme, 2014; Government of India, 2016; Millennium Ecosystem Assessment, 2005; The Economics of Ecosystems and Biodiversity, 2010; Sandilyan & Kathiresan, 2012; Mitra, 2020; Himes-Cornell, Grose, & Pendleton, 2018; Russi, et al., 2013). (Clarkson, Ausseil, & Gerbeaux, 2014; Barbier, Acreman, & Knowler, Economic Valuation of Wetlands: A guide for policy makers and planners, 1997). Mangroves could also provide inputs that are further used in cosmetic industries (Mitra, 2020).

- ***Ornamental resources/species***

Mangroves could contribute ornamental resources (Mitra, 2020; Clarkson, Ausseil, & Gerbeaux, 2014) or decorative plant and animal products such as shells etc., some of which could also be used as ornaments (The Economics of Ecosystems and Biodiversity, 2010).

- ***Genetic materials***

Mangrove species hold genetic information and materials (Clarkson, Ausseil, & Gerbeaux, 2014; Queiroz, et al., 2017; Barbier, Marine ecosystem services, 2017; Himes-Cornell, Grose, & Pendleton, 2018) which may provide resistance to certain pathogens (animal and plant) (Millennium Ecosystem Assessment, 2005; Russi, et al., 2013; Mitra, 2020; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012). This service could potentially find use in the fields of biotechnology or crop breeding (Millennium Ecosystem Assessment, 2005).

### *5.2.2 Regulating services*

Regulating services are associated with the mangrove’s capacity to regulate some processes of the ecosystem and biosphere (Millennium Ecosystem Assessment, 2005; The Economics of

Ecosystems and Biodiversity, 2010; United Nations Environment Programme, 2014; Ashokkumar & Irfan, 2018; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012)

- ***Local and Global climate regulation***

Mangrove ecosystems can have an influence on the climate both locally and globally (Queiroz, et al., 2017; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014) (Barbier, Acreman, & Knowler, Economic Valuation of Wetlands: A guide for policy makers and planners, 1997) (Barbier, Marine ecosystem services, 2017; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006; Rode & Balasubramanian, 2018). Locally, mangroves regulate air quality and other processes like rainfall and temperature (The Economics of Ecosystems and Biodiversity, 2010; Millennium Ecosystem Assessment, 2005; Sandilyan & Kathiresan, 2012; Russi, et al., 2013; Clarkson, Ausseil, & Gerbeaux, 2014; Himes-Cornell, Grose, & Pendleton, 2018; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012). Further, mangroves can protect from UV-B radiation and provide a safe environment free of such radiation (The Economics of Ecosystems and Biodiversity, 2010; Mitra, 2020; Kathiresan, 10, 2012).

At a regional and global level, mangroves play a role in combating climate change by regulating greenhouse gases and as carbon sinks that sequester carbon and store in above, underground vegetation and soils (also sometimes referred to as 'blue carbon') (van Oudenhoven, et al., 2015; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Barbier, et al., 2011; Kathiresan, 10, 2012; Pascal & Bulu, 2014; Mitra, 2020; United Nations Environment Programme, 2014; Salem & Mercer, 2012; Worthington & Spalding, 2018; Thompson, Primavera, & Friess, 2017) (Russi, et al., 2013). Mangroves are very rich in carbon, and the substantial biomass below ground and in sediments and soil results in the sequestration potential of mangroves being much higher than those of tropical terrestrial forests (Government of India, 2016; Rani, Nandan, & Schwing, Carbon source characterisation and historical carbon burial in three mangrove ecosystems on the South West coast of India, 2021). Further, carbon sequestration can also help in improving the soil quality (Kumar, et al., 2016). On the other hand, removal of mangroves causes emissions and climate change due to the carbon being released again into the atmosphere (UNEP-Nairobi Convention/USAID/WIOMSA, 2020; Rani, Nandan, & Schwing, Carbon source characterisation and historical carbon burial in three mangrove ecosystems on the South West coast of India, 2021; Murray, Pendleton, Jenkins, & Sifleet, 2011).

*Mangroves in South Kerala (Ashtamudi wetland region) are said to sequester large amounts of carbon (Joy & Paul, 2021). In a study conducted by Rani et al., (2021) in three locations in* *the Cochin estuary (Aroor in Alappuzha district in Southern Cochin, Vypin island in Northern Cochin, Mangalavanam bird sanctuary) they found that the median average total carbon burial rate across the locations to be 2.95 t C/ha/yr. Further, organic carbon found in mangrove sediments in Kochi were noted to be highly fertile and have high organic productivity (Sebastian & Chacko, 2006).*

- ***Biological regulation and control, pest and disease control***

Another ecosystem service provided by mangroves is the service of biological regulation and pest regulation and control (Clarkson, Ausseil, & Gerbeaux, 2014; Mitra, 2020; Queiroz, et al., 2017; Rode & Balasubramanian, 2018). Mangroves play a role in the preservation of functional diversity and provide resistance to invasions by various species (Millennium Ecosystem Assessment, 2005). Mangrove ecosystems also provide the service of pest and disease control (The Economics of Ecosystems and Biodiversity, 2010).

Changes to mangroves might affect abundance of crop, livestock pests, diseases and incidence of human diseases and vectors (Millennium Ecosystem Assessment, 2005).

- ***Water flow regulation (groundwater recharge/discharge)***

Mangroves contribute to water flow regulation (Clarkson, Ausseil, & Gerbeaux, 2014; Barbier, Acreman, & Knowler, Economic Valuation of Wetlands: A guide for policy makers and planners, 1997; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006; Himes-Cornell, Grose, & Pendleton, 2018) by storing, retaining, recharging groundwater for various consumptive purposes (Millennium Ecosystem Assessment, 2005; Mitra, 2020; Queiroz, et al., 2017; The Economics of Ecosystems and Biodiversity, 2010) and also prevent inland entry of sea water (Kathiresan, 10, 2012; Rode & Balasubramanian, 2018; Mitra, 2020).

- ***Control of water pollution and waste, water purification and detoxification***

Mangroves can contribute to maintenance of water quality through retention, recovery, purification, detoxification and removal, control of excess nutrients, pollutants, wastes, sediments, minerals, heavy metals and other contaminants (Millennium Ecosystem Assessment, 2005; Queiroz, et al., 2017; Barbier, et al., 2011; Mitra, 2020; United Nations Environment Programme, 2014; Salem & Mercer, 2012) (Clarkson, Ausseil, & Gerbeaux, 2014; Costanza, et al., 1997; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014) (Kathiresan, 10, 2012; Barbier, Marine ecosystem services, 2017; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006; van Oudenhoven, et al., 2015; Rode & Balasubramanian, 2018). They act as filters and barriers to trap organic and inorganic pollutants from going into water bodies (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Mitra, 2020).

- ***Shoreline stabilisation, Erosion control and regulation, Sediment retention***

Shoreline stabilisation, erosion control and sediment retention are some services provided by mangroves (Danone Fund for Nature, 2009; Clarkson, Ausseil, & Gerbeaux, 2014; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; Barbier, Acreman, & Knowler, Economic Valuation of Wetlands: A guide for policy makers and planners, 1997; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012; Barbier, Marine ecosystem services, 2017; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006; Azeez, Bhupathy, Rajasekaran, & Arun, 2004; UNEP-Nairobi Convention/USAID/WIOMSA, 2020). The mangrove ecosystem retains soil, traps silt and other debris and stabilises sediments, thereby reducing soil erosion and shoreline deterioration (Millennium Ecosystem Assessment, 2005; Barbier, et al., 2011; Kathiresan, 10, 2012; Mitra, 2020). Mangroves also contribute to controlling coastal erosion and preventing soil removal by reducing height of waves and protecting the shoreline from various natural hazards like storms, etc (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Queiroz, et al., 2017; Kathiresan, 10, 2012; Ashokkumar & Irfan, 2018; United Nations Environment Programme, 2014; Salem & Mercer, 2012).

Stabilization of shorelines is considered an important ecosystem service of mangroves in many countries and in the Indian context (Government of India, 2016). *Mangroves in Kerala have also been suggested to protect shorelines from erosion (Joy & Paul, 2021), with local respondents surveyed from Kannur and Ernakulum by Muraleedharan et al., (2009) also considering it to be an important contribution from mangroves.*

- ***Moderation of extreme weather events like storms, floods, tsunamis***

Mangroves help moderate extreme weather events (Clarkson, Ausseil, & Gerbeaux, 2014) (Barbier, Acreman, & Knowler, Economic Valuation of Wetlands: A guide for policy makers and planners, 1997; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012; Ashokkumar & Irfan, 2018) (Barbier, Marine ecosystem services, 2017; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006). They act as buffers and natural barriers which reduce intensity and magnitude of extreme events such as floods, tsunamis and storms by blocking and reducing impact and height of waves (van Oudenhoven, et al., 2015; Queiroz, et al., 2017; Rode & Balasubramanian, 2018; Millennium Ecosystem Assessment, 2005; Kathiresan, 10, 2012; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Barbier, et al., 2011; The Economics of Ecosystems and Biodiversity, 2010; Danone Fund for Nature, 2009; Mitra, 2020) (Russi, et al., 2013). Thereby, they reduce the impact of the extreme weather event on people, infrastructure and property, animals etc, although it is important to note that the mangrove width, not vegetation has predominantly been noted to be important to reduce impacts and damages (Kumar, et al., 2016; Sandilyan & Kathiresan, 2012; United Nations Environment Programme, 2014; Mitra, 2020; Brander, et al., 2012).

*In Kerala, this service was considered an important contribution of mangroves by locals surveyed from Kannur, Ernakulum (Muraleedharan, Swarupanandan, & Anitha, 2009) and flood regulation specifically in KMC and surrounding areas (Jayahari, Varghese, Sebastian, & Arun, 2020).*

- ***Pollination*** (Rode & Balasubramanian, 2018; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012)

### *5.2.3 Cultural services*

These services contribute to human well-being in non-material ways by providing environment for recreation, inspiration, aesthetic appreciation, spiritual and religious appreciation.

- ***Cultural identity, diversity and heritage***

Mangroves hold various cultural, historical, communal connotations for people, and could be a critical component of cultural identity and heritage especially in places where mangroves have been central to livelihoods for a long time (United Nations Environment Programme, 2014). Mangroves might influence social relations (Queiroz, et al., 2017). People might also associate some species or areas with historical or cultural significance (Millennium Ecosystem Assessment, 2005).

- ***Spiritual, religious experiences***

People may have spiritual or religious associations with mangroves (Millennium Ecosystem Assessment, 2005; United Nations Environment Programme, 2014; Mitra, 2020; Clarkson, Ausseil, & Gerbeaux, 2014; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; Sandilyan & Kathiresan, 2012; Barbier, Marine ecosystem services, 2017) and recognise the ecosystem as a sacred space with some defined norms (Queiroz, et al., 2017; Ashokkumar & Irfan, 2018).

This is true in many parts of India. For example, *Excoecaria agallocha* is a species worshipped in temples in Tamil Nadu (Government of India, 2016). This ecosystem service has not got much attention in the valuation literature, possibly due the enmeshed nature of relationships with other ecosystem services (Himes-Cornell, Grose, & Pendleton, 2018).

- ***Inspiration***

Mangroves might provide inspiration for folklore, art, design and various other fields (Millennium Ecosystem Assessment, 2005; Queiroz, et al., 2017; Russi, et al., 2013). People might also engage in reflection, rest etc and obtain a sense of inspiration from the various characteristics of the ecosystem.

- ***For recreation and tourism***

Mangroves provide recreation and tourism benefits (United Nations Environment Programme, 2014; Clarkson, Ausseil, & Gerbeaux, 2014; Costanza, et al., 1997; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; Barbier, Acreman, & Knowler, Economic Valuation of Wetlands: A guide for policy makers and planners, 1997) (Vo, Kuenzer, Vo, Moder, & Oppelt, 2012; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Kathiresan, 10, 2012; Barbier, Marine ecosystem services, 2017; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006). They provide various opportunities for recreation like recreational fishing, boating, bird watching and photography and for tourism (Pascal & Bulu, 2014; Salem & Mercer, 2012; Mitra, 2020; Sandilyan & Kathiresan, 2012; van Oudenhoven, et al., 2015; Millennium Ecosystem Assessment, 2005; Russi, et al., 2013; Ashokkumar & Irfan, 2018; Barbier, et al., 2011; Queiroz, et al., 2017). *Mangroves in Kochi could provide recreation for locals and tourists through walks in nature (Rode & Balasubramanian, 2018). Various places in Ernakulam and in and around Kochi have some eco-tourism activities in mangroves (Sreelekshmi et al 2021, Sudheer 2021).*

- ***Aesthetic appreciation***

Aesthetic appreciation of mangroves (United Nations Environment Programme, 2014; Clarkson, Ausseil, & Gerbeaux, 2014; Queiroz, et al., 2017; Sandilyan & Kathiresan, 2012; Brander, Florax, & Vermaat, 2006; Rode & Balasubramanian, 2018) refers to the visual value that people derive from the various characteristics of the mangrove ecosystem, and it might also provide people with a sense of place and contribute to better mental well-being (Mitra, 2020; Queiroz, et al., 2017; Millennium Ecosystem Assessment, 2005; Millennium Ecosystem Assessment, 2005). Similar to the ecosystem service of spiritual benefits from mangroves, this ecosystem service has also not got much attention in the valuation literature (Himes-Cornell, Grose, & Pendleton, 2018; Russi, et al., 2013).

- ***Information for Cognitive development- Education, research, local knowledge***

People may derive benefits on account of the various opportunities for formal, informal education and research present due to the existence of mangroves (Mitra, 2020; Clarkson, Ausseil, & Gerbeaux, 2014; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012; Barbier, Marine ecosystem services, 2017; Millennium Ecosystem Assessment, 2005). The existence of mangroves also helps ensure the continued existence of traditional ecological knowledge (Barbier, et al., 2011; Queiroz, et al., 2017), and traditional knowledge could provide critical insights on contextually appropriate management approaches (Russi, et al., 2013). The presence of mangroves can also encourage education and knowledge building activities such as birdwatching, build environmental awareness, and encourage further research in improving scientific knowledge (United Nations Environment Programme, 2014; Sandilyan & Kathiresan, 2012).

*Mangroves in Kochi could provide education on birds and biodiversity through camps, nature centres etc (Rode & Balasubramanian, 2018).*

### *5.2.4 Supporting and habitat*

Supporting services provide support to other ecosystems and ecosystem services and are necessary for the production of other ecosystem services. They are typically characterised as having indirect long-term impacts on people.

- ***Biodiversity and lifecycle maintenance***

Mangroves provide the service of biodiversity and lifecycle maintenance (Barbier, Marine ecosystem services, 2017; Baig & Iftikhar, 2010; Brander, Florax, & Vermaat, 2006; Costanza, et al., 1997; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014). This service includes a wide range of contributions provided by mangroves related to providing habitats, maintenance of lifecycle for various species (Millennium Ecosystem Assessment, 2005; Mitra, 2020; Queiroz, et al., 2017; Sandilyan & Kathiresan, 2012; The Economics of Ecosystems and Biodiversity, 2010), nursery, breeding, feeding services for fisheries and aquaculture (van Oudenhoven, et al., 2015; Salem & Mercer, 2012) (Barbier, et al., 2011; van Oudenhoven, et al., 2015; Mitra, 2020; Government of India, 2016; United Nations Environment Programme, 2014; Ashokkumar & Irfan, 2018; The Economics of Ecosystems and Biodiversity, 2010; UNEP-Nairobi Convention/USAID/WIOMSA, 2020; Anneboina & Kumar, 2017; Muraleedharan, Swarupanandan, & Anitha, 2009), protection of gene pool and maintenance of genetic diversity (Russi, et al., 2013; Clarkson, Ausseil, & Gerbeaux, 2014; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012; The Economics of Ecosystems and Biodiversity, 2010; Rode & Balasubramanian, 2018). Mangroves also contribute to survival of other marine ecosystems like coral reefs, seagrass (Sandilyan & Kathiresan, 2012; United Nations Environment Programme, 2014; Kathiresan, 10, 2012). Many mangroves also support various endangered species (Government of India, 2016). *Mangalavanam mangroves in Kerala and the mangroves in Kochi support many species (Jayson & Easa, 1999; City Development Plan) like migratory birds and the Indian flying fox* (Kochi Municipal Corporation 2020) *and has high species richness (Bhat & Sreekanth, 2018).*

- ***Soil formation***

The mangrove retains and accumulates sediments and other organic material thereby contributing to soil formation (Millennium Ecosystem Assessment, 2005; Queiroz, et al., 2017; The Economics of Ecosystems and Biodiversity, 2010; Clarkson, Ausseil, & Gerbeaux, 2014; Himes-Cornell, Grose, & Pendleton, 2018)

- ***Nutrient cycling and soil fertility***

Mangroves contribute to recycling, storage, enhancement and processing of various nutrients (Millennium Ecosystem Assessment, 2005; Russi, et al., 2013; Ashokkumar & Irfan, 2018; Queiroz, et al., 2017; United Nations Environment Programme, 2014; Sandilyan & Kathiresan, 2012; Kathiresan, 10, 2012; Ram-Bidesi, Siamomua-Momoemausu, & Faletutulu, 2014; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012). Mangroves might trap nutrients within sediments (Mitra, 2020; van Oudenhoven, et al., 2015) which contributes to soil fertility (Clarkson, Ausseil, & Gerbeaux, 2014).

## 5.3 Location and Status of Mangroves in Kochi/Kerala

Ernakulam district lies at the $9^{0}$ 58‟ N Latitude and $76^{0}$ 17‟ E Longitude. The major rivers raining into the Cochin Backwaters are Manimalayar, Muvattupuzhayar, Periyar and Chalakkudi puzha. During the South-West monsoon the estuary is filled with fresh water. Salinity is very high during the post monsoon season and may exceed the level of 30 per cent. Mangrove vegetation in Cochin area is seen along the Cochin back waters (lakes which have access to the sea through bar mouth), particularly along the banks of estuarine water bodies, in the form of small patches or narrow continuous belt. A field investigation (Madhusoodhanan and Vidyasagar (2012) provides a rough estimate of 600 ha of mangroves in the district. The major areas of spread are Mulavukad, Elankunnapuzha, Narakal, Nayarambalam, Edavanakad, Kuzhupilli (Vypeen block), Chellanam and Kumbalanghy grama panchayats (Pallruthi block) (Table 5.2).

The mangroves in Puthuvypeen and Mangalavanam are unique, due to its social and ecological significance. The mangrove formation in Puthuvypeen is reported to be unique in the state as the largest continuous mangroves close to the sea in Ernakulam, district. Mangalavanam which is in the heart of Kochi city is considered as "lungs of the city" and a roosting ground for migrant and resident birds. About 98 species of birds are reported from the area (Jayson, 2004). Being the industrial capital of the state, the threat to mangroves in Ernakulam is reported to be high owing to developmental pressures. The study was conducted covering all the eight gram panchayats of the district namely Mulavukad, Elankunnapuzha, Narakal, Nayarambalam, Edavanakad, Kuzhupilli, Chellanam and Kumbalanghi.

Table 5.2: Major centres of mangrove vegetation in the Ernakulam district

| Sl No. | CDB Block | Grama panchayat /Municipal Corporation | Location |
|---|---|---|---|
| 1 | Vypeen | Elankunnapuzha | Puthuvypeen |
| 2 | Vypeen | Narakal | Narakal |
| 3 | Vypeen | Edavanakad | Edavanakad |
| 4 | Vypeen | Elankunnapuzha | Elamkunnapuzha |
| 5 | Pallruthi | Kumbalanghi | Kumbalanghi |
| 6 | Vypeen | Mulavukad | Mulavukad |
| 7 | Pallruthi | Chellanam | Chellanam |
| 8 | | Cochin Corporation | Mangalavanam |

Mangroves are quite limited within the Kochi city area (Rode & Balasubramanian, 2018), and hence many studies consider the areas around Kochi as well in their analysis. Mangrove patches in and around Kochi are found in Panangad, Kumbalam, Chellanam, Mangalavanam, Thripunithura, Panambukad, Vypin, Mulavukad, Kannamaly Kumbalangi, Puthuvype, and Nettur (Azeez, Bhupathy, Rajasekaran, & Arun, 2004). Kochi in Ernakulam district contains the Mangalavanam bird sanctuary that covers around 2.74 ha and has been classified as a protected area (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Rode & Balasubramanian, 2018).

***Species information:***

Around 18 species have been identified in Kerala's mangroves with the highest number of species recorded in Kollam followed by Alappuzha and Ernakulam (Sreelekshmi, et al., 2018; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). ICLEI South Asia (2020) suggests that around 14 true mangrove species are present in Ernakulam. Rani et al., (2018) finds 14 true mangrove species in mangroves in Cochin that belonged to 6 families. The mangroves in Ernakulam were noted to have high species richness, but that the "monospecies dominace and lows basal area indicated poor structural development and uneven species abundances" (George, et al., 2019).

The dominant species found in Ernakulam include *Acanthus ilicifolius* and *Excoecaria agallocha* (Sreelekshmi, et al., 2018). *Sonneratia alba* was also a species found in Ernakulam which had been categorized as threatened in India by the Botanical Survey of India (Sreelekshmi, et al., 2018). Some dominant mangrove species in Kochi are *Avicennia officinalis, Sonneratia caseolaris, Derris sp, Bruguiera gymnorrhiza, Acanthus ilicifolius, Excoecaria species, Rhizophora mucronata* (National Centre for Earth Science Studies, 2014). In Kochi Municipal Corporation (KMC), ICLEI South Asia (2020) noted many birds, amphibians, reptiles, mammals in South Kochi (thevara) and Mangalavanam.

***Area under mangroves:*** In comparison to other states, Kerala has very low area under mangroves (Anneboina & Kumar, 2017). The total mangrove cover in Ernakulam is 1.82 sq km of which 0.79 sq km are moderately dense mangroves and 1.03 sq km are open mangroves for the year 2017-18 (Forest Survey of India, 2019). Area under mangroves in Kochi Municipal Corporation (KMC) reported in the literature ranges between 0.49 sq km under CRZ 1-A[11] (National Centre for Earth Science Studies, 2014), 0.57 sq km (values as of 2017) (Jayahari, Varghese, Sebastian, & Arun, 2020) and 1.19 sq km (ICLEI South Asia 2020, Kochi Municipal Corporation 2020). The National Centre for Earth Science Studies (2014) reports a buffer zone of 1.6 sq km for the mangroves of KMC. Most mangrove patches seem to be below 0.5ha in KMC for 2017 (Jayahari, Varghese, Sebastian, & Arun, 2020). Area under mangroves in KMC and surrounding areas in 2017 has been given in Figure 5.1 as reprinted from Jayahari et al. (2020).

Figure 5.1: Mangroves in KMC and surrounding areas in 2017

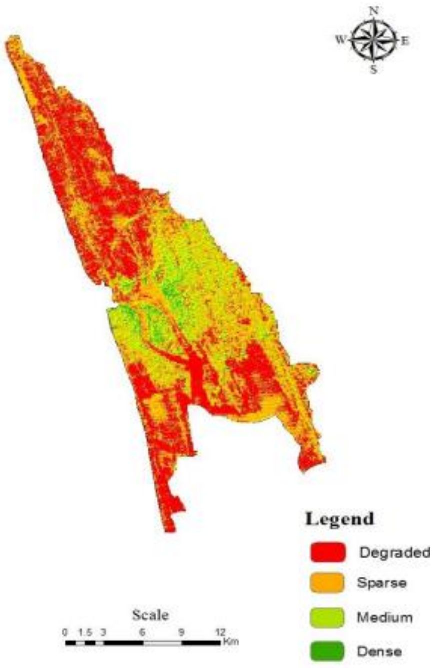
[11] Mangroves generally fall under the classification CRZ-IA ("The areas that are ecologically sensitive and the geomorphological features which play a role in the maintaining the integrity of the coast,") (Ministry of Environment and Forests, 2011; Ministry of Environment, Forest and Climate Change, 2019).


Source: Reprinted from (Jayahari, Varghese, Sebastian, & Arun, 2020)

***Changes in area under mangroves:*** Within Central Kerala, Ernakulam district and Kochi have had large declines in area of mangroves (Sreelekshmi, Preethy, et al. 2018, Sreelekshmi, Veettil, et al. 2021, Thomson n.d.). Many mangroves are Kerala and Kochi are degraded or polluted (Rode & Balasubramanian, 2018), as can also be seen in Figure 5.2 reprinted from Chandran et al. (2014). In KMC and surrounding areas, mangrove areas reduced by 24% over the period 2000-2017 (mapping carried out in 3 years- 2000, 2013, 2017) (Jayahari, Varghese, Sebastian, & Arun, 2020). Degradation of mangroves could adversely impact zooplankton richness and diversity (Sreelekshmi, Preethy and Joseph, et al. 2017). Going forward, banks of canals, rivers or ponds have been suggested as potential locations for a restoration intervention[12] in Kerala, since they may face lesser resistance from farmers who are otherwise using the land for farming (Rahman & Mahmud, 2018).

Figure 5.2: Density and degradation of mangroves in Kerala

[12] Various reports on canals and their restoration may have implications for mangroves through various interactive pathways. For instance, the Thevara-Perandoor Canal (Thevara-Perandoor Canal survey report) indicates that there is a large amount of wastewater and solid waste pollution, flow obstruction, reducing width of canal due to encroachments, and spread of diseases. Recommendations in the report included fencing of sides, building sewer lines, monitoring of waste dumping, participatory canal management, awareness, maintenance of water flows, construction of bridges for clearance, and use of the land on the sides of the canal for recreation and beautification. Another report of various canals (Kochi Metro Rail Ltd), suggested recommendations including slum removal, infrastructure development along canals (tourism parks, housing, recreation centres etc), development of navigation, canal cleaning, cutting and dredging, and bank protection.




Source: As reprinted from Chandran et al. (2014)

## 5.4 Understanding Key Aspects for Mangrove Restoration: Global Learnings

Over time, the focus on mangrove restoration and plantation has shifted from silviculture to aspects such as ensuring socio-economic benefits, restoring ecological functions of mangroves, multi-species restoration and water flow modifications (Su, Friess, & Gasparatos, 2021). We summarise here some of the key aspects that emerge from our desk analysis, which maybe of relevance for considering mangrove restoration in the Kochi area.

### *5.4.1 Natural versus Artificial Restoration*

Mangrove restoration is generally advised in situations where natural self-regeneration[13] might not be possible. It should be considered only after ruling out the possibility of natural regeneration (UNEP-Nairobi Convention/USAID/WIOMSA, 2020). A process to make this decision has been outlined in Bosire, et al (2008) including various steps such as understanding ecological, hydrological systems, understanding factors that hinder succession, local communities involvement and local knowledge, using all the information collected as basis for site selection, attempting to restore existing hydrological systems and removing impediments to natural regeneration, appropriate species selection and plantation in case natural regeneration

[13] Natural regeneration uses "direct, freely falling and dispersed mangrove propagules", while artificial regeneration involves "direct planting of desired propagules and saplings" (UNEP-Nairobi Convention/USAID/WIOMSA, 2020)

is not possible/failed, monitoring and assessment and further recommendations (Bosire, et al., 2008).

*Decisions between natural and artificial regeneration* requires examination of various factors. Whilst natural regeneration may be cheaper and the outcomes more similar to existing forests; artificial restoration may be expensive, especially if there have been changes in hydrological regimes. Outcomes for artificial restoration would also be dependent on the context specific appropriateness and mix of the species. On the other hand, artificial restoration could be controlled in terms of choice and mix of species and using genetically improved species, while that is not possible with natural restoration (UNEP-Nairobi Convention/USAID/WIOMSA, 2020). Finally, mangrove planting should be preferred if it could contribute to income generation, if there are limited natural supplies, or to reintroduce an important species (UNEP-Nairobi Convention/USAID/WIOMSA, 2020).

#### *5.4.2 Drivers for Changes in Mangroves*

In addition to restoration, it is also important to deal with the drivers causing the loss and degradation of ecosystems (Fleischman, et al., 2020). Drivers can be defined as "a factor often directly modified by human management and affects one or more ecosystem services" (Mitra, 2020).

Illegal deforestation, economic development, water flow disruptions, agriculture, aquaculture, siltation, salinity, climate change and pollution are some of the drivers of mangrove decline and degradation globally (Su, Friess, & Gasparatos, 2021; Slobodian, Chaves, Nguyen, & Rakotoson, 2018). Some major reasons for mangrove degradation and loss of area under mangroves in South Asia are conversion into other land-uses especially aquaculture and shrimp farming (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Sreelekshmi, et al., 2018; Barbier, Natural barriers to natural disasters: replanting mangroves after the tsunami, 2006), and for other land-uses like agriculture, tourism, industries, urban development, over-harvesting, pollution, fall in availability or diversion of fresh-water, silt deposition, erosion of coastal areas, extreme weather events like cyclones (Sreelekshmi, Veettil, et al. 2021, Sreelekshmi, Preethy and Varghese, et al. 2018, Barbier 2006).

In India, threats and pressures to mangroves happen due to natural disasters, extreme weather events like earthquakes, tsunamis and cyclones, pollution, saline water and siltation, rise in sea level, climate change, invasive species, encroachment and destruction of habitats, overfishing and human-wildlife conflicts. Pollution and saline water intrusion continue to be major problems (Government of India, 2016).

### *5.4.3 Community engagement for mangrove conservation and restoration*

Involvement of local communities plays an important role in determining the success of mangrove conservation and restoration interventions (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Barbier, 2006; Hema & Devi, 2020). Since ecosystem conservation and restoration interventions require long periods of investment, ensuring benefits to community, sufficient incentives to encourage participation, community support and community empowerment would be critical in determining the success of the intervention (Fleischman, et al. 2020, Barbier 2006). It is also important to conduct participatory rural appraisals to understand the community's willingness to participate in conservation/restoration, to understand potential income generating activities, existing gender-based governance practices, communities' use of resources and for forming local institutions (Government of India, 2016). Participating in artificial restoration activities could potentially help cultivate a feeling of ownership in the local community, thereby bettering the chances of buy-in and long-term sustainability of the intervention (UNEP-Nairobi Convention/USAID/WIOMSA, 2020). Locals perceiving that they have control over management of mangroves helps a lot in encouraging participation (Barbier 2006). Households tend to decide regarding the participation of individual members in restoration interventions, with participation of women depending further on other factors such as the how many children under 6 in the household and distance between the home and mangrove (Barbier 2006).

Local communities do seem to prefer managing the mangrove by themselves when compared with other management and governance alternatives (Other alternatives of mangrove management could be management and governance of mangroves by (i) the indigenous and local communities themselves, (ii) by the government and state, (iii) by private owners of land or (iv) shared governance (for example- public private partnerships)) (Slobodian, et al. 2018, Hema and Devi 2014).

Local communities around the mangroves are typically dependent on the mangroves for sustenance and livelihoods (Government of India, 2016; Ekka & Pandit, 2012) but the extent to which their households and income depend on the mangroves influences their decision of participating in restoration activities (Barbier, Mangrove Dependency and Livelihoods of Coastal Communities, 2006). Local communities could derive substantial economic values from mangroves. For example, the economic value of mangroves (including forest products, off-shore fishery linkages, protection of shorelines) for the community was in the range of $27264 to $35921/ha for some mangroves in Thailand (data from 1996) (Sathirathai & Barbier, 2001). Further, mangrove restoration could help improve provision of specific ecosystem services and provide livelihood benefits to local communities (IPBES, 2018).

### 5.5 Understanding Drivers of Change in Kerala and Kochi

Specifically, mangroves in Kerala are affected due to conversion for use for urban developmental and residential activities, agriculture (coconut plantations, paddy), sand dredging, consumption (food, fish, fodder, fuel), aquaculture, sea level rise, changes in shorelines, overexploitation of resources for fisheries, and pollution (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Joy & Paul, 2021; Government of India, 2016; Muraleedharan, Swarupanandan, & Anitha, 2009; Department of Environment and Climate Change-Government of Kerala, 2014; Mangroves for the future, 2008). An increase in sea-level rise is a concern for many coastal areas in Kerala, but it could also further affect mangroves adversely (Department of Environment and Climate Change- Government of Kerala, 2014). Mangroves require sediments to cope with the rise in sea levels, and with the decrease in sediments and limited land availability for the mangroves to move inland, mangroves and mangrove biodiversity could be destroyed and adversely affected (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021).

In KMC and surrounding areas, 3.58 sq km of mangroves were converted for alternative land uses and 2.5 sq km newly created during 2000-2017, although a lot of climax vegetation was said to have been lost in the process (Jayahari, Varghese, Sebastian, & Arun, 2020). Some drivers for mangrove destruction and degradation in Kochi have been due to construction of developmental infrastructure (roads, bridges, international container transhipment terminals and LNG petronet terminals, cricket stadiums, residential properties), agriculture (coconut plantations, fish cultivation, paddy agriculture) and clogging of water bodies (due to dumping of waste and pollution especially from plastics, building up of silt, dredging), and other developmental activities (Sreelekshmi, et al., 2018; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Rode & Balasubramanian, 2018; City Development Plan; Thomson, Economic and Social Management of Estuarine Biodiversity in the West Coast of India, 2003). Mangroves have also been affected by dredging and reclamation of the waterways and backwaters which were done to ensure navigation (Aziz, Ray, & Paul, 2018). Mangalavanam bird sanctuary in Ernakulam, Kerala is affected due to intrusion of salt water and pollution (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Rode & Balasubramanian, 2018; Department of Town and Country Planning).

## 5.6 Socio-Economic-Ecological Concerns and Community perspectives

### *5.6.1 Concerns related with mangroves*

- ***Pollution in mangroves and water logging:*** Mangroves in Kerala and Kochi are affected due to pollution (Muraleedharan, Swarupanandan and Anitha 2009, Hema and Devi 2013, Hershey, Nandan and Vasu 2020, Sreelekshmi, Preethy and Joseph, et al. 2017) from trace elements, sewage, industrial activities, run-off from agriculture and urban development (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). Mangroves in Kochi and surrounding areas are also affected due to pollution from toxic and heavy metals and effluents from industries (Sreelekshmi, Veettil, et al. 2021, Jayahari, et al. 2020, Joseph, et al. 2019, Sreelekshmi, Preethy and Joseph, et al. 2017). Areas in and around Cochin estuary were also seen to be affected by microplastics pollution (Suresh, et al., 2020). Pollution negatively affects the biodiversity of mangroves, negatively impacts local livelihoods, and the possible use of mangroves for recreational purposes (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Jayahari, Varghese, Sebastian, & Arun, 2020).
- ***Health concerns:*** Water inundation and stagnation in mangroves seems to have resulted in mosquitos and contributed to health concerns according to a contingent valuation-based willingness to pay study conducted in Kannur and Ernakulam by Muraleedharan et al., (2009) where many respondents (79%) stated it as a concern.
- ***Wildlife threat:*** Wildlife threat and human wildlife conflict was expressed as a concern for many respondents in Kerala (Muraleedharan, Swarupanandan, & Anitha, 2009; Hema & Devi, Socioeconomic Impacts of the Community-based Management of the Mangrove Reserve in Kerala, India, 2013) and in KMC and surrounding areas (Jayahari, Varghese, Sebastian, & Arun, 2020). Some species causing these issues include the smooth-coated otter which eats fish from fish farms (Jayahari, Varghese, Sebastian, & Arun, 2020), foxes, snakes and dogs which steal livestock (Hema and Devi 2013).

### *5.6.2 Willingness to pay as an indicator of community engagement in Kerala*

The literature varies substantially on the question of whether local stakeholders in Kerala support and are willing to pay for mangrove conservation and restoration interventions. For example, Sinclair et al. (2021) undertaking a choice experiment with local stakeholders in Ashtamudi lake, Kerala during 2017-2018 found that local stakeholders were willing to pay much higher for mangrove conservation in comparison to sustainably fishery management. Similarly, amongst fishermen, paddy farmers, local residents and general public in Ernakulam and Kannur, there does seem to be a willigness to pay (WTP) (around Rs. 2308/annum average) towards mangrove conservation and restoration either monetarily/as labour/volunteer (Hema & Devi, 2015). On the other hand, an older study by Muraleedharan et al., (2009) in Kannur and Ernakulam conducting a contingent valuation study found that very few people (9% of respondents) were willing to pay Rs. 100 and most decided on a lesser amount. In Ernakulam and Kannur, there seem to be people unwilling to pay for mangrove conservation and restoration and believe that mangrove protection is the government's responsibility (Based on primary surveys by Muraleedharan et al., (2009) and Hema & Devi (2015)). Local communities seem to prefer managing the resources by themselves as evidenced in a choice experiment study by Hema & Devi (2020; 2014) in Ernakulam and Kannur districts. In the study by Hema and Devi, the WTP was maximum for the general public( people who stay away from mangroves ) followed by residents,fisher men and paddy farmers in that order. The awareness on wcological service flow from mangroves are well perceived by the first group ,while they donot face the disservices on account of mangroves. The residents ,though willing to pay , are reporting the difficulties due to mangroves . The fishermen and paddy farmers, who enjoy higher income through the benefits of ecosystem services ,however are willing to pay the least.

## 5.7 Costs and benefits of mangroves and mangrove restoration

### *5.7.1 Economic values of ecosystem services benefits provided by mangroves: Global learnings*

Mangrove ecosystem services provide a large range of economic benefits, some of which are monetarily quantified and valued. Valuation of ecosystem services could have various uses like improving awareness, identifying damage costs and compensation values, information to take better informed investment decisions and to justify conservation of ecosystems and services (Ghosh N. , 2019; Ashokkumar & Irfan, 2018).

In an attempt to understand the economic values possible from ecosystem services provided by mangroves, meta-analyses[14] and comprehensive literature reviews on mangrove valuation have been summarized here and in Table 5.3. below. We find that mangroves provide substantial economic value, but the actual total economic value differs widely in the literature since studies differ in many respects. For instance, one set of figures indicates a range between 4,185 $/ha/yr to 1,94,000 $/ha/yr at 2007 prices. From the table it appears that, ecosystem services from raw materials, climate regulation, water purification and control of water pollution, shoreline stabilisation and erosion prevention, recreation and tourism are the only services for which values are available in all studies.

Mangroves were suggested to provide economic values of $194000/ha/yr from various ecosystem services globally (in $2007 terms) (Costanza, et al., 2014). Another estimate from a meta-analysis by Salem & Mercer (2012) reports much lesser total economic values from mangroves in the range between $2772/ha/yr to $80334/ha/yr (Mean: $28662/ha/yr). Non-use values (bequest, option, existence) values for mangroves work out to US$17373/ha/yr according to the meta-analysis by Salem & Mercer (2012). Another study by Brander, et al. (2012) focussed more on South-East Asia finds the mangrove ecosystem services values to be $4185/ha/yr (average) (in 2007 prices). A meta-analysis by Getzner & Islam (2020) found that average ecosystem service values in 2018 prices was around US$ 21100 /ha.a, (Majority studies were from Asia). Both studies of Himes-Cornell et al., (2018) and (Salem & Mercer, 2012), report a substantial number of studies from Asia.

While the values of moderation of extreme weather events ranged between Int$4/ha/yr - $9729/ha/yr (Russi, et al., 2013) and US$ 1086/ha/yr (Himes-Cornell, Grose, & Pendleton, 2018) according to the meta-analyses/comprehensive literature reviews, a modelling based estimate by Menéndez et al., (2020) finds the worldwide flood protection benefits of mangroves exceed US$ 65 billion/yr with India being one of the countries to receive large economic benefits.

Except for recreation, tourism and education to an extent, cultural values were not represented in this table (Table 5.3). This was also noted in the analysis by Himes-Cornell et al., (2018) who suggested that many services from mangroves that are important to locals have typically been disregarded due difficulties in monetary valuation. Comparing across studies since they have the same unit of measure (although they may not be comparable due to differences in years), we see that some of the ecosystem services with the highest values are fisheries,

[14] To be noted: We do not report on meta-analysis studies which consider wetlands in general

aquaculture, raw materials, climate regulation, waste treatment and water purification, opportunities for recreation and tourism and lifecycle maintenance.

Table 5.3: Economic values for Mangrove ecosystem services

| Ecosystem services | Economic Values | | |
|---|---|---|---|
| | Average value (US$/ha/year)<br><br>(Source from- (Himes-Cornell, Grose, & Pendleton, 2018) | Average value (US$/ha/yr)<br><br>(Source from - (Salem & Mercer, 2012)) | Range* (Minimum-maximum values) (Int.$/ha/yr)<br>(*Values include both mangroves and tidal marshes)<br>(Source from- (Russi, et al., 2013)) |
| Food, fish consumption | 8319 | | 0 – 2600 |
| Water supply | 799 | | 41 – 4240 |
| Maintenance of fisheries and aquaculture | | 23613 (Fish, shellfish;<br>includes nursery, breeding service) | |
| Raw materials- Wood and non-wood, fodder, Energy resources | 2591 | 38115 (Forestry-timber, charcoal, fuel wood, other forest products) | 1 – 1414 |
| Biochemical products | 97 (medicinal resources) | | 2 – 35 (medicinal resources) |
| Local and global Climate regulation | 34756 | 967 (Carbon sequestration) | 2 – 4677 |
| Biological regulation and control, pest and disease control | 797 (biological control) | | |
| Water flow regulation (groundwater recharge/ discharge) | 600 | | |
| Control of water pollution and waste, water purification and detoxification | 2827(Waste treatment) | 4748 (water, air purification, waste assimilation) | 1811 – 120200 (Waste treatment, water purification) |
| Shoreline stabilisation, Erosion control and regulation, Sediment retention | 930 (Erosion prevention) | 3116 (storm, coastal protection, coastline stabilization) | 97 – 755 (Erosion prevention) |
| Moderation of extreme weather events like storms, floods, tsunamis | 1086 | | 4 – 9729 |

| | | | |
|---|---|---|---|
| Opportunities for recreation and tourism | 3526 | 37927 (tourism, research expenses) | 10 – 2904 |
| Aesthetic appreciation | 256 | | |
| Information for Cognitive development- Education, research, local knowledge | 276 | | |
| Biodiversity and lifecycle maintenance | 82 (Genetic diversity maintenance)<br>1472 (Lifecycle maintenance-migratory species) | 52 | 25 – 9150 (protection of gene pool)<br><br>2 - 59645 (Lifecycle maintenance, especially nursery service) |
| Nutrient cycling, soil fertility | 428 | 44 (nutrient retention) | |
| Total studies analysed | 70 | 44 | |
| Year | Not standardized – average year of values- 2009 | Standardized | 2007 values |
| Location | World- Africa, Asia, Australia and South Pacific, North America, Central and South America, Middle East | World- Asia, the Americas, Africa, Middle East, Micronesia, Fiji | World |
| Source: | (Himes-Cornell, Grose, & Pendleton, 2018) | (Salem & Mercer, 2012) | (Russi, et al., 2013) |

Note*: includes both mangroves and tidal marshes

Source: Authors' compilation from meta-analysis/comprehensive literature review studies (Himes-Cornell, Grose, & Pendleton, 2018; Salem & Mercer, 2012; Russi, et al., 2013)

### *5.7.2 Valuing Economic benefits from mangrove ecosystem services in India*

Ecosystem services by marine and coastal ecosystems in India contribute economic values of about Rs. 1.5 trillion (underestimate) for the year 2012-13 considering the values from fisheries, coastal salts, minerals, seaweeds, use of seawater for industrial cooling and desalination, shipping, carbon sequestration and coastal protection by mangroves, carbon sequestration by seagrass and coastal recreation (Kumar, et al., 2016). Another estimate by World Bank (2013) valuing the various ecosystems and ecosystem services in India found the total value of forests, grasslands, wetlands, mangroves, lakes, rivers coral reefs to be Rs. 1.4 trillion (in 2009; central estimate, Rs.746 billion (lower bound)- Rs.2577 billion (upper bound)) of which mangroves contributed to about 2% (Rs. 25,508 million; Rs. 12754 million (lower bound)- Rs. 51015 million (upper bound)). Recreation in marine and coastal ecosystems in India was valued at Rs. 531.7 billion (2012-13) (partial estimate, using zonal travel cost method) for many Indian states (Andhra Pradesh and Telangana, Goa, Gujarat, Karnataka, Tamil Nadu, West Bengal, Kerala, Odisha, Maharashtra) of which Kerala had the highest value at Rs.209.2 billion (for 2012-13) (Mukhopadhyay & Costa, 2015).

For the state of Kerala, Hema and Devi (2015) calculated a total economic value of Rs. 117947 million through a contingent valuation study (based on a study in Ernakulum and Kannur, Kerala). Khaleel (2012) found the ecosystem service value of mangroves in North Malabar for many provisioning, regulating and supporting services (fisheries habitat, protection against extreme weather events, pollution filtration and chemical pollution, removal of heavy metals, nutrient recycling and production, oxygen production, fisheries and aquaculture, livestock, energy products, fertilizers, micro and macro climate regulation, flood and erosion control, groundwater recharge, recreation, scientific research, gene pool) together to be valued at US$ 10960/ha/year.

Some ecosystem service specific economic valuation studies for mangroves in the context of India and Kochi, Kerala have been captured below in Table 5.4).

***Provisioning services (Forestry and fishery products):*** Value of provisioning services from mangroves (timber, fuel wood, fodder, thatching, medicines, honey, material for weaving) for Bhitarkanika Conservation Area (Odisha) amounted to US$ 107/household/annum which would be around 14.5% of the total household income (Hussain & Badola, 2010).

***Fisheries and aquaculture:*** The mangroves in India play an important role in determining fish production with around 23% of the fish catch in Indian states (specifically, Kerala, Karnataka, Tamil Nadu, West Bengal, Gujarat, Goa, Maharashtra, Odisha, Andhra Pradesh, Pondicherry) being attributable to mangroves (in 2011) although this value could be an overestimate (Anneboina & Kumar, 2017). Anneboina & Kumar (2017) also note that the mangroves contribute an economic value of around Rs. 1.46 lakhs/ha (or Rs. 68 billion) (2012-13 prices) to marine fisheries in India.

The value of planted mangroves to the provision of habitat and nursery service for fisheries (inshore and offshore) in Gujarat was noted to be Rs.36.04 billion/year or Rs. 0.44 million/ha/yr (2013-14 prices) (Das S. , 2017). DebRoy & Jayaraman (2012) find the value of mangrove contribution to fisheries in Pichavaram mangroves, Tamil Nadu to be around Rs. 16 million.

Fisheries and aquaculture (shrimp, mussel, fish cultivation) contribute to around 70% of the total monthly income of the locals (Muraleedharan, Swarupanandan, & Anitha, 2009).

Specifically in Kochi Municipal Corporation and surrounding areas, Jayahari et al., (2020) finds substantial economic values from fisheries of around ₹1.7 million/ha/yr (or $24,100/ha/yr).

***Erosion prevention, coastal and storm protection:*** The coastal and storm protection service provided by mangroves for India was valued at Rs. 650 billion (average) (for 2012-13) (Range: Rs. 560–754 billion/yr) (Kumar, et al., 2016). These values only include the building damages averted and human and livestock life saved and does not include any other damages (Kumar, et al., 2016). Storm protection service by mangroves helped reduce cyclone damage in Odisha by minimising the loss incurred for the households protected by mangroves in comparison to other households without any protection/with embankments but no mangroves (Badola & Hussain, 2005). Further, villages which had wider mangroves protecting them from the coast had lesser deaths due to cyclones in Odisha in comparison to the villages with no mangroves or narrow mangroves (Das & Vincent, 2009). Mangroves also protected against damage to property due to wind during an extreme weather event, to the tune of US$177/ha for Odisha (1999 prices) (Das & Crépin, Mangroves can provide protection against wind damage during storms, 2013). The storm protection value of mangroves for Odisha was calculated in the range of US$ 4335/ha – US$ 43352/ha (Das S. , 2022). Storm protection values in Pichvaram mangroves calculated through surrogate pricing ranged between Rs. 1.6 billion to Rs. 3.2 billion (DebRoy & Jayaraman, 2012).

In Ashtamudi Wetland region (South Kerala), Joy & Paul (2021) finds the erosion prevention service values from the mangroves to be US$ 6460/yr.

***Carbon sequestration:*** The carbon sequestration service provided by mangroves in India came upto Rs. 1.21 billion (average) (for 2012-13) (Kumar, et al., 2016). In Pichvaram mangroves, Tamil Nadu, carbon sequestration values were estimated at Rs. 152 million (DebRoy & Jayaraman, 2012).

In Ashtamudi Wetland region (South Kerala), Joy & Paul (2021) finds carbon sequestration service values from mangroves to be US$ 2741250 for the carbon sequestration service. Although not a monetary estimate, Rani et al., (2021) found that the median average total carbon burial rate across some locations in Kochi was 2.95 t C/ha/yr.

***Ecotourism:*** Ecotourism valuation in Sundarbans mangroves in Bangladesh through Zonal Travel Cost method by Nobi, et al., (2021) estimated the values to be USD 53 million. In India, ecotourism values in Pichavaram mangroves, Tamil Nadu were estimated at Rs. 157 million (DebRoy & Jayaraman, 2012).

***Nutrient retention:*** The economic value of nutrient (Nitrogen, Phospates, Pottasium) retention function of mangroves in Bhitarkanika National Park (mangroves) in Odisha was US$3.37 million (for 145 sq.km of mangroves) (Hussain & Badola, 2008).

Table 5.4: Value of various ecosystem services of mangroves in India, Kerala / Kochi

| Ecosystem service | Valuation method | Economic value | Location | Source |
|---|---|---|---|---|
| Value of various ecosystem services of mangroves in Kochi and Kerala | | | | |
| Erosion control and prevention | Replacement cost (Cost of constructing artificial wall) | Annual value - US$ 6460 (assuming wall's life is 30 years) (In 2017 International $) | Mangroves in the Ashtamudi Wetland Region, South Kerala | (Joy & Paul, 2021) |
| Carbon sequestration | Damage costs and benefit transfer (Using social costs of carbon) | US$ 2741250 (for 31875 tons over 25 Ha of mangroves) (In 2017 International $) | Mangroves in the Ashtamudi Wetland Region, South Kerala | (Joy & Paul, 2021) |
| Fisheries and aquaculture | Market price method | Rs.1.7 million/ ha/yr (or $24,100/ha/ yr) (Year of data collection: 2019) | Kochi Municipal Corporation and surrounding areas – Kumbalam, Trhikkakkara, Chellanam, Cheranallur, Kadamakkudy, Kalamassery, Maradu, Thripunithura, Mulavukad, Elamkunnappuzha (No mangroves found in Kalamassery, Thrikkakara, Cheranallor) | (Jayahari, Varghese, Sebastian, & Arun, 2020) |
| Value of various ecosystem services of mangroves in various Indian states | | | | |
| Ecosystem service | Valuation method | Economic value | Location | Source |
| Provisioning services (timber, fuelwood, fish, honey, thatching material) | Market price method | US$107/household/annum Or 14.5% of total household income | Bhitarkanika Conservation Area (Odisha) | (Hussain & Badola, 2010) |
| Fisheries (Contribution of mangroves to fisheries) | Income estimation method (Values calculated based on respondents' monthly income) | Rs. 1,65,75,000 (for the village) | Pichavaram mangroves, Tamil Nadu | (DebRoy & Jayaraman, 2012) |

| | | | | |
|---|---|---|---|---|
| Marine fisheries (Mangrove contribution to marine fisheries) | Frontier production function, technical efficiency estimates | Rs. 1.46 lakhs/ha (or Rs. 68 billion) (2012-13 prices) | Various Indian states (Kerala, Karnataka, Goa, Maharashtra, Gujarat, West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Pondicherry) | (Anneboina & Kumar, 2017) |
| Nursery, habitat service- Marine fisheries (inshore and offshore) (Contribution by planted Mangroves) | Market price method | Rs.36.04billion/yr (Rs. 0.44 million/ha/yr) (2013-14 prices) | Gujarat | (Das S. , 2017) |
| Coastal and storm protection | Benefit transfer | Rs. 650 billion/yr (average) (Range: Rs. 560–754 billion/yr) (2012–13 prices) | Various Indian states (Andhra Pradesh, Goa, Gujarat, Karnataka, Kerala, Maharashtra, Odisha, Tamil Nadu, West Bengal, Andaman & Nicobar, Daman & Diu, Puducherry) | (Kumar, et al., 2016) |
| Storm protection value of mangroves | Averted damage approach, market prices, value of statistical life | Range: US$ 4335/ha – US$ 43352/ha (1999 prices) | Kendrapada district, Odisha | (Das S. , 2022) |
| Storm protection | Surrogate pricing method (cost of constructing wall) | Range: Rs. 160,00,00,000 - Rs. 320,00,00,000 | Pichavaram mangroves, Tamil Nadu | (DebRoy & Jayaraman, 2012) |
| Wind Protection from extreme weather events | Damage costs | US$177/ha (1999 prices) | Odisha | (Das & Crépin, 2013) |
| Carbon sequestration | Direct market price | Rs. 1.21 billion (average) (Rs. 0.76–1.65 billion in 2012–13 prices) | Various Indian states (West Bengal, Gujarat, Andaman island, Tamil Nadu, Karnataka, Other coastal states) | (Kumar, et al., 2016) |
| | Direct Market price method | Rs. 15,27,63,627 | Pichavaram mangroves, Tamil Nadu | (DebRoy & Jayaraman, 2012) |
| Eco-tourism | Income estimation(Values calculated based on respondents' monthly income) | Rs. 15,75,00,000 | Pichavaram mangroves, Tamil Nadu | (DebRoy & Jayaraman, 2012) |

| | | | | |
|---|---|---|---|---|
| Nutrient retention in soil (Nitrogen, Phospates, Pottasium) | Replacement cost | US$3.37 million (for 145 sq.km of mangroves) | Bhitarkanika National Park (mangroves) in Odisha | (Hussain & Badola, 2008) |

Note: Choice experiments that do not attribute values to a specific ecosystem service are not included in the above table.

### *5.7.3 Costs and benefits of mangrove restoration*

***Costs of mangrove restoration*** (plantation, labour, engineering, maintenance, transportation costs) range from US$23.22/ha to US$371326.75/ha, with a median value of US$1097.16/ha according to a meta-analysis by Su et al. (2021). (Further details and break-up of the various cost components can be found in the meta-analysis by Su et al. (2021) although a majority of studies they considered were from South-East and East Asia). Mangrove interventions should be considered long-term projects, as Das (2016) undertaking a cost benefit analysis of mangrove plantation in Gujarat noted that the cost could be recovered between 20-50 years depending on the plantation method (sowing/nursery) (at 5% discount rates) (benefits valued here were nursery, breeding for fisheries and coastal erosion protection).

***Opportunity costs of conversion of mangroves:*** Mangrove restoration presents a lot of opportunity costs for local stakeholders in the short-term especially in terms of alternative land-uses which may be more economically productive; although mangroves could provide more ecosystem service benefits in comparison to the many other alternative uses. For example, comparing economic values from storm protection service (per ha) by mangroves with land prices of agricultural land in Kendrapada in Odisha, Das (2022) found the storm protection values to be much higher. *For the Ashtamudi Wetland region in South Kerala, a study by Joy & Paul (2021) calculating the total economic value found that a major driver of mangrove decline in the area was the conversion into coconut plantations. However, there was a large difference between the economic value of the mangrove and the coconut plantation with the mangrove's economic value being around 25 times higher (Value of coconut plantation-US$4450/ha (based on yield, market value); Value of mangroves - US$109650/ha). Further, the coconut trees sequestered insignificant amounts of carbon in relation to mangroves' sequestration. Over time (1997-2017), they also noted a that the coconut plantation's productivity declined (Joy & Paul, 2021).*

***Cost variations amongst techniques of restoration-*** Artificial regeneration involves direct mangrove planting through planting of seeds or seedlings from nurseries (Government of India, 2016; UNEP-Nairobi Convention/USAID/WIOMSA, 2020). Further, in case the mangrove has species that could eat the seeds, strong waves or has been subjected to adverse climatic conditions, it might be better to plant using seedlings since direct seed planting may be unproductive (Government of India, 2016). Plantation can be done with or without canal digging. Some planting techniques used in different states in India include 'raised bed' planting, poly plot, enrichment planting, direct seed sowing, fish bone planting (Gujarat) (Government of India, 2016; Das S. , Valuation of Planted Mangroves, 2016), planting in coconut with holes made (Karnataka), dead palmyra palms to strengthen seedlings (Tamil Nadu), fishbone pattern canal planting (Tamil Nadu, Andhra Pradesh) and transplanting using bamboo containers (Kerala) (Government of India, 2016).

Costs of plantation/regeneration in Gujarat were noted by Das (2016) with variations depending on the kind of plantation method (Rs. 12,800/ha for seed sowing, Rs. 24,400/ha for nursery-based planting, Rs. 66,240/ha when including other costs like maintenance, testing of soils etc), while costs of planting (as of 2007 in Tamil Nadu) with direct planting and canal digging was Rs. 43554/ha, while canal digging and nursery-based planting cost around Rs. 51354/ha, with some maintenance costs for 2 years (Rs. 3000 annually) (Government of India, 2016) Costs would also depend on the planted mangroves' survival rates which Das (2016) suggested could be anywhere in the range of 15% to 50% for various locations..

***Cost and Benefit Variations between conservation and restoration approaches:*** Other things remaining equal, restoration could work out to be costlier than conservation (Dasgupta, 2021; Fleischman, et al., 2020). This argument is also echoed in a meta-analysis by Su et al. (2021). This meta-analysis (with most studies from South-East and East Asia) finds that restored mangroves predominantly provide lower ecosystem benefits when compared with natural mangroves, but higher benefits than unvegetated tidal flats, although restoration methods, age and species do play a role as well. Further, although mangrove restoration is cost-effective, mangrove conservation or maintenance of existing natural mangroves is suggested to be even more cost-effective. In a meta-analysis by Su et al. (2021), mangrove restoration was calculated to have benefit-costs ratio between 10.5 to 6.83 for various discount rates between (-)2% to 8%, while the benefit-cost ratios for natural mangroves could be much higher (for example 16.75 for (-)2% discount rate).

A comparison of the benefits in the meta-analysis of mangrove restoration studies by Su et al. (2021) suggests that for many ecosystem services, the economic value as determined by various valuation methods was lesser for restored mangroves in comparison to natural mangroves possibly due to the restored mangroves being younger and immature. For example, Su et al. (2021) noted wide differences for climate regulation (Mean US$205.38/ha/yr for restored mangroves vs US$899.92/ha/yr for natural mangroves), tourism and recreation (Mean US$99.78/ha/yr for restored vs US$5468.47/ha/yr for natural) and timber production (Mean US$398.36/ha/yr for restored vs US$3500.39/ha/yr for natural). Natural mangroves were also seen to provide the most ecosystem services except fish in a study in Java, Indonesia (van Oudenhoven, et al., 2015). Valuing the fishing nursery and habitat service by planted mangroves suggests a value of USD0.57 billion/annum to the fishery sector for Gujarat (S. Das 2017).

## 5.8 Suggestions for mangrove restoration/conservation based on global and local evidences

### *5.8.1 Legal and regulatory solutions-*

- ***Direct Compensation for government procurement and ensuring tenure rights:***

Direct compensation and user rights can be given to those dependent on/owning the land in case of government acquiring the land. Direct compensation or monetary support by governments could also be considered as a short-term solution to ensure continuation when the restoration may be incurring initial losses. For example, a feasibility study by Rahman & Mahmud (2018) in some mangroves in Bangladesh found that in the initial 3 years of establishment, all interventions considered (integrated mangrove-shrimp, mangrove as a biofilter next to shrimp culture areas, integrated nypa palm plantation-shrimp) except for integrated mangrove crab farming, had benefit-cost ratios (only financial costs and benefits) less than 1 (Rahman & Mahmud, 2018).

*For Kochi, the government and Kerala Forest department could take over the privately held mangroves and instead provide compensation to the owners of these mangroves (Jayahari, Varghese, Sebastian, & Arun, 2020; Rode & Balasubramanian, 2018). In addition to compensation, tenure rights for traditional fishing and mangrove use by locals should be ensured (Jayahari, Varghese, Sebastian, & Arun, 2020). The Forest and wildlife department in Kerala is said to have initiated payment for mangrove conservation for privately held mangroves in a few districts in Kerala including Ernakulam (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Jayahari, Varghese, Sebastian, & Arun, 2020).*

- ***Direct protection of mangroves through setting up community reserves:***

Community reserves are set up and notified by the government with a goal to protect biodiversity and ensure proper management of mangroves while ensuring community participation (Hema & Devi, Socioeconomic Impacts of the Community-based Management of the Mangrove Reserve in Kerala, India, 2013).

*Some community reserves already exist in Kerala. Project management is undertaken by an elected group called the Community Reserve Management Committee who also conduct awareness building activities (Hema & Devi, Socioeconomic Impacts of the Community-based Management of the Mangrove Reserve in Kerala, India, 2013). Hema & Devi (2013) noted resistance from locals on working together with the government, and concerns about potential loss of tenure rights or eviction.*

### *5.8.2 Benefit sharing mechanisms*

- ***Payment for ecosystem services (PES)***

The term, Payments for Ecosystem Services (PES), has been used in many different ways. One definition characterises it as "voluntary transactions between service users and service providers that are conditional on agreed rules of natural resource management for generating offsite services" (Wunder, 2015). In this section, we use the term PES in a generic sense, capturing mechanisms that seek to compensate providers of ecosystem services applying such a transactional principle.

PES given periodically could help ensure commitment of local community members for care, monitoring, maintenance, and support of restoration intervention over time (Rahman & Mahmud, 2018). PES schemes need to ensure that the benefit-sharing is equitable and fair especially with respect to gender (Locatelli, et al., 2014; Thompson, Primavera, & Friess, 2017), and also take into account tenure rights (IPBES, 2018). Further, the impact on ecosystem services and biodiversity due to the PES needs to be understood (IPBES, 2018). PES may also need to account for the many ecosystem services that mangroves provide (Slobodian, Chaves, Nguyen, & Rakotoson, 2018). Although PES may have some viability from the economic perspective, PES for mangroves struggles with issues in implementation and governance aspects (Thompson, Primavera, & Friess, 2017).

- ***Carbon credits and carbon based payment for ecosystem services:***

One further scheme for mangrove restoration which could also potentially contribute to improvements in local income if realised is carbon credits and carbon based PES (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Su, Friess, & Gasparatos, 2021; UNEP-Nairobi

Convention/USAID/WIOMSA, 2020) which could also be based on REDD+ projects (Slobodian, Chaves, Nguyen, & Rakotoson, 2018). Although it could potentially improve incomes, the money may be put in developmental activities which may affect sustainability of the natural environment adversely (Thompson, Primavera, & Friess, 2017).

It must also be noted that issues may arise in trading in carbon markets for mangroves due to difficulties in carbon accreditations (additionality, permanence, leakage) that exist for many forests (Locatelli, et al., 2014). Leakage is suggested by Locatelli, et al., (2014) to be a particularly difficult problem for mangroves due to the small-scale, multi-stakeholder, community-involved nature, but it could be managed to an extent by focusing on local ownerships and governance.

One commonly discussed example of mangrove PES in the literature has been given below- A community involved restoration project in Kenya (Mikoko Pamoja) in coordination with other government actors were able to set-up a small-scale carbon offset facility encouraging mangrove restoration through selling of carbon credits. The community was empowered and trained in the various aspects involved and the income generated was put into various developmental and environmental projects locally. The model has been replicated in other locations, with the addition of another location (Vanga Blue Forest) that could potentially offset enough to generate an income to the locals of US$ 3,000 per annum (UNEP-Nairobi Convention/USAID/WIOMSA, 2020).

- **Mangrove tax:**

One suggestion given by Das (2016) based on a study in Gujarat was for commercial fisheries to bear some of the costs of mangrove replantation through a mangrove tax since they benefited a lot from the mangroves.

### *5.8.3 Institutional solutions and Community related initiatives*

- ***Building knowledge, awareness and capacity building:***

Developing awareness amongst the local communities of the various ecosystem services, benefits, ecological importance of mangroves, damage caused due to pursuing alternative activities, and building their capacities (Government of India, 2016; ICLEI South Asia, 2020; Jayahari, Varghese, Sebastian, & Arun, 2020; Barbier, Mangrove Dependency and Livelihoods of Coastal Communities, 2006; Barbier, Natural barriers to natural disasters: replanting mangroves after the tsunami, 2006; Hema & Devi, Socioeconomic Impacts of the Community-based Management of the Mangrove Reserve in Kerala, India, 2013; WISA, 2013; Ekka & Pandit, 2012) could help encourage voluntary local participation in restoration of mangroves

(UNEP-Nairobi Convention/USAID/WIOMSA, 2020; Barbier, Natural barriers to natural disasters: replanting mangroves after the tsunami, 2006). Awareness may also help improve commitment to restoration since many restoration programmes might take time to show their wide range of benefits (Rahman & Mahmud, 2018).

Environmental education workshops, posters, brochures, competitions, documentaries, street theatre etc could be some ways to build awareness (Government of India, 2016). Education and improvement of skills could be very helpful, especially for women (Barbier, Mangrove Dependency and Livelihoods of Coastal Communities, 2006). In addition to building capacities of local communities, capacity building of forest departments for ecotourism, coastal protection, restoration, monitoring, and growing mangrove saplings could be beneficial (Mangroves for the future, 2008). Building capacities of citizens and locals to engage in monitoring of ecosystems could help ensure data collection at lesser costs (Mangroves for the future, 2008).

*Specifically in KMC and surrounding areas, non-resident fish farmers need to be made aware of sustainable methods (Jayahari, Varghese, Sebastian, & Arun, 2020). For implementing this intervention in KMC, some stakeholders that could be consulted are RWAs, c-hed, KMC, various NGOs, residents and members from the local community, etc. The intervention might require 1-2 years for implementation (As outlined in KMCs LBSAP by ICLEI South Asia (2020).*

- ***Joint mangrove management with government or private sector:***

Mangroves should be managed by the community and the government together, with government providing the communities with the support required (Barbier, 2006). Joint mangrove management encourages afforestation and other activities that could help generate additional income and has been implemented in Sundarbans with successful outcomes (improvements in tiger population, mangrove afforestation of around 17000 ha) (Government of India, 2016). Participatory mangrove management with public private partnership arrangements and community involvement has also found success in Gujarat with many initiatives (For example, REMAG (Restoration of Mangroves in Gujarat)) together resulting in improvements in mangrove cover (Das S. , Valuation of Planted Mangroves, 2016). This may be at odds with the community’s most preferred governance of managing the mangroves themselves. Joint forest management with people’s participation has also been attempted in Tamil Nadu, Odisha and Andhra Pradesh through a project by MSSRF and state forest departments. (Mangroves for the future, 2008; Selvam, Karunagaran, Ravichandran, Mani, & Beula, 2004).

- ***Cooperatives and community-based organisations:***

Gujarat Ecological commission is said to have encouraged participation of local communities through setting up of community based organisations at the level of the village where a part of the daily wages is deposited in a bank account and used for both mangrove maintenance and to give out loans to the group members (Mangroves for the future, 2008).

#### *5.8.4 Ecological solutions*

***De-silting***

De-silting could help improve the flow of water and ensure continued ecosystem health (Government of India, 2016)

- ***Weed infestation and control***

Documenting invasive species (ICLEI South Asia, 2020) and control of weed infestation (Government of India, 2016) could be a possible intervention. Some stakeholders that could be consulted for documenting invasive species include c-hed, subject experts, KMC, various NGOs, CUSAT, and the local community, with a possible implementation period of one year (as outlined in KMC's LBSAP by ICLEI South Asia (2020)).

- ***Control of pollution*** (Government of India, 2016)

#### *5.8.5 Other revenue generating activities*

- ***Mangrove tourism***

Eco-tourism could be a helpful way for local communities to make additional income and protect mangroves (UNEP-Nairobi Convention/USAID/WIOMSA, 2020; Mangroves for the future, 2008).

Mangroves generally fall under the classification CRZ-IA ("The areas that are ecologically sensitive and the geomorphological features which play a role in the maintaining the integrity of the coast,") (Ministry of Environment and Forests, 2011), hence there are strict restrictions on the activities allowed on these lands, although eco-tourism can be pursued after approval (Ministry of Environment, Forest and Climate Change, 2019). Mangroves have been promoted for tourism and other recreational activities, including by some local communities with an intention to earn more income, but this could have negative impacts on the mangrove ecosystem (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). Precautions might be needed to avoid these impacts. *For example Azeez et al. (2004) when discussing potential development in the Mangalavanam area, notes that ecotourism can be undertaken only in a limited smaller scale due to the region's low carrying capacity. They also suggest some precautionary steps such as not allowing visitors in certain locations during breeding seasons and setting up* *infrastructure for tourists that doesn't disturb the birds* (*Azeez, Bhupathy, Rajasekaran, & Arun, 2004*). *Some suggestions have been nature interpretation centers, aquariums and crocodile ponds (Azeez, Bhupathy, Rajasekaran, & Arun, 2004).* Ecotourism should include building awareness (Mangroves for the future, 2008). Awareness building for eco-tourism should keep in mind these guidelines of environmental awareness, cultural awareness, awareness of various ecosystem services, ensuring minimisation of adverse impact, providing learning experiences for tourists and empowering local communities (Mangroves for the future, 2008; Government of India, 2016).

Mangrove tourism is typically said to need involvement of government due to the common property nature of the resources, potential competition and resource conflict between locals and tourists, high risks involved and the natural environment's dynamic nature (Mangroves for the future, 2008).

Mangrove tourism could have potential in KMC and surrounding areas (Jayahari, Varghese, Sebastian, & Arun, 2020). *Ernakulam has been attempting various initiatives towards encouraging tourism in mangroves, for example- the Malipuram aqua tourism center (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). Eco-tourism for mangroves also seems to have been implemented in Kumbalanghi panchayat where the Tourism Department is said to have provided Rs. 5 lakhs and the panchayat spending Rs.1.25 lakh for building awareness (Sudheer, 2021).*

- ***Integrated mangrove farming systems and silvofishery/Integrated sustainable aquaculture with management of mangroves:***

Mangrove restoration has a lot of opportunity costs for the local stakeholders in the short-term especially in terms of alternative land-uses, since restoration could take many years to reach the maximum level of some provisioning ecosystem services (Su, Friess, & Gasparatos, 2021). Hence, revenue generating sustainable activities that don't threaten the mangroves could help in the acceptability of the restoration. Sustainable aquaculture is a potential option, especially since younger mangroves that have been restored could provide better biodiversity services like habitat and nursery to crabs in comparison to older restored mangroves (Su, Friess, & Gasparatos, 2021).

Silvofishery or integrated mangrove management- aquaculture systems are defined as "a low-input sustainable aquaculture integrating mangrove tree culture with brackish water aquaculture" (Fitzgerald Jr, 2002). This system requires lesser inputs and potentially provides many outputs (forestry products, fish) (Rahman & Mahmud, 2018) and if done without worsening the natural environment, could be beneficial for the biodiversity of the mangrove ecosystem (Fitzgerald Jr, 2002). It is important to note that aquaculture here has to be sustainable and undertaken in a controlled manner (Fitzgerald Jr, 2002), as similar relationships may not apply with intensive or semi-intensive farming (Rahman & Mahmud, 2018). Silvofishery may also help reducing diseases and attacks on shrimps and crabs (Rahman & Mahmud, 2018).

These systems seem to be profitable, but over longer time periods. A study by Rahman & Mahmud (2018) for some mangroves in Bangladesh helped get some insights into the financial and socio-economic feasibility of silvofishery. They found that the socio-economic feasibility and the economic benefit-cost ratio (includes financial, economic, some environmental costs/benefits) of all silvofishery practices they considered (integrated mangrove-shrimp, mangrove as a biofilter next to shrimp culture areas, integrated nypa palm plantation-shrimp, integrated mangrove crab) was greater than 1, with the highest ratio for integrated shrimp cultivation (Benefit cost ratio: 2.33; for a 35- year time period). There are some similarities between this system and the rice-fish farming systems (Fitzgerald Jr, 2002). Hence, integrated mangrove restoration-fishing/crustacean farming could make sense from the economic viability perspective (in comparison to complete conversion of mangroves for other uses) (Rahman & Mahmud, 2018) in improving local income and encouraging community buy-in for mangrove restoration. This may especially be true in Kochi, where there is a high dependence on fishing and the fishery service from mangroves (Jayahari, Varghese, Sebastian, & Arun, 2020).

Farming systems that integrate mangroves and fishing/ crustacean cultivation have been proposed in India, with suggestions of around 35% area to be kept for mangroves (Government of India, 2016). A higher percentage of coverage is suggested in an analysis by Truong & Do (2018) who suggests that when converting parts of mangrove lands to shrimp farming, optimal levels of coverage of mangroves should be around 60% to avoid adverse impacts on profitability and productivity of shrimp (based on their analysis in Mekong river delta, Vietnam).

Integrated mangrove- fish/crustacean farming has been attempted in India. One example is the integration of mangrove conservation with crab farming that was attempted in Sindhudurg (Maharashtra), with a potential inclusion of other species also analysed (Ghosh, Patki, Thigale, & Sawant) (Detailed economics of crab farming and other options (mussels, oysters, rice) is given in the report by Ghosh, Patki, Thigale, & Sawant (Best practices in coastal livelihood generation: Lessons from GoI-UNDP-GEF Sindhudurg Project (2012-2017)) published by the Mangrove Cell of Maharashtra’s Forest Department).

The existence of integrated rice- mangrove farming systems have also been noted in the literature, although since mangroves have both saltwater intrusion and fresh-water availability, the decision on types of rice could be important to pursuing integrated farming (Agyen-Sampong, 1991).

### *5.8.6 Others*

- ***Mapping of mangroves in Kochi***

Mapping of mangroves and changes over time (geo-referenced), and mapping of various mangrove landowners in Kochi could be some potential solutions towards improving information on mangroves in Kochi (Rode & Balasubramanian, 2018; ICLEI South Asia, 2020; Hema & Devi, Economic Valuation of Mangrove Ecosystems of Kerala, India, 2015). Identifying mangrove landowners and grouping them could further encourage knowledge sharing between the various owners of mangroves (Rode & Balasubramanian, 2018). Further, a mapping of mangroves and their ownership helps in understanding tenure rights and compensation in case the private mangroves are being taken over by the government. Some stakeholders that could be consulted could be the department of marine biology, KFRI, CMFRI, CUSAT, c-hed, GIS experts, KMC, subject experts and local community with a potential time frame for implementation of 3-6 months (Rode & Balasubramanian, 2018; ICLEI South Asia, 2020).

- ***Eco-labelling and certification***

In order to encourage sustainable use of fisheries and shrimp cultivation, eco-labelling or certifications could be considered, with certain safeguards and restrictions to protect mangroves. For example, for shrimp to meet the certification requirements of an eco-labelling system in Madagascar (designed by farmers, fish farmers and WWF), they had to ensure no more than 10% of the mangroves on the land were removed (Slobodian, Chaves, Nguyen, & Rakotoson, 2018). Another similar project in Vietnam called 'Markets and Mangroves' provided awareness and training for shrimp farmers on how to meet standards for organic certification, but for certification, the farmers needed to ensure at least 50% coverage of mangroves in fields (Slobodian, Chaves, Nguyen, & Rakotoson, 2018). Eco-labelling was attempted for clams in Ashtamudi Lake, Kerala and the costs of MSC certification was Rs. 3 million and fishery management costs were Rs. 161.7 million, although some possible benefits included potential access to export markets and improved awareness of long-term sustainability (Mohamed, et al., 2016).

- ***Planned or managed retreat:***

Planned or managed retreat, involves proactively moving people and infrastructure more inwards into lands to adapt from sea-level rise and climate change, which could be an effective long term adaptation strategy in comparison to in-situ adaptation in vulnerable locations, while mangrove restoration is simultaneously being undertaken in these areas. It could require substantial investments (Ghosh N. , 2018; Danda, Ghosh, Bandyopadhyay, & Hazra, 2019).

## 5.9 Operational considerations

### *5.9.1 Institutional and policy support*

***International commitments and goals:*** Mangrove interventions could potentially fall under atleast two of the Aichi targets- Target 5 ("By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.") and Target 7 ("By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.") (Convention on Biological Diversity, 2013; Government of India, 2016).

SDGs do not expressly mention mangroves, although these ecosystems could have contributions to SDG14 (Life below water) and SDG 15 (Life on land), specifically targets relating to restoration, improving resilience, conservation and reducing of degradation (Slobodian, Chaves, Nguyen, & Rakotoson, 2018).

The Ramsar Convention also encourages 'wise use' [15] of wetlands (Slobodian, Chaves, Nguyen, & Rakotoson, 2018) which could form a potential categorization for a mangrove restoration intervention.

***Policy/Regulatory support in India:*** Wetlands (including mangroves) fall under the Wetlands (Conservation and management) rules, 2017 (Ministry of Environment, Forest and Climate Change, 2020). Additionally, majority of Indian mangroves fall under the Indian Forest Act (1927), Wildlife Protection Act (1972), Forest Conservation Act (1980), Environment Protection Act (1986) and are protected under these Acts (Government of India, 2016). The mangroves are also classified into various categories (For example- national parks, wildlife sanctuaries, community reserves, reserve forests, protected forests) through these Acts. Under the Coastal Regulation Zone notification, mangroves fall under the classification CRZ-IA which has highest protection ("The areas that are ecologically sensitive and the geomorphological features which play a role in the maintaining the integrity of the coast,")

[15] Wise use of wetlands is defined as "their sustainable utilisation for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem." (Ramsar Convention Secretariat, 2010)

(Ministry of Environment and Forests, 2011; Ministry of Environment, Forest and Climate Change, 2019).

**Private ownership**: *A major concern in conservation is the private ownership of mangroves which affects the ability of the government to pursue conservation and restoration. Further, a substantial portion of mangroves (around 80%-90%) is held by private owners in Kerala (Sreelekshmi, et al., 2018; Muraleedharan, Swarupanandan, & Anitha, 2009; Hema & Devi, Factors of mangrove destruction and management of mangrove ecosystem of Kerala, India, 2014), and these private owners typically lack any economic incentives to protect the mangroves (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). Those mangroves acknowledged as forests by the state or central government, or through the various Acts will be protected by the governmental authority with the additional construction of a buffer zone, while mangroves within private land area do not need to construct a buffer zone (Ministry of Environment, Forest and Climate Change, 2019).*

*Some of the state laws and policies applicable for mangroves in Kerala have been detailed below. In Kerala, many of the mangrove species and their trees are covered under the Kerala Preservation of Trees Act, 1986 (Government of Kerala, 1986; Jayahari, Varghese, Sebastian, & Arun, 2020). Further, mangroves are included in the Kerala Conservation of Paddy Land and Wetland Act, 2008 (Government of Kerala, 2008) which may make conversion and reclamation of mangrove land for other uses difficult (Government of Kerala, 2008; Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021). Some recent amendments permit relaxations and allow conversions for specific purposes.*

*When looking at the Kochi's LBSAP (ICLEI South Asia, 2020), Focus area 8 (Marshes and mangroves) is one area that could possibly be relevant for this intervention. Specifically, Goal 8.1 ("Assessment of current biodiversity profile and development of a management framework for marshes and mangroves"), Goal 8.2 ("Prioritize areas of conservation importance and eco-restore relevant areas") and Goal 8.3 ("Community based mangrove and marshy land conservation") could be important (ICLEI South Asia, 2020).*

### *5.9.2 Factors impacting success of restoration projects*

Restoration campaigns need to focus on the exact problems in the local context, the precise goals to be achieved through the intervention, understand the governance and regulations applicable, get insights from all stakeholders and especially safeguard interests, perceptions, use, access rights and governance of local communities, identify financing and other policy/regulatory requirements, identify institutional authorities for coordination, identify appropriate sites for intervention, determine labour requirements, establish nurseries, planting and undertaking modifications based on feedback (for which monitoring mechanisms are required) (UNEP-Nairobi Convention/USAID/WIOMSA, 2020; Muraleedharan, Swarupanandan, & Anitha, 2009). Monitoring mechanisms helps implementors get timely feedback and should include activities like vegetation assessments and how the biodiversity and ecosystem services have changed (UNEP-Nairobi Convention/USAID/WIOMSA, 2020).

Precise goals are important considering that interventions to boost one ecosystem service may cause trade-offs and impacts in other services thereby causing some stakeholders to lose out. For example, mangrove restoration for the ecosystem service of storm protection could have impacts on shrimp farming (Russi, et al., 2013).

Mangrove plantation is said to fail in many cases (Kathiresan, 2019). Failure of restoration projects could be due to lack of understanding or information on the conditions and change in conditions in the specific local context, non-inclusion of local stakeholders, lack of adequate monitoring, lack of coordination between various implementing agencies and incorrect restoration techniques and choice of species (UNEP-Nairobi Convention/USAID/WIOMSA, 2020). Tree planting that is not context appropriate could affect regrowth of forests (Fleischman, et al., 2020).

### *5.9.3 Selection of species*

Species selection is one of the most important decisions in mangrove restoration, and species also vary based on the objective for restoration. For India, some suggestions for the species that could be planted for achieving specific goals (For example, these could be protection of coastline, estuaries; regeneration, harvest of forest produce, protection of fisheries and so on) are given in a report by the Government of India (Conservation and Management of Mangroves: Guidelines for Coastal State/UT Governments, 2016).

Other factors that need to be considered when choosing a species include adaptability of species to the site, pest and weed concerns, if they are local/native species, seed availability and size, sedimentation, pollution status, tidal zones preferred by species, tidal amplitude and soil and light conditions (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021; Government of India, 2016).

Although mixed or multiple species restoration are generally believed to be better than monospecific restoration, a meta-analysis by Su et al. (2021) finds that this need not be necessarily true and that there are instances where single species restoration had better outcomes. Hence, context specific evaluation is critical.

It is also important to note that details for categorising mangrove plants are not available at regional levels which makes it difficult when they have different classifications in different areas. For example, it is suggested that *Ceriops tagal* is considered common in Sundarbans, endangered in Kerala, and classified as near threatened according to the red list from IUCN (Sreelekshmi, Veettil, Nandan, & Harikrishnan, 2021).

Other aspects that Government of India (2016) outlined as aspects to keep in mind during planting were the season, spacing and depth in planting, planning of planting process and time period involved, zonation patterns, storage, soil conditions, filling of gaps and monitoring. There also some risks that can crop up post plantation, namely crab, insect infestation, growth of algae and water hyacinth, grazing by cattle, pollution, siltation and extreme weather events (Government of India, 2016)

### *5.9.4 Taking appropriate safeguards during restoration*

Wetlands need to be managed in a way that ensures continued provision of ecosystem services from an inter-generational perspective, and wetland management should follow a ‘precautionary approach’ to account for potential trade-offs, irreversibility of damages and uncertainties (Ministry of Environment, Forest and Climate Change, 2020; Slobodian, Chaves, Nguyen, & Rakotoson, 2018). For some activities, it might help to have thresholds beyond which that activity should be prohibited. For example, for fisheries the thresholds could be placed on the water quality, density of stocking and the fishing area; for sewage, the thresholds could based on water quality (Ministry of Environment, Forest and Climate Change, 2020).

## 5.10 Literature gaps

***Need for further information and evidence in the Kochi context:***

- The relationship between mangroves and agriculture/aquaculture/fisheries/integrated systems as they move from more traditional, indigenous systems to more commercialised, intensive systems would be context dependent. This could be particularly important to consider given the overlap between mangroves and Pokkali paddy areas noted in certain areas in Kerala. Considering both mangrove management, restoration and ensuring livelihoods, one solution that comes up in the literature is ‘silvofishery’ or Integrated sustainable aquaculture with management of mangroves.

Although this solution could represent a better situation over loss of area under mangroves to alternative economic uses, it seems unclear on how it compares to other solutions for restoration. The ecological benefits to mangroves through an integrated mangrove-agriculture/aquaculture system have to be mapped for specific areas proposed for conservation.

- Ecosystem services are said to have high levels of heterogeneity for mangroves even within the same forest (Thompson, Primavera, & Friess, 2017). There is a need for more site-specific assessments and making this data and information publicly available.

***Key takeaways:***

- Mangrove restoration is generally advised in situations where natural self-regeneration might not be possible and it should be considered only after ruling out the possibility of natural regeneration. Decisions between natural and artificial regeneration requires examination of various factors like costs, ecological and hydrological factors to name a few.
- Involvement of local communities plays an important role in determining the success of mangrove conservation and restoration interventions. The communities dependence on mangroves, ownership and perceived control over mangrove management, sufficient incentives, all determine the continued participation and success of the intervention. Local communities seem to prefer managing the mangrove by themselves when compared with other management and governance alternatives.
- Mangroves are quite limited within the Kochi city area with area under mangroves reported in the literature ranging between 0.49 sq km - 1.19 sq km. Many mangroves are Kerala and Kochi are degraded or polluted. Some major drivers include conversion of mangrove lands for various purposes. Problems for those living around mangroves include pollution, water logging, adverse health effects due to stagnant water, human-wildlife conflicts.
- The mangrove ecosystem services that apply in the Kochi context based on information from literature is Food, fish consumption, Maintenance of fisheries and aquaculture, non-wood products, fodder, energy resources, carbon storage and sequestration, Erosion control, moderation of extreme weather events like storms, floods, tsunamis, Opportunities for recreation and tourism and Biodiversity and lifecycle maintenance. Valuation literature in Kochi/Kerala finds economics values for mangroves from fisheries, aquaculture, carbon sequestration and erosion control and prevention.
- Relationship between mangroves and agricultural systems could be multi-dimensional and complex. Conversion of mangrove lands for paddy agriculture and aquaculture poses a threat to mangroves. Mangroves provide many ecosystem services to fisheries, agriculture, and integrated systems. Integrated mangrove management- aquaculture systems could be one solution that is economically feasible and integrates mangrove conservation with livelihoods.
- Some other solutions could be legal/ regulatory (Direct Compensation for government procurement and ensuring tenure rights, Direct protection of mangroves through setting up community reserves), benefit sharing mechanisms (Payment for ecosystem services, Carbon credits and carbon based payment for ecosystem services, mangrove tax), institutional solutions and community related initiatives (Building knowledge, awareness and capacity building, Joint mangrove management with government or private sector, cooperatives and community based organisations), ecological solutions (De-silting, Weed infestation and control, Control of pollution), other revenue generating activities (Mangrove tourism, Integrated mangrove farming systems and Silvofishery/Integrated sustainable aquaculture with management of mangroves). Some other solutions are mapping of mangroves in Kochi, Eco-labelling and certification and planned and managed retreat.

***Key takeaways:***

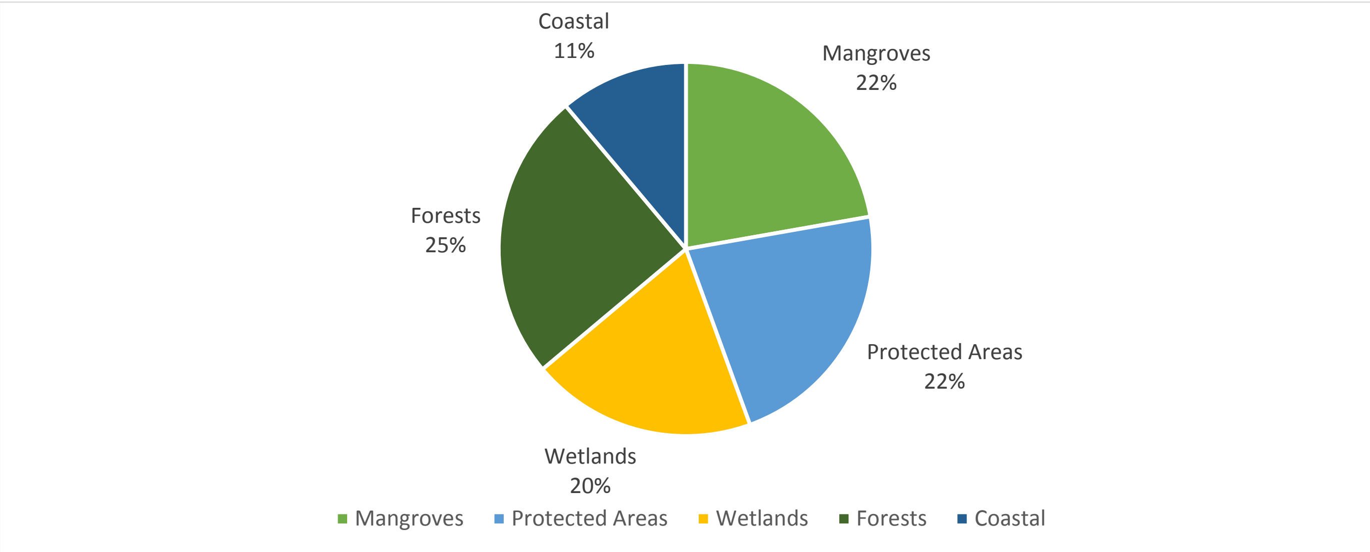
- Mangrove restoration falls under many international commitments and goals (Aichi targets 5 and 7; SDG 14, SDG 15). In Kochi's LBSAP, Focus area 8 (Marshes and mangroves) is one area that could possibly be relevant for this intervention, specifically goals 8.1 ("Assessment of current biodiversity profile and development of a management framework for marshes and mangroves"), Goal 8.2 ("Prioritize areas of conservation importance and eco-restore relevant areas") and Goal 8.3 ("Community based mangrove and marshy land conservation") (ICLEI South Asia, 2020)
- In India, many mangroves fall under some/all of the various central and state acts-Wetlands (Conservation and management) rules, 2017, Indian Forest Act (1927), Wildlife Protection Act (1972), Forest Conservation Act (1980), Environment Protection Act (1986), Coastal Regulation Zone notification, Kerala Preservation of Trees Act, 1986, Kerala Conservation of Paddy Land and Wetland Act, 2008
- A substantial portion of mangroves (around 80%-90%) is held by private owners in Kerala. A major concern in conservation is the private ownership of mangroves which affects the ability of the government to pursue conservation and restoration.

# 6 CHAPTER 6: FINDINGS FROM THE CASE ANALYSIS FOR MANGROVE RESTORATION IN KOCHI

- Community engagement is the only way to ensure success in management of mangroves.
- Explore options for blended finance – aspects of private finance, grants - combinations.
- Possibility of carbon credits/ finance can be explored

An expert analysis was conducted using a quantitative and qualitative semi-structured questionnaire (Appendix 6.1) with questions on ecosystem services, perceived problems and challenges, suggestions and recommendations, costs, opportunities for mangrove conservation/restoration/maintenance. Experts across India from varied disciplines (natural sciences, economics, social sciences) working on various aspects of natural resource management were virtually approached and responses collated (N=23 responses) (List of experts provided in Appendix 6.2). The area of expertise of the experts approached as stated included forests (as stated by 25% of respondents), mangroves (specifically) (22%), protected areas (22%), followed by wetlands (more generally) (20%) and coastal (more generally) (11%) (Figure 6.1)

Figure 6.1: Area of expertise of respondent experts

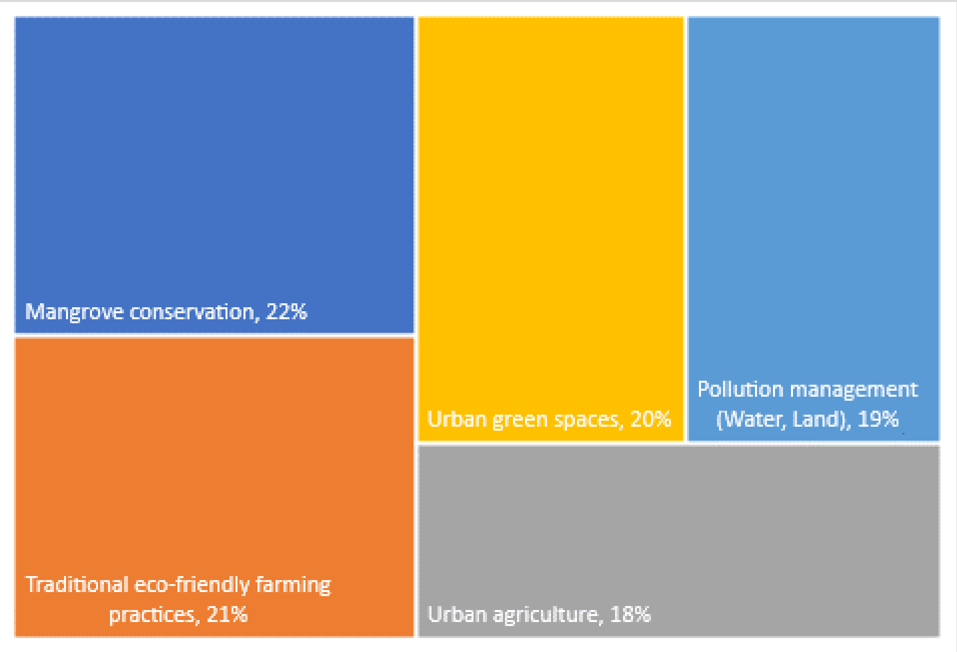



## 6.1 Prioritisation of interventions

Experts were asked for their thoughts on which intervention amongst mangrove conservation, traditional eco-friendly farming practices, urban agriculture, urban green spaces, pollution management (water, land) should be prioritised in a biodiversity action plan to meet the objectives of conservation and community welfare. One expert also suggested lake restoration as a potential intervention that could be considered. Experts also noted that a choice of interventions should be a bottom-up approach rather than top-down enforcement, and that they should consider the local context and decided in consultation with the community.

***Interventions mentioned by experts:*** In terms of the percentage of responses (as a proportion of total responses) that mentioned each intervention, there were only marginal differences. Mangrove conservation was mentioned in 22% of the responses (which was relatively the highest), while traditional eco-friendly farming practices was mentioned in 21% of responses and urban green spaces were mentioned in 20% of the responses, followed by pollution management and urban agriculture which were mentioned in 19% of responses and 18% of responses respectively (Figure 6.2).

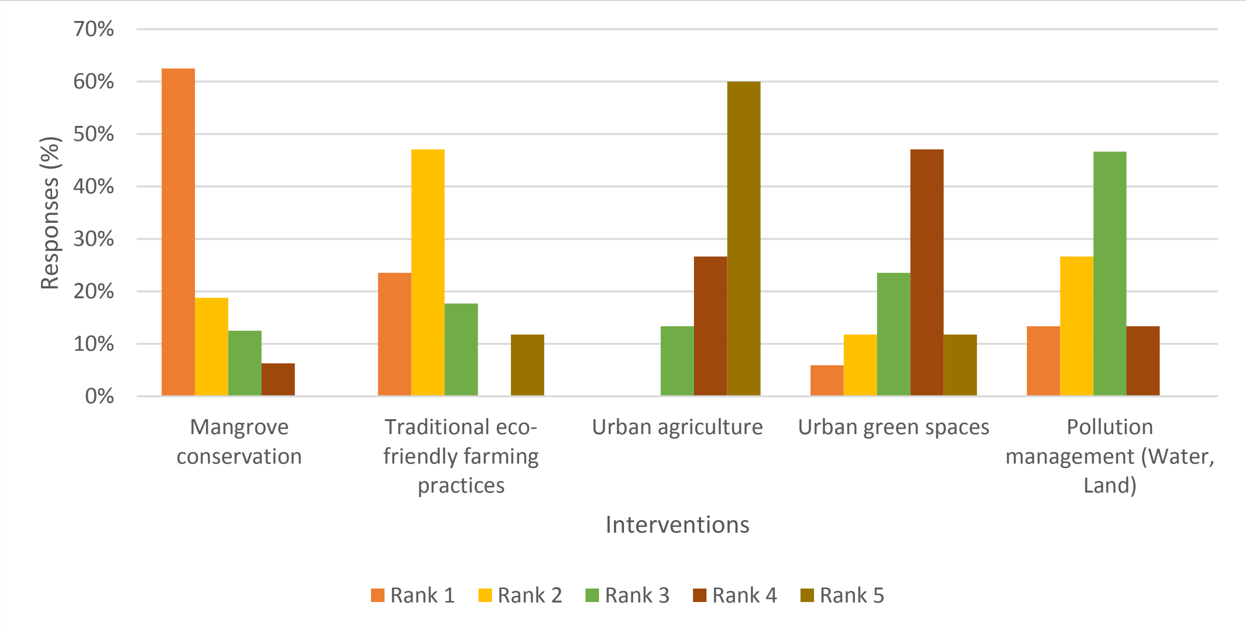
Figure 6.2: Percentage of expert responses (as a proportion of total responses) and intervention mentioned




***Comparing between various interventions- Ranking:*** The ranking between the various interventions provided further clarity on the intervention preferred by experts; with mangrove intervention dominating Rank 1. 63% of the responses gave Rank 1 to mangrove conservation, while 24% of the responses gave rank 1 for traditional eco-friendly farming practices, 13% for pollution management and 6% gave rank 1 for urban green spaces. Taking the first two ranks together suggested a prioritisation of the interventions of mangrove conservation (81% of responses) followed by traditional eco-friendly farming practices (71%). Although mangrove conservation was preferred by most experts, experts mentioned the importance of considering mangrove conservation alongside ensuring community participation, community development and livelihood generation around the mangroves. Traditional farming was suggested to be done as a part of the agro-ecological system.

Pollution management and urban green spaces were predominantly ranked 3rd and 4th position (Pollution management: 60%; Urban green spaces: 71%). Wherever urban green spaces were suggested, some experts recommended that they should be undertaken in dedicated spaces with diverse and indigenous species. Urban agriculture was noted to have limited scope and seems to be less preferred with 60% ranking it 5th, but experts noted that it could be considered considering the potential welfare benefits (Figure 6.3).

Figure 6.3: Ranking of interventions by various experts (as given through percentage share of responses)




***Comparing between various interventions- Scores:*** Garrett ranking method was used to analyse across the various interventions and obtain an overall score for each intervention. As discussed earlier in Chapter 2 on approach and methodology, Garrett's ranking method is used as part of analysing qualitative information, especially from primary surveys. A frequency table with the number of respondents for each rank and each variable was put together and multiplied with the Garrett values for each rank. The sum and average of each variable across the various ranks were calculated, which was used to assign the overall rank. In order to get the Garrett values for each rank, first the percent position was calculated (Formula: "[100*(Rij – 0.5)]/ Nj] where Rij = Rank given for the ith variable by the jth respondent, Nj = number of variables ranked by the jth respondent") (Dhanavandan 2016) and these value was converted into a Garrett value using the table given by Garrett & Woodworth (1967).

Analysis through this method (Table 6.1) suggests that the highest priority was given to mangrove conservation intervention, followed by traditional eco-friendly farming practices. Pollution management was ranked 3rd, urban green spaces 4th and urban agriculture 5th.

Table 6.1: Scoring across interventions- Garrett ranking method

| **Variables** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Rank 5** |
|---|---|---|---|---|---|
| Garrett Value for each rank | 75 | 60 | 50 | 40 | 25 |
| | **Rank given by Experts** | | | | |
| **Intervention** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Rank 5** |
| Mangrove conservation | 8 | 3 | 2 | 0 | 0 |
| Traditional eco-friendly farming practices | 3 | 6 | 2 | 0 | 2 |
| Urban agriculture | 0 | 0 | 0 | 4 | 9 |
| Urban green spaces | 1 | 1 | 2 | 7 | 2 |
| Pollution management (Water, Land) | 1 | 3 | 7 | 2 | 0 |

| | **Garrett values** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Intervention** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Rank 5** | **Sum** | **Average** | **Overall rank** |
| Mangrove conservation | 600 | 180 | 100 | 0 | 0 | 880 | 67.69 | 1 |
| Traditional eco-friendly farming practices | 225 | 360 | 100 | 0 | 50 | 735 | 56.54 | 2 |
| Urban agriculture | 0 | 0 | 0 | 160 | 225 | 385 | 29.62 | 5 |
| Urban green spaces | 75 | 60 | 100 | 280 | 50 | 565 | 43.46 | 4 |
| Pollution management (Water, Land) | 75 | 180 | 350 | 80 | 0 | 685 | 52.69 | 3 |

**Potential locations for conducting mangrove intervention:** Some suggestions made by experts on potential locations to conduct the mangrove intervention include Nettoor, Panangad, Vypin, parts of Tripunithura, Kumbalam, Chellanam, Mulavukadu, Edakochi, parts of Mattanchery, Fort Cochin, Mangalavanam, Njarackkal, Nayarambalam Grama Panchayaths and parts of Aroor along the rail track. Mangroves in many of these locations (such as Mangalavanam, Njarackkal, Mulavukkad, Nayarambalam Grama Panchayaths) are suggested to have sparse mangroves (except for Mangalavanam) and were noted to be apt locations by one expert due to the employment generation potential, land availability in that area and high biophysical feasibility.

**Stakeholders:** Stakeholders impacted due to mangrove intervention was suggested by experts to depend heavily on the location, restoration methods used and if there would be a need for people to leave the mangrove areas, and hence, an integrated impact analysis was suggested to be undertaken before deciding on the intervention.

The important stakeholders impacted by decisions to restore mangroves according to the experts were- the people and industries who have encroached the mangrove areas, local fishing communities, tourism and related service providers, landowners and those who have user rights, those building artificial shelters for storm protection and wildlife departments. It was also noted that mangrove conservation and restoration may cause conflicts between communities and local governments.

### 6.2 Ecological status of mangroves in Kochi

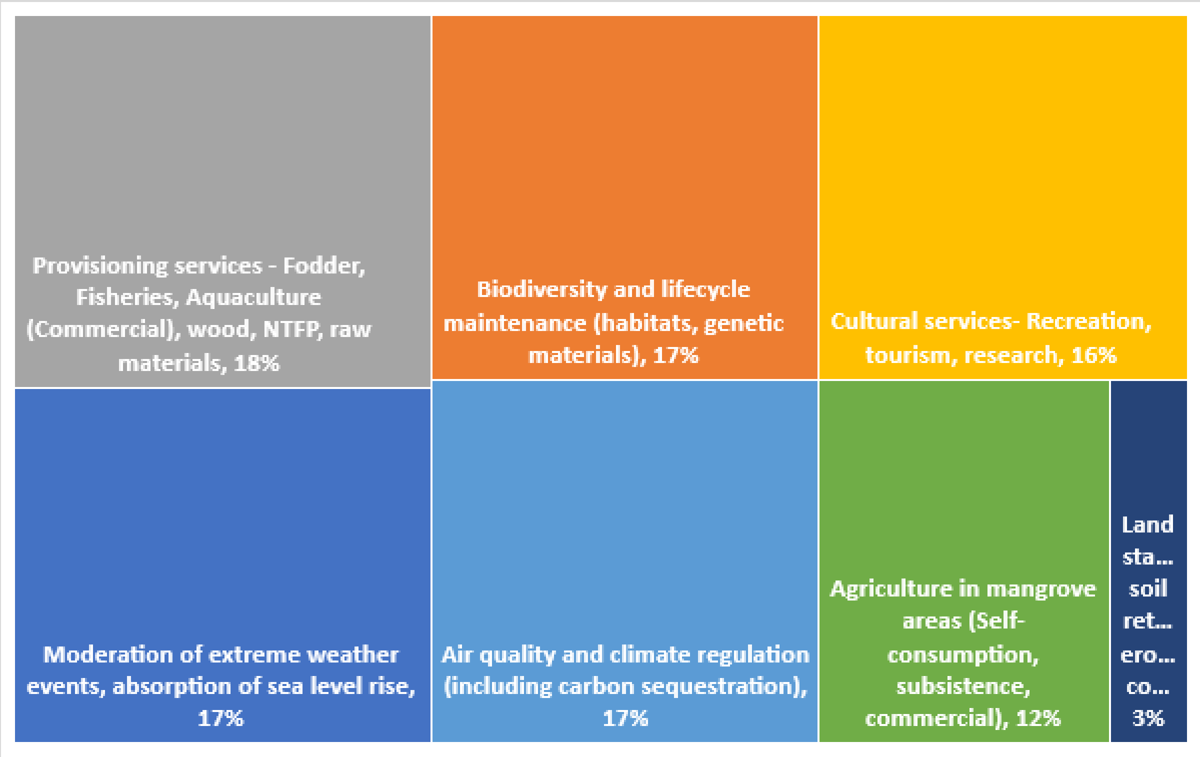
The ecological status of mangroves in Kochi was considered by experts to be rapidly deteriorating and the total area under mangroves decreasing. The density of mangroves was also suggested to be very low, although it was noted that it may be different in certain parts of the city. In terms of the species diversity, it was noted that there was not enough information to comment, but that there is a possibility of loss of species and habitats to small cats.

### 6.3 Ecosystem services from mangroves- Most relevant for the Indian context

Experts were asked for their perception on the ecosystem services from mangroves that they perceived to be most relevant in the Indian context from the context of sustainable development and were given the options of fodder, commercial fisheries, aquaculture; moderation of extreme weather events, biodiversity and lifecycle maintenance, agriculture in mangrove areas, air quality and climate regulation and recreation and tourism.

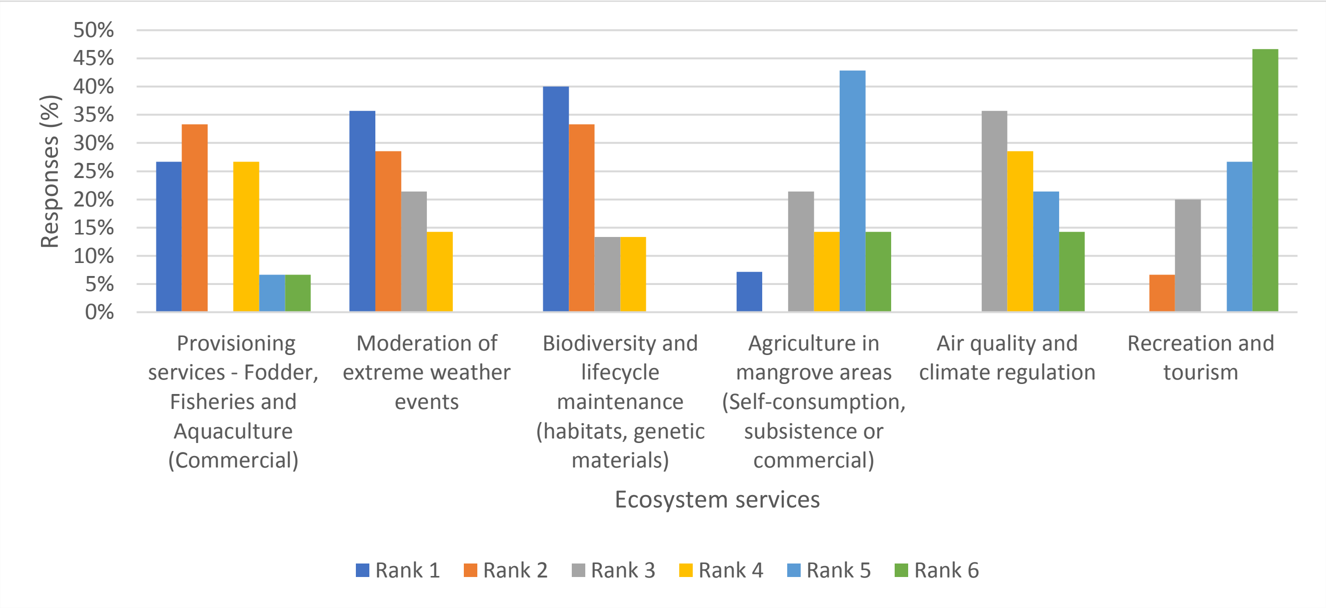
***Ecosystem services mentioned by experts:*** 18% of the responses (which was relatively the highest) mentioned provisioning services from mangroves (fodder, commercial fisheries, aquaculture, wood, NTFP, raw materials). This was also in alignment with the importance of livelihoods, specifically fishing, prawn farming which was highlighted to be of importance in the Kerala and Kochi context. Around 17% of responses mentioned moderation of extreme weather events and absorption of sea level rise as a relevant service. Air quality and climate regulation was noted to be of relevance in the Indian context in 17% of the responses. Biodiversity and lifecycle maintenance (habitats, genetic materials) was noted to be relevant in 17% of the responses. Cultural benefits provided by mangroves, namely recreation, tourism and research were noted as relevant in 16% of the responses. Subsistence agriculture, self-consumption agriculture and commercial agriculture in mangrove areas was also considered to be of relevance by by 12% of the responses. 3% of the responses pointed out and mentioned services of land stabilisation, soil retention and erosion control to be of relevance. (Figure 6.4).

Figure 6.4: Percentage of expert responses (as a proportion of total responses) and ecosystem services mentioned




***Comparing between various ecosystem services- Ranking:*** Ecosystem services of moderation of extreme weather events, biodiversity and lifecycle maintenance and provisioning services including fodder, fisheries and aquaculture were the services that most experts thought were most relevant. In terms of the ecosystem services that dominate the first two ranks (Rank 1 and Rank 2), 73% of responses gave biodiversity and lifecycle maintenance the first two ranks, while around 64% gave the first two ranks to moderation of extreme weather events, and 60% to provisioning services of fodder, Fisheries and Aquaculture (Commercial). Air quality and climate regulation was predominantly ranked either 3$^{rd}$ or 4$^{th}$ (64%) in terms of its relevance. Agriculture in mangrove areas ranked lower on the scale with 93% ranking it between Rank 3 and Rank 6 (Rank 3: 21%, Rank 4: 14%, Rank 5: 43%, Rank 6: 14%). Most experts did not seem to consider the service of recreation and tourism as relevant comparatively since it was predominantly ranked (73%) at the 5$^{th}$ or 6$^{th}$ rank. Others included the categories of land stabilisation, erosion control, soil retention and carbon sequestration which were specifically pointed out by some experts (Figure 6.5). Some ecosystem services that were thought to be moderately or very relevant in the Kochi context as noted by one expert were sediment retention, soil fertility, carbon sequestration, many provisioning services, water purification, recharge of groundwater, local biodiversity services and lifecycle maintenance, moderation of extreme weather events and recreation and tourism.

Figure 6.5: Ranking of ecosystem services by mangroves by various experts (as given through percentage share of responses)




Note: Two experts included land stabilization, erosion control, soil retention and carbon sequestration as ecosystem services that could be ranked highly in the study context.

Some experts also provided opinions on ecosystem services that are relevant for India in the present and the future (2030 and beyond). In the present, provisioning services (fisheries, honey, small timber, raw materials, food), regulating services (carbon sequestration, coastal and storm protection, prevention and control of soil erosion, water purification), cultural services, (tourism; recreation) and supporting and habitat services (fisheries maintenance) was mentioned.

In the future (2030 and beyond), regulating services (carbon sequestration, coastal and storm protection, soil retention) and cultural (research) services were mentioned by experts, while one expert noted that the services mentioned in the present like raw materials, food, tourism, recreation, water purification, erosion control, coastal protection, habitat- maintenance of fisheries would be relevant for the future as well.

***Comparing between various ecosystem services- Scores:*** Analysis through the Garrett ranking method as given in Table 6.2 suggests that the highest priority was noted for the ecosystem service of biodiversity and lifecycle maintenance followed by moderation of extreme weather events and provisioning services in that order. Air quality and climate regulation, agriculture in mangrove areas and recreation and tourism were ranked 4$^{th}$, 5$^{th}$ and 6$^{th}$ respectively.

Table 6.2: Scoring across ecosystem services- Garrett ranking method

| **Variables** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Rank 5** | **Rank 6** |
|---|---|---|---|---|---|---|
| Garrett Value for each rank | 77 | 63 | 54 | 46 | 37 | 23 |
| | Rank given by Experts | | | | | |
| **Ecosystem service** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Rank 5** | **Rank 6** |
| Provisioning services - Fodder, Fisheries and Aquaculture (Commercial) | 1 | 5 | 0 | 4 | 1 | 1 |
| Moderation of extreme weather events | 5 | 3 | 2 | 2 | 0 | 0 |
| Biodiversity and lifecycle maintenance (habitats, genetic materials) | 6 | 4 | 0 | 2 | 0 | 0 |
| Agriculture in mangrove areas (Self-consumption, subsistence or commercial) | 0 | 0 | 3 | 2 | 5 | 2 |
| Air quality and climate regulation | 0 | 0 | 5 | 2 | 3 | 2 |
| Recreation and tourism | 0 | 0 | 2 | 0 | 3 | 7 |

| | **Garrett values** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ecosystem service** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Rank 5** | **Rank 6** | **Sum** | **Average** | **Over all rank** |
| Provisioning services - Fodder, Fisheries and Aquaculture (Commercial) | 77 | 315 | 0 | 184 | 37 | 23 | 636 | 53.00 | 3 |
| Moderation of extreme weather events | 385 | 189 | 108 | 92 | 0 | 0 | 774 | 64.50 | 2 |
| Biodiversity and lifecycle maintenance (habitats, genetic materials) | 462 | 252 | 0 | 92 | 0 | 0 | 806 | 67.17 | 1 |
| Agriculture in mangrove | 0 | 0 | 162 | 92 | 185 | 46 | 485 | 40.42 | 5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| areas (Self-consumption, subsistence or commercial) | | | | | | | | | |
| Air quality and climate regulation | 0 | 0 | 270 | 92 | 111 | 46 | 519 | 43.25 | 4 |
| Recreation and tourism | 0 | 0 | 108 | 0 | 111 | 161 | 380 | 31.67 | 6 |

### 6.4 Relationship between mangroves and agriculture, aquaculture

Experts had a wide range of insights regarding the relationship of mangroves with agriculture, aquaculture, Pokkali areas and paddy-fish ecosystems. The broad understanding from these insights seems to be that while agricultural and aquaculture ecosystems benefit from mangroves, it is unclear whether mangroves benefit from these agricultural/aquaculture ecosystems. One expert noted that even in a mixed mangrove-shrimp farming system, there was not much clarity on whether there were any benefits to mangroves except for the benefit of not being cut down completely.

In terms of benefits mangroves provide to agricultural farms, experts opined that mangrove protects paddy farms from storm surges, high wind speed during cyclones, sedimentation, erosion and that the nutrient rich sediments could contribute to improving yields to some extent.

With respect to the relationship of mangroves and aquaculture, experts noted that there was a well-perceived relationship between mangroves and fisheries. Mangroves act as nurseries, shelter and breeding grounds for juveniles who were said to feed on detritus from the mangroves. Nutrients in mangroves were also said to improve growth of certain species which the fish would later feed on. It was also noted by one expert that fishermen attributed low fish availability to mangrove disappearance.

Experts opined that they were not aware of benefits that the mangroves derived from these ecosystems, but also noted that although it might be better for mangroves to grow exclusively, it might be important to find solutions so that mangroves could co-exist with livelihood activities like cultivating paddy/rice and fish in mangrove areas. In this context, one expert also noted that farmers may not be appreciative of mangroves in the fringes of paddy fields since they grew in abandoned paddy fields and had to be removed.

## 6.5 Threats/challenges to conserving and maintaining mangroves in India

Various drivers of mangrove loss and destruction, problems caused to people due to mangroves, and challenges for mangrove conservation, maintenance and restoration were mentioned by the various experts. These have been classified into various themes and given in Table 6.3 and Figure 6.6 below followed by a detailed discussion of each theme based on the experts' insights.

Experts' expertise ranged from mangroves, protected areas, forests and broader landscape restoration.

Table 6.3: Experts (percentage of responses) and problems mentioned

| Problems/threats/challenges | Number of Responses (in %) |
|---|---|
| Land use conversion | 28 |
| Pollution | 15 |
| Private Land ownership, lack of policy support | 11 |
| Low Community awareness, participation, education | 8 |
| Community dependency on mangroves | 6 |
| Human animal conflict | 3 |
| Lack of quantification and monetisation of ecosystem services from mangroves | 3 |
| Challenges to mangroves due to environmental factors (increased salinity, sea-level rise, extreme weather events, erosion) | 18 |
| Invasive species | 2 |
| Financing conservation and the costs involved | 3 |
| Other problems (Ensuring ecological Feasibility of sites, Lack of markets, Knowledge gaps, Technical capacity) | 3 |

### 1. Conversion of mangroves for other land-uses:

Land use conversion was mentioned as a concern by 28% of the responses (which is relatively the highest). Mangroves in India were suggested to be diverted for various economic and developmental activities like housing, infrastructure, aquaculture, agriculture, salt pans and salt farming, industries, ports/harbours, tourism, mining, refineries, oil pipeline passages, dams, road construction, coastal development and due to increasing urbanisation in tidal zones, increasing population and city expansion. Specifically for Kochi and Kerala, conversion of mangroves for housing, infrastructure projects and aquaculture were noted and projects such as Vallarppadam transhipment project and LNG terminal were noted with concern. It was advised that urban land use programs should define optimal open landscape to habitat ratios and follow them.

Some adverse economic, ecological and social impacts due to conversion were also noted. The sustainability of mangrove ecosystem services, particularly the services of protection from extreme weather events and biodiversity were suggested to be affected due to conversion. Further, constant expansion was also suggested to not leave space for natural mangrove regeneration. In terms of social impacts, the adverse impacts on livelihoods of local communities dependent on the mangroves especially for those who do not have alternate livelihoods, and social conflicts due to conversion were noted as concerns.

2. **Challenges to mangroves due to environmental factors:**

Environmental factors was the second most mentioned challenge to conservation (18% of responses). Within environmental factors, some of the frequently mentioned factors were increases in salinity , sea-level rise, extreme weather events and coastal and soil erosion. Except these factors, some other factors mentioned by experts were hyper ocean activity and high tidal activity, temperature changes, natural disasters, changes in hydrological regimes and less water flow to mangroves, siltation, biodiversity loss, climate change induced biodiversity changes. Soil salinity was suggested by some experts to cause some species not tolerant to the conditions to be lost. Sea-level rise, storm surges and coastal erosion due to climate change was noted to be an especially important concern for Kerala and Kochi, with soil erosion and sea level rise having suggested to have been a problem at least the last 15 years and storm surges having been suggested as a problem for mangroves in the location for around the last 10 years.

3. **Pollution:**

Around 15% of the responses noted unregulated and indiscriminate pollution of micro and macro plastics, heavy metals, wastewater, pesticides in mangroves due to municipal, residential, industrial, solid waste discharge as an issue which could inhibit or reduce the functioning and sustainability of mangrove and wetland ecosystem. Although mangroves naturally have the ability to purify and filter many substances, the scale and extent of pollution is said to be beyond its capacities. Pollution was noted by some experts to impact the ground and surface water quantity and quality, cause water logging, flooding etc. Although pollution, waste dumping and accumulation were suggested to be a major problem for Kochi, industrial waste discharge was opined to not be a major reason.

4. **Private Land ownership and lack of policy support:**

Land ownership and lack of policy support were mentioned as a concern in 11% of the responses. Experts opined that while mangroves in many other states came under public property and was protected under various acts, many mangroves in Kerala came under private/corporate property and hence lacked the same kind of protection. Nevertheless, it was noted that there was loss of mangroves irrespective of protection and that simple legislation may not offer adequate safeguards. It was also noted that private mangrove owners who don't directly depend on or benefit from the mangrove lands were willing to sell the lands and did not have an incentive to maintain the mangroves. Issues in recognition of traditional user and tenure rights was also noted as a challenge to mangrove conservation and restoration.

5. **Low Community awareness, participation and education:**

Low awareness and participation by communities was noted as a potential challenge to mangrove conversation and restoration in around 8% of responses. However, an expert opined that the breaking down of traditional local institutions which protected the mangroves might have affected. Education of communities on the importance of mangroves and their ecology was also noted as a challenge. It was also noted that there was a lack of adequate incentives to encourage restoration by communities and of citizen science-based monitoring of interventions.

6. **Community dependency on mangroves:**

Local marginalised and impoverished communities directly or indirectly dependent on mangroves were noted by experts (6%) to potentially affect mangroves due to their use and dependence of forest products for fuelwood, housing material, grazing, fodder, timber, honey and over-exploitation of fishery resources. Ensuring alternative livelihood options for dependent communities and ensuring their economic development while ensuring conservation is noted to be a major challenge.

7. **Human animal conflict:**

3% of responses noted that dependence on mangroves by local communities could contribute to the human-animal conflicts and management of conflicts is necessary.

8. **Lack of quantification and monetisation of ecosystem services from mangroves:**

The lack of quantification and monetisation of many ecosystem services from mangroves was noted to be an issue in 3% of responses. It was also noted by experts that the lack of markets and undervaluation of many ecosystem services could result in its degradation and destruction.

**9. Financing conservation and the costs involved:**

Financing conservation and the costs involved was another challenge highlighted by some experts (3%). The importance of private sector investment was noted.

**10. Other problems**

3% of the responses noted some other challenges to conservation such as feasibility of sites, lack of markets, knowledge gaps, technical capacity, lack of incentives, costs involved, some which have been discussed below-

- **Ensuring ecological Feasibility of sites for intervention:** Ensuring ecological feasibility of sites for intervention was suggested to be a potential challenge for mangrove conservation and restoration.
- **Lack of markets for products from mangrove restoration:** One challenge to restoration is the lack of market linkages and value chains.
- **Knowledge gaps and lack of capacities with various stakeholders:** It was noted that there were knowledge gaps of mechanisms, resources, strategies, and lack in technical capacities with various stakeholders in planning restoration interventions.

**11. Invasive species:** Spread of invasive species (for example- (Prosopis juliflora, Lantana etc.) could affect mangroves adversely and was mentioned in 2% of responses.

Figure 6.6: Percentage of expert responses (as a proportion of total responses) and problems mentioned


## 6.6 Some recommendations/suggestions for mangrove conservation, restoration and maintenance

Many recommendations across various policy/regulatory, ecological, institutional, infrastructural, socio-ecological, economic mechanisms, funding mechanisms, valuation etc were suggested by the various experts. These have been classified into various themes and given in Table 6.4 and Figure 6.7 followed by a detailed discussion of each theme based on the experts' insights.

Table 6.4: Experts (percentage of responses) and recommendations/suggestions mentioned

| Recommendations/suggestions | Number of responses (in %) |
|---|---|
| Policy/regulatory/legal recommendations | 16 |
| Suggestions on ecological aspects | 12 |
| Socio-ecological, community inclusive approaches | 32 |
| Designing economic and funding mechanisms (Command and control, taxes, PES, REDD+, revenue generation, others) | 21 |
| Environmental accounting and valuation | 4 |
| Institutional and building infrastructure | 11 |
| Others | 5 |

### 1. Socio-ecological and community inclusive approaches

Many experts (32% of responses) stressed on the importance of understanding the socio-ecological context and the local community's opinion and interests for mangrove conservation and restoration interventions and it was the highest mentioned recommendation. Further, the importance of improving participatory management of mangroves was noted. It was also suggested that laws and regulations should be constituted in a bottom-up way with a prioritisation of local views and traditional understanding in combination with scientific knowledge. Some suggestions under this head included documenting of local knowledge, creating cooperative society for mangrove-based products and promotion of eco-tourism, assigning, ensuring community tenure rights and legal rules to ensure equitable distribution of benefits, development of carbon markets and sharing of benefits, assessing forest dependence of the community, creating awareness on the many local benefits of mangroves, importance of protecting mangroves, science behind it, methods to protect and of the impacts on mangroves due to marine pollution; mangrove tourism, improving training, capacity and technical training of local community and farmers for agroforestry, and supporting forest departments in improving the understanding and policies required for agroforestry through stakeholder based participatory approaches. One expert also suggested that it should be made mandatory for local communities to be involved in mangrove conservation and maintenance. It was noted that including the community in mangrove plantation may also result in lesser cost investments. Another solution suggested was to encourage integrated mangrove-fishery farming, and an example of an existing system in Tamil Nadu was noted. Responsible tourism was suggested as another suggestion to potentially help improve employment opportunities and improving ownership of mangroves amongst local communities, local youth and women.

Ensuring participation and leadership of local communities was considered important for sustained conservation by some experts and the importance of community-led protection and restoration initiatives for successful restoration was stressed. An example of Maharashtra Forest department’s mangrove cell and their intended policy for community-based mangrove conservation with women community members as central participants was noted as a potential example of the same.

Improving inclusion, awareness and empowerment of citizens was also recommended by some experts. Specifically, creating committees for citizen vigilance, building of awareness on the importance of mangroves within local schools, using citizen science for monitoring progress on restoration were suggested as some of the ideas.

2. **Designing economic and funding mechanisms:**

Various economic and funding mechanisms were suggested by many experts (21% of responses) and it was the second most mentioned theme of recommendations. This includes command and control, taxes, PES, REDD+, revenue generation activities and other mechanisms.

Command and control mechanisms were suggested to be helpful for managing pollution, and pollution penalties, fines to industries and aquaculture farms were suggested by some experts. One other suggestion was to include pollution tax as part of property tax, with rebates for having open spaces in private properties. It was suggested that forest department and local government could also monitor and penalise outsiders and tourists who pollute the mangroves. Funding through CSR combined with cesses and penalties was also suggested as a solution for the problem of industrial waste.

Some other mechanisms suggested were payment for ecosystem services (PES) with a framework for PES and incentivising local community to ensure benefit sharing of the provisioning services and eco-tourism derived from the ecosystem. One expert opined that payments for ecosystem services should be encouraged for restoration, rehabilitation of mangroves in addition to conservation. Providing compensation for fishermen for income lost during the periods of fishing ban was also suggested.

Some funding mechanisms and revenue generation suggestions were also provided. Specifically on funding mechanisms, experts suggested carbon financing programs like REDD and REDD+ and other blue carbon financing programs. Further, markets for commercial products generated though restoration need to be developed wherever they don’t exist, and support provided for entrepreneurs. Institutional promotion of nature-based tourism/eco-tourism and sustainable tourism was also suggested.

3. **Policy, regulatory, legal recommendations:**

Recommendations revolving around policy, regulatory themes were noted in 16% of responses. It was also noted by experts that a whole set of policies may be required, and piece-meal approaches may not be effective.

Stricter enforcement and effective implementation of various regulations and policies such as the ICZM, CRZ, Wildlife Acts was suggested to potentially contribute to better mangrove management. Further, experts also opined that legal regulation to protect mangrove lands, building the capacities and training of forest departments on agroforestry value chains, implementing management action plan in selected mangroves could be helpful ways forward. For the mangroves under government protection, one suggestion from expert was to notify all the mangroves as protected areas and put them under state control. In terms of mangroves held privately especially in Kerala, it was suggested that mangrove owners were willing to sell these areas and hence they could be purchased and conserved or declared as reserve forests.

4. **Suggestions on ecological aspects:**

Some suggestions on the ecological front were made in 12% of responses and included ensuring minimum freshwater flow to mangroves, possibly through scientific dredging in upper estuarine reaches. Scientific dredging was noted to require substantial investment which may be feasible mainly through government intervention or through beneficiaries from the intervention provided adequate incentives (for example, reduced taxes) could be given. One other suggestion was to allow natural regeneration of mangroves with some legal support although it was noted that since implementation may be ineffective in many cases hence it would help to include local communities in the management as well. It was suggested that natural regeneration may not require extensive funding and could benefit the local communities and improve overall societal welfare.

Reducing forest dependence was suggested to have potential in reducing the man-animal conflict and allowing for natural regeneration. Organic mangrove regeneration and managed retreat to be considered in instances of extreme sea-level rise and inability to live in the location. Further, the importance of maintaining floral composition, diversity of mangroves, and protection of low-salt tolerant species was noted to be of importance. Another suggestion mentioned was to ensure a demarcation of buffer zones around mangroves.

5. **Institutional and building infrastructure:**

Recommendations around building of infrastructure and institutional suggestions were made in 11% of responses. The importance of developing infrastructure in coastal and marine protected areas was noted. In terms of dealing with the problem of pollution, it was suggested that waste collection, disposal, recycling and treatment facilities could be set up possibly at the block level. Constructing channels for fresh water to protect species with low salt tolerance was also suggested.

Some solutions to enhance institutional support were provided. For example, a mangrove conversation authority or agency with all stakeholders represented was suggested by one expert. Further, encouraging local NGOs to work with fishing communities on mangrove conservation, and providing fishermen identity cards to ensure compensations and benefits reach them were suggested.

6. **Environmental accounting and valuation:**

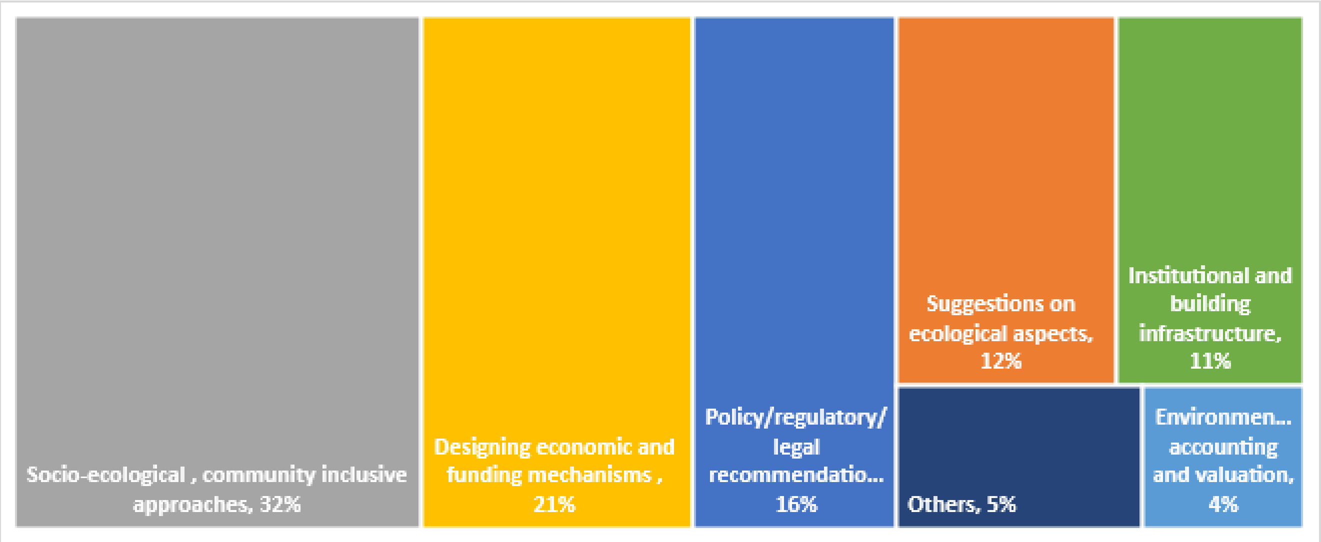
Environmental accounting, quantification and economic valuation of mangrove ecosystem services were suggested as some potential solutions in 4% of repsonses. It was suggested that such valuation and environmental accounting exercises could help sensitize policy makers and general public, encourage investments, identify pay-off periods, and act as a base for setting up institutional mechanisms.

7. **Others:**

Some other suggestions that came up (5% of responses) include-

- Encouraging use of clean cooking fuels
- It was advised that urban land use programs should define optimal open landscape to habitat ratios and follow them
- Monitoring systems to encourage lesser disposal of waste

Figure 6.7: Experts (percentage of responses) and recommendations/suggestions mentioned




## 6.7 Costs of inaction and action

Various costs of action and inaction were highlighted by the experts and have been discussed below. It was although noted by experts that the nature and type of costs incurred depend both on the mangrove and the issue, and hence costs would be context dependent to an extent.

Broadly, costs were divided into costs of action and inaction. Costs due to inaction included costs due to near-, medium- and long-term loss of mangrove services and possible damage costs/losses, while costs of action include the possible financial costs, income and livelihood generation and unintended consequences on SDGs, well-being etc.

### *6.7.1 Costs of inaction*

In the short and medium term, provisioning services related to prawn and aquatic fishes' availability and population, fuelwood, agro-forestry, fisheries, agriculture, aquaculture, tourism and local livelihood related mangrove ecosystem services were suggested to be some of the major services that could be affected due to inaction. Additionally, some experts also opined that local climate regulation, effects to biodiversity like fishing cats and jackals, air quality, water quality regulation, reduction in resilience and loss of life and property due to extreme weather events and tidal surges, nursery, habitat service for fish and wild species, increased vulnerability to sea-level rise could also be affected. Short- and medium-term inaction was also suggested to contribute to and encourage further degradation of mangroves. It was noted that these losses may result in distress migration or increased vulnerability of communities dependent on the mangroves.

In the long term, costs of inaction were suggested to affect many ecosystem services provided by mangroves, specifically in relation to biodiversity and habitat losses, fisheries and other provisioning services, tourism, increased susceptibility and reduced protection from extreme weather events, local climate regulation and carbon sequestration, water quality regulation and BOD and COD capabilities of mangrove, shore stabilisation, coastal erosion and flood control, and survival of species dependent on mangroves. One other cost mentioned by experts was the losses in carbon sinks and blue carbon, which could exacerbate climate change impacts and emissions and may not be reversible.

On potential damage costs that could be incurred due to inaction, experts opined that these could be in relation to risks of disasters and floods, pollution discharge and lack of carbon sequestration.

### *6.7.2 Costs of action*

Financial costs as suggested by experts included costs spent on reforestation and restoration, planting, fencing, canal digging, guards, biodiversity conservation, processing of forest-based products, transportation, weed removal, trenching, bio shield development, weed control, waste management and treatment, costs of training/awareness programmes, maintenance costs to sustain large scale restoration interventions and possible remuneration to local communities to engage in mangrove plantation. It was opined that large costs could be involved in revitalising local institutions and for incentivising vested interests. One expert noted that although they did not know specific costs of financing mangrove protection/restoration, landscape restoration costs (based on their analysis for a district in Madhya Pradesh) worked out between Rs. 440 crores to Rs.750 crores for 363000 ha. It was suggested that in case the private mangroves were purchased, those costs could also be included here.

Income and livelihood generation were considered an important outcome to be ensured from mangrove conservation interventions. Suggestions to encourage income, employment and livelihood generation included considering integrated aquaculture with mangroves, sustainable fisheries, nature-based tourism/eco-tourism. Restoration activities were noted to also create employment and increase wage income, generate revenue from sale of saplings and encourage development of microenterprises for various tree species which could in turn generate employment. Income and livelihood generation for farmers, fishing communities, industry owners, loss of revenue for the state, wage employment were some aspects that were considered important. It was although noted that there would be an opportunity cost to the land since farmers would lose the land for potential agricultural activities and for other economic activities. Some experts opined on the prioritisation between the various income generation activities and suggested that fisheries should be prioritised followed by farmers, wage employment, industry owners and loss of revenue for the state.

Some unintended consequences of mangrove management could be meeting or progress towards some SDG targets, strengthening and empowering forest communities especially women's participation, encouraging forest-based businesses and industry. Some potentially negative consequences noted were the possibility of differences between land use preferences of different groups like the young and elderly.

## 6.8 Local communities' involvement in mangrove restoration

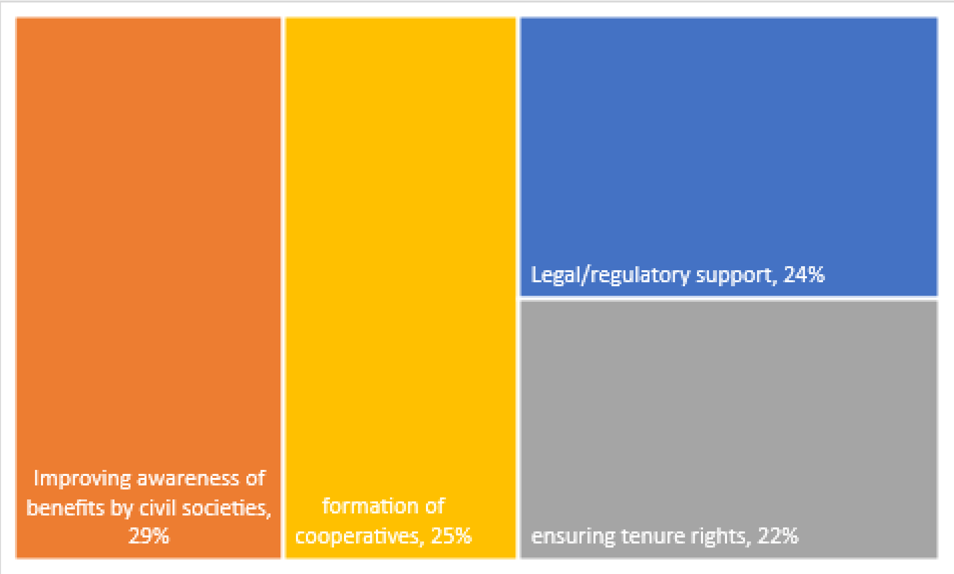
Experts were asked for their thoughts on how local communities can be involved in mangrove restoration and what institutional support and economic incentives should be prioritised and considered.

### *6.8.1 Institutional support*

Experts were asked to choose between formation of cooperatives, ensuring tenure rights, legal/regulatory support and improving awareness of benefits by civil societies. Experts opined that the institutions in the local context should be studied.

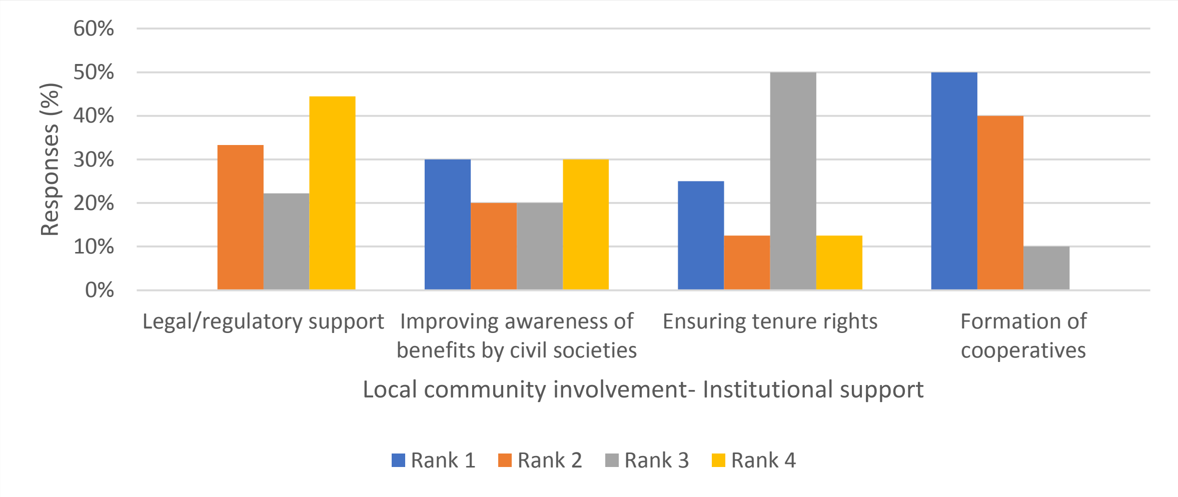
***Suggestions for institutional support mentioned by experts:*** Improving awareness of benefits by civil societies was the support mechanism mentioned in relatively the highest percentage of responses (29%), followed by formation of cooperatives (25% of responses), legal/ regulatory support (24% of responses) and ensuring tenure rights (22% of responses) (Figure 6.8).

Figure 6.8: Percentage of expert responses (as a proportion of total responses) and institutional support mentioned




***Comparing between various institutional support mechanisms- Ranking:*** Looking amongst experts who had ranked the various institutional support mechanisms (Figure 6.9), it can be noted that formation of cooperatives was preferred by most experts since 90% of responses gave Rank 1 and Rank 2 to it. Although improving awareness was mentioned by most experts (as given in Figure 6.8), looking at the ranking suggested a mixed picture (Rank 1: 30% of responses, Rank 2: 20% of responses, Rank 3: 20% of responses, Rank 4: 30% of responses). Ensuring tenure rights was given predominantly given Rank 3 (in 50% of responses), and Rank 1 in 25% of responses, while legal/regulatory support mechanism to encourage community involvement seemed less preferred with 67% giving it Rank 3 and Rank 4 and 33% of responses giving it Rank 2 (Figure 6.9).

Figure 6.9: Ranking of local community involvement (institutional support) by various experts (as given through percentage share of responses)




Some other suggestions provided were to consider the involvement of other institutions like NGOs and corporate sector, including communities in decision making through participatory frameworks, capacity building of restoration entrepreneurs, and building inclusive monitoring mechanisms through participatory approaches.

***Comparing between various institutional support mechanisms- Scores:*** Analysis through the Garrett ranking method as given in Table 6.5 suggests highest priorities for the institutional mechanism of formation of cooperatives followed by ensuring tenure rights (2nd), improving awareness of benefits by civil societies (3rd rank) and legal regulatory support (4th).

Table 6.5: Scoring across various institutional support mechanisms- Garrett ranking method

| **Variables** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** |
|---|---|---|---|---|
| Garrett Value for each rank | 73 | 56 | 44 | 27 |
| | **Rank given by Experts** | | | |
| Institutional support mechanisms | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** |
| Legal/regulatory support | 0 | 3 | 1 | 4 |
| Improving awareness of benefits by civil societies | 2 | 1 | 2 | 3 |
| Ensuring tenure rights | 2 | 1 | 4 | 1 |
| Formation of cooperatives | 4 | 3 | 1 | 0 |

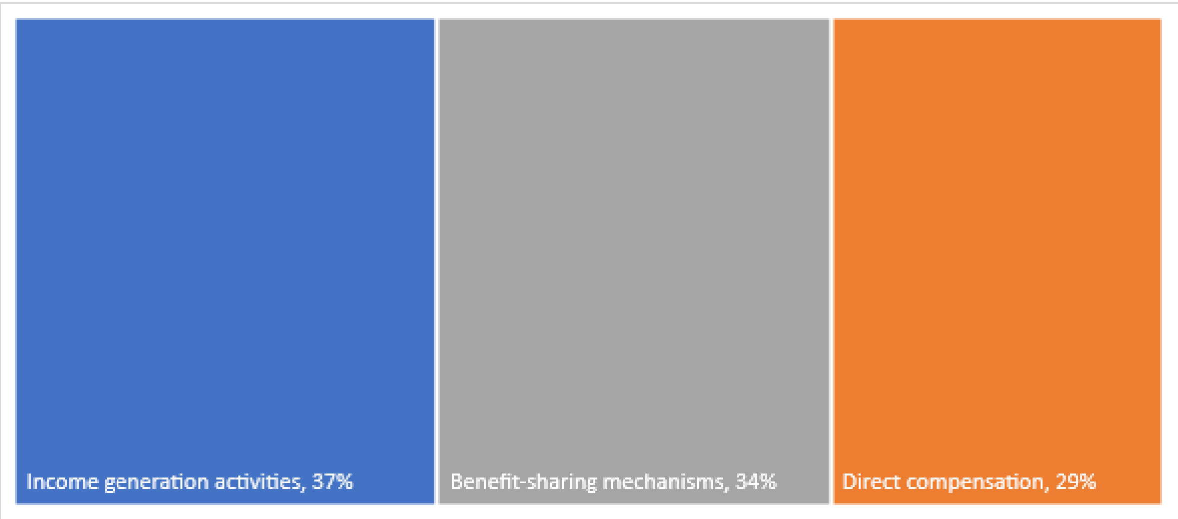
| | Garrett values | | | | | | |
|---|---|---|---|---|---|---|---|
| **Institutional support mechanisms** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Sum** | **Average** | **Overall rank** |
| Legal/regulatory support | 0 | 168 | 44 | 108 | 320 | 40.00 | 4 |
| Improving awareness of benefits by civil societies | 146 | 56 | 88 | 81 | 371 | 46.38 | 3 |
| Ensuring tenure rights | 146 | 56 | 176 | 27 | 405 | 50.63 | 2 |
| Formation of cooperatives | 292 | 168 | 44 | 0 | 504 | 63.00 | 1 |

### *6.8.2 Economic incentives*

Experts were asked to rank between economic incentives of direct compensation, benefit-sharing mechanisms and income generation activities like mangrove tourism in terms of priority for action.

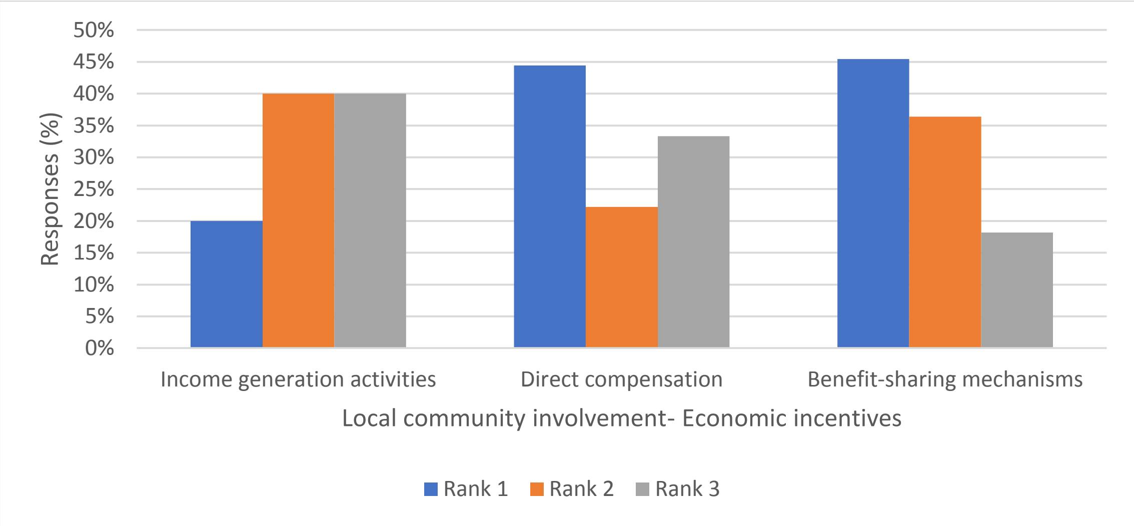
***Suggestions for economic incentives mentioned by experts:*** Income generation activities were mentioned by most experts (37% of responses), followed by benefit sharing mechanisms (34% of responses) and direct compensation (29% of responses) (Figure 6.10). Income generation activities like mangrove tourism were also noted to potentially be useful in certain cases to encourage better monitoring.

Figure 6.10: Percentage of expert responses (as a proportion of total responses) and economic incentives mentioned




***Comparing between various economic incentive mechanisms- Ranking:*** Looking at the ranking of the various responses to the various economic incentives for encouraging involvement of local communities (Figure 6.11), it can be noted that benefit sharing mechanisms seem to be the most preferred since 82% of the responses give it either Rank 1 and Rank 2. Income generation activities seem to relatively be lesser preferred with 80% of responses giving it Rank 2 and Rank 3.

Figure 6.11: Ranking of local community involvement (economic incentives) (as given through percentage share of responses)




Other ideas for incentives and economic mechanisms included performance-based payments, credits, grants, benefit sharing, PES, and some non-monetary mechanisms such as extension services for building awareness and technical support and improvement in value chains.

***Comparing between various economic incentive mechanisms-Scores:*** Analysis through the Garrett ranking method as given in Table 6.6 suggests both benefit sharing mechanisms and direct compensation which were both given rank 1, followed by income generation activities.

Table 6.6: Scoring across various economic incentive mechanisms - Garrett ranking method

| **Variables** | **Rank 1** | **Rank 2** | **Rank 3** |
|---|---|---|---|
| Garrett Value for each rank | 69 | 50 | 31 |
| | **Rank given by Experts** | | |
| Economic incentive mechanisms | **Rank 1** | **Rank 2** | **Rank 3** |
| Income generation activities | 2 | 3 | 4 |
| Direct compensation | 4 | 2 | 3 |
| Benefit-sharing mechanisms | 3 | 4 | 2 |

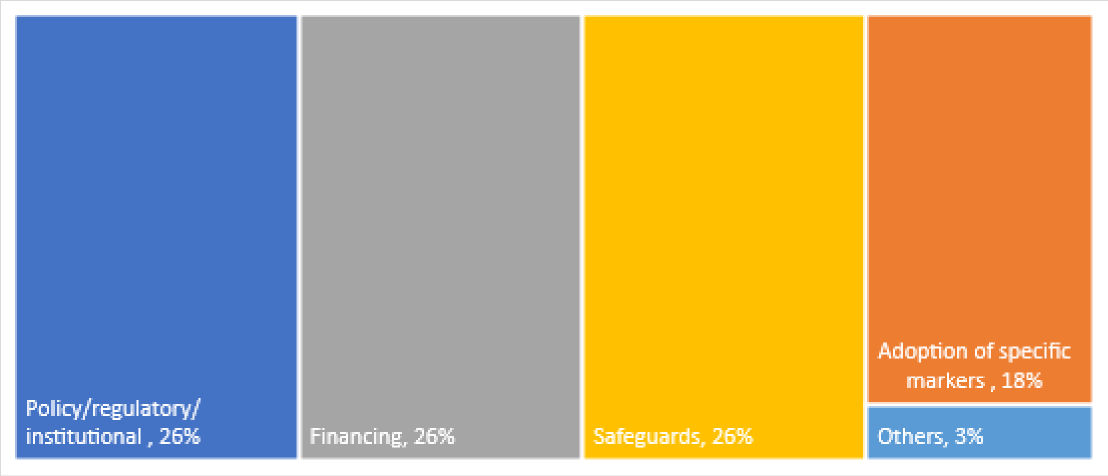
| | Garrett values | | | | | |
|---|---|---|---|---|---|---|
| **Economic incentive mechanisms** | **Rank 1** | **Rank 2** | **Rank 3** | **Sum** | **Average** | **Overall rank** |
| Income generation activities | 138 | 150 | 124 | 412 | 45.78 | 3 |
| Direct compensation | 276 | 100 | 93 | 469 | 52.11 | 1 |
| Benefit-sharing mechanisms | 207 | 200 | 62 | 469 | 52.11 | 1 |

## 6.9 Opportunities for encouraging investment in mangroves

Experts were asked about the opportunities that existed for encouraging investment in mangroves in India and given the options of policy/regulatory/institutional actions (e.g. enacting specific regulation - CSR, forming dedicated community institution), adoption of specific markers (eg for M & E to aid donor evaluation), financing (eg any new instruments, dedicated fiscal resources, private), safeguards (social/environmental), and any other suggestions.

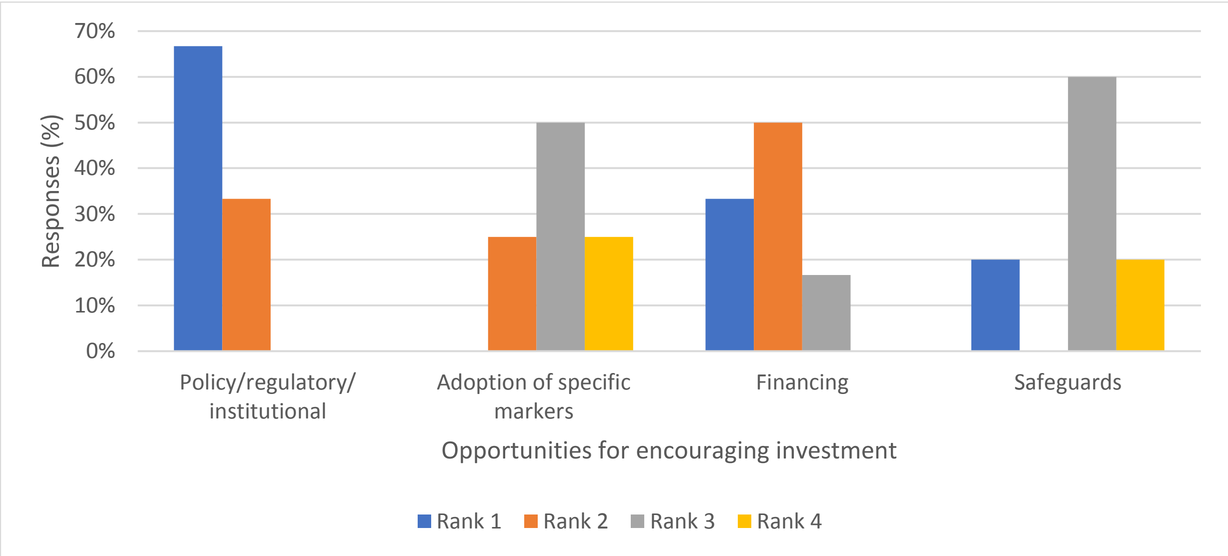
***Opportunities for encouraging investment mentioned by experts:*** Policy/regulatory/institutional actions, financing opportunities and safeguards were the most mentioned opportunities for investment (26% of responses for each, relatively the highest), followed by adoption of specific markers (18% of responses) (Figure 6.12). The category of others (3% of responses) includes a suggestion of mangrove tax on coastal fisheries. In terms of policy/regulatory/institutional actions, CSR, forming dedicated community institutions, encouraging mangrove conservation to be reported in ESG were suggested. In terms of safeguards, it was suggested that local communities and other stakeholders should be consulted to understand the possible regulations required.

Figure 6.12: Percentage of expert responses (as a proportion of total responses) and opportunities for encouraging investment mentioned




***Comparing between various opportunities for encouraging investment - Ranking:*** Ranking given to the various investment opportunities (Figure 6.13) suggests that policy/regulatory and institutional opportunities were suggested for prioritisation with 67% of responses giving Rank 1 to it. Comparing rank 1 and rank 2 together suggests that policy/regulatory and institutional opportunities and financing opportunities were preferred with 100% of responses giving Rank 1 and Rank 2 to policy/regulatory and institutional opportunities, and 83% of responses giving Rank 1 and Rank 2 to financing opportunities. Adoption of specific markers seemed to be less preferred (75% of responses give it Rank 3, Rank 4) (Figure 6.13).

Figure 6.13: Ranking of opportunities for encouraging investment by various experts (Percentage of responses)




Some other opportunities suggested by experts included mangrove tax on coastal fisheries, employing unemployed youths for restoration activities, PES, encouraging benefit sharing amongst local communities. Subsidising private costs of migration for populations that need to be relocated was suggested.

***Comparing between various opportunities for encouraging investment - Scores:*** Analysis through the Garrett ranking method as given in Table 6.7 suggests opportunities in policy, regulatory and institutional areas, followed by financing. Safeguards were ranked 3rd and adoption of specific markers was ranked as 4th.

Table 6.7: Scoring across opportunities for encouraging investment - Garrett ranking method

| **Variables** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** |
|---|---|---|---|---|
| Garrett Value for each rank | 73 | 56 | 44 | 27 |
| | **Rank given by Experts** | | | |
| | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** |
| Policy/regulatory/ institutional | 4 | 1 | 0 | 0 |
| Adoption of specific markers | 0 | 1 | 1 | 3 |
| Financing | 1 | 3 | 1 | 0 |
| Safeguards | 0 | 0 | 3 | 2 |

| | **Garrett values** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Sum** | **Average** | **Overall rank** |
| Policy/regulatory/ institutional | 292 | 56 | 0 | 0 | 348 | 69.60 | 1 |
| Adoption of specific markers | 0 | 56 | 44 | 81 | 181 | 36.20 | 4 |
| Financing | 73 | 168 | 44 | 0 | 285 | 57.00 | 2 |
| Safeguards | 0 | 0 | 132 | 54 | 186 | 37.20 | 3 |

***Key takeaways:***

- An expert analysis was conducted using a quantitative and qualitative semi-structured questionnaire with questions on ecosystem services, perceived problems and challenges, suggestions and recommendations, costs, opportunities for mangrove conservation/restoration/maintenance.
- In total, 23 responses were obtained and the area of expertise of experts were mainly forests, mangroves and protected areas.
- Experts were asked for their thoughts on which intervention should be prioritised in a biodiversity action plan to meet the objectives of conservation and community welfare, and mangrove conservation and traditional eco-friendly farming practices were most preferred.
- Experts were asked for their perception on the ecosystem services from mangroves that they perceived to be most relevant in the Indian context from the context of sustainable development and ecosystem services of moderation of extreme weather events, biodiversity and lifecycle maintenance and provisioning services of fodder, fisheries and aquaculture were the services considered the most relevant.
- Experts had a wide range of insights regarding the relationship of mangroves with agriculture, aquaculture, Pokkali areas and paddy-fish ecosystems, but the broad consensus seems to be that while agricultural and aquaculture ecosystems benefit from mangroves, it is unclear whether mangroves benefit from these agricultural/aquaculture ecosystems.
- Various drivers of mangrove loss and destruction, problems caused to people due to mangroves, and challenges for mangrove conservation, maintenance and restoration were mentioned by the various experts with land use conversion and environmental factors being mentioned as a concern by a large number of experts, followed by pollution and land ownership and policy support. Other concerns mentioned (in decreasing order of frequency) include Community awareness, participation and education, Community dependency, Human animal conflict, Lack of monetary quantification of ecosystem services from mangroves, Financing conservation and other problems.
- Many recommendations were suggested by the various experts. Many experts stressed on the importance of socio-ecological and community inclusive approaches. Other concerns mentioned include (in decreasing order of frequency) designing economic and funding mechanisms, Policy, regulatory, legal recommendations, Ecological suggestions, Institutional and building infrastructure, Environmental accounting and valuation and others.
- Various costs of action and inaction were highlighted by the experts. Costs of inaction included various provisioning services and some regulating services predominantly said to be affected in the short- and- medium term, while many services across all categories were suggested to be impacted in the long term. In terms of costs of action, Income and livelihood generation were considered an important outcome to be ensured from mangrove conservation interventions.
- For encouraging community involvement in mangrove interventions, institutional support mechanisms of formation of cooperatives was most preferred, while in terms of economic incentives to encourage community involvement in mangrove interventions, benefit sharing mechanisms and direct compensation mechanisms seem to be the most preferred.
- Experts were asked about the opportunities that existed for encouraging investment in mangroves in India and policy/regulatory and institutional opportunities were suggested for prioritisation by most experts.

# 7 CHAPTER 7: SUMMING UP- SOME KEY TAKEAWAYS

## 7.1 Restoring and Conserving Ecosystems for Biodiversity Conservation

In the context of Kochi, two distinct ecosystems can be considered for conserving biodiversity. While one of these is an agroecosystem, the other is mangroves. Both are important in contributing to biodiversity specifically, and ecosystem services that contribute to the sustainability of Kochi city. These can be pursued as separate interventions for investing in biodiversity conservation or as a set of linked interventions. Irrespective of the approach, the case for biodiversity conservation is served by investing in a set of linked activities, which can support both the interventions on mangroves and rice-fish farming. These relate to pollution and waste management for the city and the promotion of awareness and ecotourism on the importance of biodiversity conservation within the agroecosystem and within mangroves.

The integrated sustainable rice - aquaculture rotation farming provides an option for joint management with mangroves in certain areas. The mangroves, along the border in such ecosystems, promote nutrient recycling and act as breeding ground for many species and support crabs. The presence of mangroves add to the ecosystem service flows, ensuring sustainability. Mangroves, often referred to as the lungs of the cities, is a fragile ecosystem for Kochi city. Unlike in many other parts of the country, the mangroves in Kochi are mainly under private ownership.

There are many biophysical factors to consider in promoting traditional versus high yielding varieties, and in ensuring that market creation activities are consistent with sustainability considerations. Conflict resolution, impact assessment and stakeholder consultations are a must with extensive engagement of local communities, and a pre-requisite for success in interventions. For any intervention, gainers and losers must be clearly recognised and compensations, income generation activities, and benefit transfer mechanisms must be instituted and supported with adequate resources. Specific recommendations have been made in the report.

## 7.2 Suggestions on pilots for Kochi city

The Pilot Project area can be selected according to the preferred approach. For instance, one approach could be to run a pilot at two sites in parallel, one with only mangrove restoration and one with Pokkali –Integrated rice-fish cultivation with presence of mangroves in bordering areas. Based on the field sites seen within the scope of the present study, Pambayimoola

(Edakochi): two wards viz. Edakochi North (Ward No.15) and Edakochi South (Ward No.16) may be one such option.

The region was under Palluruthy Gramapanchayat till mid of 1960 s and later on, around 1965 the region was attached to BMC as two wards, Edakochi South and North. Agriculture was the main source of livelihood for almost 70-80% of the population in the region and Edakochi North ward occupied around 65-70% of the pokkali lands. Later, during 1985-95, large tracts of these lands were converted for residential and commercial purposes. Improved communication and transportation facilities also triggered the shift of livelihood sources away from agriculture. The formation of NH -47 linking Wellington islands to Aroor and the associated habitat losses due to developmental activities around the roadsides have had consequences for the pokkali farms. Currently this is the only rice growing tract within the corporation limits. But paddy farming is not undertaken seriously and is taken up only where aquaculture is taken up. The remaining areas are left unattended, and often regarded as wastelands.

a) Location I (Pokkali rice-aquaculture integrated farming): Pokkali fields bordered by mangroves)

The plot identified for the intervention is located in 15$^{th}$ and 16$^{th}$ wards of the KMC which was previously utilized for integrated Pokkali –shrimp culture. 60 acres (24 hectares) of continuous Pokkali land (50 acre field is known as chettipadam padashekaram and the rest 10 acre field is known as puthankari) can be identified as the location for conservation and tourism. Chettipadam padashekaram consists of around 40 landowners whereas the 10 acre puthankiri is owned by a single person. Presently the land is leased throughout the year for aquaculture. The rice farming has not been seriously taken up for the past 20-25 years.

The location demands major restoration works which involve bund /sluice constructions, canal clearing, clearing drainage channels, construction of culverts etc. Modest and rudimentary estimates for making the padasekharam (Plot 1) ready for farming at a basic level work out to be Rs. 2.5 crores, and for Plot 2 at around 7.5 crores. However, more detailed scientific estimates need to be prepared once the specific location is decided upon.

b) Location II: (mangroves only)

The second plot identified is within ward 15 and it is a single plot stretching roughly around 25 acres. The land was previously used for Pokkali fish integrated farming. Later on the field was left unused and that had resulted in natural encroachment by mangrove species. Later on in 2009 the area was purchased by Kerala Cricket Association with a plan to construct a stadium meeting international standards, with a water front. However, the proposal could not be launched due to legal restrictions. Currently this field has been seeing the spread of mangroves. This can be actively managed as a mangrove ecosystem, with specific investment in activities to turn it into an ecotourism cum educational hub.

## 7.3 Integrating income generation with conservation: Designing economic and financial instruments

The economic viability of the ecosystem is a major driver of social acceptance of conservation measures. The role of the state as well as operator (farmer) in this process is equally important. We suggest below a few approaches to designing economic and financial instruments that can support the income generation alongside preserving the nature-people relationship.

***Designing economic and financial instruments:***

A host of instruments can be used for implementing the interventions. These can be summarized as follows:

- Legal/ regulatory - Direct Compensation for government procurement and ensuring tenure rights, Direct protection of mangroves through setting up community reserves; levying a mangrove tax/cess
- Benefit sharing mechanisms - Payment for ecosystem services (PES: from non-residents to residents directly impacted by mangrove and traditional Pokkali cultivation), Carbon credits and carbon-based payment for mangrove ecosystem services
- Revenue generating and enhancing activities - Eco-labelling and certification (enabling marketing)

## 7.4 Institutional support mechanism

It is appropriate to have an exclusive institutional mechanism to implement the conservation plan with representatives from concerned departments (Agriculture/Forest, representatives of farmers/ residents/farm workers/ traders and similar stakeholders).

Community engagement and leadership with stakeholder participation is the approach that seems to work best in contexts such as those in Kochi city, through say a joint co-ordination mechanism). It is also important to ensure state presence (LSGD/State Government). The agency may take up the following:

- Pre-intervention activities
- Impact analysis
- Conflict resolution
- Designing compensatory mechanism
- Technical Support (supply of Quality seeds, marketing, mechanization wherever possible)
- Infrastructural aspects (Water management /pollution management /waste management /Marketing Support)
- Monitoring
- Community related initiatives - Building knowledge, awareness and capacity building

### 7.5 Monitoring and Performance indicators

Ecosystem/Mangrove restoration falls under many international commitments and goals (Aichi targets 5 and 7; SDG 14, SDG 15). In Kochi's LBSAP, Focus area 8 (Marshes and mangroves) is one area that could possibly be relevant for this intervention, specifically goals 8.1 ("Assessment of current biodiversity profile and development of a management framework for marshes and mangroves"), Goal 8.2 ("Prioritize areas of conservation importance and eco-restore relevant areas") and Goal 8.3 ("Community based mangrove and marshy land conservation") (ICLEI South Asia, 2020). In India, many mangroves fall under some/all of the various central and state acts- Wetlands (Conservation and management) rules, 2017, Indian Forest Act (1927), Wildlife Protection Act (1972), Forest Conservation Act (1980), Environment Protection Act (1986), Coastal Regulation Zone notification, Kerala Preservation of Trees Act, 1986, Kerala Conservation of Paddy Land and Wetland Act, 2008.

In order to ensure that sustainable Nature Based Solutions (ecosystem-based practices) are adopted and pursued, it is important to be able to agree on monitoring and performance indicators. In the context of Kochi, which has scope for a complementary relationship between agriculture and mangroves, while having a high population density, the SDGs are a good starting point in this regard, especially in choosing indicators that expressly encourage the nurturing of the human-nature relationship, rather than those that only emphasise the biodiversity or ecosystems aspects.

# 8 APPENDIX

Appendix 2.1: Literature used for identifying criteria and methods used in the literature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Appendix 2.2: Stakeholders and experts consulted for the study

1. Shri Adv Anil Kumar, Mayor, Kochi
2. Dr. Rajan, C-HED
3. Sri. Balan, Programme Executive, AIR Kochi (FM)
4. Dr Bijoy Nandan, CUSAT
5. Dr P. S. Easa, Retired Scientist, KFRI
6. Sri. Sujith Karun, Forest Officer & Programme Coordinator, Haritha Kerala Mission, Eranakulam
7. Sri. Mohan Kumar, Resident of Thrippunithura
8. Dr. Nirmala Padmanabhan, St. Theresa’s College
9. Dr Vishnu Priya Kartha, CUSAT
10. Sri Renjith, Pokkali Farmer (Social worker)
11. Mr. Sanuraj
12. Mr. Sajith
13. Mr. Robin
14. Mr. Abhilash
15. Ms. Jeeja
16. Mr. Basil
17. Dr. K R. Viswambharan
18. Ms. Prathibha
19. Mr. Ramachandran
20. Sri E Sreedharan, Retd IRSE Officer, ex- UN Advisory group on Sustainable Transport
21. Dr.K R Viswambharan, Former District Collector
22. Agricultural Officers (4 Nos)/Assistant Director of Agriculture(vyttila)
23. Community representatives (anonymised)
24. Mr. Serene Philip, Former ADA Vyttila
25. Mr. Rajan, Agricultural Officer, Vyttila
26. Dr. Disha Bhattacharjee, NITI Aayog
27. Dr. Upasna Sharma, IIT-Delhi
28. Dr. Santadas Ghosh, Visva-Bharati University
29. Dr. K Kathiresan, Annamalai University
30. Dr. Kanchan Chopra, Institute of Economic Growth
31. Dr. Gopal Kadekodi, Centre for multi-disciplinary development research
32. Dr. K S Kavikumar, Madras School of Economics
33. Dr. M Hema, Kerala Agricultural University
34. Dr K M Jayahari, World Resources Institute India
35. Dr. Saudamini Das, Institute of Economic Growth
36. Dr. Nilanjan Ghosh, Observer Research Foundation
37. Dr. Namrata Thapa, Institute of Economic Growth
38. Dr. Abhra Chanda, Jadavpur University
39. Dr. Nisha Priya Mani, The Nature Conservancy
40. Dr. Alpana Jain, The Nature Conservancy
41. Dr. Ruchika Singh, World Resources Institute India

42. Ms. Marie Duraisami, World Resources Institute India
43. Dr. Ramasamy Ramasubramanian, M S Swamininathan Research Foundation
44. Dr. Anjal Prakash, Indian School of Business
45. Ms. Ishita Sachdeva, Delhi University
46. Dr. KN Ninan, World Resources Institute India
47. Dr. L Venkatachalam, Madras Institute of Development Studies
48. Dr. Vikram Dayal, Institute of Economic Growth
49. Dr. Yamini Gupt, Delhi University
50. Dr. M N Murthy, Institute of Economic Growth
51. Community representatives (anonymised)
52. Faculty Colleagues from Subject area at Delhi University, Institute of Economic Growth, Kerala Agricultural University
53. Dr. Monalisa Sen, ICLEI
54. ICLEI South Asia Project Team members

Appendix 3.1: Agro-tourism potential in Pokkali lands- Operational Design: Nature Based Approach for conservation

Agritourism in Pokkali Farms Proposed area: Pokkali Farming in Pambaayimoola, Edakkochi

1. Geographic location:

Edakochi is known to be the land between erstwhile Travancore and Kochi provinces which is located towards the western side of the Kochi Municipal Corporation (KMC). It is surrounded on its three sides by Vembanad lake. The Kannanghat bridge links the land to Kundanoor - Willington highway which allows an easy access to Thevara amd Kundanoor regions of KMC. Pambayimoola (edakochi) includes two wards viz. Edakochi North (Ward No.15) and Edakochi South (Ward No.16). The area is bordered by Kumbalam island on its East and Aroor (Kochi mainland link to alapuzha district) on its south, Wellington islands towards its north and Perumpadappu regions to its west.Pambayimoola forms a major part of Edakochi region.

The region was under Palluruthy Gramapanchayat till mid of 1960s and later on around 1965 the region was attached to BMC as two wards as Edakochi South and North. Agriculture was the main source of livelihood for almost 70-80% of the population in the region and Edakochi North ward occupied around 65-70% of the pokkali lands. Later on, during 1985-95 period large tracts of these lands were converted for residential and commercial purposes. Improved communication and transportation facilities also triggered the shift of livelihood sources from agriculture. The formation of NH-47 linking Wellington islands to Aroor and the associated habitat losses due to developmental activities around the roadsides have seriously impacted the pokkali farms. Currently this is the only rice growing tract within the corporation limits. But paddy farming is not undertaken seriously and is taken up only where aquaculture is taken up. The remaining areas are left unattended leading to spread of mangroves and is regarded as wastelands.

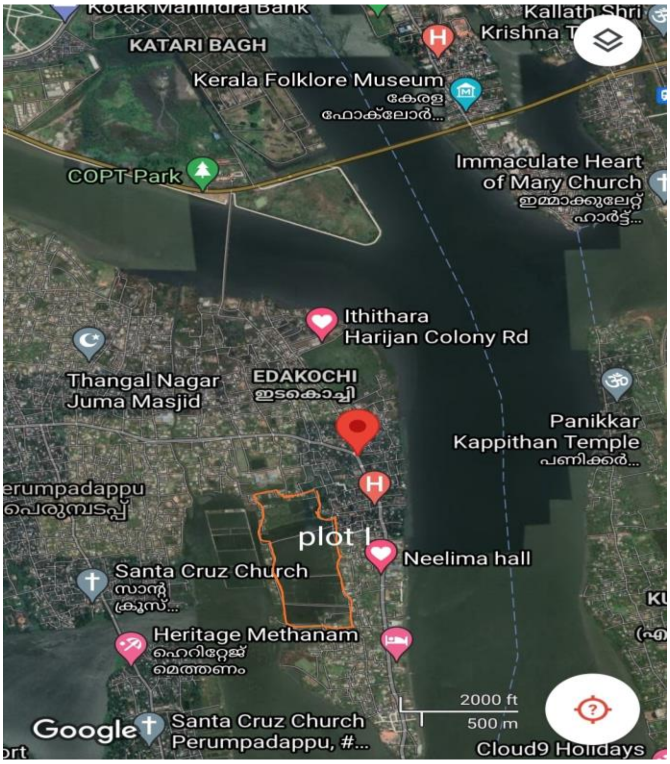
This tract of Pokkali ecosystem can be brought under the traditional rice-fish rotation thus facilitating the conservation of agrobiodiversity and ecosystem. The location is ideal for developing as an agritourism site, integrating pleasure and education, as the model for Nature Based approaches for conservation, while supporting the livelihoods of the population. The scenic view created by Chinese fishing nets and cruising on the waterbodies and an exposure on checking out the fish processing in the backyards of Kochi can also form part of the tourism circuit. The location is endowed with over 100 Chinese nets and huge cantilevered fishing nets believed to have been brought by the Portuguese. It is well connected by roads allowing easy access to the location.

The project for agritourism in this location help in employment and income generation apart from conservation.

Plots identified for intervention and current significance:

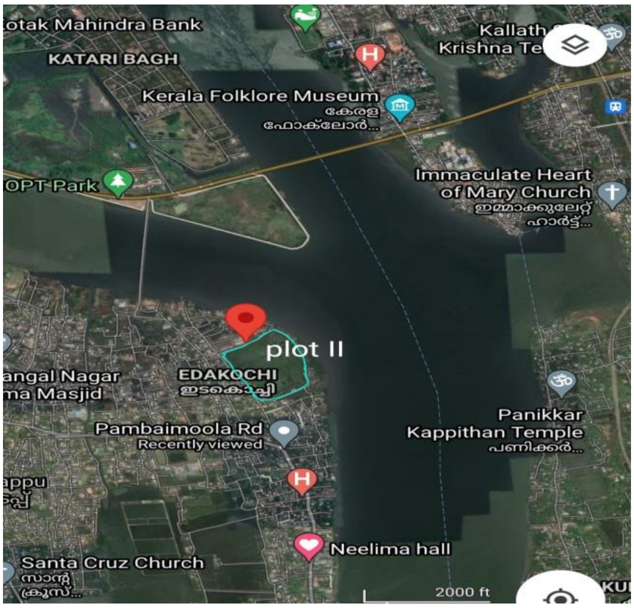
a) Plot I

The plot identified for the intervention is located in 15th and 16th wards of the KMC which was previously utilized for integrated pokkali-prawn culture. 60 acres(24 hectares) of continuous pokkali land (50 acre field is known as chettipadam padashekaram and the rest 10 acre field is known as puthankari) can be identified as the location for conservation and tourism. Chettipadam padashekaram consists of around 40 landowners whereas the 10 acre puthankiri is owned by a single person. Presently the land is leased throughout the year for aquaculture. The rice farming has not been seriously taken up for the past 20-25 years.




b) Plot II

The second plot identified is within ward 15 and it is a single plot stretching roughly around 25 acres. The land was previously used for pokkali fish integrated farming. Later on the field was left unused and that had resulted in natural encroachment by mangrove species. Later on in 2009 the area was purchased by Kerala Cricket Association with a plan to construct a stadium meeting international standards, with a water front. However the proposal could not be launched due to legal reasons as it was in the ecologically sensitive zone and as it also involved clearing of mangroves. The Kerala Promotion of Tree Growth in Non-Forest Areas Act mandates prior permission for uprooting mangroves in non-forest areas. Currently this field is lying idle.




2. Challenges and requirements:

The plots that are identified at Pambayimoola (plot I) has not not been under rice farming for over a quarter century. So the challenges include

1) Clearing the boundaries off mangroves
2) Strengthening the bunds and clearing the canals for drainage and setting sluices
3) Facilitating the domestic drainage through alternate methods, which currently is released to pokkali system
4) Establishing drainage system (traditional Petti and Para– an indigenous pumping arrangement)
5) Mechanisation in rice farming

'Petti and Para' which is used for managing the water level in the land for ensuring an optimum level for the cultivation of pokkali. As part of land preparations complete receding of water from the plot is to be ensured. Some regions with natural receding mechanisms don’t make use of petti and para and in regions where natural receding of water is difficult petti and para are brought into use. As cultivation has not been carried out in that area since the last two decades there is a need for restoration of bunds and removal of unwanted vegetations in that region. The water channels in between the fields which maintains the waterflow between the fields and the main river are to be deepened. As of now there are four major channels in the plot that are to be deepened. Due to unscientific construction of drainages which pollutes the fields with various solid and chemical wastes there arise the need for construction of a 500 m drain channel to redirect the flow of these wastes from these pokkali lands. The tidal variations also create a rise in water level at the lower regions and they suggested the need for a sluice to check the water from vembanad kayal entering into their region}

An approx. budget:

After rounds of discussions with the landowners and the padshekara samithi we could reach a consensus on the necessary infrastructural and related requirements to be necessitated for reviving back the location to successful pokkali farming which are listed as below with the sketch of the proposed plot for intervention.

Budget estimate for plot I

| Sl. No | Activities /Infrastructure required | | Length (in mtrs) | Area (Sq. m) | Rate per unit | Total cost each step of infrastructure | Total cost on each section |
|---|---|---|---|---|---|---|---|
| 1 | Drain | Earthwork | 650 | 1268 | 650 | 824200 | 11238000 |
| | | P. C. C | | 98 | 8000 | 784000 | |
| | | R. C. C | | 406 | 20500 | 8323000 | |
| | | Plastering | | 2178 | 600 | 1306800 | |
| 2 | Culvert | Earthwork | 6 | 62 | 650 | 40300 | 1063900 |
| | | P. C. C | | 7 | 8000 | 56000 | |
| | | R. C. C | | 46 | 20500 | 943000 | |
| | | Plastering | | 41 | 600 | 24600 | |
| 3 | Water channel(Thodu) | Deepening | 330 | 50 days | 7500 | 375000 | 375000 |
| 4 | Retaining walls | Bund formation | 2x330 | 10 | 7500 | 75000 | 7882700 |
| | | Increasing depth | | 10 | 7500 | 75000 | |
| | | P. C. C | | 12 | 8000 | 96000 | |
| | | Rubble Masonary with pointing | | 1069 | 6500 | 6948500 | |
| | | Top plastering | | 792 | 850 | 673200 | |
| | | Water discharging | | 10 days | 1500 | 15000 | |
| 5 | Vertical pump | Water lifting device | | | | 700000 | 1500000 |
| | | Pump house and accessories | | | | 800000 | |
| 6 | Kammaty clearing (undesired vegetation ) | Plucking and depostion to a | | 20 | 7500 | 150000 | 150000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | specified location | | | | | |
| 7 | Fencing | Earthwork | 900 | 27 | 650 | 17750 | 1631850 |
| | | P. C. C | | 6 | 8000 | 48000 | |
| | | R. C. C | | 9 | 20500 | 184500 | |
| | | Pre cast piller | | 302nos | 2000 | 604000 | |
| | | Tail twist nylon coated mesh | | 1728 | 450 | 777600 | |
| | Gross amount (in ₹) | | | | | | 23841450 |

Budget for conversion of plot II may require an amount roughly 3x times that of plot I

Appendix 4.1: Interview Schedule for collecting information on Pokkali, fish and shrimp Farming

Institute of Economic Growth

University of Delhi

Interview Schedule for collecting information on Pokkali Farming

This study is conducted as part of the larger project called INTERACT-Bio (Integrated subnational action for biodiversity: Supporting implementation of National Biodiversity Strategy and Action Plans through the mainstreaming of biodiversity objectives across city-regions) by ICLEI. Our task as part of this ICLEI study is to carry out the economic feasibility of doing an intervention in the Kochi municipal corporation area (and surrounding areas) that can have benefits for the community as well as help with biodiversity conservation. We will evaluate the rationale for a feasible investment in such interventions. However, we need to first get an understanding of the context and the possible interventions. Normally, we would have travelled to the field areas and interacted personally with experts and various stakeholders to understand the ground realities and possible interventions. However currently, we are quite constrained in this regard due to the COVID-19 situation. Hence, we would like to request if you could share your expertise on these issues by answering this questionnaire. We thank you for your time.

GENERAL INFORMATION

Name of the Farmer:

Address:

| Sl.no | Name | Age | Occupation | | Annual Income | | Educational qualification |
|---|---|---|---|---|---|---|---|
| | | | Part time | Full time | Agriculture | Non agriculture | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

LANDED PROPERTY (POKKALI)

| Area OWNED | OPERATED | Leased | AREA UNDER | Fish Farming |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| | | | POKKALI RICE | |
| | | | | |

Organizational Aspects

Whether part of Padasekhara Samithy or not

If yes Name the samithy

Extend of Financial support from Government:

Details of Rice Farming (season: from to )

Variety:

Area: Acres

A1. Labour

| Sl no | Particulars | Total labours (Numbers) | Men Wage rate /day = (Numbers) | Women Wage rate /day = (Numbers) | Total labour cost |
|---|---|---|---|---|---|
| 1 | Land preparation(making of bunds & mounds) | | | | |
| 2 | Sowing of seeds | | | | |
| 3 | Transplanting | | | | |
| 4 | Weeding(if any) | | | | |
| 5 | Water management | | | | |
| 6 | Harvesting | | | | |
| 7 | Threshing &post harvest operations | | | | |

A2. Others (seeds/materials /rent/implements etc). specify.

| Sl no | Particulars | Quantity | Rate per unit | Total cost |
|---|---|---|---|---|
| 1 | Seed (variety ) | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

| | | | | |
|---|---|---|---|---|
| 5 | | | | |
| | | | | |

A3. Sources of Capital

| Sl.no | | Amount (Rs) |
|---|---|---|
| 1 | Source of capital (own /borrowed/combined) | |
| | Source of borrowed capital | |
| | Amount borrowed | |
| | Rate of Interest | |
| | Whether repaid fully or not | |
| | Outstanding amount if any | |
| | Overdue | |

A 4 Yield and Returns

| Particulars | Quantity (Kgs)/<br>Price per kg |
|---|---|
| Total Quantity of output | |
| Quantity taken for home consumption | |
| For wages (if any) | |
| For seed | |
| Cultural /religious purpose /other domestic purposes) | |
| Quantity sold | |
| Price received per kg | |
| Marketing cost( If any)(gunny bags/labour/transportation ) | |
| Bye product if any | |

A5. MARKETING

| Sold to whom | Marketing cost incurred if any | Problems encountered in marketing |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

A6. PROBLEMS FACED BY POKKALI FARMERS

Labour problems

| No | Reasons | Very severe | Severe | Not severe |
|---|---|---|---|---|
| 1 | Non –availability of labour | | | |
| 2 | High labour cost | | | |
| 3 | Inefficiency of labours | | | |

Financial problems

| | | | | |
|---|---|---|---|---|
| 1 | Credit supply sufficient or not | | | |
| 2 | Interest rate | | | |
| 3 | Repayment problem | | | |
| 4 | Delay in the disbursement of loan | | | |
| 5 | Corruption | | | |

Marketing problem

| | | | | |
|---|---|---|---|---|
| 1 | Lack of marketing facilities | | | |
| 2 | Distance to the market& transportation problem | | | |
| 3 | Quality of the product | | | |
| 4 | Problem of getting reasonable price | | | |

Operational problem

| | | | | |
|---|---|---|---|---|
| 1 | Availability of quality seeds | | | |
| 2 | Machinery problem | | | |
| 3 | Lack of governmental support | | | |

Natural problem

| | | | | |
|---|---|---|---|---|
| 1 | Availability or non - availability of rain | | | |
| 2 | Incidence of pest & diseases | | | |
| 3 | Problem of weeds | | | |

**II. Fish Farming**

LANDED PROPERTY (Fish Farming)

| Area OWNED | OPERATED | Leased | AREA UNDER Fish Farming |
|---|---|---|---|
| | | | |

Organizational Aspects

Whether part of Padasekhara Samithy or not

If yes Name the samithy

Extend of Financial support from Government:

3.Cost of Cultivation Details (Fish Farming)

A1. Labour

| Sl no | Particulars | Total labours (Numbers) | Men Wage rate /day = (Numbers) | Women Wage rate /day = (Numbers) | Total labour cost |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |

A2. Others (seeds/materials /rent/implements etc )specify

| Sl no | Particulars | Quantity | Rate per unit | Total cost |
|---|---|---|---|---|
| 1 | Fishlings ( variety ) | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| | | | | |

A3. Sources of Capital

| Sl no | | Amount (Rs) |
|---|---|---|
| 1 | Source of capital (own /borrowed/combined) | |
| | Source of borrowed capital | |

| | | |
|---|---|---|
| | Amount borrowed | |
| | Rate of Interest | |
| | Whether repaid fully or not | |
| | Outstanding amount if any | |
| | Overdue | |

A4. Yield and Returns

| Particulars | Quantity (Kgs)/Price per kg |
|---|---|
| Total Quantity of output | |
| Quantity taken for home consumption | |
| For wages (if any) | |
| For seed | |
| Cultural /religious purpose /other domestic purposes) | |
| Quantity sold | |
| Price received per kg | |
| Marketing cost( If any)(gunny bags/labour/transportation) | |
| By product if any | |

A5. MARKETING

| Sold to whom | Marketing cost incurred if any | Problems encountered in marketing |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

A6. PROBLEMS FACED BY POKKALI FISH FARMERS

Appendix 4.2: Summary statistics- Pokkali rice farming

| S. No | Variable | Value/ Mean | Min | Max |
|---|---|---|---|---|
| 1 | Age (in years) | 56.05 | 33 | 80 |
| | Operated area (in ha) | | | |
| 2 | Leased in (in ha) | 3.70 | 1.8 | 5 |
| 3 | Own (in ha) | 1.59 | 0.1 | 12 |
| 4 | Operated area (leased in + own) (in ha) (Average across respondents) | 1.76 | 0.1 | 17 |
| | Inputs- Labour | | | |
| | No of labourers by process (in Nos per ha) | | | |
| 5 | Land preparation | 32.36 | 8.82 | 115.38 |
| 6 | Sowing | 8.87 | 2.29 | 50 |
| 7 | Transplanting | 14.25 | 0 | 100 |
| 8 | Weeding /intercultural operations | 1.8 | 0.24 | 15 |
| 9 | Water management | 17.34 | 0.12 | 10 |
| 10 | Harvesting | 27.54 | 2.35 | 112.5 |
| 11 | Threshing | 1.52 | 0.17 | 20 |
| | Labour charges by gender (in Rs/day) | | | |
| 12 | Men | 864.94 | 700 | 1000 |
| 13 | Women | 431.72 | 350 | 600 |
| | Labourers by gender (in Nos per ha) | | | |
| 14 | Men | 49.7 | 8.82 | 115.38 |
| 15 | Women | 53.98 | 9.94 | 212.5 |
| 16 | Total Labour cost | 66292 | 3946.43 | 165625 |
| | Inputs- seeds | | | |
| 17 | Seed quantity | 130.32 | 15.15 | 500 |
| 18 | Seed price | 77 | 40 | 160 |
| 19 | Seed cost | 10035 | 1060.61 | 64285.71 |
| 20 | Total Cost of Cultivation | 76327 | 8232.14 | 185714.3 |
| | Output | | | |
| 21 | Quantity of output | 345.24 | 35.71 | 2500 |
| 22 | Price of output | 56.09 | 30 | 100 |
| 23 | Value of output (in Rs/ha) | 19364 | 3750 | 175000 |

Appendix 4.3: Summary statistics- fish and shrimp farming

| S. No | Variable | Obs | Value/ Mean | Min | Max |
|---|---|---|---|---|---|
| 1 | Age (in years) | 31 | 52.42 | 32 | 73 |
| | Operated area (in ha) | | | | |
| 2 | Leased (in ha) | 30 | 9.62 | 0 | 140 |
| 3 | Owned (in ha) | 31 | 1.76 | 0 | 35 |
| 4 | Operated area (Leased + Owned) (in ha) (Average across respondents) | 31 | 11.07 | 0.43 | 140 |
| | Seed quantity (by seed varieties) (number of seeds per ha) | | | | |
| 5 | V1-Shrimp type 1(Naran) (in number of seeds per ha) (Total number of seeds for the specific species/total operating area across respondents reporting the species =4618000 /201.41) | 22 | 22928 | 12371.13 | 43750 |
| 6 | V2-Shrimp type 2(Kara) (in number of seeds per ha) (Total number of seeds for the specific species/total operating area across respondents reporting the species =6200000/185.3) | 22 | 33460 | 7142.86 | 40000 |
| 7 | V3-Crab (in number of seeds per ha) (Total number of seeds for the specific species/total operating area across respondents reporting the species =103600/28.05) | 13 | 3693.4 | 200 | 1351.35 |
| 8 | V4-Pearlspot (Karimeen) (in number of seeds per ha) (Total number of seeds for the specific species/total operating area across respondents reporting the species =65000/14) | 3 | 4642.86 | 321.43 | 1500 |
| 9 | V5-Grey mullet(Thirutha) (in number of seeds per ha) (Total number of seeds for the specific species/total operating area across respondents reporting the species =9500/2) | 2 | 4750 | 625 | 700 |
| 10 | V6-Thilapia/Milkfish (in number of seeds per ha) (Total number of seeds for the specific species/total operating area across respondents reporting the species =102000/20) | 5 | 5100 | 357.14 | 2000 |
| | Output quantity (by variety) (in kg/ha) | | | | |
| 11 | V1- Shrimp type 1(Naran) (in kg/ha) (Total quantity of output for the specific species/total operating area across respondents reporting the species =33381/158.2) | 22 | 211 | 140 | 375 |
| 12 | V2- Shrimp type 2(Kara) (in kg/ha) (Total quantity of output for the specific species/total operating area across respondents reporting the species =36855/185.3) | 22 | 198.9 | 14.29 | 200 |

| | | | | | |
|---|---|---|---|---|---|
| 13 | V3-Crab (in kg/ha)<br>(Total quantity of output for the specific species/total operating area across respondents reporting the species =2815/13.96) | 12 | 201.7 | 5 | 108.33 |
| 14 | V4-Pearlspot (Karimeen) (in kg/ha)<br>(Total quantity of output for the specific species /total operating area across respondents reporting the species =3370/ 14) | 3 | 240.71 | 15 | 115 |
| 15 | V5-Grey mullet (Thirutha) (in kg/ha)<br>(Total quantity of output for the specific species /total operating area across respondents reporting the species =105/0.62) | 2 | 170 | 6.5 | 10 |
| 16 | V6-Thilapia/Milkfish (in kg/ha)<br>(Total quantity of output for the specific species /total operating area across respondents reporting the species =4670/14.83) | 4 | 315 | 17.86 | 80 |

Appendix 6.1: Mangrove questionnaire

Title of Study: Developing an Investment Case for Kochi under the Integrated Sub National Action for Biodiversity: Supporting Implementation of NBSAP (INTERACT-Bio Project)

Institution: Institute of Economic Growth

Study Interview

Introduction

This study is conducted as part of the larger project called INTERACT-Bio (Integrated subnational action for biodiversity: Supporting implementation of National Biodiversity Strategy and Action Plans through the mainstreaming of biodiversity objectives across city-regions) by ICLEI. This ongoing IEG study, funded by ICLEI, Bonn, is part of an effort to help Kochi Municipal Corporation implement action under the National Biodiversity Action Plan. The objective is to develop an investment case for an intervention in biodiversity restoration and conservation in Kochi municipal corporation area (and surrounding areas), which will also have some benefits for the community. Our objective was to shortlist a set of possible interventions and then build the investment case for a couple of these interventions. Based on initial field work and stakeholder interactions, we shortlisted three possible interventions: traditional pokkali (paddy-fish) cultivation, mangrove restoration and biodiversity parks in the city. In the second phase, we collected field survey-based data (experts, farmers and local government) for traditional cultivation. For mangroves, we have some biophysical data on possible locations and species. However, due to the pandemic we are unable to go to the field as much as we had wanted to when we planned the study.

Thank you for supporting our study. Please be assured that all responses will be anonymised and collated for analytical purposes for this particular research only. There will be no individual attribution in terms of any quotations, findings, results or recommendations. We have a longer disclaimer and introduction on the study, and would be happy to share that with you in case you would like us to do so. However, in appreciation of your extremely busy schedule, for now we would be grateful if you could let us know the following:

1. Would you be ok with inclusion of your name in a list of experts who have been consulted in online mode for the study, which will be provided in an appendix to the study report?

Please respond: Yes / No

2. Would you be ok with us acknowledging you by name in the list of persons to whom we would like to openly express our gratitude in the acknowledgements section?

Please respond: Yes / No

3. Please indicate your area/s of expertise with regard to specific natural resource management:

Mangroves (specifically)

Protected Areas (National Parks, Sanctuaries)

Wetlands (in general)

Forests (in general)

Coastal (in general)

4. Please feel free to share any caveats/disclaimers which you feel maybe relevant for our study.

Questions

*Note:* Please respond to these questions keeping in mind the context for Kochi and surrounding areas. In case this is not possible, please respond in the context of the state of Kerala or India.

Please mark which of the following is applicable for your responses: Kochi/Kerala/India

1. In your opinion, which ecosystem services from mangroves are most relevant for India, in the context of sustainable development? Please rank in order of priority:

- Fodder, Fisheries and Aquaculture (Commercial)
- Moderation of extreme weather events
- Biodiversity and lifecycle maintenance (habitats, genetic materials)
- Agriculture in mangrove areas (Self-consumption, subsistence or commercial)
- Air quality and climate regulation
- Recreation and tourism
- Any other (please specify):

2. Which interventions do you think should be prioritised in a biodiversity action plan to meet the twin objectives of conservation with community welfare?

Please rank in order of priority:

- Mangrove conservation
- Traditional eco-friendly farming practices
- Urban agriculture
- Urban green spaces
- Pollution management (Water, Land)
- Any other (please specify)

3. Do you have any suggestions on specific locations within the Kochi Municipal Corporation area and surrounding areas where mangrove restoration can be undertaken?

4. Please provide your views on the ecological status of mangroves in Kochi at present -

(a) Overall status: Well-maintained and stable / Degraded and stable / Rapidly deteriorating

(b) Specific markers: Please describe changes in the last 10 years in terms of the following specific aspects on whether there is Increase / Decrease / No change

(I) Total area under mangroves:

(II). Density of mangroves:

(III). Species diversity- plant:

(IV). Species diversity- fauna:

5. (a) Do you think that there is a symbiotic relationship between mangroves around the Pokkali areas/paddy-fish ecosystems (for both paddy production and fish production)?

(b) If it is complementary, in your opinion, to what extent does the existence of mangroves influence the yield of paddy and/or fisheries?

(c) Is there any scientific evidence on these aspects which you could point out for us?

6. In your view, what are the most significant threats/challenges to conserving and maintaining mangroves in India. In case, your expertise lies in some other natural resource management field, please indicate this and respond accordingly. Please elaborate to the extent possible. Thank you.

For instance, some of the challenges could be pollution discharge, human-wildlife conflict due to species inhabiting mangroves, land scarcity or unemployment leading to alternative land use (e.g.agriculture, aquaculture), disruption of fresh water flows, and more depending on the natural resource you have in mind.

Please respond

Natural Resource: Mangroves or other (please specify)

Please elaborate, if possible by category of challenge:

Economic:

Social:

Ecological:

7. Please share your suggestions/recommendations on how to tackle the challenges mentioned in your response to question 6 above.

For example, a conventional command and control type economic response to tackle pollution discharge can be to levy an additional 10% cess and penalties on polluting industries. An ecological response maybe to simply leave the mangrove area to regenerate, aided by legal instruments. A socio-ecological approach may promote institutional responses with strong onboarding of local communities in conservation.

What would be the two or three topmost recommendations you would like to suggest?

1.

2.

3.

8. I would be very happy to hear your insights on the costs that may be incurred for either inaction or taking action on your suggestions in response to question 7 above. Please note we understand that costs can be monetary or non-monetary, and that there will be costs to society that arise from inaction as much as from action. If any of the sub-questions are unclear, please do respond as per your own understanding and to whichever part you wish to, as we do not wish to be prescriptive but would rather understand and learn from your expertise.

Costs of Inaction: (please list)

1. Long term loss of mangrove services - please specify which services

2. Near term to medium term loss of services - please specify which services

3. Please indicate any estimates on potential losses/damage costs that you are aware of for any of the services -

Costs of Action:

1. Heads on which financial costs will be incurred: (eg. fencing, guards, any reforestation/restoration) - please list.

2. Income and livelihood generation: (e.g. farmers, fisheries, industry owners, loss of revenue for the state, wage employment) - please list in order of priority for taking action on designing compensation/incentives

3. Unintended consequences - (for instance: mental well-being, social stress, meeting other SDG targets) - please list

9. Are there any ecosystem services which may be lost during a mangrove restoration intervention in the study area?

10. We would value your suggestions on how local communities can be involved in mangrove restoration. Please rank in terms of priority for action.

a. Institutional support:

 formation of cooperatives

 ensuring tenure rights

 legal/regulatory support

 improving awareness of benefits by civil societies

 Any other:(please specify)

b. Economic incentives

 benefit-sharing mechanisms

 income generation activities (e.g.mangrove tourism)

 direct compensation

Other (please specify):

c. Any other suggestions are welcome:

11. We would value your suggestions on opportunities for encouraging investment in mangroves in India. Please feel free to list these and help us by indicating which ones should be prioritised.

1. Policy/regulatory/institutional (e.g. enacting specific regulation - CSR, forming dedicated community institution)

2. Adoption of specific markers (eg for M & E to aid donor evaluation)

3. Financing (eg any new instruments, dedicated fiscal resources, private)

4. Safeguards(social/environmental)

12. Any names of experts or literature that maybe relevant for the study:

Appendix 6.2: List of experts consulted for expert analysis for mangrove restoration intervention

1. Dr P. S. Easa, Retired Scientist, KFRI
2. Dr. Disha Bhattacharjee, NITI Aayog
3. Dr. Upasna Sharma, IIT-Delhi
4. Dr. K Kathiresan, Annamalai University
5. Dr. Kanchan Chopra, Institute of Economic Growth
6. Dr. Gopal Kadekodi, Centre for multi-disciplinary development research
7. Dr. K S Kavikumar, Madras School of Economics
8. Dr. Santadas Ghosh, Visva-Bharati, Santiniketan
9. Dr. M Hema, Kerala Agricultural University
10. Dr. Saudamini Das, Institute of Economic Growth
11. Dr. Nilanjan Ghosh, Observer Research Foundation
12. Dr. Namrata Thapa, Institute of Economic Growth
13. Dr. Abhra Chanda, Jadavpur University
14. Dr. Nisha Priya Mani and Dr. Alpana Jain, The Nature Conservancy
15. Dr. Ruchika Singh and Ms. Marie Duraisami, World Resources Institute India
16. Dr. Ramasamy Ramasubramanian, M S Swamininathan Research Foundation
17. Dr. Anjal Prakash, Indian School of Business
18. Ms. Ishita Sachdeva, Delhi University
19. Dr. KN Ninan, World Resources Institute India
20. Dr. L Venkatachalam, Madras Institute of Development Studies
21. Dr. Yamini Gupt, Delhi University
22. Dr. M N Murthy, Institute of Economic Growth
23. Some other names have been anonymised on request

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