Water Science and Technology Library

Sourav Das
Abhra Chanda
Tuhin Ghosh *Editors*

Pond Ecosystems of the Indian Sundarbans

An Overview

Springer

Water Science and Technology Library

Volume 112

The aim of the *Water Science and Technology Library* is to provide a forum for dissemination of the state-of-the-art of topics of current interest in the area of water science and technology. This is accomplished through publication of reference books and monographs, authored or edited. Occasionally also proceedings volumes are accepted for publication in the series. *Water Science and Technology Library* encompasses a wide range of topics dealing with science as well as socio-economic aspects of water, environment, and ecology. Both the water quantity and quality issues are relevant and are embraced by *Water Science and Technology Library*. The emphasis may be on either the scientific content, or techniques of solution, or both. There is increasing emphasis these days on processes and *Water Science and Technology Library* is committed to promoting this emphasis by publishing books emphasizing scientific discussions of physical, chemical, and/or biological aspects of water resources. Likewise, current or emerging solution techniques receive high priority. Interdisciplinary coverage is encouraged. Case studies contributing to our knowledge of water science and technology are also embraced by the series. Innovative ideas and novel techniques are of particular interest.

Comments or suggestions for future volumes are welcomed.

Vijay P. Singh, Department of Biological and Agricultural Engineering & Zachry Department of Civil and Environment Engineering, Texas A&M University, USA Email: vsingh@tamu.edu

All contributions to an edited volume should undergo standard peer review to ensure high scientific quality, while monographs should also be reviewed by at least two experts in the field.

Manuscripts that have undergone successful review should then be prepared according to the Publisher's guidelines manuscripts: https://www.springer.com/gp/authors-editors/book-authors-editors/book-manuscript-guidelines

More information about this series at http://www.springer.com/series/6689

Sourav Das · Abhra Chanda · Tuhin Ghosh
Editors

Pond Ecosystems of the Indian Sundarbans

An Overview

Springer

Editors
Sourav Das
School of Oceanographic Studies
Jadavpur University
Kolkata, West Bengal, India

Abhra Chanda
School of Oceanographic Studies
Jadavpur University
Kolkata, West Bengal, India

Tuhin Ghosh
School of Oceanographic Studies
Jadavpur University
Kolkata, West Bengal, India

ISSN 0921-092X ISSN 1872-4663 (electronic)
Water Science and Technology Library
ISBN 978-3-030-86785-0 ISBN 978-3-030-86786-7 (eBook)
https://doi.org/10.1007/978-3-030-86786-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Dedicated to the people of Indian Sundarbans who are incessantly struggling with climatic disasters

Preface

Inland aquatic bodies play a crucial role in regulating the atmospheric gaseous concentrations (especially greenhouse gases) and providing a habitat for various flora and fauna and other ecosystem services. The lakes and reservoirs all through the world have received substantial attention from the global scientific community. Several pieces of research focused on their biogeochemical dynamics, role in present-day society, and the implication in earning a livelihood. The comparatively smaller water bodies, i.e., the ponds, have received much less attention. In the recent past, several pieces of research indicated that these small aquatic bodies are capable of governing climate phenomena on a synoptic scale. Ponds are a common landscape feature of rural sectors in various tropical countries, and India is no exception. The Sundarbans (shared by India and Bangladesh) is renowned as the largest mangrove forest in the world. This unique ecosystem shelters a spectrum of both floral and faunal biodiversity. Besides, this region is an abode for more than 4.4 million people. Situated in the lower end of the world's largest delta (the Ganga-Brahmaputra-Meghna delta), this region shelters a marginalized section of society in the majority. The ponds are essential in carrying out several daily life activities and are available in almost every household in this part of the world. Lately, the uncertainty in capture fisheries and the increasing demand for fish jointly led to the flourishing of aquaculture ponds in this region (as also observed in many coastal sectors throughout the globe). The purpose of most of the household and community ponds is to meet the freshwater requirements. It has been a tradition in the Indian Sundarbans to dig a pond in the household plots, which meets several purposes in day-to-day activities. Bathing, washing utensils, feeding the agricultural lands during the dry season, homestead gardening, and feeding the cattle are some of the most common activities related to ponds in the Indian Sundarbans. Though these ponds are in plenty through the Indian Sundarban Biosphere Reserve, their biogeochemistry, greenhouse gas emission potential, productivity rates, nutrient, and pollutant dynamics are scarcely studied. This book is perhaps an endeavor of the first of its kind, which tried to cover all these aspects of the ponds of Indian Sundarbans, under one umbrella. This timely book can act as the foundational basis for limnologists and hydro-geologists to have firsthand baseline information on these crucial lentic ecosystems. Estuarine and marine scientists, ecologists, biogeochemists, environmentalists, and social scientists, whose interest lies in the use and performance of lentic ecosystems of the coastal sector of India and other parts of the world, would find interest in the present title. Intermediate to advanced level students can be beneficial by going through this book.

The book opens with an introductory chapter on the ponds of the Indian Sundarbans, which presented a basic overview of these lentic ecosystems. The second chapter dealt with the land use/land cover dynamics (we considered four administrative blocks as representatives for the entire region). We emphasized the size class of the ponds and their distribution pattern. The third and fourth chapters studied the impact of water quality on the livelihood of local people and the fish diversity in the lentic ecosystems of this region. The fifth chapter discussed the role of iron fertilization to enhance the fish yield from these ponds. The role of these ponds in greenhouse gas emission was discussed explicitly in the sixth to eighth chapters. The ninth chapter hinted at the possible ecosystem services of these ponds. The tenth chapter studied the relevant social aspects related to the ponds of a particular community development block of Indian Sundarbans. The eleventh to thirteen chapters covered the biogeochemical and pollutant dynamics. The observations discussed in this book can prompt future research actions from the perspective of achieving the sustainable development goals (of United Nations) like zero hunger (SDG 2) and clean water and sanitation (SDG 6). Overall, this book tried to reflect a holistic understanding of these lentic ecosystems from several viewpoints. However, many of the issues and aspects need further study. Thus, this book can act as a guide for future researchers. The findings discussed in this book indicate the aspects that require more attention.

Kolkata, India

Sourav Das
Abhra Chanda
Tuhin Ghosh

Acknowledgments

We thank Dr. Sanjibakumar Baliar Singh, Dr. Anirban Akhand, and Dr. Sudarsana Rao Pandi for their help in reviewing several chapters. We also thank the editor of Springer Nature (Margaret Deignan) for her kind help and encouragement. We specially thank Dr. Andrew C. G. Henderson (School of Geography, Politics and Sociology, Newcastle University, UK) for his kind support and encouragement throughout this book project. Moreover, we would like to acknowledge the contribution of the countless people of Indian Sundarbans who selflessly gave them their time to talk about their ponds and what it means to them.

Kolkata, India

Sourav Das
Abhra Chanda
Tuhin Ghosh

Contents

About the Editors

Dr. Sourav Das is a Post-doctoral Research Associate of the UKRI-GCRF Living Deltas Hub in the School of Oceanographic Studies at Jadavpur University, India. His research interests include biogeochemistry of marine and coastal water, ocean remote sensing, optical properties of water (inherent and apparent optical properties), and air quality monitoring. He has twelve years of research experience and has more than 60 research articles in reputed peer-reviewed journals including two books.

Dr. Abhra Chanda is an Assistant Professor, School of Oceanographic Studies at Jadavpur University, India. His research interest encompasses the biogeochemistry of lentic and lotic aquatic systems and pollutant dynamics. Blue carbon dynamics is one of the priorities of his research. He has eleven years of research experience and has more than 75 research articles in reputed peer-reviewed journals to his credit.

Prof. Tuhin Ghosh is Professor and Director of the School of Oceanographic Studies at Jadavpur University, India. He has more than two decades of research experience in coastal geomorphology, disaster management, climate change impacts, adaptation strategies, and human migration. He has more than 80 research articles in reputed peer-reviewed journals to his credit.

List of Figures

List of Tables

Chapter 1
An Introduction to the Ponds of Indian Sundarbans—An Essential Socio-Ecological System

Sourav Das, Abhra Chanda, and Tuhin Ghosh

Abstract Ponds are small lentic bodies that are abundant throughout the world. In the rural setup of many Asian countries, especially in the deltaic regions (where adjacent waters are mostly saline), ponds serve as an essential source of fresh water. The Sundarbans is renowned for being the largest mangrove forest on Earth. India and Bangladesh share this unique ecoregion. The Indian part shelters a thickly populated marginalized section of people, who exclusively rely on this forest to meet their livelihood demands. The mangroves and other land use classes of the Indian Sundarbans have received ample attention in the past. However, the millions of ponds in this setup did not receive the adequate scientific focus, which it deserves. The present book is perhaps the first attempt to furnish a holistic overview of the biogeochemical status and socio-economic importance of these ponds. Given proper management, these ponds can play a crucial role in provisioning food resources for the local inhabitants, and thus, can serve to achieve a few of the United Nations Sustainable Development Goals (SDG 2—Zero hunger; SDG 6—Clean water and sanitation). At present, these ponds remain neglected with no proper attempt of nurturing the potential ecosystem services that these aquatic ecosystems can offer. This chapter detailed the nitty–gritty of the ponds of Indian Sundarbans from all possible viewpoints and provides a foundation for the entire book.

Keywords Lentic ecosystems · Indian Sundarbans · Freshwater · Socio-economic issues · Aquatic pollution · Biogeochemistry · Gender inequality · Cultural context · Aquaculture farming · Pond management

1.1 Introduction

When biological ecosystems and the interactions within are governed and regulated by external social and economic institutions, they are defined as socio-ecological ecosystems (SESs), thus acknowledging the complex interlinking between human and natural systems (Colding and Barthel 2019). Deltas are significant SES, offering

S. Das (✉) · A. Chanda · T. Ghosh
School of Oceanographic Studies, Jadavpur University, Kolkata, West Bengal 700032, India

S. Das et al. (eds.), *Pond Ecosystems of the Indian Sundarbans*, Water Science and Technology Library 112, https://doi.org/10.1007/978-3-030-86786-7_1

a range of ecosystem services to society. They comprise only 1% of land cover worldwide but support the livelihoods of 500 million people (Ericson et al. 2006). These deltaic ecosystems provide provisional (water for irrigation and domestic purposes, food, fertilizer) and regulatory (nutrient sequestration, wastewater treatment) services. They also offer cultural (traditional knowledge systems, religious importance) and supporting (nutrient and water cycling, primary production, species diversity). Standing aquatic bodies in Indian Sundarban, such as ponds, are unlike other ecosystem service providers, such as the main river channels, mangrove forests, on account of their high economic value, multi-functionality.

The interest in pond ecosystem services (water retention) and conservation have grown over recent years. However, research efforts have been Europe-centric, focusing on the omission of ponds from the European Union Water Framework Directive (Oertli et al. 2005). There is a lack of information on the value of ponds, their water chemistry, conservation, and management practices in Southeast Asia (especially Indian Sundarban). Ponds in Indian Sundarbans are socio-ecological systems embedded in the cultural character of these areas and provide essential ecosystem services. However, they are also severely undervalued and polluted water sources. Elsewhere large concentrations of ponds, termed pondscapes, have been shown to support high biodiversity that contributes more to catchment-wide aquatic biodiversity than lakes, streams, and rivers (Davies et al. 2008). At present, no study supports the existence of pondscapes in Indian Sundarbans on account of their number and land area and their contribution to biodiversity. The present book will discuss some of these topics under one umbrella.

Ponds are ‘hotspots’ of anthropogenic activity. However, these lentic ecosystems have experienced severe environmental degradation. The pollutant loads have increased significantly in these water bodies leading to human and biodiversity health risks (e.g., eutrophication and toxic algal blooms) (Jahan et al. 2010). Moreover, these are essential natural resources to address the UN Sustainable Development Goals (SDGs), which aim to encourage strategies that improve health and education, reduce inequality, and increase economic growth while tackling global environmental change and conserving our ecosystems. This book also addresses few SDGs in terms of the pond as a resource.

The Sundarbans area is a rich ecological unit spread on the Ganges–Brahmaputra–Meghna (GBM) delta. The estuarine segments of the Rivers, Ganga, Brahmaputra, and Meghna between 21°32′N and 21°40′N and 88°05′E and 89°E (in both India and Bangladesh) shelters this unique eco-region (Spalding et al. 1997). The Indian Sundarbans have unique biodiversity, including globally threatened species, for example, the Ganges River dolphin (Platanista gangetica), the northern river terrapin (Batagur baska), the brown-winged kingfisher (Pelargopsis amauroptera), the Irrawaddy dolphin (Orcaella brevirostris), and the Royal Bengal tiger (Panthera tigris)—the only mangrove tiger on Earth (RAMSAR 2019). The mangrove ecosystem, which makes up the Indian Sundarbans, is an interconnected network of rivers, creeks, rivulets, and semi-diurnal tides with direct marine influence on the most seaward parts (Fig. 1.1). Hence, there is a range of hydrological impacts (including freshwater and coastal water) on the mangrove forest, and when combined

Fig. 1.1 Study area map of Indian Sundarbans consisting of nineteen community development blocks

with its topographic heterogeneity, it results in rich biodiversity (Gopal and Chauhan 2006). Because of this reason, Sundarbans mangrove forest being designated a World Heritage Site by the International Union for Conservation of Nature (IUCN) in 1987; and a wetland of international importance according to the RAMSAR convention in the year 2019; a Biosphere Reserve by United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1989 (Fig. 1.1).

1.2 Ponds as Socio-Ecological Systems

1.2.1 The Nature and Uses of Ponds in Indian Sundarbans

Ponds of Indian Sundarbans have multiple functions, like irrigation, aquaculture, potable water, sanitation, bathing, and water storage. As a result, they are a common feature in the rural landscape (Roy and Nandi 2010) (Figs. 1.2, 1.3, 1.4). The majority are manually-dug with rainwater during the monsoon, groundwater, or tidal exchange (Johnston et al. 2002; Dubey et al. 2017; Kale 2017) as the primary water sources. Traditionally ponds were created for use at a domestic scale (Nhan et al. 2007), with large numbers of households in rural India (Manoj and Padhy 2015) having a pond around their home. In India, the primary function of ponds in coastal villages is for drinking water, washing, and small-scale irrigation activities (Manoj and Padhy 2015). In more recent years, the ‘blue revolution’ encouraged the enhancement of global food production through aquaculture, ponds and industrial aquaculture now have a high economic value in India (Ahmed 2013). Most farmers excavate the pond every six months to increase the productivity levels (Christensen et al. 2008). In that way, during the blue revolution era, pond digging will be the largest employment sector for non-landowners in Indian Sundarbans in the future (Figs. 1.2 and 1.4).

1.2.2 The Social Context of Ponds

Ponds are crucial in the day-to-day life of the Indian Sundarbans. The natural-cultural heritage of ponds in this region has followed a route from spiritual sites to multi-functioning sites of economic and domestic activities. In more recent centuries, ponds became critical spaces for community domestic and cultivation purposes, highlighting a shift in societal perception of ponds as sites of livelihood options. For instance, in the GBM delta under British colonial rule, ponds were the responsibility of the “zamindars”; local landlords and tax collectors, and who determined which ponds the communities could use for different activities; i.e., aquaculture, bathing, drinking water for cattle (Kränzlin 2000). Further, land conversion to ponds for irrigation and fish stocking led to a rent reduction (McLane 1993). Since India’s independence in 1947 and the collapse of the “zamindar” system, many ponds became abandoned.

The growth of “the blue revolution” in recent decades, however, has increased the economic value of ponds again (Pucher et al. 2015). Mud crab aquaculture is quite popular in the Indian and Bangladesh Sundarbans (the world’s largest mangrove

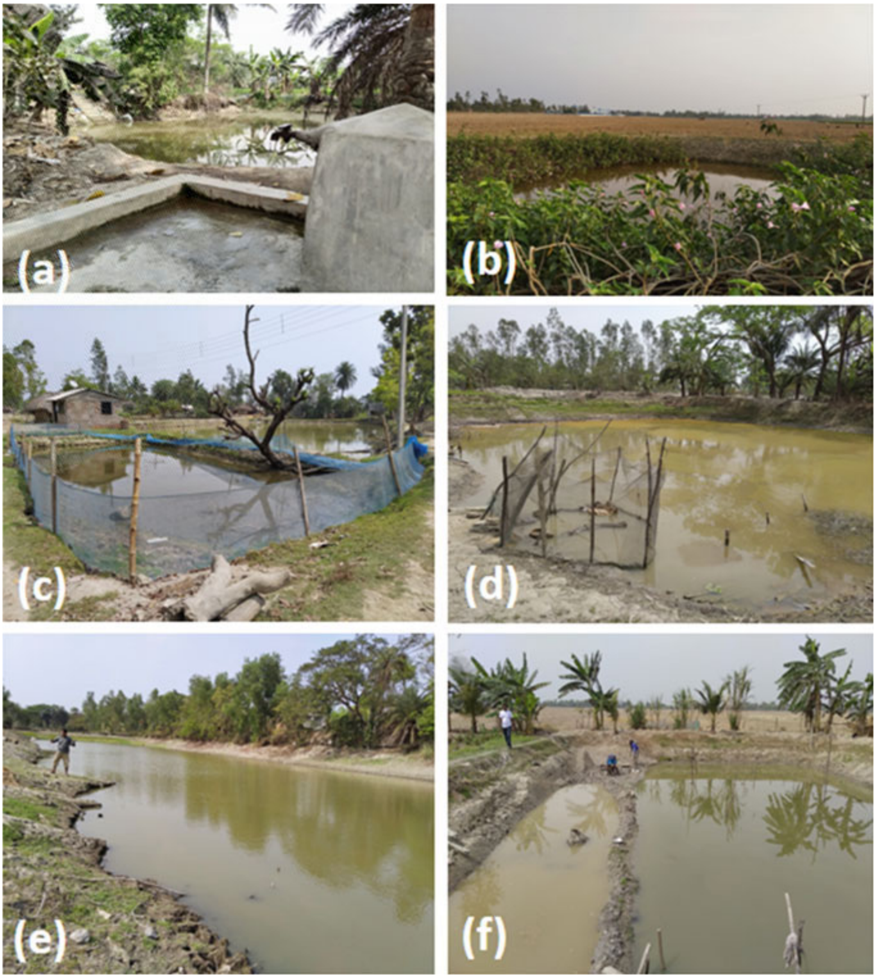

Fig. 1.2 Photographs showing some of the types, functions and management of ponds in Indian Sundarbans **a** Homestead Pond (also showing community water supply tap), **b** Agriculture Pond, **c** Crab fattening Pond, **d** Duck farming in a pond, **e** Fish Pond and **f** Increasing pond dimension before monsoon season to store more rain water (*Photos* are taken by Sourav Das)

forest, which contributes to the coastal GBM system). It can yield profits of 22,812.5 US \$ ha^{-1} $year^{-1}$ for culture (where young crabs are grown for several months until they reach a desirable size), and 30,820.8 US \$ ha^{-1} $year^{-1}$ for fattening (where soft-shelled crabs are reared for a few weeks until their exoskeleton is hardened, and typically fetch a much higher profit than "soft" crabs) (Sathiadhas and Najmudeen 2004). For rural and marginalized delta communities, however, ponds remain multi-functional entities that are central to the community and household life. The demand

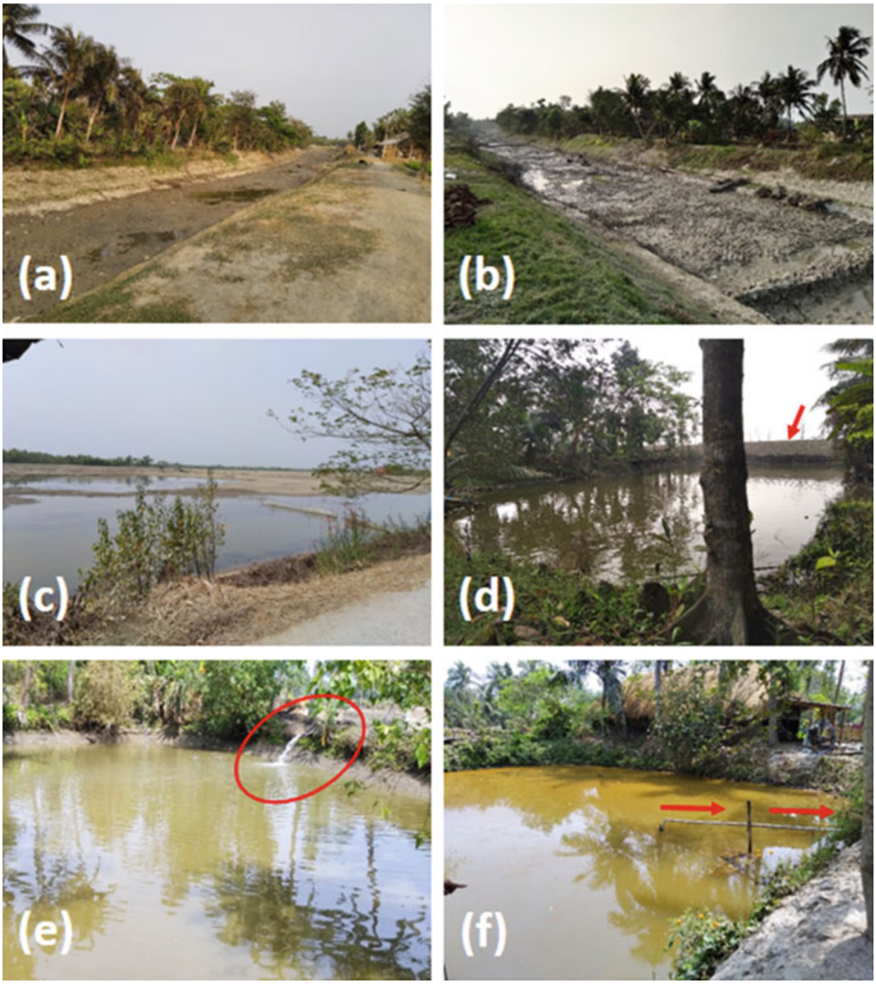

Fig. 1.3 Photographs showing some of the types, functions and management of ponds in Indian Sundarbans (**a**) and (**b**) Community canal to store rain water for irrigation and other activities, **c** Fish Pond, **d** Pond beside embankment (indicating by arrow), **e** Sweet water supply (indicating by arrow) into the fish pond during summer season to maintain the water level, **f** Water supply system (indicating by arrow) for sanitation purpose from Homestead Pond (*Photos* are taken by Sourav Das)

for ponds to generate profit continues to occur alongside their need to provide local subsistence of food, water, and sanitation (Fig. 1.3).

In earlier centuries, Indian ponds grew in the vicinity of Hindu, Muslim, and Buddhist sites. In Hindu culture, water means life and pervades rituals and myths surrounding ponds as treasure keepers, sacrificial sites, and links between the underworld, spirits, and human beings (Kränzlin 2000). In Muslim culture, water is an

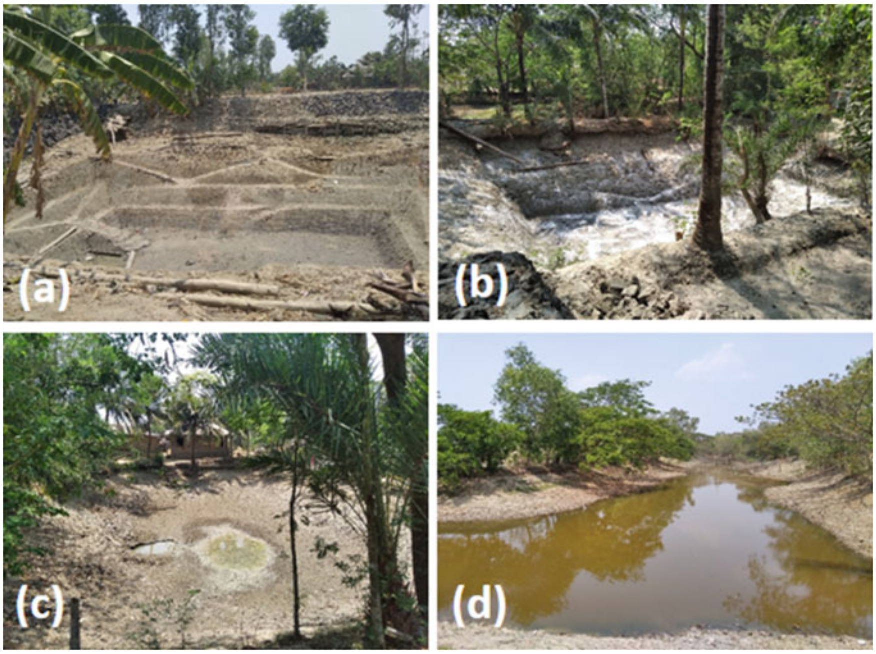

Fig. 1.4 Photographs showing some of the types, functions and management of ponds in Indian Sundarbans **a** Homestead Pond digging, **b** Liming of Homestead Pond, **c** Dried up Pond during summer season and **d** Community canal water (*Photos* are taken by Sourav Das)

element of purification, with the Muslim period in the Bengal delta heralding the digging of ponds to allow water for the whole community free of cost (Kränzlin 2000). Today, ponds remain at sacred sites for these religions.

Water remains an important symbol of life and rebirth in many delta cultures. However, the mightier river channels often overshadow the ponds. For instance, constitutional amendments in India and Bangladesh have granted rivers rights to life, meaning harm or damage to a river is akin to harming a living entity. Further, rivers predominate religious ceremonies. In the Ganges river, pilgrims take part in the annual Hindu holy dip for 'Gangasagar Mela' (Sinha et al. 2020). Ponds do not possess the same reverence as the delta rivers despite being central actors in daily delta life.

1.2.3 Pond Owner and User Identity

There exist hierarchal social structures between pond owners and users. In rural GBM districts, private pond ownership used to be a custom, with pond owners often more financially stable than their non-pond-owning counterparts (Belton et al. 2012). In

Bangladesh, pond size reflects social status. Wealthier households own larger ponds compared to the poorer ones who own smaller ponds. The small ponds are usually less productive and undergo intensive aquaculture (Belton et al. 2012). However, nearly a third of medium and small pond owners live below the poverty line, with more at risk of slipping below the line due to unexpected events (e.g., cyclones and ill-health) that threaten production and results in the loss of income (Belton and Azad 2012; Belton et al. 2012).

1.2.4 Ponds (Aquaculture), Migration and Loss of Livelihoods

The expansion of export-orientated aquaculture in tropical deltas has resulted in land-use changes from virgin mangrove forests to agricultural land to ponds. Indeed, government incentives and policies aimed to increase the conversion of common property such as mangrove forests to aquaculture ponds with minimal rent to alleviate rural poverty (Ahmed 1999). The displacement of traditional agricultural landscapes in the rake of growth in aquaculture has led to a surplus of agricultural workers. These laborers had to seek employment in not only other sectors but often had to migrate away from their homes (Haque and Saifuzzaman 2003). The survey of this book also revealed such types of cases in the Indian Sundarbans delta.

Aquaculture expansion has also resulted in further marginalization of communities reliant on subsistence and harvest of forestry-based products (Luttrell 2006). In the Indian Sundarbans, rural individuals who do not own ponds are typically involved in forest-based crab and prawn seed collection to supply aquaculture and have much lower incomes than those employed by the aquaculture industry directly as their income responds to local market economics compared to international markets (Chand et al. 2012). Furthermore, demand for aquaculture-wild-seed has promoted over-fishing and led to illegal fishing activity. The permits that aim to limit fishing effort restrict the collection of wild stocks to certain forest areas on specific dates. Fishers will then continue to fish in restricted forest areas, with the economic profits from selling wild stock to aquaculture overriding occasional financial penalties from illegal forest collection (Ghosh 2015).

1.2.5 Ponds and the Gender Inequality

Gender inequality is widespread in many tropical delta countries, with aquaculture highlighting this. If women get the opportunity to seek employment in this industry, they will typically earn less than their male counterparts. Women often carry out insecure, low-paid, labor-intensive works related to aquaculture, such as harvesting and packing (Gammage et al. 2006). Rural women often single-handedly run the households, which makes them vital pond users. Given the different needs of female physiology and reproductive health, this heavy pond use makes them at increased risk of health implications from poor pond water quality (Upadhyay 2005; Benneyworth et al. 2016). For instance, consumption of saline pond water, more prevalent in the dry season, has been documented to increase the risk of high blood pressure and preeclampsia in pregnant women in the Sundarbans area (Khan et al. 2011). Ponds can be an unsafe place for female users. For example, females are at greater risk of sexual harassment and physical or verbal abuse when bathing in communal ponds (Joshi et al. 2011). Menstruation remains taboo in several delta communities, which compels many women to avoid bathing when on their period (Joshi et al. 2011).

1.3 Environmental Challenges

Human activities have increased in deltaic systems like Indian Sundarbans vis-a-vis the global sea-level rise and climatic variability. Such anthropogenic and natural hazards are placing the aquatic ecosystem of Indian Sundarbans under increasing stress. Several ponds have outlets to neighboring river creeks or channels (Kränzlin 2000) due to a lack of firm river banks or embankments (Dubey et al. 2017), which allows water to be exchanged, particularly during monsoon season (heavy rainfall) and flood situations. This water exchange contaminates the surrounding water bodies (Tho et al. 2014). Dubey et al. (2016) highlighted several environmental concerns regarding the freshwater ponds of Indian Sundarbans. Saltwater inundation to the pond, disease or epidemics, storm surges, cyclones due to climate change, and uncertain rainfall lead to significant deterioration of these ponds.

1.3.1 Saltwater Inundation

Accelerated sea-level rise, increased frequency and intensity of storm surges, and the upstream withdrawal of freshwater are concerns for coastal wetlands worldwide. The upstream withdrawal patterns are often exacerbating during the pre-monsoon season due to low river discharge allowing saltwater intrusion further inland. Moreover, Chand et al. (2012) described that the saline water inundation for flooding and sea-level rise destroys the inland freshwater ecosystems. Dubey et al. (2017) revealed that more than 18% of fish farmers confirmed that these mechanisms altered more and more freshwater pond to brackish water pond day by day. Hence, increasing pond salinity may result in ponds being unusable for irrigation, bathing, and freshwater fish cultivation in the future.

1.3.2 Exchange of Dissolved Organic-Rich Waters

Indan Sundarbans receive excess organic load and nutrients from varied anthropogenic sources, i.e., household and municipal waste and surface runoffs. Due to the organic load and high temperatures, harmful algal blooms (HABs) are common in the delta pond ecosystem. Toxin producing HAB causing fish kills decreases biodiversity and increases human health risks such as headaches and skin irritations (Jahan et al. 2010). Indian delta communities witnessed several cholera outbreaks due to pond water. Mukherjee et al. (2011) reported that increasing nutrient levels and salinity of ponds enhance the longevity of V. cholerae (cholera causing bacteria) and may lead to increased future outbreaks. Pond user activities that increase the risk of such spread include mouth washing and cooking with pond water, bathing, washing utensils in ponds. Ponds used for industrial aquaculture often obtain fertilizers that are rice by-products, human and livestock waste, and crustaceans from rice grounds (Nhan et al. 2007). However, industrial and domestic discharges are more significant than ponds for nutrient loading to surrounding waters (Tho et al. 2014). However, the blend of nutrient loading and salinization of ponds has caused a drop in species diversity of phytoplankton and zooplankton (Tho et al. 2014).

1.3.3 Faecal Coliform Pollution

Open place excretion, poor sanitation, and the absence of wastewater treatment within delta systems have resulted in the substantial contamination of surface water with fecal coliform bacteria and pathogens. In India, open ponds have the maximum counts of animal and human fecal indicators compared to other water sources (Schweirer et al. 2015). Therefore, ponds act as transmitters of waterborne disease and diarrhea (Islam et al. 2000). Diarrhea is a leading cause of child mortality in India. The weakened development across the Indian Sundarbans delta points to ponds is a significant human health concern.

1.3.4 Uncertain or Irregular Rainfall Pattern

Due to the changing monsoon rainfall dynamics in tropical deltas, drought has become a typical occurrence (Kale 2017). Indian Sundarbans exclusively rely on monsoon rainfall to sustain water levels of ponds as well as groundwater. Due to low precipitation in deltas, groundwater is abstracted for irrigation and to fill up ponds (Kale 2017). Abstraction of groundwater and resulting in the lower label of the water table allows saltwater inundation.