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## Ecosystem Services, Well-Being and Deltas: Current Knowledge and Understanding

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### 1.1 Introduction

Deltas are often attractive places to live and work, with more than 500 million people living in these environments worldwide (Ericson et al. 2006). Many large deltas have high population densities in productive rural areas as well as significant coastal cities. Such density of use and population is a legacy of their highly fertile soils, productive aquatic and coastal ecosystems, diverse landscapes and ease of navigation. In short, delta environments provide for and enhance the well-being of their human populations.

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In the past decade, the description of such positive relations has been increasingly expressed in terms of ecosystem services: the benefits to society from nature. At the most fundamental level, the survival and flourishing of human populations in deltas are, of course, entirely dependent on biotic and abiotic earth systems and how these systems interact with social-economic and governance structures.

In this introductory chapter, we describe the state of knowledge in the emerging interdisciplinary science of ecosystem services and how that science is applied to delta environments in order to highlight key research questions and issues that are explored in this book. We review the science of ecosystem services and describe relevant processes in deltas. We then examine the nature of well-being derived from these services and the mechanisms in delta environments that constrain and modify the distribution of those benefits, before outlining the contribution of the new underpinning research on the Ganges-Brahmaputra-Meghna (GBM) delta to this area of knowledge.

## 1.2 Ecosystem Services: Current Understanding

It is well established that ecosystem services support human well-being. The study of ecosystem services is a distinct field at the interface of natural and social sciences. It initially emerged at the boundaries of ecology, conservation biology and ecological economics, and highlighted the

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benefits to humans of ecosystem processes. The Millennium Ecosystem Assessment (MEA 2005) popularised the term and drew on findings across hydrology, systems modelling, development economics, resilience theory and others to advance the concept and its applications. Much of the effort in ecosystem services has been in delineating and classifying ecosystem service types and processes, and in mapping and measuring ecosystem services and their benefits (Nicholls et al. 2016; Naidoo et al. 2008). In addition, the Millennium Ecosystem Assessment sought to characterise long-term future trends and sustainability through global and sub-global scenarios.

The principal tenets of ecosystem service science are firstly that the observed decline in ecosystem services at all scales is widely caused by human action. The drivers of decline include the scale of economic activity, not least in extraction of renewable resources such as forests and fisheries, unsustainable pollution loading and the trade-off between the selective enhancements of some ecosystem services at the detriment of others (MEA 2005; Bennett et al. 2009).

In the field of ecological economics, initial aggregation of the benefits of nature sought to make them commensurable, and to compare aggregate ecosystem service benefits to the scale of economic activity. Costanza et al. (1997) strongly argued that ecosystems provide unaccounted-for benefits to society that are of greater magnitude than the whole of the global economy by standard economic metrics. Assessments of interventions to preserve natural areas or conserve specific ecosystem functions show that such actions generate benefits that are often orders of magnitude greater than their costs (Balmford et al. 2002).

Yet many elements of the relationship between ecosystems and the environment remain poorly established, not least in coastal and marine environments, such as deltas. What constitutes an ecosystem service, for example, comes into sharp relief in delta environments. In practice, classification systems for ecosystem services are based on both the characteristics of the ecosystem of interest and the decision-making context. Ecosystems provide direct provisioning for humans, through processes of cultivation or extraction of food and fibre. Ecosystems regulate the environment through absorbing and processing pollutants or acting as shelter, barrier or other elements of human habitat. Ecosystems also have

meaning beyond these direct benefits that mean their loss is keenly felt and ecosystems are highly valued. Hence there is a common distinction, used throughout this book, between provisioning, regulating and cultural ecosystem services.

There is also a distinction between ecosystem processes or functions on the one hand and the specific services that they provide on the other. Ecosystem services in aggregate are the benefits that humans derive from ecosystems, which means that they can either be defined as the end point (e.g. food production), rather than the intermediate process (agriculture), or they can be defined to include processes from which humans benefit indirectly (e.g. purification of water). Ecosystem processes can also be detrimental to well-being: the so-called dis-services such as agricultural diseases and pests (Zhang et al. 2007).

Fisher et al. (2009) suggest that ecosystem services are the aspects of ecosystems used actively or passively to generate human well-being and do not necessarily relate to specific ecosystem functions. For example, the benefits of ecosystem services in helping people to feel attached to their places of residence and work are highly contextualised and spatially variable, relating more to ideas of landscape. Indeed these benefits of nature to well-being may not necessarily relate to specific functions of the ecosystems. There is, therefore, a complex set of relationships between intermediate services, final services and benefits flowing from all ecosystems, including delta ecosystems. This uncertainty is reflected in the diversity of classification systems for ecosystem services.

Despite impressive estimates of the economic value of ecosystem services to society, net ecosystem services are in decline. When Costanza et al. (2014) re-estimated the economic value of nature, they showed a reduction of land-related ecosystem services of up to \$20 trillion (US\$ 2007 values) in the decade since 2005. Such declines reflect increased levels of pollution, human efforts to enhance specific services (e.g. agriculture) often at the expense of others, habitat loss, species decline, and loss of underlying environmental processes (Bennett et al. 2009). The decline in ecosystem services is charted in ecological as well as monetary metrics. The large-scale global assessment of ecosystem status under the Millennium Ecosystem Assessment in 2005 similarly documented the decline in ecological functions and benefits provided to humans, including

in coastal areas (Agardy et al. 2005). Common delta habitats such as coastal marshes and mangroves are globally in decline with at least 11 mangrove species threatened with extinction (Polidoro et al. 2010), while the seagrass habitat has declined by approximately 30 per cent in the past century (Waycott et al. 2009). Many deltas are also losing relative elevation due to strong subsidence and a lack of sedimentation, reflecting the presence of polders and increasingly engineered landscapes (Syvitski et al. 2009).

A second area of research highlights the trade-offs between elements of ecosystem services and other societal goals. This area is more contested. It is clear that many regions of the world have increased their standard of living and well-being through exploitation of natural capital, turning this into other forms of built and human capital. Exploitation of forest and resources, for example, generated significant growth in countries such as Indonesia, but at the cost of declining natural capital stocks (Neumayer 2003). It is noted that economies sustain themselves and aggregate income and well-being have not collapsed in places where ecosystem services are in decline. Raudsepp-Hearne et al. (2010) explain this so-called environmentalist paradox in two potential ways. First, economies may not yet have reached key tipping points and the continued loss of ecosystem services may yet crash ecosystems, especially those that provide food and fibre, with catastrophic consequences, a contention supported by the concept of safe operating spaces (Rockström et al. 2009). Second, the paradox may be explained by the fact that standard measures do not account for the real, but hidden, costs of ecosystem degradation.

Other evidence highlights the positive benefits of conserving ecosystem services, but identifies the trade-offs involved in this process. Hence there is a continuing uncertainty on whether natural resources can be managed to optimise well-being, conservation of services and development processes (Barrett and Constanas 2014). If there are trade-offs, then these may involve temporal questions: the short-term enhancement of human welfare compared to longer-term sustainability. And there are other issues such as distributional effects and the trade-offs between different users (Daw et al. 2011).

The ecosystem service approach also makes a strong argument that mapping and measuring ecosystem services and, in particular, the creation

of economic incentives or markets for services, leads to greater recognition and balance in the optimisation processes (Daily et al. 2000). Efforts to incorporate ecosystem services into planning for conservation have been advocated and appraised as having enabled new insights and greater realisation of sustainability. For example, Arkema et al. (2015) facilitated new coastal planning that brought multiple benefits from coastal ecosystem services into a structured plan for coastal protection in Belize.

The monetisation of ecosystem services enables market solutions to their conservation, but there is less certainty about the benefits of such interventions. There are, for example, multiple examples of markets and interventions designed to promote conservation of ecosystem services, ranging from the carbon sequestration services of terrestrial ecosystems such as forests and wetlands, through to regulating services for clean water. While these have often been deemed to promote maintenance of specific ecosystem services, the distribution of the benefits and hence the legitimacy of the market mechanism are often in doubt (Pascual et al. 2014).

### 1.3 Ecosystems and Well-Being: The Current Debate

It is well established that ecosystem services provide benefits to society in terms of well-being, but less clear how those benefits are distributed in society. A key issue, not least in delta settings, is whether ecosystem services have greater importance for populations with low levels of well-being, and whether ecosystem services and their provision can represent a pathway out of poverty. The Millennium Ecosystem Assessment proposed that ecosystems bring benefits through maintaining and enhancing the health of people, through life-sustaining goods and services, and through options for use that represent opportunities for development in material and non-material ways. Beyond direct economic use of ecosystem services, benefits include impacts on health through pathways such as nutrition, clean air and clean water, but also psychological well-being. Further elements of well-being can include positive associations with place and identity in constructing meaning and purpose in life and how ecosystems ameliorate risk, providing a safety net and refuge.

The absence of well-being is most often regarded as poverty. Given that multiple dimensions of well-being are derived from nature, the absence of ecosystem services is likely to be manifest in multiple dimensions of deprivation and poverty. Hence poverty is the absence of material well-being for basic needs (food, water and shelter), along with the absence of positive health and nutrition, and an inability to participate fully in society. In essence, there are alternative ways of conceptualising poverty that focus not only on the command over commodities and income but also more broadly the capability to live a dignified life, which incorporates both the material dimensions and relational dimensions of an individual's place in society (Alkire 2007).

Many elements of poverty can be assessed and measured through objective indicators associated with income, expenditure, assets, educational attainment and objective health outcomes (Bourguignon and Chakravarty 2003). Yet the perceptions of exclusion and subjective elements of well-being are often hidden and are only revealed through social science approaches and methods, including direct measurement through social survey and participatory appraisals. Indeed, many elements of social well-being relate to the ability of individuals to perform their social roles and to participate meaningfully in society (Diener et al. 1985; Larson 1993).

How do ecosystem services relate to the distribution of well-being and poverty? At the most basic level, ecosystem services can provide well-being that lifts individuals above a poverty threshold or maintains levels of well-being above such thresholds. In other words, ecosystem services can serve to alleviate poverty in the short term and prevent poverty in the longer term (Daw et al. 2011). This distinction is important, as poverty is persistent and the ways to alleviate it are not clear. Direct benefits from ecosystems, including provisioning ecosystem services, have been argued to be more important for poverty prevention than for alleviation (Fisher et al. 2014). Thus direct consumption of food, materials for shelter and disaster mitigation have been shown to be critical as strategies for populations seeking to avoid poverty in various contexts (Daw et al. 2011), but not necessarily in improving welfare.

There are diverse interventions to try to alleviate poverty and then help people accumulate skills, capital and assets necessary to maintain raised

well-being, preventing a return to poverty over time (e.g. Banerjee et al. 2015). Many provisioning services provide resources that are traded rather than consumed. Ecosystem services that provide a source of cash income can be significant in the alleviation of poverty but could potentially involve short-term sacrifice of ecosystem quality for long-term sustainability. For example, populations can raise their income levels by over-exploiting fisheries in the short term before switching to other forms of higher income employment. However, with time, this raises the potential of driving an ecosystem service system over a threshold from which an irreversible decline in service is inevitable (Hossain et al. 2017).

Poorer sections of populations are more directly dependent on ecosystem services than the general population in virtually all environments. This includes delta regions where there is high dependence on agriculture and fisheries, and undiversified rural economies mean that income and subsistence are often insecure and variable. Provisioning ecosystem services from collectively owned or open access resources such as mangrove forest areas and fisheries represent a disproportionate share of income for poorer populations (Dasgupta et al. 2016). The implications of this high dependence on ecosystem services are magnified by long- and short-term threats to the environment.

Hence if ecosystem services are threatened by long-term environmental change, then poor populations are likely to suffer disproportionately. This is a strong conclusion from global studies of disasters by the World Bank (Hallegatte et al. 2017) and those focused on coastal environments. Barbier (2015), for example, shows that 90 per cent of the poor populations in coastal zones globally reside in 15 countries (with Bangladesh being number two in the rankings) and that these countries are susceptible to significant climate and sea-level rise impacts that threaten the livelihood of those poor populations. Whilst it is clear that ecosystem services play a central role in the dynamic processes of welfare within rural poor of coastal zones, anthropogenic impacts of policy and interventions such as infrastructure development and market access can be a significant or even dominant role. For example, Amoako Johnson et al. (2016) identify a lack of road networks as a primary association with asset-based poverty west of the Lower Meghna River in coastal Bangladesh. Of course, the access that such a network provides can be



thought of as facilitating the utilisation of ecosystem services and as such the two are not unrelated.

In summary, ecosystems play roles in poverty and well-being through direct provision of goods and services, by acting as a safety net for the poor, and potentially as a route out of poverty, sometimes in a non-sustainable manner. In the simplest sense, ecosystem services are effective at preventing downward movement into greater poverty, but less effective at actively elevating people out of poverty. All of the ways ecosystem services affect well-being are mediated by issues of access and control. Analysis in this book therefore considers the distribution of the benefits from these delta ecosystems accessed by different sets of people and the integrity and future of the functioning and management of ecosystems themselves. Key questions include identifying how the presence of so-called provisioning and regulating ecosystem services make a particular difference for different sections of delta populations.

## 1.4 Ecosystem Processes and Services in Deltas

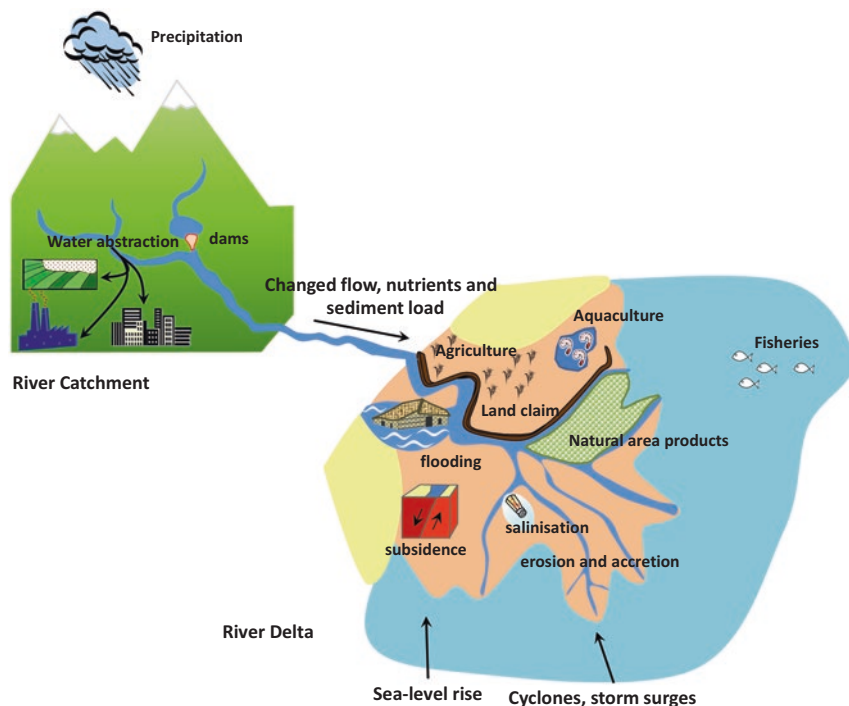
The Millennium Ecosystem Assessment showed in detail how many ecosystem services across the world are under stress and in decline. These trends are apparent in delta regions under stress (Nicholls et al. 2016). In the GBM delta, for example, there are high levels of soil and water salinity (Amoako Johnson et al. 2016). Globally, mangrove areas have been in significant decline, and natural habitats for aquatic species have shown stress due to over-exploitation and pollution (Polidoro et al. 2010).

Deltas are distinct in terms of the concentration of freshwater, nutrients and especially sediment inputs to a small concentrated area of the coastal zone, creating conditions ideal for fertile ecosystems, dense population and high economic activity (Bianchi 2016). Associated ecosystem services are high in number and include benefits such as productive agriculture and aquaculture, water provision and physical protection from the periodic impacts of extreme events such as coastal storms and cyclones. Ecosystem services can act as a safety net for poor populations. Akter and Mallick (2013) show in the GBM region that those populations

with access to Sundarbans forest resources were more resilient following Cyclone Aila in 2009.

Importantly, virtually all services are directly affected by water and its flow through delta systems (Costanza et al. 1995), and there are multiple stresses which can significantly change their natural dynamics.

The processes supporting ecosystem services in deltas have developed over thousands of years (Woodroffe et al. 2006; Syvitski 2008; Wilson and Goodbred 2015), and historical development provides an important context to their present and future status. The nature of the link between the delta and its river catchment (Fig. 1.1) means processes occurring in one place within the deltaic system can lead to benefits or losses elsewhere. In particular, many human processes, such as river catchment management and land claim, modify water flows and the natural sedimentary



**Fig. 1.1** Interventions and processes related to ecosystem service provision in delta environments

processes that maintain deltas (Syvitski et al. 2009; Day et al. 2016). This, combined with climate-driven processes such as precipitation, sea-level rise and storm intensity and frequency, means that delta areas are subject to changes such as periodic and permanent submergence (Ericson et al. 2006), erosion and accretion and salinisation.

More specifically, Fig. 1.2 outlines the principal ecological and physical processes of delta systems, which include both the ecosystems themselves and abiotic processes such as sediment transport that are definitive of delta environments.

The ecosystem service consequences of these process changes have been less considered and this is one of the key topics considered in this book. Erosion and submergence processes bring negative consequences to economic activity and health in terms of human well-being. Increases in water salinity are also important and have significant negative consequences for agricultural productivity and health. For all deltas, ecosystem services are highly diverse in terms of temporal and seasonal variation.

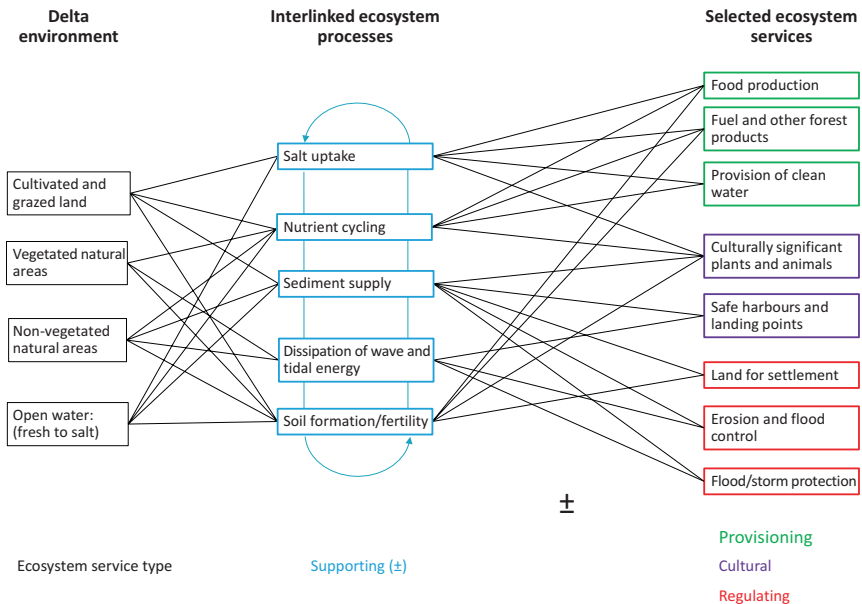


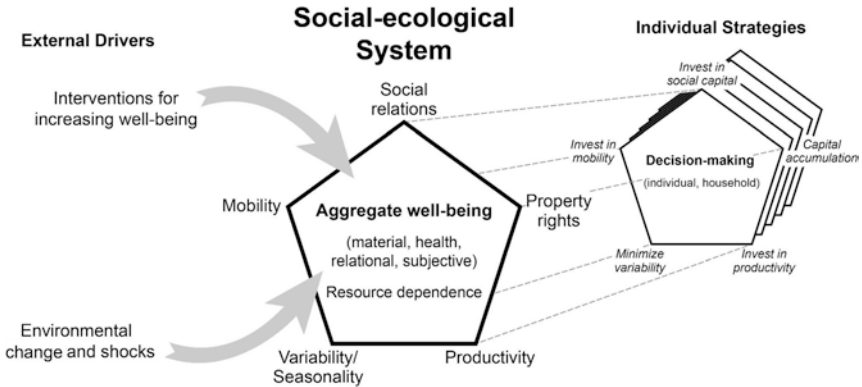
Fig. 1.2 Principal ecosystem processes and services in delta environments

The diversity and mobility of such services have significant implications for the distribution of well-being and poverty and how best to intervene to prevent or alleviate poverty and other social goals.

## **1.5 Social Drivers, Constraints and Dynamics in the Realisation of Well-Being from Ecosystem Services**

Ecosystem service science is critical for the effective management of delta environments. Any decline in ecosystem services is likely to adversely impact the well-being of poor populations; this raises fundamental issues of development priorities as discussed in Chap. 2. A range of social processes attenuate or reinforce the benefits from ecosystem services. Secure and broad rights to ecosystem services, for example, have been shown to buffer against seasonal fluctuations and income shocks. Social relations, through a moral economy of hierarchical structures, reciprocity and compliance with informal rules, allow those without formal property rights to ecosystem services to gain access. However, in coastal Bangladesh informal access has not been upheld when it comes to commercial development of land; many people have lost informal access to water and land through enclosures for the development of brackish shrimp aquaculture. Credit is an essential means of obtaining the capital required to access ecosystem benefits, but often comes with exploitative conditions. Migration is used as a livelihood risk-spreading strategy to access alternative labour markets during seasonal fluctuations, as a short-term coping mechanism against shocks and to overcome chronic livelihood insecurity, but is again subject to exploitative practices of labour. Thus any attempt to consider improving the benefits associated with ecosystem services needs to consider the rights associated with the services and the system that support the engagement of the poor with those services (e.g. credit) and the degree to which they can be protected.

The processes that mediate between aggregate well-being and ecosystem are outlined in Fig. 1.3. It represents the interactions between elements of well-being, resource productivity and the social and economic structures that constrain livelihoods, highlighting that all these elements



**Fig. 1.3** Social-ecological systems and decision-making over ecosystem services

are dynamic and interrelated. The pentagon in Fig. 1.3 represents the processes that link ecosystem services to well-being through five components: the productivity of ecosystems, property rights, access and social relations, seasonality and climate variability and mobility.

The issues of property rights to ecosystem services and the ability of groups to maintain them, their appropriate assignment and their distribution are fundamental aspects of the role of ecosystem services in the provision of well-being because secure and broad access to ecosystem services provides security and allows consumption to be predictable. Property rights have implications for the sustainability of ecosystem service use: the way that decisions are made on resources has a large impact on who is able to benefit from them, how much and for how long. The relative merits of different property rights, ranging from private, to state-controlled, to open access resources have been studied extensively, showing that sustainability requires equitable and transparent systems of control and compliance (Dietz et al. 2003). Adhikari et al. (2004), for example, demonstrate how wealth, landholding and social status determine unequal patterns of access to commonly held forest resources. The way that natural resources are managed influences the ability of people to access the benefits they provide, as well as affecting the sustainability of that resource. These issues of access capabilities and an ability to function in society are central to defining poverty (Leach et al. 1999).

Social relations structure economic relations and create what Scott (1977) refers to as a moral economy of hierarchical structures, reciprocity and compliance with informal rules. Thus potential benefits from ecosystem services accrue to local power holders. Institutional arrangements such as debts and loans and sharecropping, gained through and creating exploitative social relations, are the most common way of smoothing these fluctuations. However, other patron-client relations include reducing rents during poor harvests, paying for education and other social payments. These arrangements have been shown to further the interests of patrons as they ensure the continuation of the community as a whole and ensure support that maintains privileged positions in society (Wood 2003). For those with limited rights, social mechanisms such as patron, patron-client and other reciprocity provide access to ecosystem services. However, many of these social mechanisms are a major constraint on capital accumulation and hence constitute poverty traps.

However, the Millennium Ecosystem Assessment (2005) systematically demonstrated that the *productivity* of ecosystem services is central to continued well-being and that degradation of such services has direct knock-on effects to sustaining material, relational and cultural dimensions. The productivity of all agricultural systems, for example, are directly determined by the interaction of ecosystem functions, and the process of agriculture is, in effect, the management of those functions, in optimising outputs for food, fibre and sustainable landscapes (Zhang et al. 2007). Thus while social processes affect the ability of the poor to access benefits of ecosystem services, levels of well-being are also contingent on the initial productivity of the system. The provision of different ecosystem services is directly connected by the underlying ecological functions.

Seasonality and inter-annual variability in ecosystem services have a significant impact on the transitory or chronic nature of poverty. There is a large body of evidence that shows that the phenomenon of seasonal poverty is widespread in agrarian economies, driven by weather and crop failure and by knock-on effects on seasonal demand for labour. The phenomenon of seasonal poverty is masked by annual average measures of consumption (Dercon and Krishnan 2000) and implies large numbers of households are vulnerable to seasonal poverty and drops in consumption across agricultural-based economies (McKay and Lawson 2003). In Ethiopia, for example,

Dercon and Krishnan (2000) showed high variability in poverty from surveying 1,400 households over two years, both reflected in income and consumption, through direct effects of seasons and weather and in indirect effect in prices and labour demand.

The relationship between migration and ecosystem services is complex. Migration can act as a route out of poverty, but has a diversity of impacts and feedbacks on ecosystem services (Black et al. 2011). Migration can cause degradation of ecosystem services through migration to forest and other frontiers, particularly when migrants are unfamiliar with new agro-ecosystems and risks (Winkels 2008). Migration can also cause the degradation of ecosystem services through the investment of remittances in capital-intensive enterprises such as shrimp farming or cash crops (Adger et al. 2002; Naylor et al. 2002). At the same time, shocks to ecosystem services directly affect migration, with evidence from Bangladesh, for example, showing that crop failures induce additional temporary migration, but there are 'significant barriers to migration for vulnerable households' (Gray and Mueller 2012 p. 6000). Mobility is central to much ecosystem service use, not least because people migrate to pursue ecosystem services, for example, by accessing alternative labour markets in different regions where crops are harvested at different times. Ecosystem services associated with fisheries are themselves mobile, and so individuals may choose to migrate to follow that resource (Kramer et al. 2002). Mobility can also reduce the ability of institutions to manage ecosystem services as common pool resources, as people from outside the local area may extract ecosystem services without respecting, or being aware of, local arrangements for their sustainable management.

These five factors variously act as social and environmental constraints on well-being at the system level. They are the arenas by which individuals and households seek to overcome constraints to their well-being, by investing in social relations through social capital, productivity including human capital through education, mobility or reducing variability through smoothing consumption and production processes (right panel of Fig. 1.3).

Hence there are a set of complex relationships between ecosystem services and livelihood and development processes. In Fig. 1.3, well-being is highlighted as having material, relational and subjective

dimensions relating to agency and quality of life (Gough et al. 2007). Thus poverty, as a lack of well-being, has those multiple dimensions, including outcomes such as ill health, perceived insecurity and social marginalisation and exclusion, as well as direct lack of material well-being and deprivation. Specific research has focused on determining where and when the contribution of ecosystem services is important for those with low levels of well-being, particularly in resource-dependent societies and populations in poverty. This is the point from which the research activities and their outputs, described in this book, makes a distinct contribution.

## 1.6 Contributions of this Book

The book builds on current knowledge of ecosystem services, well-being and environments in an integrated and policy-relevant analysis of the processes and potential futures of societies living in deltas. It does so by focusing on the GBM delta. This is the world's most populous delta, with a critical role in the lives of a significant proportion of the population of Bangladesh and West Bengal (India). In particular, it focuses on a study site in coastal Bangladesh as explained in more detail in Chap. 4. While the analysis is particular to that study site and the wider delta, the generic lessons for the future of deltas and coastal environments are considered. The integrative analysis is structured into seven parts and comprises 29 chapters. Part 1 comprises Chaps. 1, 2, 3 and 4 and summarises the major conclusions of the work, including the fundamental relationship between ecosystem services and human well-being, and the links to policy processes and development. Chapter 4 also provides an overview of the methods and approach of the study, including consideration of the research questions. Part 2 comprises Chaps. 5, 6, 7 and 8 and introduces the study area and some of its key characteristics. Part 3 comprises Chaps. 9, 10, 11 and 12 and develops a set of biophysical and social-economic scenarios that facilitates policy-relevant analysis of the future of the study area. Part 4 comprises Chaps. 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 and 23 and analyses a wide range of elements of the delta social-ecological systems



using observations and models from the scale of the catchments and Bay of Bengal down to micro-level processes. Part 5 comprises Chaps. 24, 25, 26 and 27 and considers the implications of these changes for specific ecosystem services such as the Sundarbans mangroves and capture fisheries. Part 6 considers the integration of the preceding material into a policy-relevant integrated framework of analysis culminating in an integrated systems model for the delta. This allows an analysis of the biophysical and social future of the study area to inform policy. Part 6 also considers the science policy interface of the emerging knowledge and how it is used by stakeholders and wider society.

The core objective of the research is to integrate knowledge and to generate specific ideas for managing resources and implementing policy and practice in deltas. Figure 1.4 shows how these elements contribute to the overall vision. The chapters build on process and empirical insights into biophysical systems and ecosystem services, along with social and economic systems around health, economic activity and demographic change. They do so in order to generate policy insights, with chapters on elements of current governance and potential futures, directly engaging with the perceptions of key stakeholders.

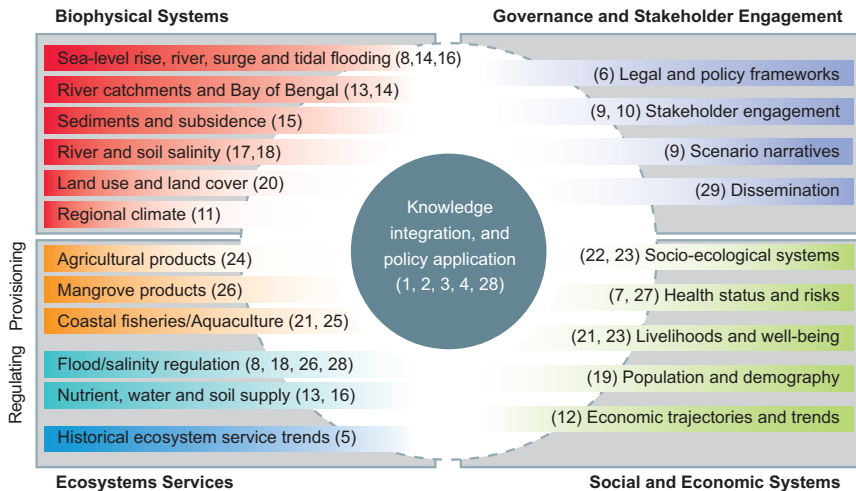


Fig. 1.4 Guide to the individual and integrated research discussed in this book

## 1.7 Conclusion

This book builds on insights from a multidisciplinary perspective on ecosystem services and their importance to human well-being and applies these ideas in deltas in an integrated manner to inform decision-making for poverty alleviation. There is, of course, a wide variety of approaches and unresolved questions and relationships between elements of well-being and the underlying ecosystem processes (Norgaard 2010; Pascual et al. 2017; Suich et al. 2015). But at their core, the key scientific issues relate to how ecosystems bring multiple benefits to society, both in material terms and through other pathways. The benefits from ecosystem services include those associated with direct economic use, with protecting health and mitigation of hazards.

The book explores the issues outlined in this chapter in detail for delta environments in order to give context to the broad assessment of the sustainability of a range of possible future trajectories within deltas, focusing on both the biophysical processes of their productivity and the prospects for securing ecosystem services for poverty alleviation objectives. The following chapters also, for the first time, explore in a systematic manner how social processes such as migration, access and property rights, and social relations interact with ecosystem services to result in the distribution of well-being in deltas. The book highlights the leverage points for action on these mechanisms that have been uncovered through integrated modelling and an increased understanding of delta social-ecological systems. Integration across diverse knowledge domains and model simulation is a key and novel aspect of the research, and as such the findings in this book, linking biophysical changes to human well-being within a coupled model framework. This allows the exploration of possible futures in a participatory and policy-relevant manner that can engage with national stakeholders.

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