

CPWF Project Report

Valuing the role of living aquatic resources to rural livelihoods in multiple-use, seasonally-inundated wetlands in the Yellow River Basin of China, for improved governance

Project Number 69

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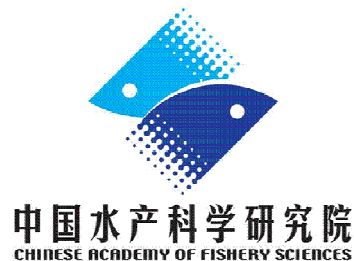
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Program Preface:

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase the resilience of social and ecological systems through better water management for food production. Through its broad partnerships, it conducts research that leads to impact on the poor and to policy change.

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Project Preface:

Supported by the CPWF, this two-year project titled “Valuing the role of living aquatic resources to rural livelihoods in multiple-use, seasonally-inundated wetlands in the Yellow River Basin of China, for improved governance” focused on linking the use of wetlands resources by local communities and value of wetlands ecosystem services with management implications for the riverine and coastal wetlands in Henan and Shandong provinces. A study on this Chinese situation of pursuing a rapid development agenda while recognizing the need to conserve critical wetland areas would provide insights on the issues and possible avenues for sustainable wetlands management that may be relevant to other developing countries.

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PROJECT HIGHLIGHTS

The wetlands of the Yellow River basin, both coastal and inland, are under pressure from rapid economic development. Their formation and stability are influenced by the flow of the Yellow River and the sediment it deposits. Their state of health depends on sufficient water and nourishment from the river, which supplies water for agricultural, industrial and domestic use for the nine provinces that it flows through. Modern industrial and agricultural development places additional pressure on water demand and increases water pollution. Despite these emerging problems, the Chinese government had the foresight to designate large areas in the Yellow River delta and upstream stretches as nature reserves for conservation of migratory aquatic birds that stop over or winter over in these wetlands. The youngest expanse of accreting wetlands at the present estuary is also protected. However the birds and other denizens of the natural wetlands have to share the wetland resources with people who have been using these resources since early times to settle, collect and grow food. The main challenge in managing these wetlands is to permit their use without impairing the ecosystem functions of the natural ecosystem within the mosaic of land use in the Yellow River basin. Opportunities to improve wetlands management hinge upon recognizing their broader ecosystem services and how their value can be enhanced.

The Challenge Program for Water and Food supported a two-year study to address these issues. The study focused on the freshwater riverine wetlands of the main-stream Sanmenxia reservoir in Henan province and the deltaic wetlands of Dongying municipality in Shandong province. In Sanmenxia, the study's findings highlighted the livelihood dependence of riverine communities on the wetland resources primarily for crop cultivation with aquaculture, fishing and nature recreation as secondary activities. In Dongying, the study used multi-criteria evaluation and mapping tools to demonstrate to participating stakeholders that if broader ecosystem services of the wetlands were considered, the natural wetlands perform as well if not better than areas already modified and converted for various economic activities including agriculture, aquaculture and salt production. This dispels the prevailing notion that wetlands have little or no value and that the benefits of converting them to more 'productive' uses outweigh those derived from the maintenance of wetlands in their functional state.

The study made specific recommendations to local authorities on strategies for increasing the chances of sustaining the wetlands while improving the general environment in line with visions of balanced development such as that expressed by the Dongying municipal government. In nature reserve areas already subjected to economic activities, delineation of functional zones with clear guidelines on use and clearly-designated institutional responsibility is a more pragmatic alternative to the strict stipulations of exclusion that exist on paper for nature reserves but are impossible to abide with in practice. Management of these areas, particularly in the Sanmenxia nature reserve, should incorporate the livelihood context of communities located close to the Yellow River. The pristine protected wetlands in the Yellow River estuary offer opportunities for detailed scientific studies to provide evidence of the values that their ecosystem services offer beyond direct economic benefits. Of particular interest is the role of wetlands as carbon sinks, which is gaining prominence in light of global warming. Evidence of this role will back the claim that temperate estuarine wetlands should be eligible for credits under Reducing Emissions from Deforestation and Forest Degradation (REDD) schemes, thereby financially rewarding the conservation of these carbon-sequestering wetlands. Scientific evidence generated locally will also strengthen the case for ensuring that the freshwater flow from the Yellow River is

adequate to continue nourishing these wetlands despite competing demands on the river's water resources from upstream users.

EXECUTIVE SUMMARY

The issue

The wetlands of the Yellow River basin in China have been subjected to changes due to the highly-modified hydrology of the Yellow River to control floods and allocate water to meet upstream demands of the nine provinces that it flows through. These changes have impact upon the patterns of formation and transformation of the delta wetlands, and also their ecosystem functioning and health. Direct conversion of wetlands to other uses, including agriculture, urban and industrial uses have reduced the area of natural wetlands, while the remaining natural areas are under threat of habitat fragmentation and pollution. The prevailing view among decision makers is that wetlands have little or no value and that the benefits of converting them to more 'productive' uses outweigh those derived from the maintenance of wetlands in their functional state. This view stems from inadequate or lack of appreciation of the broader ecosystem services that wetlands provide, and hence they are under-valued. There is an urgency to bring to the attention of agencies making policy decisions and managing the use of natural resources for economic development - the target group of the project - the importance of wetlands beyond their direct contribution to the money economy.

Study objectives

The main purpose of the research project was to provide evidence and raise awareness of communities' livelihood dependence on wetland resources, highlight trade-offs in terms of how wetlands ecosystem services are compromised under current use and management regimes, and the additional benefits of raising the profile and value of the wetlands. The research was conducted for two wetland systems within the Yellow River basin – the freshwater riparian wetlands in Sanmenxia municipality of Henan province, and the brackish-water coastal and estuarine wetlands in the Yellow River delta in Dongying municipality of Shandong province. Stakeholders at the two study sites identified different management issues that called for different study objectives. The main objective of the Sanmenxia study was to document and understand the dependence and perception of riverine communities on wetland resources, and to draw implications on the wetlands of the Sanmenxia reservoir that have been designated as nature reserve. The main objective of the Dongying study was to assess how the ecosystem services of the coastal wetlands have been affected due to modification and conversion of wetlands for various economic activities, in order to identify strategies for reducing development impacts and enhancing use value of the wetlands.

The Sanmenxia study

The Sanmenxia study focused on the stretch of the Yellow River upstream of the Sanmenxia dam that is now a main-stream reservoir with natural and manmade wetland features including seasonally-flooded mudflats, water reservoirs, aquaculture pond and an off-river marshy expanse of Dinghuwan lake. The entire stretch of Sanmenxia reservoir was legally designated as a nature reserve in 2005 primarily for the conservation of aquatic birds. The area is visited annually by tens of thousands of white swans from Siberia that winter over. Historically the area of the nature reserve has been used by riverine communities for growing crops, fishing and collection of other aquatic products such as reeds. We adopted an integrated approach that used a combination of geographical information systems (GIS) mapping, field survey and participatory tools to document the land resources, survey and analyze livelihood dependence and perceptions that the communities within the nature reserve have on the importance of the wetland resources.

While national regulations stipulated for nature reserves prohibit human activities in the legally-delineated core zone, and limited activities compatible with scientific research, public education and nature tourism in the buffer and experimental areas, in reality use of the land and resources within these zones by riverine communities predate the nature reserve and continue to the present day. This study revealed the varying extents that riverine communities derive livelihood benefits from the land and water resources within the boundaries of the nature reserve. The dominant economic activity is crop cultivation on former wetlands that are now permanently exposed when the maintenance water level of the reservoir was lowered since 2000, and the present seasonally-flooded mudflats that appear when water is released every summer from the Sanmenxia dam, in tandem with two other dams along the Yellow River, to flush the accumulated sediment from the reservoirs. Other secondary and minor activities include pond aquaculture, fishing mainly for subsistence, and riverside tourism and recreation business. Dependency on the wetland resources is higher for villages that have more cultivable land and reduces when villagers have access to off-farm employment particularly in villages close to and have better access to urban areas. Villagers farming on former and present wetlands placed greater importance on the economic uses of wetland resources, particularly for crop cultivation, while those who don't expressed preference for conservation. They associated water quality regulation with the conservation aspect of the wetlands ecosystem services and rated it highly. This reflects the widespread concern over water pollution, which was cited as a major impact of the past 30 years felt by the villagers, second only to the loss of mudflats due to the shifting river course.

There are multiple jurisdictions of line agencies in terms of land and water administration and managing the various sectors - agriculture, aquaculture, fishing, forestry, water extraction and water quality monitoring. Representatives of the key agencies recognize the need for better coordination in carrying out their management functions. Based on the findings of this study, recommendations were made that could contribute towards improving this coordination. First, it is important that the various agencies arrive at a common understanding of what the nature reserve is for. Accepting the reality that multiple economic uses are allowed to be carried out within the nature reserve, and recognizing that the strict definitions of core, buffer and experimental zones are meaningless in this context, it would be more expedient to define functional zones for specific use and management purposes. Rules and guidelines need to be clearly developed for the functional zones, and overall management responsibility relegated to the most relevant agency. Examples of the kinds of functional zones, their uses and the responsible agencies were offered.

The integrated approach adopted for the study has permitted a more holistic assessment of the Sanmenxia Nature Reserve, its resources and management and contributed to a greater understanding of the livelihood context of communities located close to the Yellow River. This livelihood dependence caught the attention of the local authorities. It is critical that any management decisions should consider these dependent communities and ensure that they can still benefit from the resources within the nature reserve.

The Dongying study

The Dongying study focused on the eastern part of the municipality encompassing four townships and includes the present estuary of the Yellow River where 37,000 ha of the youngest and pristine wetlands formed by the accreting delta forms the core zone of the Yellow River Delta Nature Reserve. In the other 5,000 ha of buffer and 49,000 ha of experimental zones within the nature reserve boundaries

in the study area, there are already human activities - mainly agriculture and oil exploration – and modifications to the natural habitats. Outside of the nature reserve area, the coastal wetlands have been subjected to various forms of uses, principally agriculture, aquaculture (brackish-water along the coast, freshwater inland), petroleum extraction, salt production and other industrial and urban uses. Dongying sits on the second richest oil field in China, and the petroleum industry fuels a rapid pace of economic development, industrialization and modernization in Dongying municipality. A protective sea dyke along the eastern shoreline that prevents natural tidal ingress and artificial drainage of the land targeted for future development renders the remaining patches of reed meadows a fate of gradual ecological decline. The study area is therefore a mosaic of wetlands in the natural condition (protected within the nature reserve and not outside), manmade wetlands and former wetlands that have been converted for agriculture, urban and industrial uses.

This study adopted an approach that focused on evaluating impacts on the ecosystem services of the delta wetlands and trade-offs in the present uses of these resources based on available evidence locally and in other countries in Europe and the United States of America. The assessment tool used is multi-criteria evaluation conducted within a GIS platform for mapping the impacts. The assessment criteria were four wetlands ecosystem services considered important in the Dongying context - providing direct economic uses including aquatic animal and plant products and land for conducting economic activities, supporting biodiversity through providing habitats for breeding and food web support, water quality regulation through nutrient retention, and mitigating climate change impacts through carbon sequestration. Local experts were consulted to rate, by assigning scores, the extent to which each of these ecosystem services are changed by the different uses of the wetlands in the study area after being presented with available evidence. Using present land use as the map base, the scores were mapped for each ecosystem service. The resulting four maps were combined using weightings that reflect different emphases on the ecosystem services, to produce a map that showed the spatial pattern of the overall score within the study area.

The mapped results show that the direct economic value of the nature reserve area is low compared with other areas where economic activities are carried out. For the other criteria representing ecosystem services associated with indirect use values, the natural wetlands areas rate highly. There are areas outside the nature reserve that were rated as providing reduced support to the ecosystem services associated with wetlands, particularly the manmade wetlands such as aquaculture ponds. There is scope for reducing the impacts and enhancing these ecosystem services if these areas are managed more sensibly.

Based on the findings of the study, two main recommendations were made. The first concerns using the continuum of ecological succession evident in the young and pristine wetlands in the core nature reserve area as an outdoor laboratory for conducting scientific studies for a more thorough quantification of the important wetlands ecosystem services. These include food web support to fish and other aquatic organisms important to the commercial fisheries, and the roles of the wetlands as nutrient and carbon sinks. The role of wetlands as carbon sinks is gaining prominence in light of global warming, with important economic implications. It will back the claim that temperate coastal and estuarine wetlands should be eligible for credits under Reducing Emissions from Deforestation and Forest Degradation (REDD) schemes, thereby financially rewarding the conservation of carbon-sequestering wetlands. Scientific evidence generated locally will also strengthen the case for ensuring that the freshwater flow from the

Yellow River is adequate to continue nourishing these wetlands despite competing demands on the river's water resources from users in nine provinces upstream. Second, opportunities exist for further greening the economy of Dongying, augmenting the city's ecological and economic strengths, and reducing the impact of development on natural wetlands both within and outside of the reserve. These opportunities include practicing low-impact and biodiversity-enhancing agriculture, especially on land within the nature reserve boundaries. It has been observed that recent replacement of maize and other food crops with cotton, which consumes a lot of water and is ecologically more sterile, has reduced bird diversity and numbers in these areas. Low-carbon aquaculture can provide good economic returns with a small carbon footprint. Examples include culturing species that feed low in the food chain (e.g. algae and sea cucumber) and shellfish that sequester carbon for shell formation. Cleaner industries that create less water pollution can reduce threats to the health of the natural wetlands and pond aquaculture. Protecting wetlands does not have to mean depriving people of opportunities for economic benefits. Carefully chosen economic activities can coexist with natural wetland conservation and, further, complement the ecosystem services that the wetlands provide. This can help realize the "highly efficient eco-economy" that Dongying municipality envisions, and for it to be a model for emulation elsewhere in China and around the world.

The approach adopted in this study has been effective in terms of actively engaging local stakeholders in the process of evaluating the impacts of land use on the wetlands ecosystem services. In doing so, it constituted a first step in heightening their awareness about ecosystem functions and services of the wetlands in their vicinity. Without being thoroughly quantitative (given constraints of data availability and time), but by presenting outputs in maps, the study has been able to flag key issues relating to the management of the wetlands and other land uses in the Dongying context effectively to key stakeholders.

Impacts and international public goods

An evaluation exercise conducted with research partners and local stakeholder at project closing revealed that overall, the project has been able to raise their awareness and understanding of the importance of wetlands ecosystem services, heightened their recognition of livelihood linkages with wetlands management, and developed their skills in research planning and to conduct participatory research.

Insights gained from research findings at the Dongying site regarding the challenges of managing wetlands in the face of aggressive economic development can help in anticipating trends and issues that are likely to be encountered in other developing countries. The strategies and avenues identified for Dongying to reduce impacts on and enhance benefits of wetlands ecosystem benefits while greening the economic sectors are applicable to similar situations elsewhere.

At the technical level, the project compiled guides on conducting integrated and participatory field investigations, with Chinese translated versions, that were used for training partners and conducting the field surveys in the Sanmenxia site. For the Dongying study, the project developed research techniques and computer programs to enable real-time GIS mapping of expert inputs that have proven to make elicitation sessions more efficient and meaningful for the participants. These techniques and programs can be readily adapted to other similar research situations.

1. INTRODUCTION

The development problem and reasons for the research

The wetlands of the Yellow River basin in China have been subjected to changes due to the highly-modified hydrology of the Yellow River to control floods and allocate water to meet the upstream demands of the nine provinces that it flows through. These changes have impact on the patterns of formation and transformation of the delta wetlands, and their ecosystem functioning and health. Direct conversion of wetlands to other uses, including agriculture, urban and industrial uses have reduced the area of natural wetlands, while the remaining natural areas are under threat of habitat fragmentation and pollution.

The prevailing view among decision makers is that wetlands have little or no value and that the benefits of converting them to more 'productive' uses outweighs those derived from the maintenance of wetlands in their functional state. This view stems from inadequate or lack of appreciation of the broader ecosystem services that wetlands provide, and hence they are under-valued. There is also a general lack of appreciation that local communities may be dependent on the wetlands, directly and indirectly, for their livelihoods and food security. Often it is the poorer communities and households that are more dependent on the wetland resources, and the informal and non-commercial nature of their livelihood activities renders them invisible and excluded from the mainstream planning and economic development that impinges upon wetlands.

The development context in which the wetlands of the Yellow River basin occur represents an advanced stage along the trajectory that many developing countries in this region are moving towards. Population growth and the quest for land and water resources for rapid economic growth bring development to the doorstep of wetlands and threaten their ecosystem health and survival. Can the wetlands in the Yellow River basin coexist with modern development encroaching upon them? Is there sufficient appreciation that these wetlands are worth caring for and maintaining their health is crucial? There is an urgency to bring the importance of wetlands beyond their direct contribution to the monetary economy to the attention of policy makers and agencies that manage the use of natural resources for economic development - the target group of the project.

The need for a more comprehensive valuation of the ecosystem services of wetlands is being more widely recognized. Methods for conducting such valuation such as total economic valuation tools are still grounded on the basis of placing monetary value on the various ecosystem services. However there are constraints in the use of some of these tools in estimating non-market and non-use values of the broader ecosystem services. For example the use of contingency methods, such as willingness to pay, assumes that respondents are aware and have adequate understanding of the wetlands ecosystem services and their associated use values (apart from the direct use and extraction of products) to the extent that they can place monetary value on various other ecosystem services. In many developing countries there is still lack of scientific studies and quantifiable evidence of important ecosystem support services (such as providing breeding, feeding and refuge areas for commercially-important food fish and other aquatic products) and regulatory services (e.g. water, nutrients and greenhouse gas emission) that can inform scientists, decision makers, stakeholders and the general public. This is indeed the situation in the Yellow River basin.

Therefore an important research imperative was to establish the linkage of wetlands to people's livelihoods and the inherent value of wetlands that cannot be measured against our constructed values. It is also important to articulate the research findings in ways that can effectively convince stakeholders that proper management of wetlands deserves attention in its own right, and matters in the agenda of overall sustainable development.

2. OBJECTIVES

Overall project objective and study sites

The main purpose of the research project was to provide evidence and raise awareness of communities' livelihood dependence on wetland resources, highlight trade-offs in terms of how wetlands ecosystem services are compromised under current use and management regimes, and the additional benefits of raising the profile and value of the wetlands. The research was conducted for two wetland systems within the Yellow River basin – the freshwater riparian wetlands in Henan province and the brackish-water coastal and estuarine wetlands in the Yellow River delta in Shandong province. The two study sites have contrasting characteristics, summarized in Table 1.

Table 1. Comparison of wetlands in Henan and Shandong Provinces.

	Henan Province Sanmenxia prefecture	Shandong Province Dongying prefecture
Nature of wetlands	Linear stretch of freshwater wetlands of the Sanmenxia Reservoir along the main stream of the Yellow River; estimated area of 28,500 ha	The coastal (saline-brackishwater-freshwater) wetlands of the Yellow River delta; estimated area of 260,000 ha.
Existing uses	There has been a long history of use of the wetlands resources by dependent communities. The riverine mudflats used for cultivation are transient and subjected to seasonal fluctuation of the reservoir water level. The entire riverine wetlands have been designated as nature reserve since 2005.	The delta was recently settled, in 1934. A 153,000 ha area of younger wetlands at the present and old estuary was designated as nature reserve in 1992, of which 79,000 are under strict conservation. Outside the nature reserve, wetlands are subjected to changes and conversion for agriculture, aquaculture, industrial and urban use.
Main issues	There are significant livelihood issues related to the use of the wetland resources.	There are issues of impacts of the various economic activities on the environment and the wetland ecosystems.
Management challenges	Managing wetlands within the nature reserve that are already subjected to multiple uses while ensuring that user communities continue to derive livelihood benefits	Reducing development impacts and enhancing use value of the wetlands

The study objective, approach and research methodology adopted were different for the two sites in order to address the different issues and management challenges identified by key stakeholders comprising the main government agencies involved in managing activities related to wetland uses. Hence the next section of this report focuses on each study site in turn.

3. THE SANMENXIA STUDY

The study site covers a 100-km stretch of the Yellow River that is the mainstream Sanmenxia Reservoir upstream of the Sanmenxia dam in Henan province. The dam started functioning in the 1960s as part of the flood control scheme for the Yellow River system – an issue of over-riding concern affecting multiple provinces since the early civilizations of China. The communities living along the river had historically been subjected to its ravages. The flood control scheme now in place along the entire stretch of the Yellow River has effectively contained the scale of flood damage, but at the same time changed the distribution and nature of wetlands to what exists along the banks of the reservoir today.

3.1. Objective and methods

The main objective of the Sanmenxia study was to document and understand the dependence and perception of riverine communities on wetland resources within the Sanmenxia Nature Reserve. We adopted an integrated approach that used a combination of field survey and participatory tools to document the wetland resources, livelihood dependence and value that the communities place upon wetland resources. The methods used included:

- a. Satellite imagery to document the dynamics of the wetlands and impacts on user communities. Landsat 5 TM and Landsat 7 EMT+ (Path 126 Row 36) were downloaded from the USGS Global Visualization Viewer (<http://glovis.usgs.gov>) and USGS Earth Explorer (<http://earthexplorer.usgs.gov>), and geo-registered. Cloud-free scenes in 2007 were available for every month except July and were used as evidence of the seasonal changes in water level in the Sanmenxia reservoir and the resulting dynamics of the seasonally inundated mudflats. Satellite imagery acquired in summer when the water level in the reservoir is at its lowest shows the river course most distinctly. Hence available summer scenes of the study area at roughly yearly intervals from 2001 to 2007 were geo-registered, and the river course mapped and then superimposed to track its shifts through the years.
- b. Livelihoods surveys conducted on riverine communities using a toolkit of participatory techniques

The livelihood study was conducted in two phases

- First a broad-scale survey (BSS) covering 35 riverine villages was carried out to obtain a baseline reference of a representative sample of communities located within the study area with regard to their awareness of the wetlands resources, their use in connection with their livelihood activities, and their impressions of changes and impacts.
- Based on the findings of the broad-scale survey, four villages were selected for more detailed case studies (DCS) to investigate in greater detail the livelihoods and socio-economic aspects of selected households. The locations of the villages surveyed in the BSS and DCS are shown in Figure 1.

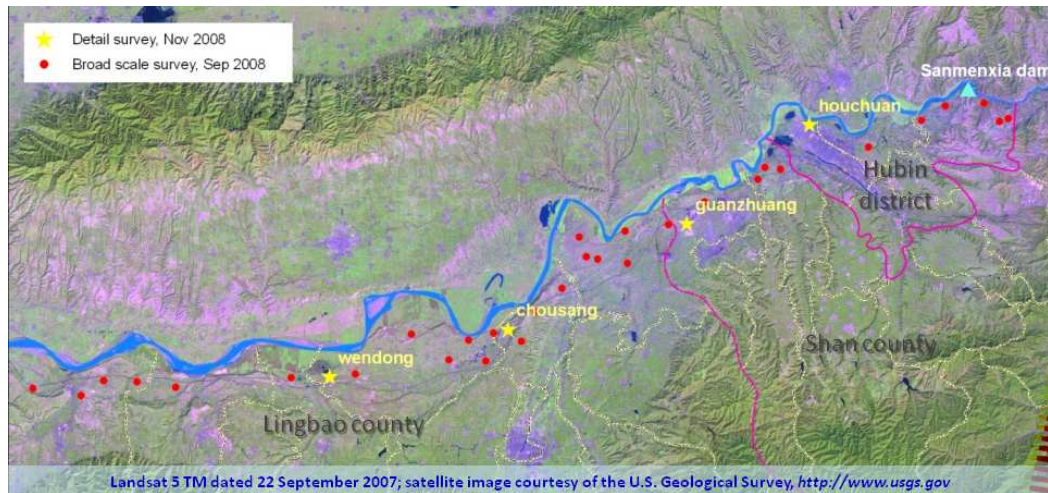


Figure 1. Target study area in Sanmenxia.

The marked villages were covered by the field surveys conducted by this project; county / district boundaries are colored magenta; township boundaries are yellow dashed lines

- c. Production function analysis of the household economic activities conducted for the four DCS villages (35 households per village) to quantify the use and importance of various inputs that generate household income; and
- d. Analytic hierarchy process (Saaty, 1980) for qualitative valuation of wetland services conducted for the four DCS villages to determine the preferences of villagers (20 respondents per village) between conservation and economic development, and the relative importance placed on different ecosystem services of the wetlands.

A range of qualitative and quantitative assessment tools were used to elicit a broad range of information during the broad scale survey and the detailed case studies (Table 2). To guide the development of AHP questionnaire, local stakeholders were asked to identify wetlands functions that they considered important, and these were grouped as shown in Figure 2 below. Scoring cards were prepared and respondents (20 from each of the four DCS villages) were asked to rate the relative importance of (a) the three groupings of wetland ecosystem services; and (b) the specific ecosystem services within each grouping. Rating was done in a pairwise manner, for all possible pair combinations. The results of the pairwise ratings were processed to produce rankings for the groupings and for the ecosystem services within each grouping.

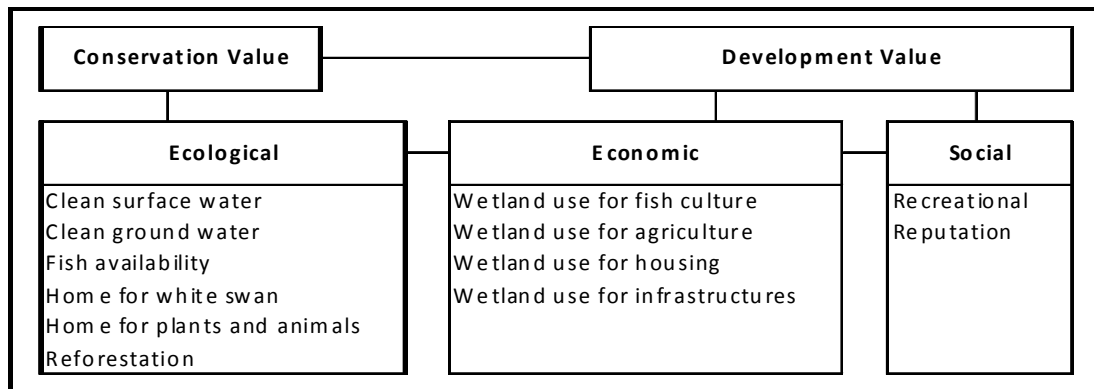


Figure 2. Stakeholders' classification of wetlands ecosystems services for AHP elicitation.

Table 2. Survey tools and purpose.

Tool	Purpose/data generated	Tool used in	
		BSS ^a	DCS ^b
Field verification of GIS mapping	Ground-truthing of wetland mapping output from interpretation of satellite imagery	✓	
Network Mapping	To identify main institutions involved in natural resources planning and management, their relationships and relative strengths/opportunities and weaknesses		✓
Transect walk	For each resource unit, identify the crops grown, water sources and soil characteristics, problems, and other relevant information.		✓
Participatory Mapping	Information on wetland resources (mudflats, birds, fish) that villages recognize as present in their vicinity Information on where, what and when resources are being used and by whom	✓	✓
Livelihood flows	Used to record key livelihoods flows and migrations, use of natural resources, agricultural inputs, labour, credit, etc.		✓
Historical profile	Derives information to understand short term shocks and long term stresses, and their impact on people/communities and how they coped and adapted. Puts case study data into historical context.		✓
Open and Key Informant Interviews	Narrative descriptions structured according to emerging issue(s). Triangulation (verification) of data from other tools and used to fill information gaps	✓	✓
Seasonal calendar	To understand what different groups do and when. Also to elicit information on the relative importance of different activities by group/season		✓
HH Livelihoods System Diagnosis	A tool used to derive a deeper understanding on household livelihoods with an emphasis on exploring the range of HH livelihood objectives and visions and key problems in meeting these		✓
Household Production Function Survey	A questionnaire survey focused on the types of production activities, labor utilization, costs and prices, sources of income and expenditure, with emphasis on the contribution of wetland resources in income generation.		✓
AHP Survey	An interactive procedure to elicit responses regarding the wetlands ecosystem services that are important to respondents and their ratings of relative importance of the services, considered pairwise.		✓

Note: ^a BSS: Broad-scale survey; ^bDCS: Detailed case study

3.2. Results

3.2.1. *The Yellow River dynamics and effect on seasonally-flooded mudflats*

Apart from the open waters of the Yellow River and its tributaries, the main wetland features in the Sanmenxia study site include the following:

- a) Seasonal flats and in-river islands, which constitute the most dominant feature along the length of the Sanmenxia reservoir;
- b) Seasonally-flooded agricultural land, which are seasonal mudflats that are suitable and used for cropping;
- c) Water storage areas, i.e. reservoirs constructed off the main channel reservoir, for storage of water for domestic, industrial and agricultural use;
- d) Aquaculture ponds; and
- e) A permanent, shallow and marshy freshwater lake at Dinghuwan, a unique wetlands feature off the main stream of the Yellow River in Lingbao country.

The water level in the Sanmenxia reservoir used to be maintained at 335 m above sea level; but with the commissioning of the Xiaolangdi dam downstream in 2000, it was reduced to 318 m. This 17-m drop in the water level caused former wetlands to be permanently exposed, forming new arable land particularly in the western part in Lingbao county, to the benefit of the communities farming on these former wetlands. In the field surveys conducted by this project, the farming communities still referred to these lands as wetlands.

In Figure 3 sub-scenes of the monthly Landsat scenes for 2007 show the seasonal flooding of an area of mudflats in response to fluctuations in the reservoir water level, as indicated by the graph in the upper left corner. The drop in the water level at the end of June coincides with the annual release of water from the Sanmenxia dam in summer, in tandem with two other mainstream dams along the Yellow River, to flush the sediment accumulated in the reservoirs. The largest area of inundation (indicated with the ellipse in scene #6) occurred at the highest water level recorded (on 02 Jun), among the dates of imagery acquisition that were plotted. It was only after the release of water from the Sanmenxia dam in late June that the mudflats appeared. The August scene (#7) shows signs of an early crop stage. The cropped area is more obvious in the September scene (#8) and by mid-October (#9) harvesting was already in progress before the abrupt rise in the reservoir water level so that two weeks later the mudflats were already inundated again (#10). This transient nature of the seasonal mudflats brings uncertainty to villagers dependent on these mudflats for crop cultivation annually.

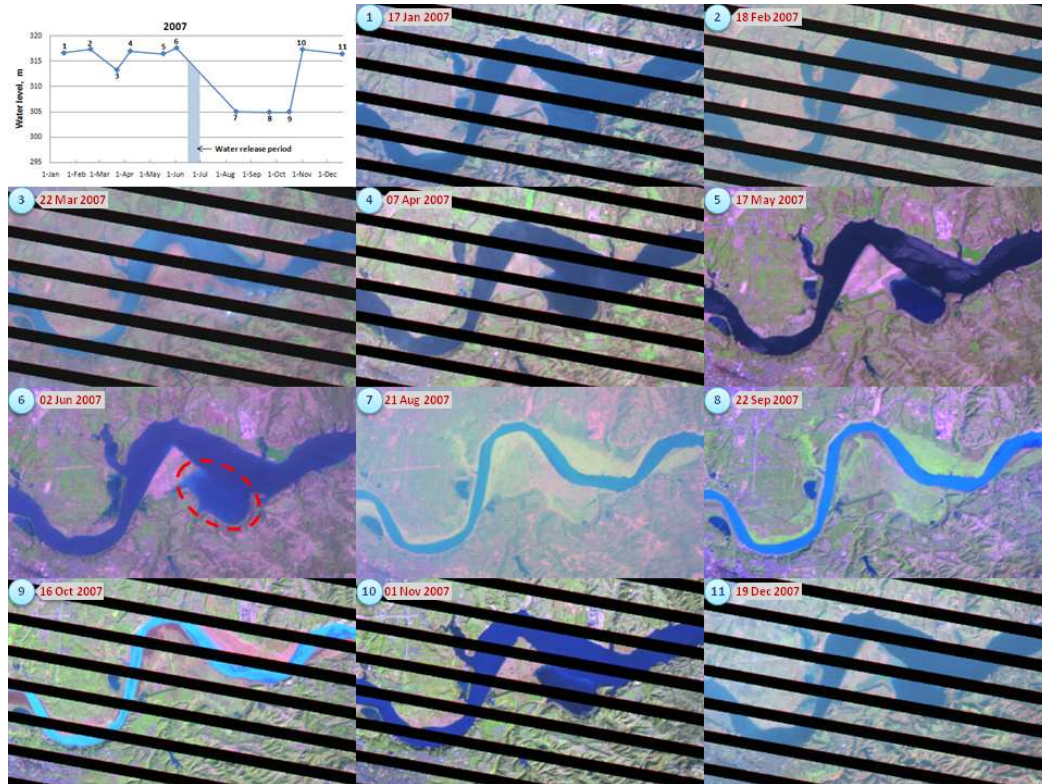


Figure 3. Seasonal changes in river morphology, in relation with water level fluctuations in Sanmenxia reservoir (m, Huanghai elevation as datum level).

Data sources: Landsat 5 TM and Landsat 7 EMT+ imagery from USGS; water level data from the Yellow River Conservancy Commission¹.

Figure 4 shows how the changing course of the Yellow River over the years (2001-08) has caused loss of mudflat areas in Henan province and accretion of mudflat areas in the neighboring Shanxi province (north of the Yellow River). The net loss of mudflat area from Henan province has caused some Sanmenxia villages to lose physical area of the seasonally-inundated mudflats to cultivate their crops. This was confirmed by findings from the conducted field surveys.

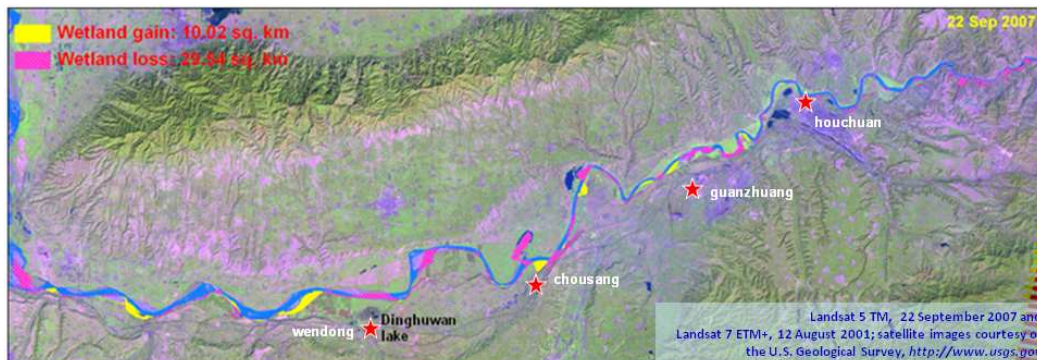


Figure 4. Gain and loss of mudflat area in Sanmenxia prefecture resulting from changing course of the Yellow River over the 2001-2007 period (shown in blue is the 2007 river course)

¹ Note: The black striping in some of the images is due to a faulty member of the sensor array in Landsat 7; despite the bad scan lines most of the features of interest are still visually discernible.

3.2.2. *The Sanmenxia Wetlands Nature Reserve*

A 205-km stretch of the Yellow River, with its fringing land, has been legalized as a joint nature reserve by Henan and Shanxi provinces in May 2005. The main impetus for designating the wetlands in this area as nature reserve is the seasonal appearance of huge flocks of aquatic birds, most notably the white swan, that stop over on their southbound winter migration and occupy the wetlands by the tens of thousands in October and November. In accordance with national guidelines, core, experimental and buffer zones have been delineated within the nature reserve area, with the core zone meant to be exclusively for conservation purposes. Figure 5 shows the zones in the study area in Sanmenxia. Where the core zone is broad, such as in Hubin district and various parts in Lingbao county, the area includes not only the wetlands (i.e. the open water and the seasonally-inundated mudflats) but also the low-lying arable land that was previously wetland but is presently no longer inundated, due to the lowering of the water level in Sanmenxia reservoir after 2000. The core zone also includes the unique wetland feature of Dinghuwan lake in Lingbao county.

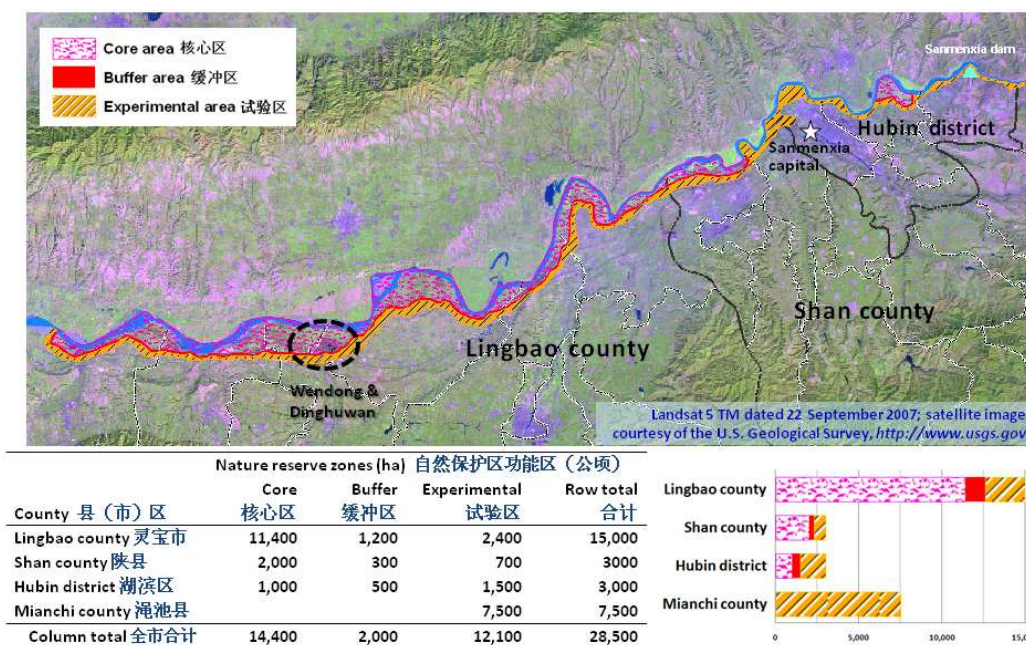


Figure 5. The core, experimental and buffer areas of the Sanmenxia Yellow River Nature Reserve.

In practice, various economic activities continue to be carried out within the delineated nature reserve zones, particularly the core zone, as local communities had already done prior to the establishment of the nature reserve. The main economic activities include agriculture, fishing and aquaculture, and recreation and tourism. While management of the nature reserve is the responsibility of the Forestry Bureau, other agencies are responsible for the various economic sectors – crop cultivation by the Agriculture Bureau, fisheries and aquaculture by the Fisheries Bureau, and water extraction (for industrial and domestic use) and tourism by the municipal government. In effect the land and water resources of the nature reserve are managed by multiple institutions.

3.2.3. Socio-economic profile of riverine communities

The results of the socio-economic surveys are summarized below.

Economic activities in the primary sector: Agricultural activities dominate the livelihood activities of surveyed communities. Communities produce on average three different types of crops. Corn production provides the main activity for households in 57% of communities (n=35), followed by fruit orchards (51%) and vegetable production (31%). Forestry and livestock production provide a principal occupation in households of 25% and 17% of communities respectively. Livestock production provides secondary occupation in 54% of communities. According to respondents aquaculture did not provide a main activity in any of the villages covered by the survey.

Use of the wetland resources: The majority of communities surveyed are located in close proximity to seasonally flooded mudflats (71%). The cultivated mudflat area ranged from 200 to 16,000 mu, with an average of 2,480 mu² for 18 villages reporting use of mudflats for cultivation. Eight of the 35 communities surveyed do not lie close to the Yellow River although representatives of 14 villages reported access to a river or channel besides the Yellow River. Pond aquaculture takes place in seven of the communities; however only 2 village representatives mentioned aquaculture as a secondary activity.

Villagers' perception of wetlands importance: The availability of land for cropping and cultivation was the most frequently reported reason for wetland importance (34% of total responses, from respondents in 20 villages reporting wetland importance). The income and economic benefits from the wetland areas referred primarily to the cultivated mudflats and hence the value of the wetland area as a source of 'affordable farm land', as one respondent commented. The importance of the wetland as a flood protection barrier was reported by two respondents. Provision of resources to support livestock production, with duck raising referred to specifically by one respondent, was reported as an important service provided by wetland areas by two respondents. Provision of water, and land for forestry, were also cited as important by two respondents. Individual respondents also commented on the value of wetland resources for fishing, aquaculture, ecological value, lotus production and 'resolving the problems of villagers'. Mudflats were considered the most important wetland resource by 95% of respondents.

Changes over the past 30 years: The shifting course of Yellow River appeared to be the main change mentioned by the surveyed communities as having a direct impact on their livelihoods. Deteriorating water quality due to pollution was the second most important change reported by respondents. There was also a perception of declining living aquatic resources, including fish, both in quantity and size.

The BSS showed that communities located along the margins of the Yellow River are greatly influenced by their proximity to urban centers and access to infrastructure, particularly roads and transportation. In Figure 6, villages marked with darker shaded circles reported higher proportion of households engaged in economic activities using former and present wetlands. Villages located in Lingbao county, particularly those farming on former wetlands and present seasonal mudflats have higher dependency on the wetlands compared to villagers located towards the east in Hubin district where proximity to the growing urbanization around Sanmenxia city provides off-farm employment opportunities.

² Mu is the Chinese unit of land area; 1 ha is equivalent to 15 mu.

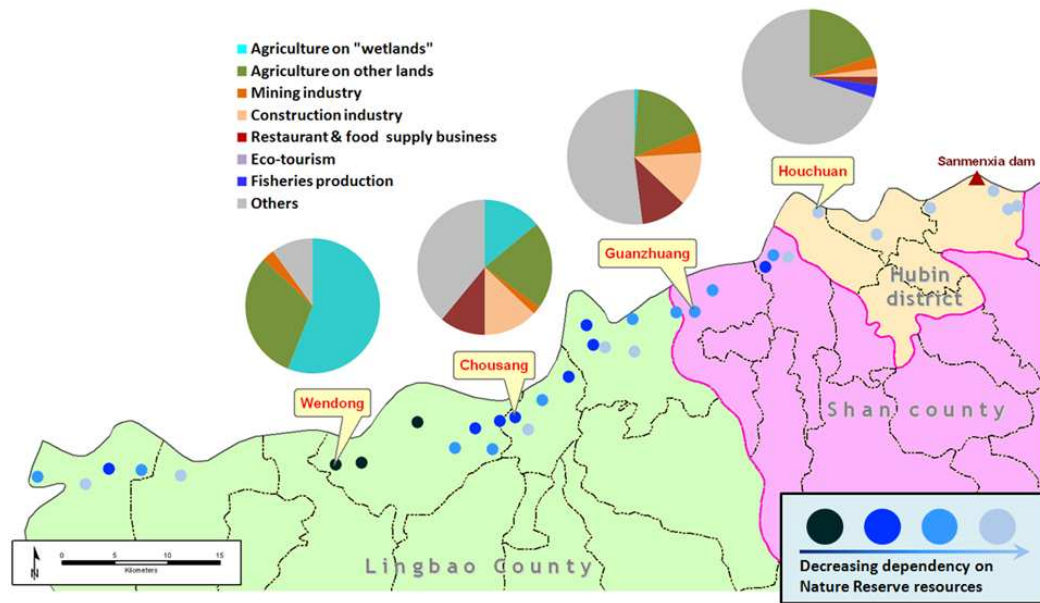


Figure 6. Livelihoods & dependency of riverine villages on the Nature Reserve resources.

The pie charts in Figure 6, which depict the average percentage of household income from economic activities for the four villages covered by the DCS, further illustrate this trend. Wendong village in the west reported the highest percentage of income (57%) from wetland based resources, particularly crop cultivation on former wetlands surrounding Dinghuwan lake. The villagers used to have access to the lake for fishing until the use of the lake resources was subsequently contracted out to people outside of Wendong village, and became separately managed. The livelihoods survey revealed that about 5% of the households were engaged in aquaculture but fish production was not featured in the household income survey.

Chousang village, the poorest of the four villages surveyed, derives about 0.13% of their income from wetland resources, with only 2000 mu of mudflat available for cultivation. Part of the village is on elevated ground. When the Yellow River changed its course in 1998, the village lost two-thirds of its mudflat area. Villagers reported fishing in the Yellow River and collecting wetland plants such as reeds, bulrush and tamaris for their own consumption and use. The village also has the poorest road accessibility among the four villages surveyed but despite that an estimated 20% of the youths seek employment outside of the village.

The Guanzhuang villagers lost 45% of their mudflats when the Yellow River changed its course in 2002 and are left with 1200 mu of seasonally-flooded mudflats, with another 1800 mu of former wetlands for cultivation. Houchuan village, which is the closest of the four villages to the urban area of Sanmenxia city, had most of its wetland area taken over and made into a water reservoir and public park. For both these villages, wetland resources contribute relatively low percentages to household incomes, even though some Houchuan villagers reported operating fish ponds, catching fish and collecting wetland plant products for their own use. Given their proximity to the urban and industrial areas, the tendency is for the young people to seek off-farm employment. There are in fact factories within and surrounding Houchuan village.

Results from the AHP suggest that overall villagers expressed preference for wetlands ecosystem functions that relate to conservation, over economic and social benefits

(Figure 7). The exception is Wendong village, which derives a substantial proportion of income from cultivation on the former wetlands (see Figure 6), hence the stronger preference stated for economic benefits from wetlands.

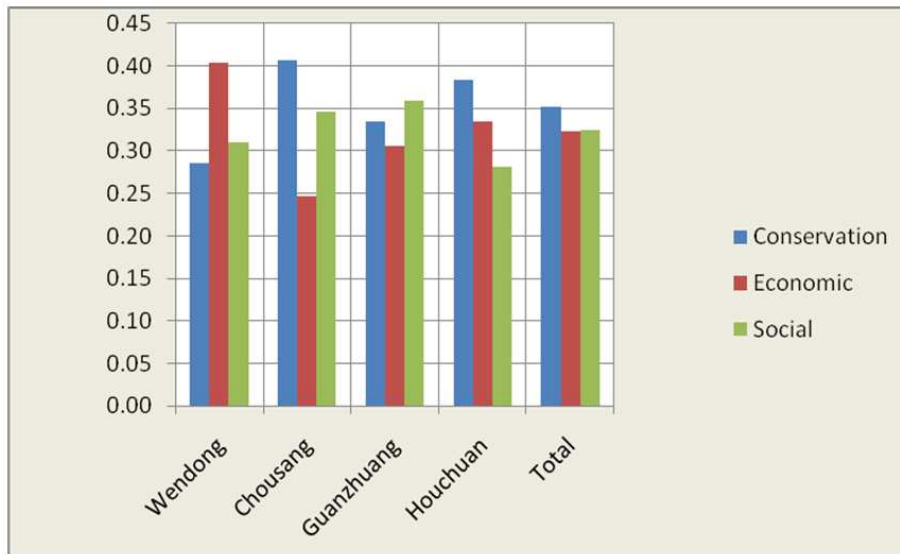


Figure 7. Villagers' stated preferences for conservation, economic and social aspects of wetlands ecosystem services.

Among the ecosystem services that provide economic benefits, the strongest preference for agriculture was expressed by respondents in all four villages (Figure 8). This reflects the over-riding economic importance of the seasonally-flooded mudflats and former wetlands in providing land area for cultivation to the villagers. Fish culture comes next in importance.

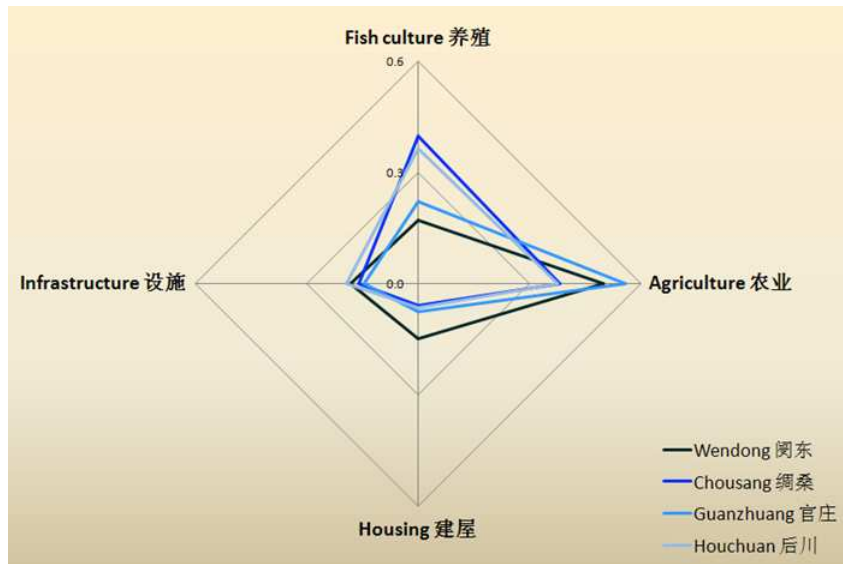


Figure 8. Villagers' stated preferences for wetland ecosystem services that provide economic benefits.

In the case of conservation-related ecosystem services, there was a clear preference for clean underground water (i.e. the water purification function of the wetlands), and to a lesser extent for clean surface water, expressed by all four villages (Figure 9). This

concern over water quality echoes the finding from the BSS whereby majority of the riverine communities reported deteriorating water quality as the second most discernible change they have experienced, after the shifting river course. The villagers also rated highly reforestation of the wetlands (or former wetlands) as something they can relate to because two of the villages (Chousang and Guangzhuang) contract out part of their “wetlands” for planting of poplar trees and hence derive economic benefit from it. Of the biodiversity support function of the wetlands, a higher preference was stated for birds (represented by the white swan) than for fish, partly because of the higher visibility of the former and partly because villagers now place less importance on fishing the wild population in the river.

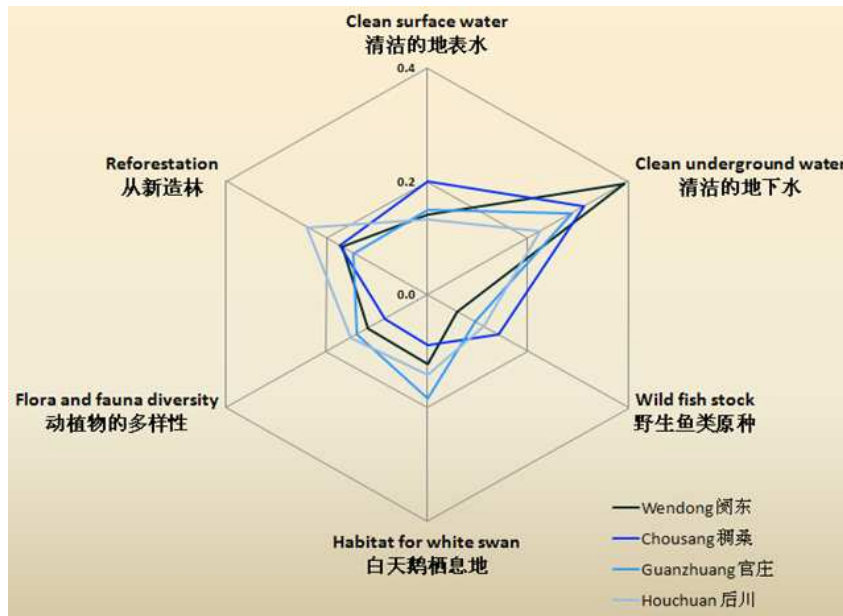


Figure 9. Villagers’ stated preferences for wetland ecosystem services related to conservation.

3.2.4. Dinghuwan lake

A specific investigation was done by this project on Dinghuwan lake situated within the physical area of Wendong village in Xiyan Township of Lingbao County, because of its unique wetlands features. This shallow lake, with an average water depth of 1.5m and covering an area of 667 ha, has the largest inland reed marsh within the study area. The lake was formed in a low depression by Yangping river, a tributary of the Yellow River. The flow of the Yangping river was subsequently diverted, and its inflow into the lake was stopped. A dam constructed at the outflow end of the lake further limited the lake’s water from draining into the Yellow River. Hence the lake is now hydrologically disconnected from the rivers that fed and drained it.

Dinghuwan lake (Figure 10) constitutes an ecologically unique wetland ecosystem that is different from the riparian wetlands along the river bank. Because of its marsh environment, it offers an added attraction for aquatic birds, some of which reportedly prefer the reeds of the lake over the riverine mudflats according to locals familiar with the lake environment. The lake resources have been subjected to multiple uses. Initially used by Wendong villagers for fishing, the lake is now managed by three external contractors who have started culturing various exotic fish species in the lake and partitioning their contracted sections with earthen bunds. This further reduces the limited water circulation within the lake. One indication of possible eutrophication is the

spread of aquatic vegetation within the lake that leaves behind decaying debris. At the southern edge of the lake where access is constructed to the closest road, facilities are in place for floating and lakeside restaurants and recreational boating operated by concessionaires of the three main contractors. Lotus is cultivated in ponds fringing the southern lakeside.



Figure 10. Dinghuwan lake.

3.3. Discussion

The dynamic situation of the wetlands along the main stream of the Yellow River, coupled with a changing economic structure and expanding urbanization and industrialization and a government policy encouraging villagers to embrace modern living and employment opportunities, all have implications for managing the nature reserve and livelihoods of communities living within its boundaries. Because use of the wetlands resources by local communities predates the designation of the Sanmenxia reservoir and its peripheral wetlands as nature reserve, managing it as a conservation area is faced with challenges. The reality is that the legally designated core, experimental and buffer zones of the nature reserve cannot function in accordance with the strict definitions under the national protected area regulations. The regulations on nature reserves define three management zones – a core zone that excludes human use; a buffer zone where limited collection and scientific research are permitted; and an experimental zone where scientific experimentation, public education, tourism and raising of rare and endangered species are allowed (Xu and Melick, 2007).

The results of this study reveal the extents to which riverine communities still derive livelihood benefits from the land and water resources within the boundaries of the nature reserve, in conducting economic activities including agriculture on former and present wetlands, aquaculture, fishing, and nature recreation. Consequently there are multiple jurisdictions of line agencies in terms of land and water administration and management of various sectors - agriculture, aquaculture, fishing, forestry, water extraction and water quality monitoring. Representatives of the key agencies recognize the need for better coordination in carrying out their management functions. Based on the findings of this study, we offer the following recommendations that could contribute towards improving this coordination.

3.3.1. A common understanding of the purpose of the nature reserve

It is important that the various agencies arrive at a common understanding of what the nature reserve is for. Presently the most obvious conservation function of the nature reserve concerns aquatic bird biodiversity. The Sanmenxia reservoir and the seasonally flooded mudflats are visited annually by more than 10,000 white swans on their migration path from Siberia. The aquatic birds are also the most visible and recognized aspect of biodiversity by the villagers who consider that crop production in the mudflats and, in some cases, active feeding contribute to providing forage and therefore attract the birds. On the other hand, the unique wetland ecosystem of Dinghuwan lake and its prospect of being conserved for its existence value is not widely appreciated.

3.3.2. Functional zones for managing activities within the nature reserve

If it is generally accepted by the local authorities that multiple economic uses are allowed to be carried out within the nature reserve, and that the delineation of core, buffer and experimental zones bear no relationship with current and future use, then it would be more expedient to define functional zones for management purposes. It is recommended that the relevant agencies confer and agree on:

- a) identifying and delineating these functional zones in terms of primary use of the resources therein;
- b) developing rules and guidelines for their use; and
- c) relegating overall management responsibility to the most relevant agency.

Examples of functional zones are:

- The open water of the Yellow River
- Former wetlands that are now permanently cultivated and used for pond aquaculture
- Riverine mudflats that are seasonally exposed
- Riverine areas developed for multi-purpose public recreation
- Re-afforestation areas
- Strict conservation area

Areas and sites falling under these functional zones may not be contiguous, but the management jurisdiction ought to be clear. Some of these areas already exist, while new ones may be identified and developed with clear guidelines.

Table 3 illustrates how the main allowable purposes and lead agency for technical management may be identified and assigned for each of the functional zones. Overall land administration comes under the authoritative agency relegated by the municipal government or the Yellow River Migration Bureau as the case might be.

Table 3. Functional zones within the Sanmenxia wetlands nature reserve.

Functional zones 功能区	Main/allowable purposes 主要允许的活动	Lead agency for technical management 技术管理牵头部门 ¹
Open water of the river 河中开放水域	Water extraction & navigation, with monitoring of water & fishery resources 取水\航运,监测水质和渔业资源	YRCC, Fisheries Bureau 黄委会,渔业局
Permanently arable land 永久耕地	Low-impact agriculture/ aquaculture, with priority for dependent communities 发展有利于民生、对环境影响小的农业和水产养殖业	Agriculture/Fisheries Bureau 农业局、渔业局
Riverine mudflats 河边滩地	Seasonal cultivation, with priority for poor and landless villagers 季节性农业生产,照顾贫困和无土地的农民	Agriculture Bureau 农业局
Public multi-purpose recreation areas 河边公共区域	Low-impact recreation, scenic tourism, recreational fishing 对环境影响小的休闲旅游活动,钓鱼等	Municipal government 市政府
Public re-afforestation areas 退耕还林区	Greening and habitat creation for biodiversity enhancement 开展绿色经济,恢复生态系统,提高生物多样性	Forestry Bureau 林业局
Strict conservation area 严格控制区	Low-impact eco-tourism, education and research 开展对环境影响小的生态旅游、教育与科研活动	Forestry Bureau 林业局

¹Land administration responsibility rests with the municipal authority; conditions of use on advice of technical agency
土地管理职责由市政府指定, 利用条件由技术部门提出建议

3.3.3. Dinghuwan lake: case for a true conservation area

This study identified Dinghuwan lake, covering about 670 ha in Xiyan township of Lingbao county, as having the most unique wetlands ecosystem within the nature reserve that is worth designating as a true conservation area. However, the present uses of the lake are likely to cause irreversible changes to the lake ecosystem to the extent that this opportunity will be missed if remedial measures are not taken. There is need for institutional coordination to take the following measures:

- Review the present uses and impacts on the ecology of the lake;
- Identify which activities are compatible and which are incompatible with the ecological functions of the lake;
- Develop a proper plan for managing DHW as a conservation area; and
- Sort out the institutional jurisdictions for a better coordinated and efficient management of the lake.

Figure 11 depicts how the present deteriorating conditions in Dinghuwan lake can still be rectified to rehabilitate the lake's environment and ecology so that it can deliver the ecosystem services that are consistent with a true conservation area.

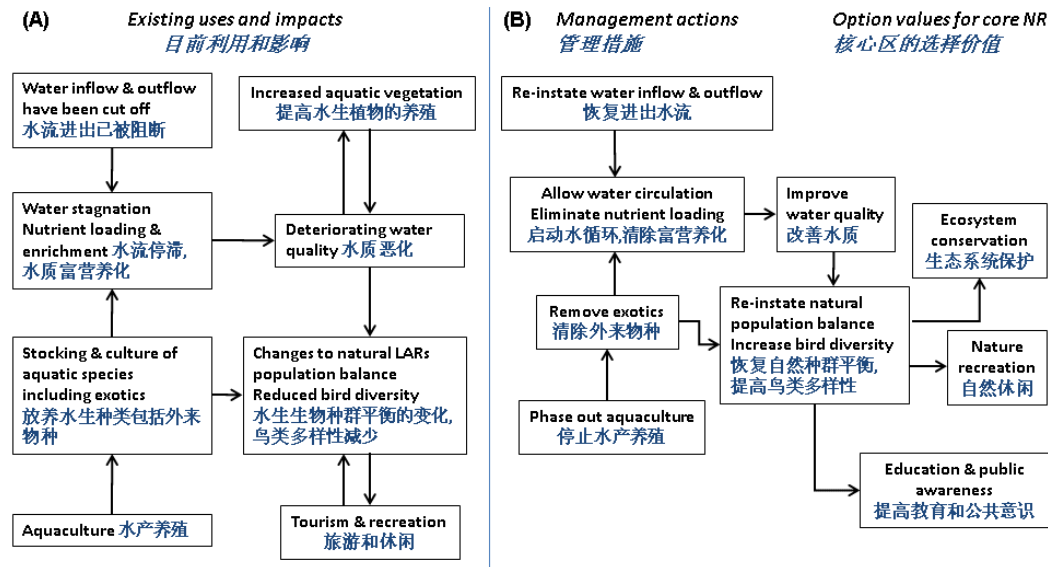


Figure 11. Current conditions of Dinghuwan lake (A), and ameliorative measures for restoring its ecology (B).

Studies had been conducted and specific recommendations made for reinstating the hydrological flow to restore the ecology of Dinghuwan lake, suggesting the technical feasibility of doing so (Fang, 2006). Other measures need to accompany this restoration of the lake's hydrology, as indicated in Figure 11 (B), but these hinge upon a genuine intention to make the lake a true conservation area, and the political will and institutional coordination to execute this intent.

3.4. Conclusions

The integrated approach adopted for the study has permitted a holistic assessment of the Sanmenxia Nature Reserve, its resources and management. By using methods as diverse as GIS, qualitative livelihoods analysis and economic valuation tools, the project contributed to better understanding of the livelihood context of communities located close to the Yellow River. The analysis revealed how the dynamic nature of Yellow River, coupled with expanding urbanization, has implications for both the nature reserve and the livelihoods of communities living within its boundaries. The quickening pace of urban and industrial development has brought benefits to communities that are able to access off-farm employment opportunities. However, those with poorer access to urban centers remain vulnerable and are still significantly dependent on wetland resources. It is critical that these dependent communities should be considered in management decisions to ensure that they can still benefit from the resources within the nature reserve.

Defining functional zones that permit specified activities within defined areas of the nature reserve is recommended as an option for managing activities for the protection of resources and livelihoods. Based on the nature and location of resources and the ecosystem services they provide, zones may be identified where activities such as aquaculture, agriculture and industry are most appropriate and can be more effectively managed. Continued evaluation of changing livelihoods and the potential impact of new management initiatives would ensure that vulnerable livelihoods are supported and the needs of wetland resource users are considered.

4. THE DONGYING STUDY

The present Yellow River delta (YRD) is located in the northeast of Shandong province. Much of the YRD area is under the jurisdiction of Dongying, a municipality of 2 million people in Shandong province. The YRD is now a highly urbanized and industrialized region, fueled mainly by oil extracted from its subterranean fields. The Shengli oilfield underlying the delta is the second largest in China. Land and water are the premium natural resources under increasingly heavy demand given the industrial-oriented economic development strategy of Dongying and its surrounding region.

Development of coastal defense infrastructure, i.e. sea dykes, is an imperative for protection of the land of the YRD and all the economic activities it supports. The resulting modifications to the coastal hydrology would eventually alter the ecology of the enclosed wetlands areas that are yet to be converted. Yet in the midst of these developments, the Chinese government has designated 150,000 ha of the youngest and growing wetlands around the estuary as the Yellow River Delta Nature Reserve (YRDNR). The nature reserve is gaining increasing international stature for avian biodiversity and protection including rare and endangered aquatic birds of the crane, stork and swan species. This recognition of the supporting ecosystem function and services of the wetlands is commendable, considering the tremendous economic development pressure.

However the ecosystem health of this protected wetland area depends on continued nourishment from the sediment-laden river discharge into the sea, and even this is uncertain in the face of the ever-present demand for upstream water extraction for agricultural, industrial and urban use. This demand is likely to become exacerbated by climate change impacts on rainfall patterns and sea level rise. The 2009 drought – the worst since the 1950s – that caused massive crop failures in the wheat belt in the upstream provinces of the Yellow River underscores the critical demand for the river’s water resources up to levels that threaten to undermine its baseline flows. Outside of the nature reserve area, the coastal wetlands have been subjected to various forms of use and changes. The delta area is a mosaic of wetlands in the natural condition (protected within the nature reserve and not outside), man-made wetlands (including fresh- and brackish-water aquaculture ponds, salt evaporation pans, water reservoirs) and former wetlands that have been converted for agriculture, urban and industrial uses. Dongying Municipality, in its recent modernization, aspires to achieve a balance between rapid economic development and environmental and ecological sustainability. The balance is a delicate and challenging one - can the coastal wetlands of the YRD co-exist with modern development encroaching upon them? Is there sufficient appreciation that these wetlands are worth caring for, and hence maintaining their health is crucial? These are key questions that this study attempted to respond to, with the aim of raising awareness and understanding of the value of wetlands beyond their immediate and direct economic contributions. Piloted in the eastern part of Dongying Municipality, the project attempted to demonstrate how this understanding might inform decision makers and guide their achievement of Dongying’s vision of sustained and balanced development. The study area in eastern Dongying covers four coastal townships and includes the part of the Yellow River Delta Nature Reserve (YRDNR) associated with the present estuary of the Yellow River. The pattern of land use in the study area reflects the diversity of economic activities affecting the wetlands of the delta.

4.1. Objective and methods

The main objective of the Dongying study was to assess how the ecosystem services of the coastal wetlands have been affected by modification and conversion of wetlands for various economic activities, in order to identify strategies for reducing impacts and enhancing use value of the wetlands.

Within a two-year time frame, we realized it would not be possible to take a quantitative approach for a comprehensive valuation of the wetlands resources, particularly Living Aquatic Resources (LARs), given the existing, general lack of data on the broader ecosystem roles of the wetlands in the Yellow River basin. In any case a past study on wetlands valuation in the Yellow River delta conducted by Xu (2001) estimated the wetlands use value at RMB3.2 billion. This pales in comparison with the revenue generated by the petroleum industry for Dongying Municipality. In 2008 the GDP of Dongying was RMB 2.065 trillion (about USD300 billion) - an almost 100-fold increase from about RMB21 billion in 1995 - and growing at a rate of 13.7% per annum. About 30% of its 2 million people are engaged in the primary sector (agriculture, livestock, fisheries & aquaculture, forestry), but the sector outputs account for barely 3% of the gross regional product. Given the prevailing political and economic climate in Dongying as part of the greater Bohai Rim Economic Region (one of seven cross-provincial economic regions of China), the economic argument of retaining wetlands outside of the nature reserve is weak. Xu (2001) also investigated the non-use value of the Dongying wetlands using contingent valuation – willingness-to-pay method. The study pointed to weaknesses in the Total Economic Valuation methods that depend on respondents' ability to quantify non-use values, which assumes their awareness of the ecosystem services of the wetlands and assign monetary values for these services. According to Xu (2001) there was little evidence of this awareness and understanding, hence the non-use value was not high from local perceptions.

This study adopted an approach that focused instead on evaluating impacts on the ecosystem services of the delta wetlands and trade-offs in the present uses of these resources based on available evidence locally and elsewhere. The assessment tool used is multi-criteria evaluation (MCE) conducted within a geographical information systems (GIS) platform for mapping the impacts. The main steps in the methodology are described below.

1. Literature review was conducted to collect evidence and quantification of ecosystems services of wetlands, particularly of the types found in the Yellow River delta, from studies conducted locally and in other countries in Europe and the United States of America.
2. Consultation with stakeholders (mainly managerial and technical staff of relevant line agencies including Fisheries, Agriculture, Forestry, Water Conservancy and Tourism Bureaus, and the petroleum and salt industries) to identify the main wetlands ecological functions and ecosystem services that they recognize as important in the local context.
3. Fact-finding missions were carried out with local authorities and experts to collect specific information and data on uses of the wetlands and production characteristics of the various economic sectors.
4. GIS mapping was done for land use of the study area based on visual interpretation of satellite imagery (Landsat 5TM and Landsat 7 ETM+ scenes for Path 121 Row 34; 2001-09) and with the guidance of the 2009 land use map obtained from the Dongying Bureau of Land and Resources. The output map was verified in the field and with locals familiar with the land use pattern in the study area.
5. Stakeholder consultation was carried out to engage local experts representing the different economic sectors (agriculture, fisheries, forestry, water conservancy, municipal planning) in rating the relative contributions of wetlands ecosystem services for the main land uses in the study area. Before the elicitation sessions, detailed explanations were provided to the stakeholders on the key physical and ecological functions of the wetland habitats that underpin the ecosystem services that the wetlands deliver. The opinions of experts were then elicited on how they perceived the levels of ecosystem services would have been modified by changes to their hydrology (e.g. prevention of tidal inundation, draining the wetlands) and

different uses of the wetlands such as conversion to agriculture, aquaculture and salt production, collecting seafood products from natural wetlands and nature recreation. A ranking exercise was conducted with experts for each ecosystem service across land use types found in the study area. Their assigned rankings were mapped in real time and displayed for subsequent examination and refinement of their ratings.

6. The outputs from the expert elicitations were used in MCE modeling, which was also conducted during the consultation sessions to produce the output maps real-time for interpretation and eliciting feedback. The maps depict the impacts of various land uses and economic activities on the ability of the wetlands to provide ecosystem services, and the associated trade-offs.

4.2. Results

4.2.1. Use of land and wetland resources in the study area

Figure 12 shows the land use pattern of the study area, comprising two townships in Kenli county and two townships in Dongying district. About 100,000 ha of the YRDNR's total area of 153,000 ha, located at the present estuary of the Yellow River, are within Huanghekou township. The Yellow River is still depositing sediment and forming mudflats that extend seaward at a rate of about 2 km per year. With this continual growth the wetlands along the present estuary are at different stages of maturity, uniquely providing a text-book profile of habitats across the saline through brackish-water to fresh-water habitats rich with plant and animal life. The young wetland habitats immediately surrounding the tail end of the Yellow River are within the core zone of the nature reserve and managed as a strict conservation area, except for oil extraction activities using derricks. In the other 5,000 ha of buffer and 49,000 ha of experimental zones within the nature reserve boundaries in the study area, there are already human activities (mainly agriculture and oil exploration) and modifications to the natural habitats, due to historic reasons. Outside of the nature reserve area, the coastal wetlands have been subjected to various forms of use and changes. The study area is therefore a mosaic of wetlands in the natural condition (protected within the nature reserve and not outside), manmade wetlands and former wetlands that have been converted for agriculture, urban and industrial uses.

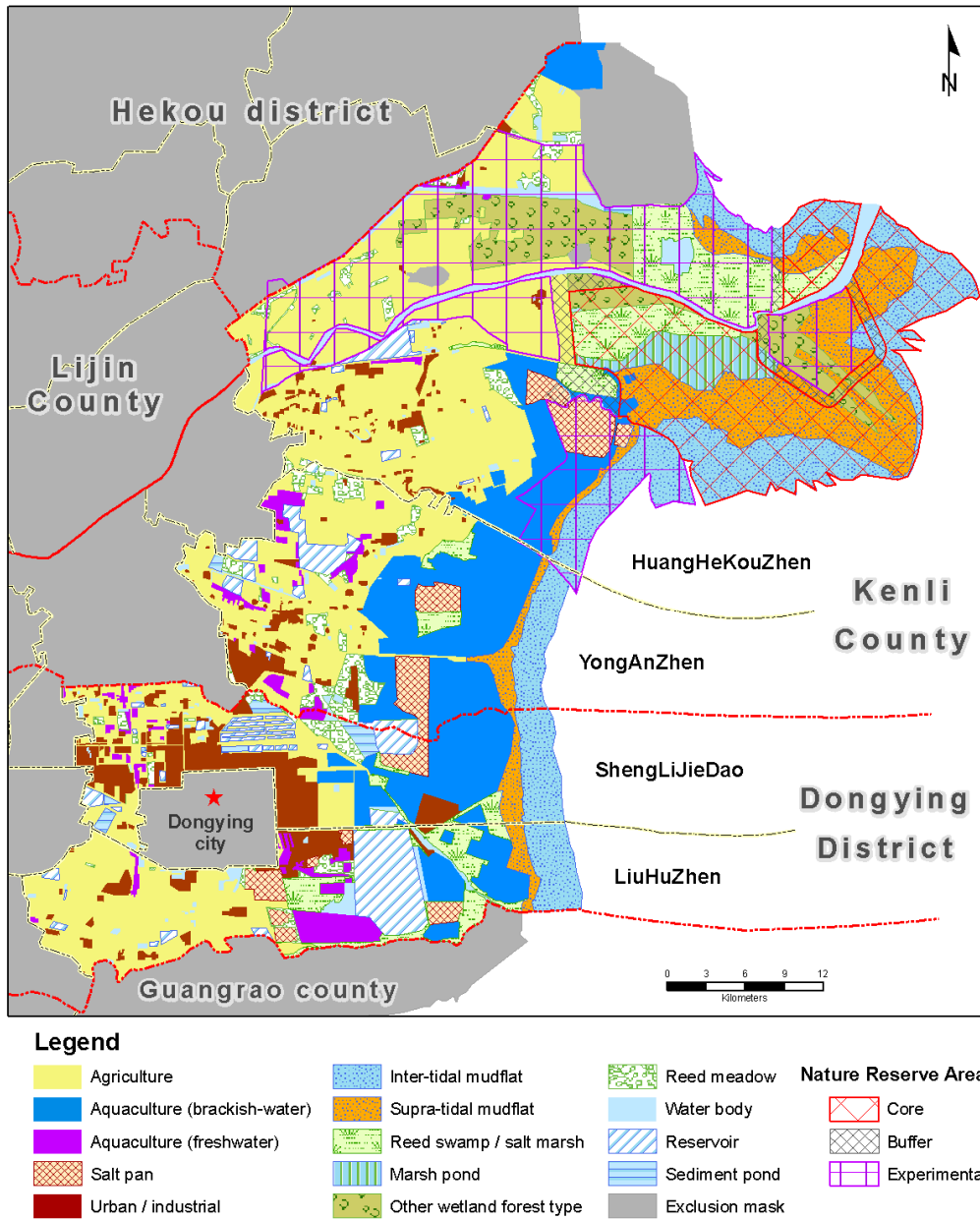



Figure 12. Landuse of the study area in Dongying, 2009.

Apart from the open waters of the river and the coastal waters covering the sub-aqueous delta, the most obvious natural wetlands in the Yellow River delta that are subjected to various direct and indirect uses include the tidal mudflats (both inter-tidal and supra-tidal), the saline reed marshes, other wetland forest types of higher ecological succession stages, and isolated pockets of freshwater reed meadows. Figure 12 shows the spatial pattern of occurrence of these wetland types. The manmade wetlands in the Yellow River delta include aquaculture ponds (both brackish- and fresh-water), salt evaporation pans and water storage reservoirs for agriculture, aquaculture, municipal and industrial use. Table 4 lists the current uses of the land and wetlands within the study area, in relation with the main categories of use values generally recognized for natural resources. Quantification of economic value is generally easier for the direct uses

than for the indirect uses. Estimating the indirect use values for regulatory and biological functions of wetlands requires detailed understanding of the underlying physical, geomorphological, hydrological and ecological processes that drive these functions and quantification of these processes. Some of such thorough scientific studies have been done in developed countries (Maltby et al., 1996) but are particularly wanting in developing countries (Brander et al., 2006).

Table 4. Current uses of the wetlands in eastern Dongying municipality.

	USE VALUES 利用价值	Current use 利用现状
	DIRECT USE 直接利用	
	Conversion: physical land area 转换: 土地面积	Urban/industrial 城市/工业 Agriculture 农业 Salt production 盐业 Aquaculture - freshwater 淡水养殖 Aquaculture - brackish water 海水养殖
	Consumptive: product extraction 消费类: 产品提取	Mollusk , crustacea, fish 软体, 虾蟹, 鱼 Reeds , medicinal plants 芦苇, 中草药
	Non-consumptive 非消费类	Recreation, tourism 休闲, 旅游 In-situ research, education 建立研究, 教育设施
	INDIRECT USE 间接利用	
	Regulatory (due to ecological processes) 监督管理 (基于生态调节)	Storm protection 风暴保护 Water purification 水质过滤 Climate change mitigation 减缓气候变化
	Biological (living organisms including LARs) 生物 (包括水生物资源)	LAR recruitment/feeding 水生物资源繁衍/ 饵料提供 Biodiversity 生物多样性

4.2.2. Evaluation of land use impacts on wetlands ecosystem services

The ecosystem services identified with local experts as being important in the context of the YRD wetlands included provision of direct economic uses including aquatic animal and plant products and land for conducting economic activities, supporting biodiversity through providing habitats for breeding and food web support, water quality regulation through nutrient retention, and mitigating climate change impacts through carbon sequestration and reduced emission of greenhouse gases (GHG). These were correspondingly used as the economic, water quality, climate change and biodiversity criteria in the analysis of land use impacts on the wetlands ecosystem services. For each of these criteria one or more indicators were identified, as listed in Table 5.

Table 5. Criteria and indicators of the key ecosystem services of the wetlands in the Yellow River delta.

Criteria categories	Wetland service	Indicator
标准分类	湿地生态功能	指标
Economic 经济	Direct human use	Production value 生产价值
	直接利用价值	Harvesting mollusks 收获贝类
		Harvesting reeds 收获芦苇
		Aquaculture 水产养殖
		Salt production 盐业
		Agriculture 农业
		Eco-tourism 生态旅游
	Cultural value 文化价值	
Water quality 水质	Purification 净化	Nutrient (N, P) retention 营养 物质保持
Climate change 气候变化	GHG^a mitigation 减少温室气体的危害	C storage & GHG emission 碳沉积和温室气体的排放量
Biodiversity 生物多样性	Food web support 维持食物链	Bird diversity 鸟类多样性

^aGreenhouse gases 温室气体

For the economic indicator, the production value of the major direct uses was estimated, based on available secondary data, for each of the economic activities prevalent in the study area (Table 6).

Table 6. Estimates of production value for economic indicators related to direct use of wetland resources.

Per unit area production value 每单位面积产值	yuan/ha 元/公顷
Harvesting mollusks 收获贝类	4,300
Harvesting reeds 收获芦苇	2,300
Aquaculture 水产养殖	
Freshwater – crab 淡水蟹	21,600
Freshwater - fish 淡水鱼	40,500
Freshwater - shrimp 淡水虾	120,000
Brackishwater - shrimp 海水虾	67,500
Brackishwater - sea cucumber 海水海参	120,000
Salt production 盐业	47,000-310,000
Agriculture 农业	12,000-28,000

For the biodiversity indicator, which relates to the role of the wetlands in providing food web support to a wide variety of aquatic living organisms, the indicator identified was bird biodiversity. Birds are higher up the food chain and therefore their occurrence is a good indicator of ecosystem richness. Birds are also more easily spotted and counted.

The YRDNR is world-renowned for providing breeding and feeding grounds for almost 300 species of birds. Many of these species are migratory birds that stop over or winter in the YRD wetlands, among which 208 are listed under Sino-Japan and Sino-Australian protection agreements. The YRDNR authority actively monitors bird numbers and diversity, hence providing local data that can be used as an indicator of biodiversity in this study. Table 7 compares the occurrence of four important crane species in different habitats in the YRD. It clearly shows that the reed swamp supports the highest diversity and numbers of cranes, followed by the tidal flats. With conversion of wetlands to agriculture and aquaculture, the biodiversity supporting function declines.

Table 7. Aquatic bird occurrence in different habitats in the Yellow River Delta Nature Reserve.

		河道 River	潮间带 Tidal flat	养殖池 Aquaculture pond	芦苇沼泽 Reed swamp	农田 Farm land	草地 Grassland
Area (hm ²)*面积	2001	5152	38534	7966	32772	8759	18143
	2002				35422		15493
Grus leucogeranus 白鹤 Siberian crane IUCN: Endangered	2006				39042		11873
	2001	34	3				
	2002		50				
	2003	7					
	2004		7		192		
Grus monacha 白头鹤 Hooded crane	2005		55		97		
	2006	9	9		597		
	2001	2		2			
	2002						
	2003				4		
Grus vipio 白枕鹤 White-naped crane IUCN: Vulnerable	2004				76		
	2005		16		9	15	
	2006				61		
	2001	4	24				22
	2002						
Red-crowned crane Grus japonensis 丹顶鹤 IUCN: Endangered	2003		12		162		
	2004				1187		
	2005				139	18	
	2006				702	24	
	2001	49	93	24		3	17
	2002	62	269	24	126	2	2
Grus grus 灰鹤 Common crane	2003		193	27	203		
	2004		117		1128		
	2005	137	1051		1618	16	15
	2006	186	1169		4992		12
	2001	1	8	73		5	111
	2002	8	6	38	283	236	
	2003				138	152	
	2004				41		
	2005	74	20		1926	1859	
	2006	361	176		1654	2977	21



Source:
Yan & Shan
2009

For the water quality criteria, which relates to the purification function of wetlands in removing nutrients from polluted waters, the indicator identified was nutrient (nitrogen, phosphorus) retention. For the climate change indicator, which relates to the mitigation of GHG emission, the indicator was the carbon storage or sequestration capacity of the wetlands. No local data was available for these indicators, so evidences were based on studies conducted elsewhere. Studies of fertilizer runoff conducted in the Chesapeake Bay in the United States of America and other estuaries suggest that tidal freshwater marshes trap 35% of the nitrogen and 80% of the phosphorus that would otherwise leach into the broader environment (Merrill and Cornwell, 2000). Table 8 lists the estimates of removal rates of nitrogen and phosphorus obtained from a study of Dutch wetlands, indicating the high efficiency of the reed marsh in providing the water purification function in comparison with other land cover types.

Table 8. Nutrient removal rates of wetland types (example from the Netherlands).

Land cover	Nutrient removal (kgN/ha/yr)	
	N	P
Agricultural use	0	0
Reed marsh	279	13
Open water	45	0
Woodland	95	9
Reservoir	0	0

Source: Goosen, 2006

Table 9 compares the carbon standing stock and carbon storage rates of different forest types. The estimates for temperate tidal salt marshes compiled from studies conducted in the United States coasts and the Mediterranean Ocean (Chmura, 2009) indicate a very high carbon sequestration capacity of this wetland type, similar to that found in the Yellow River delta. Saline conditions in the tidal salt marshes also inhibit bacteria that produce methane, another GHG that is associated with freshwater marshes.

Table 9. Carbon sequestration capacities of different forest types.

Ecosystem	Standing carbon stock (gC m ⁻²)		Long-term rate of carbon accumulation in sediment (gC m ⁻² y ⁻¹)
	Plants	Soil	
Tropical forests	12,045	12,273	2.3-2.5
Temperate forests	5,673	9,615	1.4-12.0
Boreal forests	6,423	34,380	0.8-2.2
Tropical savannas and grasslands	2,933	11,733	
Temperate grasslands and shrublands	720	23,600	2.2
Deserts and semi-deserts	176	4,198	0.8
Tundra	632	12,737	0.2-5.7
Croplands	188	8,000	
Wetlands	4,286	72,857	20
Tidal Salt Marshes			210
Mangroves	7,990		139
Seagrass meadows	184	7,000	83
Kelp Forests	120-720	NA	NA

Source: Kennedy and Bjork (2009)

The information contained in Table 8 and Table 9, supplemented with explanation given of the environmental conditions that favor nutrient retention and carbon storage (summarized in Table 10), provided the basis for local experts to judge how changes made to the wetlands in the study area would compromise the water quality regulation and climate change mitigation services. The ratings provided by local experts and also the study team were expressed as standardized scores on a 1-10 scale, for each of the four criteria for wetland ecosystem services. For criteria other than the economic indicator, benchmark conditions would be those of the undisturbed natural wetland habitats within the core nature reserve, which was assigned the maximum score of 10. The ratings results, summarized in Figure 13, indicate recognition by stakeholders that

while increasing the direct economic value, conversion of wetlands for agriculture, aquaculture and industrial development compromises other ecosystem services.

Table 10. Factors that favor carbon and nutrient retention in wetlands.

Factors that favor 指标	GHG mitigation 减少温室气体	Nutrient sinks 营养物沉积
High rate of sediment accumulation 底物沉积率高	Increases C burial 提高碳的沉积量	Increases nutrient (N, P) burial 提高营养物质的沉积量（氮、磷）
High biomass (roots, microflora, phytoplankton) 生物量（根类，微生物，浮游植物）高	Captures atmospheric CO ₂ 吸收大气中的二氧化碳	Some vegetation types increase N burial 一些植物也可提高氮的沉积量
Low O ₂ condition 氧含量低	Discourages CO ₂ and NO ₂ release 降低CO ₂ 和NO ₂ 排放量	Encourages N ₂ release 促进氮气的排放
Saline condition, high SO ₄ ²⁻ 含盐量、硫酸根量高	Lowers CH ₄ generation 甲烷生成量低	

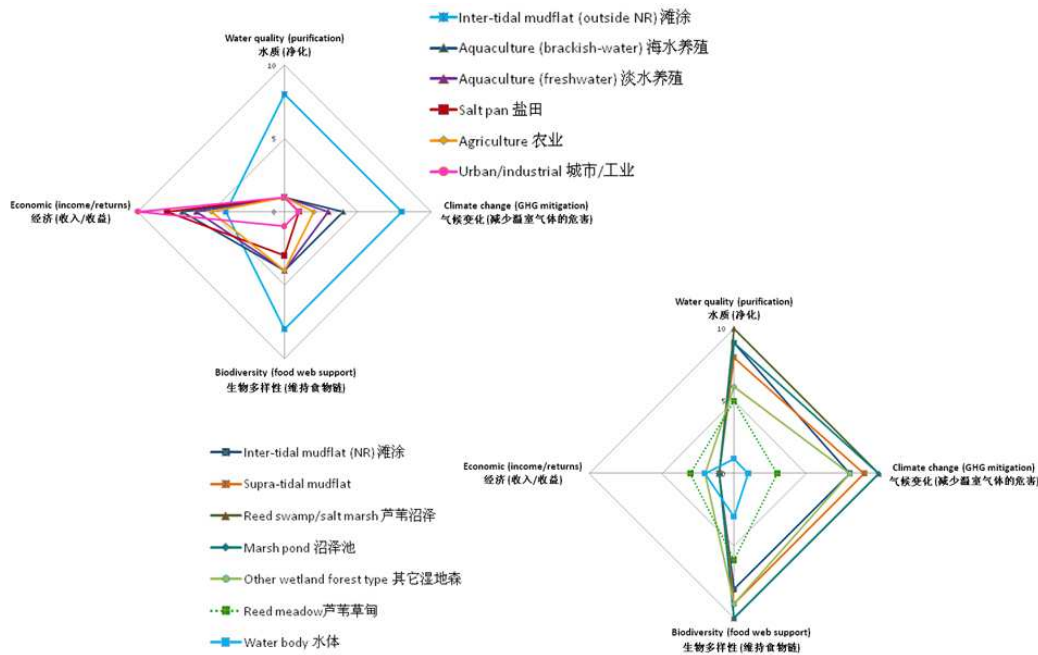


Figure 13. Standardized rating scores on wetland ecosystem services for different land use types.

The geographical location of the natural wetlands at the Yellow River estuary and along the coast versus conversional use of wetlands further inland provides the sharp contrast seen when the indicator scores are mapped (Figure 14), particularly for the water purification and economic indicators. The direct economic value of the nature reserve area is low compared with other areas where economic activities are carried out. In the case of the economic criterion, the production values of the urban and petroleum sectors were not included because the disproportionately high values of these sectors would distort the standardized scoring scale used. Correspondingly the highly urbanized area of the capital of Dongying and the concentration of oil platforms north of the Yellow River estuary (greyed out polygons) were omitted from mapping the ratings scores.

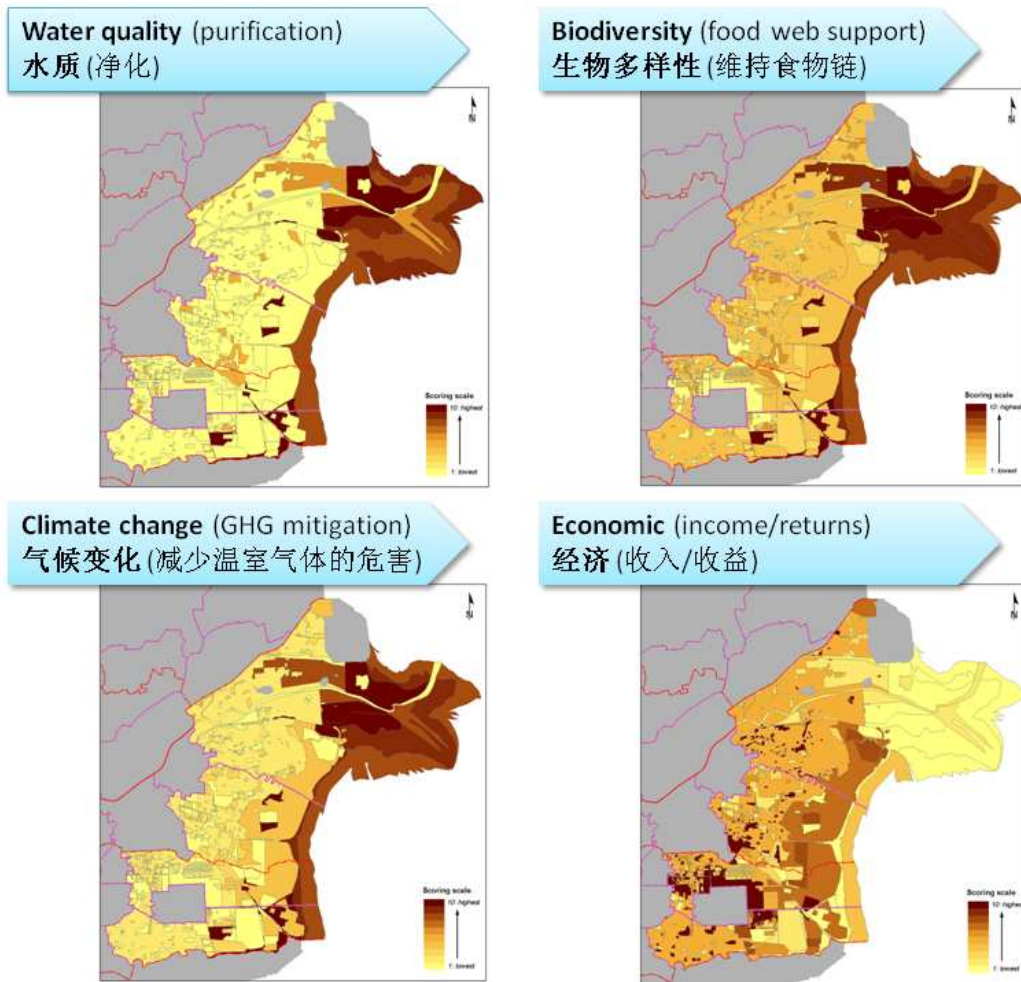


Figure 14. Mapped results of standardized rating scores on wetland ecosystem services for different land use types.

For the other criteria representing ecosystem services associated with indirect use values, the natural wetlands areas rate highly. There are areas outside the nature reserve that were rated as providing reduced ecosystem services, particularly the manmade wetlands such as aquaculture ponds. There is scope for reducing the negative impacts and enhancing these ecosystem services if these areas are managed more sensibly.

Figure 15 shows the output of the four criteria maps combined with equal weighting to obtain an overall score for the four ecosystem services. It shows that if the non-economic aspects of wetlands ecosystem services are given equal consideration as the direct economic use, the natural wetlands have higher overall importance in delivering these services. Even when greater emphasis (50% weight) is given to the direct economic use criterion, the overall value of natural wetlands is still substantial (Figure 16). The key message is that if due consideration is given to the wetlands ecosystem services, the natural wetlands of the YRD warrant safeguarding and enhancing the environmental conditions to ensure their continued survival.

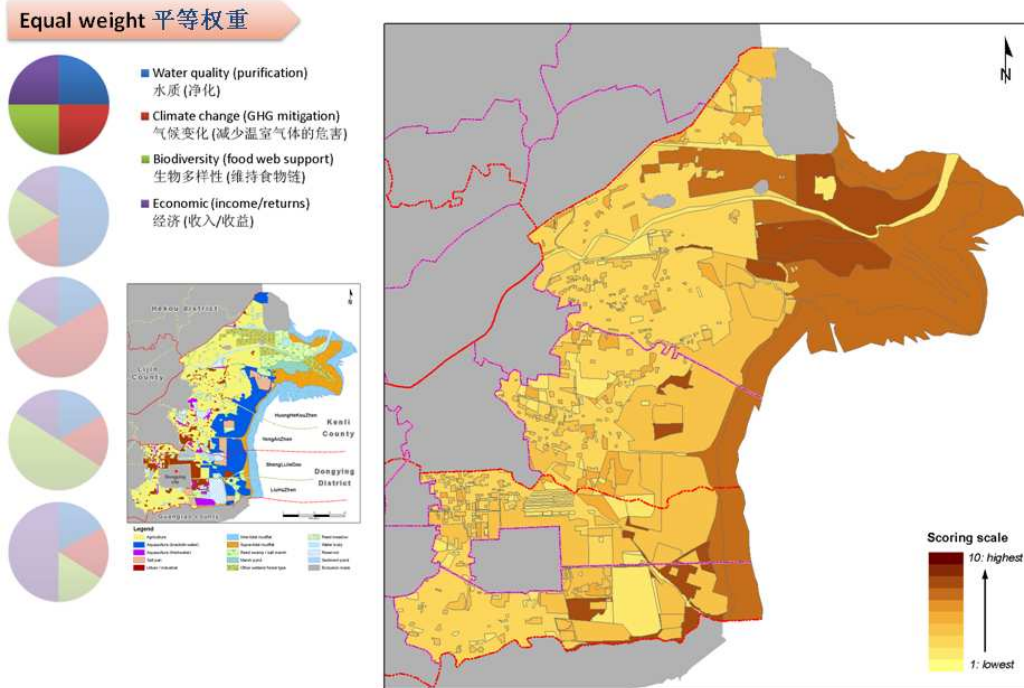


Figure 15. Overall rating of wetland ecosystem services for different land use types, with equal weighting for the four criteria – direct economic value, water quality regulation, climate change mitigation and biodiversity support.

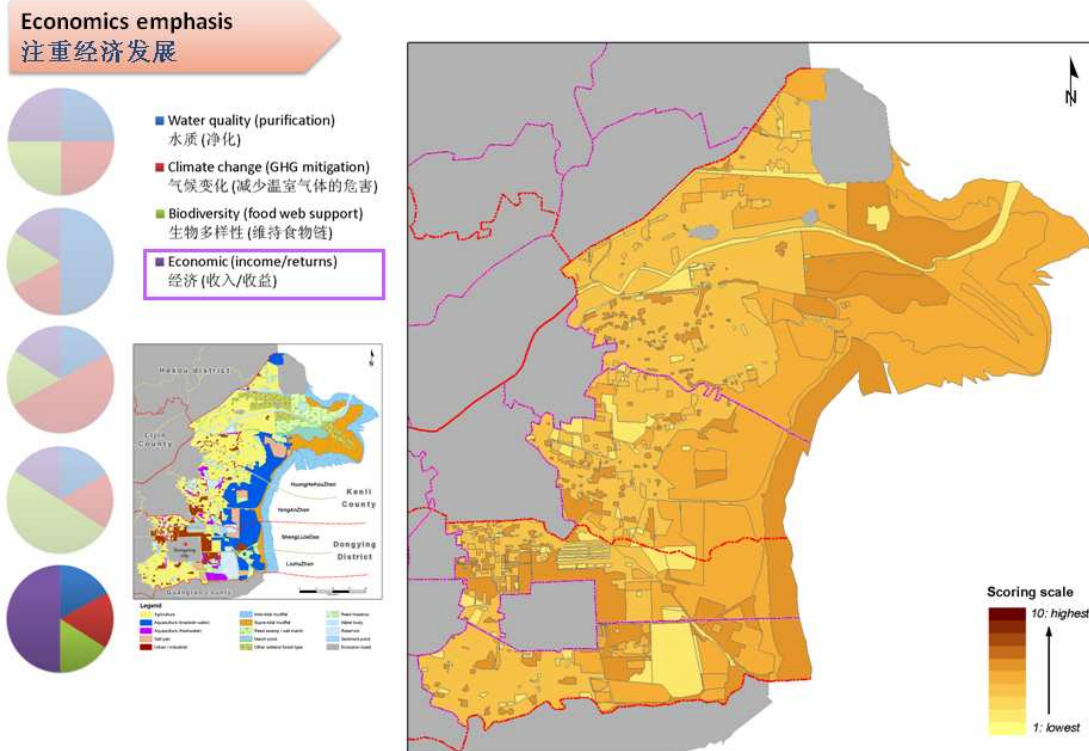


Figure 16. Overall rating of wetland ecosystem services for different land use types, with 50% weighting for direct economic value and the remaining 50% equally weighted among the other criteria - water quality regulation, climate change mitigation and biodiversity support.

4.3. Discussion

Wetlands are fragile ecosystems whose health depends on continual nourishment in the form of sediment to build its soil base and water to supply the semi-aquatic and aquatic habitats of plant and animal communities. The recent history of reduced water flow in the lower Yellow River and its impact on the wetlands ecosystem proves this point. Increasing withdrawal of water from upstream stretches of the Yellow River reduced its discharge into the sea starting in the mid-1980s, causing freshwater marshes in the estuarine wetlands to degrade and disappear. Careful monitoring of a subsequent 10-year ecological restoration project in the Yellow River estuary proved that a sustained supply of freshwater is key to maintaining the health of wetlands in the Yellow River delta (Shan and Lu, 2007). The health of delta wetlands depends on and is influenced by surrounding and upstream land and water use.

Opportunities to improve the management of the wetlands of the Yellow River delta hinge on recognizing the broader ecosystem services of wetlands, both natural and manmade, and how their value can be enhanced. The following recommended strategies can, if there is political will to undertake them, increase the chances of sustaining the wetlands and improve the general environment of Dongying in line with its vision of balanced development.

4.3.1. *Enhance the benefits of the nature reserve*

A more complete valuation of ecosystem services can strengthen the argument for continued conservation of the wetlands nature reserve and dispel the notion that wetlands are wastelands. The richly diverse coastal wetland habitats that are kept in pristine condition in the core reserve offer a veritable outdoor laboratory for conducting research locally that can help scientifically quantify the various indirect benefits of coastal and estuarine wetlands in the temperate zone:

- a) Biologically, wetlands are natural gene banks for plants and animals and recruiting grounds for commercially important fish species.
- b) In their regulatory role, wetlands retain and recycle nutrients and purify water.
- c) Toward mitigating global warming, wetlands absorb carbon and thereby reduce emissions of the greenhouse gases carbon dioxide and methane.

Local awareness of these ecosystem services of the Yellow River delta wetlands is low, mainly because they are hard to perceive or systematically quantify. Studies conducted on similar wetlands elsewhere have firmly established, for example, the important roles of wetlands in recruiting fish and other aquatic species that support fisheries and in regulating water flow and quality. As indicated in Table 8 and Table 9, studies conducted elsewhere indicate the important roles that wetland types, similar to those occurring in the YRD, play as nutrient and carbon sinks. The role of wetlands as carbon sinks is gaining prominence in light of global warming, and has important economic implications. As shown in Table 9, the carbon sequestration rate per m² of the tidal salt marsh is even higher than that of tropical mangroves and estimated to be 100 times that of tropical forests.

Scientific evidence generated locally will strengthen the case for ensuring that the freshwater flow from the Yellow River is adequate to continue nourishing these wetlands despite competing demands on the river's water resources from users in nine provinces upstream. It will back the claim that temperate coastal and estuarine wetlands should be eligible for credits under Reducing Emissions from Deforestation and Forest Degradation (REDD) schemes, thereby financially rewarding the conservation of carbon-sequestering wetlands. Precedents exist. The role of upland forests in GHG mitigation is now widely

accepted, qualifying many developing countries to participate in REDD schemes. Mangrove conservation has recently been made eligible for REDD funding on the strength of substantial evidence of mangroves' mitigation of climate change. As many of Asia's temperate coastal wetlands are in China, much of making the case for their eligibility for REDD-like schemes must come from that country. This makes the Yellow River delta even more valuable as an outdoor laboratory.

4.3.2. *Green the economy*

Opportunities exist for further greening the economy of Dongying, augmenting the city's ecological and economic strengths, and reducing the impact of development on natural wetlands both within and outside of the reserve.

Low-impact and biodiversity-enhancing agriculture needs to be encouraged, particularly in and near the reserve. This entails selecting crops and cropping practices with lower demand for water and creating an agroforestry landscape that offers habitats attractive to birds. It was observed by staff of the YRDNR authority that bird diversity declined outside of the core nature reserve when farmers shifted from grains and soybeans to cotton, which consumes a lot of water and is ecologically more sterile. Forestry bureau plans to plant more trees in belts and along roads and canals can be coordinated with plans for encouraging agricultural diversity and organic farming to establish a landscape of diverse vegetation without compromising the economic benefits from agriculture and agroforestry. Remnants of wetland meadows that have been drained can be revived to restore some ecosystem services such as water regulation and purification while attracting birds and other aquatic life that can enhance the appeal of the rural landscape.

Low-carbon aquaculture can provide good economic returns with a small carbon footprint. There is already a move away from dominant shrimp aquaculture, which is fraught with disease problems, toward culturing more diverse aquatic organisms including crabs and sea cucumber. This move opens up opportunities for introducing low-carbon aquaculture of species that feed low on food chain, such as sea cucumber. That sea cucumber requires good water quality is an impetus for sound environmental protection and management of the land and sea around the culture area. Farming shellfish such as oysters and mussels is not only good business but also helps clean coastal waters and sequester carbon. Culturing algae and seaweeds, which are at the bottom of the food chain, converts carbon dioxide into green matter with high market value as health food.

Cleaner industries that create less water pollution can reduce threats to the health of natural wetlands and pond aquaculture. While the mainstream of the Yellow River and its large and medium-sized reservoirs have fairly good water quality, meeting Grade 3 of China's Environmental Quality Standards for Surface Water (usable for swimming and purification into drinking water), agricultural runoff and industrial effluents render the water of small associated rivers too polluted for Grade 5 (agricultural and general landscape uses), which means it is essentially useless. Establishing cleaner industries and strictly enforcing sound environmental protection guidelines such as those established by Shengli oilfield are necessary to reduce water pollution.

4.4. Conclusions

The approach adopted in this study has been effective in terms of actively engaging local stakeholders in the process of evaluating the impacts of land use on the wetlands ecosystem services. In doing so, it constituted a first step in heightening their awareness about ecosystem functions and services of the wetlands in their vicinity. Without being thoroughly quantitative (given constraints of data availability and time), but by presenting outputs in maps, the study has been able to flag key issues relating to the

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management of the wetlands and other land uses in the Dongying context effectively to key stakeholders. It is hoped that the project's outputs provide sufficient impression on the stakeholders to take more serious consideration of the value of their wetland resources and sufficient motivation for the relevant agencies to undertake more in-depth studies along the lines of the recommendations that we have made.

Protecting wetlands does not have to mean depriving people of opportunities for economic benefits. Carefully chosen economic activities can coexist with natural wetland conservation and, further, complement the ecosystem services that the wetlands provide. This can help realize the "highly efficient eco-economy" that Dongying municipality envisions, and for it to be a model for emulation elsewhere in China and around the world.

5. OUTCOMES AND IMPACTS

5.1. Proforma

Summary Description of the Project's Main Impact Pathways

Actor or actors who have changed at least partly due to project activities	What is their change in practice? I.e., what are they now doing differently?	What are the changes in knowledge, attitude and skills that helped bring this change about?	What were the project strategies that contributed to the change? What research outputs were involved (if any)?	Please quantify the change(s) as far as possible
General changes in knowledge and practice of provincial level agencies as a result of project activities:				
Dongying: Water Conservancy; Forestry Bureau; Shandong Yellow River Delta National Nature Reserve Conservancy; Development and Reform Commission; Tourism Board; Ocean and Fishery Bureau; Municipal Bureau of Land and Resources	<p>Greater consideration given to wetland ecosystem functions in considering activities that will take place in the wetland areas of the Yellow River Delta at Dongying.</p> <p>Interest in conserving wetlands as potential carbon sinks and means of trading in the future under the REDD.</p>	<p>Increased knowledge of wetlands as functional ecosystems rather than 'wastelands', and the connection between wetlands and climate change.</p> <p>Increased familiarity with the delineation of zones within the Nature Reserve and the need to consider the validity and feasibility of zonation.</p> <p>Awareness of a range of possible development scenarios, based on differing priorities, and the trade-offs that have to be made to</p>	<p>Representatives from government agencies were involved in the project from inception to completion. Workshops and meetings were held at regular intervals throughout the 2 year project. The meetings were designed to share information, which employed participatory methods to encourage stakeholders to identify wetland functions and define priority areas for action.</p> <p>In Dongying, the project focused on the creation of a range of scenarios based on development criteria favouring water purification</p>	

		achieve development objectives and conservation needs.	functions of wetlands, food web support, greenhouse gas mitigation and economic returns, and a combination approach that gives equal weight to all criteria. The visual presentation of the scenarios was well-received by stakeholders who appreciated the clarity of maps produced as a tool for decision making.	
Sanmenxia: Agriculture Bureau; Shan County Water Conservancy Bureau; Hubin District Agriculture Bureau; Water Conservancy Bureau; Yellow River Office; Municipal Bureau of Land and Resources; Development and Reform Commission; Forestry Bureau; Mianchi District Water Conservancy Bureau; Minachi District Fishery	The principal change in actors in Sanmenxia is recognition of the needs of local people who are vulnerable to environmental change and show a dependency on former and present wetland resources within the nature reserve. During workshops and evaluation interviews, stakeholders expressed surprise at the level of importance of wetlands to the livelihoods of local people, particularly those with few alternative options. The need for clean ground	As a result of the project, local government agencies have an increased awareness of the nature of the livelihoods of local people, and the linkages between environment and livelihoods, particularly for the most vulnerable communities. The project also reported the preferences of local communities for a range of wetland functions and	The project emphasized an inter-disciplinary approach to understanding the context of wetland resource use and management. As a result, a detailed analysis was presented of the range of activities in which communities living close to the Yellow River are engaged, the available natural resources they use to support their livelihoods, the diversity of flora and fauna and the relative value placed on ecosystem	

<p>Station; Hubin District Agriculture Bureau; Sanmenxia Development Zone; Lingbao County Agriculture Bureau; Municipal Fishery Station</p>	<p>water, as expressed by local communities, was also taken up by the relevant agencies.</p> <p>Stakeholders will give greater consideration to the needs of local people, and the need to conserve importance wetland functions in future planning for the area. Tourism and the maintenance of habitat that attracts the white swan to Henan were of particular importance. The reclassification of zones within the Nature Reserve will be considered, and the management and jurisdiction of the NR reviewed. However, zonation in the NR is decided at the national level, and will require further discussion and negotiation before change can take place.</p>	<p>services, which highlighted a preference at all case study locations for clean ground water.</p>	<p>services by the community.</p>	
<p>Yellow River Conservancy Commission (YRCC)</p>				
<p>Changes in individual actors (in addition to changes described above), as reported during in-depth evaluation interviews at project closing:</p>				
<p>Chief, Sanmenxia Fisheries Bureau</p>	<p>Consideration of livelihoods of communities when designing policies or recommendations.</p>	<p>As above</p>	<p>As above</p>	

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	<p>Support to communities through extension work, including provision of economically important species for culture and training of farmers. Assist farmers to increase incomes and reduce wetland dependency.</p> <p>Support plans for infrastructure improvement for communities, including roads, electricity and water access.</p> <p>Future work will emphasize protection of wetland resources.</p>			
Station Chief, Lingbao County Agriculture and Fishery Administration	<p>Work with farmers living within the NR and using wetland resources to identify agricultural practices and crop production that sustain wetland functions and respect the zones within the NR.</p>	<p>Raised awareness of the importance of the wetland and the Sanmenxia Nature Reserve.</p> <p>New knowledge about the Sanmenxia Nature Reserve and the functions of the different zones within the NR.</p>	<p>Representatives from the Agriculture and Fishery Administration were involved in the project from inception to completion. Workshops and meetings were held at regular intervals throughout the 2 year project. The meetings were designed to share information, but also using participatory methods to encourage stakeholders to identify wetland functions and define priority areas for action.</p>	

<p>Chief, Dongying Ocean and Fishery Research Institute</p>	<p>Including voices and opinions of a broader range of stakeholders, including researchers at the Bureau and local communities, in deciding how research should be conducted and in gathering information.</p>	<p>Familiarity with a participatory research approach.</p>	<p>Inclusion of stakeholders in training in participatory research methods, and first-hand experience working with local communities and a multi-disciplinary, international team of researchers.</p>	
<p>Changes in national research partner, Chinese Academy of Fishery Science (CAFS):</p>				
<p>Researcher; Research Assistants (CAFS); Graduate Students, Shanghai Ocean University</p>	<p>Research assistants reported that the project had an important impact on the way they will conduct research in the future. A lead researcher and two RAs who participated in in-depth evaluation interviews commented that the participatory methods, particularly mapping exercises and historical timelines, were particularly interesting and useful and provide important information to support data collected using questionnaire survey techniques.</p> <p>Both research assistants and graduate students commented on the step-by-step approach to research that the</p>	<p>The research team developed skills in research planning and participatory research.</p> <p>Knowledge of wetland ecosystems was increased for all team members.</p> <p>Team members learned about the livelihoods of low income, rural households who live in close proximity to the Yellow River.</p>	<p>The project placed a great deal of emphasis on capacity building. Training in livelihoods analysis, the application of participatory research methods and interview techniques was made available to members of local government agencies as well as the CAFS team. All members of the research team were actively involved in the identification of research priorities and the design of survey instruments for the multi-disciplinary analysis in Sanmenxia.</p> <p>The CAFS team were engaged in</p>	

	<p>project used, an approach which was new to them and which they were keen to use in the future. They were also keen to incorporate the views and opinions of a range of stakeholders in their future research.</p>		<p>regular field visits to wetland locations in both Henan and Shandong provinces, giving them first-hand experience in the application of participatory research techniques. This also gave the team an opportunity to interact regularly with communities using the wetland resources and the local agencies managing the resources.</p>	
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Of the changes listed above, which have the greatest potential to be adopted and have impact? What might the potential be on the ultimate beneficiaries?

The idea of developing low-carbon aquaculture technologies is most likely to be pursued by the Dongying Ocean and Fisheries Research Institute. The Institute’s Director, who is also the strongest supporter of the project, has expressed strong concern about environmental issues that will impact the aquaculture sector, and is also mindful of the problem and risk of over-dependency of shrimp as an aquaculture product because of recurring disease problems. The Institute is already researching on and demonstrating diversification of aquaculture products including sea cucumber and mud crab culture, and would be amenable to embrace principles of reducing the carbon footprint and mitigating climate change impacts through judicious selection of culture species and testing of more environmentally-friendly practices. The ultimate benefits to the aquaculture farmers would be lower levels of risk and increased market opportunities by diversifying their products.

What still needs to be done to achieve this potential? Are measures in place (e.g., a new project, on-going commitments) to achieve this potential? Please describe what will happen when the project ends.

There is scope for closer collaboration between the Chinese Academy of Fisheries Sciences (the national research partner in this project) to bring in the research resources to support the local research institute. At this point there are no on-going commitments nor a new project proposed yet to move this idea along. The collaboration initiated as a result of this project between the two institutions opens up opportunities for their joint effort to pursue a research program to take the idea further along to actual action.

Each row of the table above is an impact pathway describing how the project contributed to outcomes in a particular actor or actors.

Which of these impact pathways were unexpected (compared to expectations at the beginning of the project?)

The impact of the project in raising the awareness and knowledge of the provincial-level stakeholders about the importance of wetlands ecosystem functions, and their receptiveness towards more engagement with local communities using participatory tools, were quite unexpected.

Why were they unexpected? How was the project able to take advantage of them?

As many of the provincial stakeholders are with agencies responsible for management of the natural resources associated with land and water in the agriculture and aquaculture sectors, it was initially expected that they would have a generally higher level of understanding ecological functions of the wetlands on which their clients depend. At the initial stages of the project when participatory tools were introduced for our field studies and stakeholder consultation sessions, we sensed discomfort and resistance on the part of the local partners who stand by official statistics collected in the usual officious, top-down manner and formal briefings from prepared texts, facts and figures.

We were able to take advantage of the new insights and interests expressed by partners and stakeholders to highlight the virtues and potential of harnessing the wetlands ecosystem services. For example the notion that the carbon sequestration role of the coastal wetlands can potentially reap economic benefits through REDD-like schemes was particularly appealing to the local authorities.

What would you do differently next time to better achieve outcomes (i.e. changes in stakeholder knowledge, attitudes, skills and practice)?

The project faced barriers in bringing our partners from the Chinese Academy of Fisheries Sciences (CAFS) to the WorldFish headquarters in Malaysia to provide on-the-job training and to engage them more closely in the data processing, consolidation and analysis work despite having budgeted for this purpose and provided the funds to CAFS, because of overseas travel restrictions imposed on CAFS staff throughout 2009. This weakened an important link in the capacity strengthening chain that CAFS researchers provided between WorldFish researchers and the local partners. In hindsight, we could have circumvented the problem by having WorldFish handle that part of the CAFS budget targeted for the working visits of CAFS staff, but this constraint could not have been foreseen.

5.2. International public goods

Insights gained from research findings at the Dongying site regarding the challenges of managing wetlands in the face of aggressive economic development can help in anticipating trends and issues that are likely to be encountered in other developing countries. The strategies and avenues identified for Dongying to reduce impacts on and enhance benefits of wetlands ecosystem benefits while greening the economic sectors are applicable to similar situations elsewhere.

At the technical level, the project compiled guides on conducting integrated and participatory field investigations, with Chinese translated versions, that were used for training partners and conducting the field surveys in the Sanmenxia site. For the Dongying study, the project developed research techniques and computer programs to

enable real-time GIS mapping of expert inputs that have proven to make elicitation sessions more efficient and meaningful for the participants. These techniques and programs can be readily adapted to other similar research situations.

5.3. Partnership achievements

This project has nurtured further the partnership between WorldFish and the Chinese Academy of Fishery Sciences (CAFS) and introduced to the Chinese partners a range of participatory tools for conducting field surveys and engaging stakeholders in consultations. Although not new, participatory methods are not intrinsic to the Chinese research culture. Our Chinese partners demonstrated an openness and keenness to learn these approaches that were novel to them and their feedback regarding this skills enhancement opportunity that this project has provided has been positive.

This project has also helped in strengthening the partnership between CAFS and the Henan Fisheries Bureau, which started in an earlier project involving WorldFish-CAFS collaboration as well. Besides, this project initiated partnership between CAFS and provincial agencies in Dongying. In both cases there developed camaraderie among the national and provincial partners that eased cooperation and mutual learning in trying out more participatory research approaches and methods within the Chinese context.

An evaluation exercise conducted at the end of the project revealed appreciation and value placed by local partners in both the Sanmenxia and Dongying study sites on the first international partnership they had engaged in, and the learning gained on new knowledge and techniques that they would attempt to use in their future work.

The project team also initiated and maintained contact with the Yellow River Conservancy Commission (YRCC), the Basin Coordinator for the Yellow River basin as a benchmark basin under Phase 1 of the CPWF. The YRCC provided information on the water levels in the Sanmenxia reservoir. The YRCC was also represented at the mid-term and final workshops in Beijing.

5.4. Recommendations

Despite the contrasting features of the wetlands and management issues of the two study sites in Henan and Shandong provinces, there are some commonalities as well. In both sites the ecosystem health of the wetlands is influenced by the hydrology of the Yellow River and modifications to its flow. In both sites areas of wetlands have been designated as nature reserve primarily for aquatic bird conservation, with legally-delineated core, buffer and experimental zones. In practice historical use of the land and wetland resources within the nature reserve boundaries renders the official use designation of these zones impractical. Except for the core zone of the Yellow River Delta Nature Reserve, there is lack of clarity in the function and management of the nature reserve zones. This is confounded by the multiple institutional jurisdiction with regard administrative and technical management of the wetlands at both sites.

Besides the specific recommendations listed in sections 3.3 and 4.3 for the two study sites, some recommendations of a more general nature are provided below.

5.4.1. Increase understanding of wetlands ecosystem functions and services

Quantitative valuation of wetland resources and ecosystem services requires solid scientific data, which is generally lacking. Research is needed to elucidate the roles of wetlands in

- recruitment and food web support for living aquatic resources particular species of food and commercial importance;

- regulation of water resources, both in terms of quantity and quality; and
- greenhouse gases mitigation.

Scientific studies are being carried out to survey and inventory the fisheries resources in the Yellow River. Adding an ecological dimension to such biological studies would enhance the utility of the research efforts. Investments to support such scientific studies will help provide the evidence to strengthen justification for maintaining the ecosystem health of the wetlands. This is particularly important in the case of the Yellow River where demands on its water resources for both the rural and urban economy are very high that maintenance of environmental flows is often challenged. The argument for making eligibility claims on international programs to support mitigation of climate change impacts such as the Reducing Emissions from Deforestation and Forest Degradation (REDD) can be compelling for investing in scientific studies to produce the evidence. The existing nature reserves covering wetland areas, including the Yellow River Delta Nature Reserve, are veritable outdoor laboratories for conducting such scientific studies.

5.4.2. Evaluate impacts and enhance ecosystem services of natural and manmade wetlands

More in-depth studies are also needed on the use and impacts on wetlands ecosystem services and ways of enhancing these services. The Sanmenxia study highlighted the importance of bringing in livelihoods aspects in researching and evaluating the economic sectors that are dependent on wetlands, such as fisheries and aquaculture.

In the case of aquaculture there is ample scope for researching and demonstrating technologies and practices designed for low-impact aquaculture production systems that have low carbon footprint, in freshwater, brackish-water and marine regimes. China has a strong and amply-funded scientific research base for orienting research priorities towards such strategies.

5.4.3. Adopt a pragmatic approach in the conservation and management of the wetlands

The circumstances of the two nature reserves studied reflect a broader, nation-wide phenomenon whereby current protected-area regulations stipulate strict definitions when in reality almost no protected areas conform to them (Xu and Melick, 2007). Human exclusion from conservation areas is therefore impractical in most parts of China except in very special areas where new pristine ecosystems are still being formed such as the Yellow River estuary. This very uniqueness of the core nature reserve at the Yellow River estuary warrants strict conservation and a strong commitment to ensure its healthy growth. In most other areas, strict exclusion particularly of dependent local communities is not an option; rather engaging them in sustainable practices and providing the appropriate incentives for community-assisted management of the wetlands would be a more practical and viable strategy. Taking such a strategy would be consistent with the new conservation approach in China to have ecological function conservation areas. The aim is to provide coherent guidance to land use across certain critical ecological zones. These management zones may overlies existing reserves within which there are already settlements and a wide range of human activities such as the Sanmenxia Wetlands Nature Reserve as well as parts of the Yellow River Delta Nature Reserve outside of the core zone. The specific recommendations on possible management strategies provided in sections 3.3 and 4.3 are in line with this new approach.

5.5. Publications

Publications, including working paper, policy brief, journal, theses and other tangible outputs (e.g. presentations and training materials) based on the research work conducted under the project are listed below. Digital copies of these publications are submitted separately from this report.

Working paper

Kam et al. (work in progress³). Synthesis report on the status of information about the wetland study sites.

Policy brief

Kam, S.P. 2010. Policy brief on the management of wetlands in the Yellow River basin.

Journal article

Hou, X.L. and Fan, E.Y. 2010. The Conflict and Coordination of Economic Development and Ecological Protection: a Case of Yellow River Wetland Nature Reserve in Sanmenxia. *Hunan Agricultural Sciences (in Chinese with English abstract)*.

Huo, X.W. The present status of Dongying wetland utilization for aquaculture development and it's environmental impact analysis. *Jiangsu Agricultural Sciences (in Chinese with English abstract)*.

Theses

Huo Xiang Wei. 2010. The environmental impact analysis study of Dongying present status of wetland aquatic resources development and utilization. Master thesis submitted to Shanghai Ocean University, China.

Hou Xiao Lei. 2010. The research on protection of wetland and the sustainable development of district in Sanmenxia. Master thesis submitted to Shanghai Ocean University, China.

Powerpoint presentations

Kam, S.P. 2008. Progress of the project presented and main research issues highlighted at the Second International Forum for Water and Food, Addis Ababa.

Kam et al. 2009. Summary of the Sanmenxia wetlands and management issues.

Kam, S.P. 2009. Basis for evaluating the ecosystem services of the coastal wetlands in the Yellow River delta.

Training materials

Kam, S.P. and Teoh, S.J. 2008. User guide for GPS data collection.

Guides on participatory tools for field surveys (in English and translated into Chinese).

Guides on participatory approaches for livelihood diagnosis.

Guide on Tools for Compilation and Analysis of Livelihoods Survey Data.

Write-shop Guide for Capturing Knowledge.

³ Publication intended to be published in the second half of 2010

Web site

URLs for

(a) public viewing:

<http://sites.google.com/a/cp1105-worldfish.org/china-wetlands>

(b) project team access:

<http://sites.google.com/a/cp1105-worldfish.org/china-wetlands-member/>

User guide to provide instructions using and updating the contents of various pages in both public viewing and team accessed website.

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Through knowledge creation and awareness-raising, the project will inform and provide the basis for relevant and concerned stakeholders (policy makers, provincial and local authorities, line agencies and resource managers) to duly account for the value of wetland LAR in land use and water policy and planning initiatives.

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