11. Conclusion and interdisciplinary recommendations

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11.1 Internationalisation: A healthier planet

On a global scale, water problems stem from our failure to meet basic human needs, ineffective institutions and management and an incapability to balance human needs with the needs of the natural world. These difficulties are imbedded in a wasteful use of water, characterised by poor management systems, underinvestment and unseemly economic incentives, failure to apply existing technologies and an outdated mind-set focused almost wholly on developing new centralised supply chains. This is to the exclusion of conservation strategies in which the delivery of water-related services matches user needs and resource availability (Pacific Institute 2014). Our interdisciplinary research team compliments the growing worldwide trend of focusing on efficiency and restoration measures, at all levels, to create sustainable communities and a healthier planet.

This book has presented a number of examples of exploring sustainable water management and sound strategies for wetland restoration. In a combined effort, we have specifically researched these two topics, over the past four years, from a multi-scientific standpoint. These two topics have predominantly grown in-parallel and, in anticipation of our findings have indicated otherwise. We have learnt, to some degree, that from an

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interdisciplinary point of view they touch base and, their relationship, begins to show characteristics that intertwine at a conceptual or theoretical level. These characteristics indicate a cohesive past, present and future-based manner of reasoning, and point toward a societal transition to better understand sustainable action and its relating pathways.

Sustainable water management primarily looks at water as one of the basic needs for survival. Literally, water is life due to the fact that virtually no species can survive without it. While, wetland restoration focuses on the rehabilitative capability of such land that has been degraded or destroyed. For both topics, land preservation and conservation are a key to establish a harmonised viewpoint and a supportable generational-friendly future. Interdisciplinary recommendations for a sustainable water management scheme – inclusive of wetland restoration strategies – is developed throughout this chapter. A brief look into northern China examines the significance and sets the tone for the recommendations that follow.

11.1.1 Insight: Water crisis in northern China

As noted throughout this book, in northern China there is a growing pressure on water resources. This pressure effects environmental well-being, social parity and economic progress. Northern China is not immune from its nation's rapid infrastructure development, pollution concerns or population challenges – as engagement programs throughout much of the north, and west for that matter, continue to date (Wu & Ci 2002; Dowling & Wignaraja 2006; Zhou et al. 2008; UNDP 2012). China, as a whole, is still modernising itself like many other wealthier countries did in the past half century – by growing first and, hopefully, cleaning up later. According to a UNDP (2012) report on sustaining human progress, the world cannot afford a China that follows this model. Mechanisms that can assist in alleviating this challenge include (1) agricultural production (i.e. changes primarily in growing crops, raising livestock, land use and deforestation); (2) fair and balanced consumption; (3) design and creation of greener cities and technologies; (4) raising rural resilience; and (5) support for cleaner energy generation (i.e. to reduce or eliminate pollution). To this end, northern China faces critical challenges that go well beyond water management and wetland restoration. However, these two topics offer some first-step insight or potential resolution to the growing concerns since issues of this magnitude are connected (i.e. from local to global in scale and structure).

11.1.2 Regional transparency: Central Asia

We contend the geographic study areas, based in northern China, have a degree of transparency with much of the neighbouring regions of Central Asia. This is due to the nature, or mosaic, of the landscapes, wetland environments and industry-related conditions region-wide (Kreuzberg 2005; Perelet 2007; Thevs et al. 2012). The extent of our recommendations, therefore, though specific to northern China, are not exclusive. Bordering Central Asian countries with China are especially pertinent as they share direct trade routes and important cultural and historical linkages. Moreover, the recommendations have a backdrop of complexity and diversity ranging from somewhat rural, poverty-stricken to booming-like urban municipalities. Northern China, and parts of Central Asia (as noted in Chapter 2), face this type of development crisis (Zhou et al. 2008; Zerbe & Thevs 2011; UNDP 2012).

11.2 Interdisciplinary recommendations: The science

The science behind our recommendations are based on rigorous scientific experimentation and are verifiable via methodologies that can be reproduced and tested. Much of the work has been published in international peer-reviewed scientific journals. The basis of this book and our research has followed this format as closely as possible, with little exception. The extent of this book is not to write policy, but to be a tool for decision-makers and management personal, in the study areas, working within the field of sustainable water management and wetland restoration.

The state-of-the-art of typical shallow macrophytic lakes in northern China (including Wuliangsuhai Lake, Baiyangdian Lake and Bosten Lake) is that they are at risk of shrinking or even disappearance. The shrinking of these water bodies is mostly due to human interference by way of resource utilisation. The disappearance combines the human factor, just mentioned, with reed and submerged plant overgrowth, which is due to eutrophication of the water and plant residual deposits. The key to keeping northern China's macrophytic lake areas healthy is the continual purification of the water quality by aquatic plants or by harvesting and utilising them. The basis of developing a sustainable water management scheme is to understand the science and to continue to monitor the issues.

The recommendations, first, start with a brief look at the complex political issues which demonstrate the difficulties of maintaining healthy wetlands and reed production. Second, an examination of anti-pollution based research, by way of environmental indicators, help strategise wetland restoration and conservation practice. Common reed, used as an example and key species throughout much of this book, is an important resource and component to sustainable living patterns in which local people are the beneficiary. Third, economic uses of reed are exemplified through different utilisation of plant stocks. Fourth, in conclusion a holistic viewpoint is argued.

11.3 Wetlands in China: Political frontiers

The political processes in China are complex, making it difficult to pinpoint solutions in an environmentally-stricken country. This is mostly due to rapid development by way of a strong economic and political drive. These political actions are not sustainable; infrastructure and economic goals are prioritised. The environmental ethics of comprehending the basic question "*Why preserve nature?*", argued in Chapter 1, debates this by stating human beings and future generations are and, most likely, will be dependent on the ongoing utilisation of nature (as a resource, reservoir, sink and medium) since certain states of it bring feelings of joy, pleasure, well-being, peace and delight. This understanding of nature puts forth a paradigm in which scientists, themselves, are challenged to uphold and prototype this basic question in their work. The SuWaRest project is no different. Working within China, scientific rules or norms, are mostly construed to data-mining based research. This poses somewhat of a problem when authorities are questioned or issues of political correctness arise. Local people are under a moderate amount of pressure not to intervene with any level of authority. This political clout needs to be looked at closer, if wetland environments, or any natural habitat for that matter, are to be conserved and preserved anywhere in China. Placing this argument aside, wetlands throughout China have had some national attention and conservation planning over the last few years – stating their importance and ecological benefits as key driving factors.

According to China's State Forestry Bureau (2014), the National Wetland Inventory Survey between 2009-2013 indicated the area of wetlands within Qinghai Province, Tibet Autonomous Region, Heilongjiang Province and Inner Mongolia exceed five million ha, which accounts for about 50 % of the total wetland area in China (i.e. 53.6 million ha). As a vital ecosystem, wetlands perform key ecological functions in these arid, semi-arid and semi-humid regions in which they conserve important water resources for down-stream users. Specific to this book, wetlands in Zhangye, Gansu Province and Wuliangsuhai Lake, Inner Mongolia represent two of the typical wetlands in the arid and semi-arid regions of northern China.

A large number of swamp wetlands exist in piedmont alluvial-diluvial fans adjacent to Tianshan Mountain, Qilian Mountain and Taihang Mountain from where groundwater is withdrawn and river discharges flow (UNESCO 2006). Along these passes there is a relatively high abundance of water resources. Cities are often densely located flanking alongside these piedmont areas. Some examples include cities like Zhangye, Jiuquan and Wuwei that are located in the piedmont of Qilian Mountain. Similarly, an economic zone composed of ten or more cities can be found along the piedmont of Tianshan Mountain where cities including Urumqi, Shihezi and Karamay are located. Finally, some large and medium-sized cities like Beijing, Baoding, Shijiazhuang, Xingtai and Handan are located along the piedmont of Taihang Mountain. In China, piedmont wetlands shrink and can even disappear due to damming of mountain passes. They also frequently suffer from groundwater overuse which can leave entire cities without water for extended periods (Appleyard 2007; Chen et al. 2008; Hubacek et al. 2009).

Unfortunately, the degradation does not end there, it has been reported that residual wetlands are often polluted from urban wastewater discharge (Lu et al. 2009; Jolivet et al. 2014), as noted by Borruso (2014) in Zhangye.

As a result of this over-development, the Chinese government has increased its attention towards wetland protection. Scientific research is one of the aspects these initiatives incorporate. Its goal of expanding wetland areas, as stated at the 18th National Congress of the Communist Party of China, is part of an important national ecological program (Hu 2012; MOFCOM 2012). A redline for wetland areas measuring 53.3 million ha has been put forward in a plan for the promotion of ecological progress (State Forestry Bureau 2014). In theory, as a result, the area of wetlands stated should be preserved until the year 2020 (i.e. all present wetlands should be reclassified as park land). This corresponds with a number of Chinese scientific studies that state any heightened period of development due to both human activity and climatic change, have an urgent need to budget key ecological systems and services, such as wetlands (i.e. rice paddies and natural wetlands) and lakes (i.e. inclusive of reservoirs and ponds), which are sensitive to these changes (Yuan et al. 2014; Feng et al. 2013; Chen et al. 2013; Wang & Liang 2013). Apart from national initiatives, from a research standpoint, the shrinkage of wetland areas due to overgrowth and residual sedimentation should immediately be monitored for any change in water quantity or functional level of water quality (i.e. water degradation).

At the national level, China has put forward the idea that the development of ecological progress should be combined with political, economic, social and cultural means. At present, there is a plan to develop a close relationship between ecological problems and society, economy, culture and institutions – and research, such as potential reed economies, the well-being for peasant farmers, water resource utilisation and pollution discharge from an environmental and ethical aspect be closely considered (Hu 2012). It focuses on solutions that integrate the perspectives of society, economy and culture – and research ideas and achievements to provide an important reference point for ecological progress being carried out China-wide (State Forestry Bureau 2014).

11.4 Anti-pollution: Environmental indicators and reed stand-based research

The two study sites investigated in northern China offered a vast assortment of data and results from a multi-array of scientific perspectives. In Zhangye, we find a modern city on its way to developing as an impressive industrial and tertiary-based conurbation. Zhangye's wetlands face problems with industrial wastewater pollution. While, the Hetao Irrigation District and Wuliangsuhai Lake are agricultural areas that have potential at becoming important recreational zones for ecotourism. They face serious concerns of eutrophication and salinisation. At large, these points are prime hurdles for the regions' environmental management and advancement. Both areas, unfortunately, have an intensified level of pollution due to industrial and agricultural activities. In consequence, a key question for local administrators, when dealing with these issues, is the assessment of its water purification systems. This can be better understood with the use of reed stand-based research. Much of the work within this book is formulated on these observations and their potential use of environmental indicators and relating linkages.

Ecosystem quality of wetlands, covered within Chapter 5, found that plant nutrient stoichiometry can be utilised as an indicator for ecosystem characteristics. Plant nitrogen and phosphorus stoichiometry research in contrasting reed ecotypes (i.e. from aquatic and terrestrial environments), concludes that reed can perfectly adapt to differing conditions with distinct leaf and root functional traits. Isometric biomass allocation patterns are also key. Suggestive resource acquisition strategies suggest that reed can be used as an important bioindicator for understanding and managing reed dominated wetland ecosystems. This conclusion complements the following recommendation from our microbiology studies.

11.4.1 Microbiological research: The use of bioindicators

Our microbiological research illustrates how bacterial communities are powerful bioindicators for different types of pollution. In Chapter 3 and 6, a better understanding of what kind of pollution, historically, effects the two study areas, as noted in Chapter 2, is disclosed using freshwater sediment examination. To date, this type of pollution assessment is one of the best methods when looking at past pollution data.

First, in Zhangye, nutrients like nitrogen and phosphorous are important study-pollutants in urban areas, together with cadmium and mercury, whose concentrations are strong enough to affect bacterial community diversity and composition. In industrial zones, several metals are very widespread, increasing the probability of dangerously impacting upon ecosystems and human population. The effects of these different pollutants decrease in agricultural areas and in the Heihe River. There is a significant presence of genes conferring antibiotic resistance. This genetic trait widely correlates with antibiotic use (i.e. probably from hospitals and clinics, but also husbandry) and metal ions pollution. Consequently, a quite diffused pollution level continues to influence the city area of Zhangye, even though a newly installed wastewater treatment plant ameliorates freshwater quality for urban use.

Collected reed stand samples from a nearby national park appear to be cleaner than other samples from around the city. Hence, it can be deduced that the phytoremediation potential of *P. australis*, and of its associated bacterial communities, are structurally similar to those from the cleanest areas of Heihe River Basin. Moreover, it is noteworthy to state that a strongly eutrophic pond on the outskirts of Wuliangsuhai Lake, in the middle of a highly polluted industrial area, contains a bacterial community quite similar to its adjacent agricultural areas (Borruso 2014). Since eutrophication is known to have an excess amount of nutrients, *P. australis*-associated bacterial communities that are located within typical cleaner areas, indicate that *P. australis* and other macrophytes are capable of water purification even in a very adverse environment. This is a positive point for

Zhangye's management and environmental advisory. On the west side of the industrial zone there are extended lowlands, only partially used as pastures. These areas can be used as a natural and extended reed phytoremediation plant zone that include already existing reed stands and could be adjoined as park lands or, similarly, as recreational areas.

Second, considering the Hetao Irrigation District, adjacent with Wuliangsuhai Lake, our focus has been on the main channel and one secondary drainage channel that leads up to the lake itself. Our analyses show a general good environmental quality, especially in the western part of the main drainage channel. We found this part of the channel with a vast coverage of *P. australis* stands. The presence of reed-covered areas decreased from the middle part of the main drainage channel, mainly due to a larger basin and livestock grazing. In this area, additional water from other drainage channels, some of that from nearby industrialised towns, decreased slightly due to freshwater sediment quality, without dramatically affecting overall ecosystem levels. The secondary drainage channel has been more influenced by human activities, since villages discharge their urban wastewater directly into the channel. A weak antibiotic resistance gene signal is evident in the middle part of the main drainage channel, signalling a worrisome concentration of antibiotics already in the environment. Our recommendation is to prolong the potential use of *P. australis* stands in cleaning these water systems. The growth and harvesting of reeds could also be extended along the main drainage channel, leaving free localised areas to allow for sheep and other livestock space water access. Together with a greener industrial behaviour, this will lead to an increase in water quality and decrease of Wuliangsuhai Lake's ecological stress. On the long-term, our recommendation is to continually monitor the areas and introduce an environmental impact assessment plan. Such a plan would become a key for environmental policies and should help administrators alike choose better strategies to increase health and future sustainability practices.

11.4.2 Wetland restoration strategies in northern China

Wetland restoration is a process that assists in transforming a degraded wetland area that has been impacted by human activities in order to re-establish certain ecosystem services (e.g. self-purification of water, reed production, tourism and recreation). The process might be long-term oriented and requires a detailed understanding of the environment. This includes the historical consideration of the area and its succession through time to better help decide how such a restoration process and its management are to be conducted. Success can be ascertained if the wetland area can recapture its natural dynamics and original ecosystem services. However, it is impossible to refashion ecosystems back to a virgin state, as nature itself is made up of the changing entropic elements that structure our planet.

Different types of wetlands require different strategies. In northern China, we have examined stream corridor and open aquatic lake systems in which fresh water environments exist. Differing restoration strategies depend on the degradation level (Timmermann et al. 2009). After having carried out restoration measures, a continual monitoring is crucial in detecting concerns before they develop into something unmanageable. Monitoring will involve biological, geological, hydrological, chemical and physical components of the wetland areas. Specific to northern China, wetland strategies and management should take into account material risk; that is, the restoration process should not have a material adverse impact on the accessibility of water, safeguarding of biodiversity, employment, local peoples and community or land access for agriculture.

Ecological concerns and physical restrictions are imperative when a scheme for wetland restoration or creation is planned (Lüderitz et al. 2010). Wetland restoration can nowadays be based on many decades of experience (VanAndel & Aronson 2006; Lüderitz et al. 2010). According to Kentula (2002), destroying the function of an existing wetland, or other ecosystem, in exchange for another wetland function encompasses numerous questions such as "*Which is more important, the existing or the replacement function?*", "*Will the proposed wetland increase wildlife diversity?*" and "*Is the increased diversity worth the loss of habitat of any endangered species?*" Questions of this manner always should be asked during the planning stages of any wetland restoration and creation blueprint. Zeng et al. (2012), Kusler and Kentula (1990) and Kentula (2002) have all reported wetland restoration as more of an art than a science; that is, its functional proxy has not been overwhelmingly corroborated. In northern China, the science and engineering of wetland restoration has two key probable factors that limit its effectiveness for a successful wetland restoration project: (1) lack of data on ecologically mature restored and created wetlands, and on the maturation process; and (2) the limited number of well-devised and well-constructed project wetlands that can be used as exemplar prototypes (Kentula 2002). Generally speaking, restoration is prospectively going to be more successful than a full-scale creation. Within the two study sites, the restoration of damaged or destroyed wetland areas will have a greater chance of establishing a range of prior wetland functions, if a monitoring program is incorporated. Our recommendation is a long-term persistent scheme in which the restored wetlands facilitate the potential use of *P. australis* reed stands in cleaning the waterways and wetland ecosystems. With this in mind, we briefly will touch upon the varying reed production in northern China and recommend it as a future-based resource for wetland restoration and ecosystem quality of such wetland restoration settlements.

11.4.3 Reed production: A resource for the future

With our long-term recommendation for restoring the studied wetlands with common reed, *P. australis*, a community-based viewpoint should be integrated with an economic one. For a restored wetland to co-exist primary reed production must have an outlet in which local communities and businesses can strive to survive on. The primary reed production areas of China are located in northeast China, northwest China (Xinjiang) and Inner Mongolia. Broken down, the large areas of reed are found in the Liaohe River Delta, Songnen Plain and Sanjiang Plain of northeast China; Bosten Lake, Ili Valley and Emin River Valley in Tacheng of Xinjiang; Baiyangdian Lake and Hengshui Lake of the North China Plain; and Hulunbeier

Grassland and Xilin Gol Grassland of Inner Mongolia. At the moment, the level of industrialised reed exploitation in these areas remains quite low (Köbbing et al. 2014a). Most of the reed is used for paper and straw mats (as stated in Chapter 8). Additionally, biomass technology has not yet been kick-started due to a lack of economic and inefficient utilisation of reed (Patuzzi et al. 2013a). Currently, the biomass approach of burning straw generates a large amount of air pollution and causes great concern for the environment.

Desperately needed research in reed resource utilisation – beyond the traditional use of it in China as fodder, mats, baskets, huts, construction material and fire starting material (Hansmann 2008a) – has more recently moved towards large-scaled paper production plants (see Chapter 8). However, even though reed is managed all over China, its most promising uses are its usability as an energy source (i.e. via combustion or ethanol), within environmentally-friendly paper mill manufacturing, natural water treatment plants and, in some cases, reed panels. Unfortunately, at the moment, none of these usages are economical and encroaching agricultural lands and urban and suburban limits continue to hamper sustainable water management and wetland restoration planning. An immediate recommendation, in accordance with the Report of the 18th National Congress of the Communist Party of China's (Hu 2012; MOFCOM 2012) wetlands initiative, is to implement this initiative as soon as possible, by way of state-wide preservation and conservation methods. In prospect of this accord, the following years should be ample time to implement a viable usage for reed production, while at the same time creating and implementing a stronghold wetland restoration program.

11.5 Economic costs and benefits for different reed utilisation

As stated previously in this chapter, reed is a plant with multiple functions and services in which many, to date, have been overlooked. Commercial utilisation of reed can raise awareness regarding the importance of wetlands, but should be also analysed regarding profitability under market conditions. In remote areas of northern China, to be competitive against cheap coal at the household or power plant level, reed biomass feedstock has to be exploited locally – to limit transportation costs – and subsidised by the government. According to our economic analysis performed, the evaluation of energetic use of reed under the scenario of local decentralised heating and large-scale cogeneration plants, even a 30 MW power plant could barely be profitable under current conditions. Presently, China's energy policy has focused primarily on large-scale power plant industry, many of them in the developed southeast. Small, decentralised projects, which are important for remote rural areas lack support. One reason for this shortfall from renewable energy is the pre-existing energy implementation law, in which refusal to the energy grid by big energy companies or technical handlings demonstrate the difficulties and irregularities for reed-based renewable energy. The dominance of state, coal-based energy prevents the growing of alternative decentralised – mostly renewable energy – bottom-up approaches.

Nevertheless, conditions may change. On the one hand, decreasing investment costs due to a high rate of innovation and increasing energy prices may positively influence the net positive value of combined heat and power production plants. Whereas, on the other hand, labour and transportation costs may augment due to the economic growth and rising energy prices. This would negatively affect the net positive value. Considering variable reed costs, a balanced benefit-cost relation for a 30 MW plant can be achieved if the reed price decreases, within the region, by 5 CNY/t (approximately € 0.60/t) to 365 CNY/t (approximately € 42.90/t). From the perspective of reducing greenhouse gas emissions, local utilisation should be favoured over long transportation distances. Benefits can be possibly increased by accounting the greenhouse gas emission mitigated by use of biomass energy under the Kyoto Protocol. Clean Development Mechanisms (CDM) in the United Nations Framework Convention on Climate Change are implemented to allow developing countries reducing their greenhouse gas emissions by financing mitigation projects in such countries. Each reduced ton of CO_2-equivalent can be traded as "Certified Emission Reduction" (CER) on the international carbon market. Renewable energy projects play only a minor role in CDM which are mostly restricted to larger scales, due to high transaction costs. Unfortunately, the price for CER trading experienced a rapid decline in recent years, accounting only for € 0.24/CER in November 2013.

Using the example of Wuliangsuhai Lake, if prices increase again, CDM could play a role in financing a reed cogeneration plant. Considering that the CO_2-emission factor for coal is 93 kg/MJ, an amount of 86.7 kg/MJ and 260,000 t of CO_2 could be saved considering the present and potential harvesting of reed in a cogeneration plant of 10 MW and 30 MW. In addition, considering a distributed energy cogeneration scenario suitable to generate the same two overall power levels, 92.5 kg/MJ and 309,700 t of CO_2 would be saved, respectively. Furthermore, non-market values could also be considered in a holistic management scheme in and around the Wuliangsuhai Lake area. Regular harvest of reed removes a considerable amount of biomass from the lake, which prevents a rapid silting and "second pollution" by way of decomposition. Also considering local employment during the winter season, reed cutting plays an important role, currently employing up to 2000 workers. Hence, the economic costs and benefits for different reed utilisation further supports our recommendations, for long-term restoration, of planting and utilising common reed in northern China's wetlands.

11.6 A holistic standpoint

The potential debates on possible water management schemes for the two research sites opens the argument to what has happened in the past, what currently is in practice and what future scenarios can be thought up. Management schemes should be sustainable and should include ideologies that embed local cultures. Our examination of the different "water cultures" has looked at sustainability concerns via differing methodologies (Chapter 9 and 10). Within a holistic viewpoint, water in settlements and agriculture have been intertwined within the SuWaRest project's interdisciplinary fields. They include (1) site, vegetation and restoration; (2) phytoremediation and water quality, including microbiological aspects; (3) energy production; (4) cost-benefit analysis of reed use; and (5) water culture and sustainability. From a holistic viewpoint, our recommendations are an alteration in the concept of water perception, value, attitude and utility at a societal scale. Successful conservation practice requires legal regulation but it also touches upon the background of culture itself, its habits, customs, traditions, modes of perception and framings. This is especially accurate within the merging highly diverse cultures that are site-specific, found throughout much of Central Asia. The use of technical skills in conjunction with managerial-based socio-economic thinking is an urgent matter. Environmental improvements, using up to date environmental standards, must continue to be validated and should ethically be substantiated, ideally, by way of local communities actively participating in decision-making processes. This would be a starting point towards a fully holistic outlook on sustainable water management and a better threshold point for the relating-settlements' wetland restoration.

Sustainable water management indicates a cohesive need to better fully understand environmental, social and economic aspects at play. This especially includes the alternative scenarios, as discussed in Chapter 10, which exemplifies future-based modelling from where it can take us to how it may fully function. Our final recommendation, and visionary goal, is for a strong sustainability of the two study sites. The existing opportunity to achieve such a goal, however, gradually is closing and will become virtually unachievable if continued weak sustainability, even worse, non-sustainability targets are reached. Our international and interdisciplinary team has strived to derive our recommendations in a hope that waters and wetlands in northern China, and beyond, adopt a sustainable management plan that has a holistic viewpoint for these, ever so, vital ecosystems.