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Strategies to cope with uncertainty in the development of water management practices in tidal areas

H.P. Ritzema[1]

[1] Assistant Professor, Wageningen University, Wageningen University and Research Centre, Wageningen, the Netherlands

Abstract

Throughout the world, tidal areas have been and are being developed. The initial development is generally for agriculture, often in combination with flood protection. These developments will continue as food production will need to be doubled in the next 25 years. The development focus in tidal areas is, however, gradually moving to ports, harbours, transportation routes, industries, and aquaculture, housing and recreation facilities. These developments can be a threat to the valuable natural resource functions of these tidal areas. For sustainable development appropriate land and water development strategies have to be developed. Models are often used to develop these strategies. These models normally require long-time data sets, which are often not available in emerging countries. New ways have to be found to address the shortcomings of traditionally validated simulation models. This paper presented case studies in Surinam, India and Vietnam in which the traditional validation process was replaced by joint plausibility discussions and shared vision building in order to improve the understanding of cause-effect relationships and proposals for water management measures. The aim was to match the tacit knowledge of the local stakeholders with explicit scientific knowledge in order to create a mutual basis for an integrated approach as opposed to single-issue measures and a mutual agreement on follow-up steps needed to sustain both the livelihood of the people as well as the natural resource functions. The participatory modelling approach proved to be a useful tool to obtain a consensus of opinions among the stakeholders.

Key words: tidal areas; sustainable development; integrated land and water management, participatory modelling

Introduction

The implementation of national water policies in tidal areas, which it's many and frequently conflicting land use functions, is a major struggle. A major challenge in planning improvements in the land and water management systems in tidal areas, especially in developing countries, is the general lack of (reliable) data sets, especially of long-term data records. Often there is not much time or funds to collect additional data on these hydrological and societal complex ecosystem. Organisational complexity and involving stakeholders are important constraints and at the same time important conditions for success. Collaborative or participatory research and social learning have become buzz words to tackle these issues. The concept of social (or collaborative) learning refers to learning processes among a group of people who seek to improve a common situation and take action collectively. It is also 'learning-by-doing'. Over the past decades progress has been made both on the social and technical aspects, but there is still a large gap between the views of the social and more biophysical oriented scientists.

To deal with this type of complexity, the decision-making process should be incremental, iterative and continuous (d'Aquino et al., 2002). Focusing on dynamics instead of results and focusing on wide-ranging analysis instead of quantitative data is a way to enable progress in complex, conflict-laden negotiations. Participatory modelling has emerged as a powerful tool that can (i) enhance the stakeholder's knowledge and understanding of a system and its dynamics under various conditions, as in collaborative learning, and (ii) identify and clarify the impacts of solutions to a given problem, usually related to supporting decision making, policy, regulation or management (Voinov and Bousquet, 2010).

Participatory modelling is a way of linking the tacit knowledge of local stakeholders with the explicit knowledge of researchers by incorporating all stakeholders, including the public and decision makers, into an otherwise purely analytical modelling process (Voinov and Brown Gaddis, 2008). Models are useful to get a better understanding of complex water management problems with many stakeholders and limited data records. Furthermore, participatory modelling is a useful tool for finding a balance between top-down control and bottom-up collaborative planning as simulating alternative solutions is a method to encourage stakeholders to negotiate alternative solutions (La Grusse et al., 2006). Simulation models can be used to elucidate interrelationships between interventions and to suggest solutions that are acceptable to all stakeholders. Examples are "Waterwise", a bio-economic model developed in the Netherlands for spatial planning of lowland basins (van Walsum et al., 2007) and "Aquastress", an EU-integrated project to develop participative approached in water stress management (Máñez et al., 2007). Similar initiatives with participatory modelling were initiated in the United States, where the Institute for Water Resources of the US Army Corps of Engineers, developed the Shared Vision Planning Method (SVP). The SVP method integrates planning principles, modelling and collaboration into a practical forum for making water resources management decisions (Institute for Water Resources, 2009). A participatory modelling approach that involves local stakeholders with their (tacit) knowledge of the local conditions and circumstances allows researchers to concentrate on the modelling process, rather than on the often time-consuming data collection (Argent and Grayson, 2003). Participatory modelling can help to achieve a common understanding or vision of how water resource systems function and how they can be managed in a sustainable way (Loucks, 2006). Even for complicated situations, simple, easy-to-understand models designed in collaboration with the stakeholders are useful tools to assist in planning (Berkhoff, 2007).

The basic principles of collaborative modelling were introduced a while ago and have gradually evolved over time. Voinov and Bousquet (2010) in their position paper on collaborative modelling show that in far too many cases the model developers have merely paid lip service to the stakeholders and that the engagement of the latter group has consequentially been quite nominal. They show that participatory modelling is still a top-down approach orchestrated by the model developers. The participatory research approach adopted for this study is based on a combination of the principles of Integrated Water Resource Management (IWRM), Participatory Learning and Action (PLA) and experiences with participatory modelling from Europe and the USA (Ritzema et al., 2011). Based on collaborative research projects to improve the water management in three polder areas in respectively India, Surinam and Vietnam, the lessons on learning to narrow this gap are discussed.

Strategies to improve water management in two rice polders in the Red River Delta in Vietnam

The Red River Delta (1.7 Mha), located in the north of Vietnam, is one of the most densely populated areas in the world supporting about 1,000 people per km2. An extensive centuries-old system of more than 3,000 km of river dikes and 1,500 km of sea dikes reduces the vulnerability to flooding (Pilarczyk and Nuoi, 2005). Agriculture accounts for about 35% of the gross domestic product, compared to 24% for industry and 41% for services (Bakker et al., 2003). The Red River Delta is the cradle of the wet rice cultivation in Vietnam, producing about 20% of Vietnam's annual rice production. Rice is planted twice a year and followed by winter crops if possible. Farm holdings are small, on average about 0.3 ha per household. The irrigation and drainage systems were designed and constructed in the 1950s and '60s and serve virtually all agricultural land in the Delta. Many of these systems are complex, using dual-purpose canals and pumped irrigation and drainage. In the period 1995 to 2001, the irrigation and drainage infrastructure was rehabilitated and upgraded under the Red River Delta Water Resources Sector Project. A review of the project showed that improvements in the irrigation system performed reasonably well, but the improvements in the drainage systems performed less than anticipated (Asian Development Bank, 2001). The reasons for this inadequate functioning of the drainage systems are diverse and complicated. Firstly, in the Red River Delta, with its low elevations, drainage rather than irrigation is often the limiting factor affecting agricultural production (Water Resources Consulting Services, 2000). The average rainfall varies between 1,600 and 1,800 mm, of which 80-85% falls in the rainy season from May to October. The rains that cause waterlogging always occur in July-August and coincide with the occurrence of storms, floods and floodtide. Secondly, the drainage systems have not been designed and constructed in an integrated, comprehensive way, but have gradually expanded over the last 30 - 40 years. Consequently, the capacity of the pumping stations does not always match the capacity of the main canal and field drainage systems (Capacity Building in the Water Resources Sector Project, 1999). Thirdly, given the dynamic situation, the official research and extension system does not always effectively respond to farmers' needs (Linh, 2001). Fourthly, maintenance, repairs and upgrading practices are poor, resulting in a continuous deterioration of the systems (Vietnam Institute for Water Resources Research, 2003). Fifthly, water storage in the agricultural fields has also decreased due to changes in cropping patterns, i.e. introduction of high-yield rice varieties and 'dry-foot' crops. On top of this there is a gradual change in land use: urbanisation and non-agricultural use has rapidly increased over the last decades. These changes have increased the burden on the drainage systems as the non-rice areas have on average less storage capacity and higher run-off intensities (Water Resources Consulting Services, 2000). Finally, the organisation of the water management is complicated and fragmented. The management transfer from government authorities to farmers, initiated in the 1980s, has not yet brought the expected benefits. The management of the drainage system is shared by several organisations, a clear overall responsibility is lacking, staff are poorly trained and service facilities and funding are insufficient (Fontenelle, 1999; Fontenelle, 2000).

To overcome these constraints the Second Red River Basin Sector Project was initiated in 2002. The project promotes integrated water resources management and stakeholder participation at local and basin level. Within the framework of this project, a participatory research study was conducted in two polders in the Red River Delta (Ritzema et al., 2008). The project adopted the participatory learning and action approach. The main objective of the study was to match the tacit knowledge of the various local stakeholders (groups) with the explicit scientific knowledge of the researchers in order (i) to overcome the shortcomings of traditionally validated simulation models; (ii) to improve the mutual understanding of the complexity of the existing irrigation and drainage system, and (iii) to reach agreement on the outlines for an integrated action plan. The study started with a series of workshops in which (representatives of) farmers, communes, local government, unions, NGO's and scientists assessed the problems they face and identified and prioritized their preferences (Figure 1). The workshops were followed up by a participatory pre-investigation to identify and quantify the constraints in the functioning of the water management systems. Next, the drainage system was modelled and computer simulations were used to develop conceptual designs to improve the functioning of these systems. In concluding workshops with the stakeholders recommendations to improve the institutional capacity of the drainage system management were formulated and prioritized. Next to technical innovations, recommendations to reform the complex institutional setting were formulated. The collaborative modelling approach proved to be a useful tool to tackle the hydrological and social complexity, to overcome the lack of long-term data records and to get consensus among the stakeholders on the outline of an integrated approach.

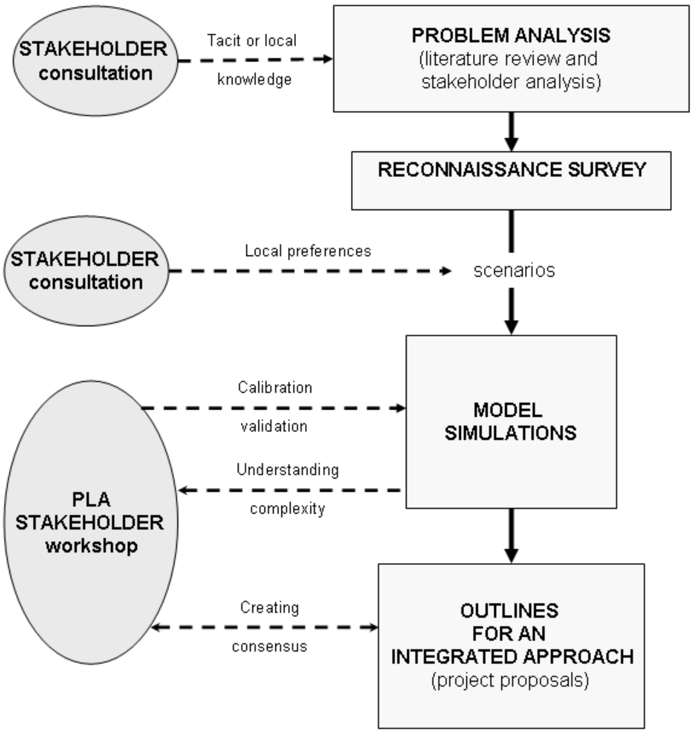

Figure 1 Four-step approach for the participatory modelling study adopted in the Kolleru Lake Study

Environmental planning for the restoration of the Kolleru-Upputeru wetland ecosystem in Andhra Pradesh, South India

Lake Kolleru (30,855 ha) is the largest freshwater wetland ecosystem in South India (Durga Prasad and Padmavathi, 2003). It is located in between the deltaic plains of the Godavari and Krishna Rivers on the east coast of Andhra Pradesh (16032'- 16045'N and 81005'- 81020' E). The Lake is connected to the Bay of Bengal through the Upputeru River or "Salt Stream". The Lake is shallow and fresh but, because of its low elevation, brackish conditions prevail in the south-eastern part, especially during dry summer months, due to salt water intrusion through the Upputeru River. The Lake, home for 189 species of birds, including the rare and endangered Grey Pelican, has been designated as a RAMSAR site and was declared a wildlife sanctuary for the protection of birds and other wildlife in 1999 (Government of Andhra Pradesh, 1999). This wetland ecosystem is under threat due to: (i) siltation as a result of erosion in the upland catchment; (ii) conversion of open water into fish ponds and paddy fields; (iii) pollution with dissolved salts, pesticides and fertilizers from neighbouring agricultural lands; (iv) sewage and industrial waste water from sugar, paper and food processing industries, and; (v) salt water intrusion due to reduced outflow and the construction of a straight cut canal (M16) in the mouth of the Upputeru River (Anjaneyulu and Durga Prasad, 2003). This has led to a sharp reduction in the lake's area and volume and to excessive growth of weeds and water hyacinth. In combination with over-fishing by the local population, this has resulted in a sharp decline in fish catches, loss of biodiversity, flooding of the adjacent agricultural lands and salinization of the downstream areas. The degradation of the lake not only threatens the fragile ecology but also the livelihoods of the local population (about 200,000 people) living in 148 villages and fishing communities in and around the lake (Shivaji Rao, 2003). The Government of Andhra Pradesh has recognized the urgent need to stop further degradation and has initiated a number of restoration measures. The latest measure, dismantling of fish ponds below the 1.5 m+ MSL (mean sea level) contour line, has led to fierce opposition from local fishermen and fishpond owners. The opposition became so severe that, at the end of 2006, the Government had to enforce a curfew, i.e. part of the region was placed under martial law and declared restricted area. A major point of conflict is that the restoration measures in general focus on only one of the problems and subsequently often deteriorate the conditions in other parts of the system. For example, the shortcut M16 was excavated in the mouth of the Upputeru River to increase the hydraulic gradient and flow rates in order to reduce the silting-up of the river mouth (note that this siltation is mainly caused by sand transport along the coast and not so much by sediment transport in the river itself). This shortcut, however, resulted in increased salinization during the dry season.

A participatory modelling study was conducted to overcome the problem of data scarcity (Ritzema et al., 2010). New ways had to be found to address the shortcomings of traditionally validated simulation models. The traditional validation process was replaced by joint plausibility discussions and shared vision building in order to improve the understanding of cause-effect relationships and proposals for restoration measures. This study has aimed to match the tacit knowledge of the local stakeholders with explicit scientific knowledge in order to create a mutual basis for an integrated approach as opposed to single-issue measures and a mutual agreement on follow-up steps needed to sustain both the livelihood of the people as well as the wetland ecosystem. The challenge was to address the hydrological and social complexity. On the basis of a literature review, input data for model simulations were generated from the location-specific knowledge of stakeholders and a rapid field appraisal (Figure 2). The model simulations were used to predict the effects of a number of restoration options. In two workshops, these restoration options were discussed with the stakeholders in order to improve the mutual understanding of the complexity of the wetland system and to reach an agreement on the outlines of an integrated action plan. The participatory modelling approach proved to be a useful tool to obtain a consensus of opinions among the stakeholders.

Figure 2 The participatory research approach adopted in the Red River Delta Study

Participatory modelling to improve the water management in the Nickerie District, Surinam

In Surinam, the contribution of the exploitation of the natural resources (minerals and forest products) is gradually decreasing. Subsequently, the agricultural sector (mainly the rice sector) becomes more important for the national income and food security. The rice sector, however, has become less competitive as the knowledge on recent developments in cultivation practices and land & water management is poor, the infrastructure has been neglected and vocational education facilities in the Nickerie district, the main rice cultivation district, are lacking. A research project was initiated to develop recommendations how to improve the water management systems, both the physical system as well as the institutional setting, in the rice polders in the Nickerie District in West Surinam. In the Nickerie district (5353 km^2), with a population of about 35,000, rice is cultivated in 22 polders (about 15,000 ha) (Naipal, 2005). The majority of the farmers are smallholders with an average plot size of 3.1 ha. The source of the irrigation water is the Nani Swamp, a Nature Reserve of about 54,000 ha and famous for its populations of spectacled caiman (*Caiman crocodilus*) and manatees (*Trichechus manatus*) (Baal, 2005). In dry period, when the Nani swamp cannot provide sufficient water, additional irrigation water is pumped from the Corantijn River and transported through the 67 km long Corantijn Canal. The costs of pumping are, however high and often no diesel is available to run he pumps. The polders were reclaimed over a period of more than hundred years and consequently the irrigation and drainage systems were enlarged over time. It has resulted in a complex system without many possibilities to control both the irrigation and drainage flows. Not only the physical infrastructure is complex and outdated, but also the institutional set-up is complex. In 2007, the Water board OW-MCP, was established with the aim to get the overarching responsibility over the water management in the Nickerie Polders. At present, however, there are still many with many (Government) organizations involved in the operation and maintenance (Table1).

DUFLOW, a one-dimensional, non-steady state, model for water movement and water quality (Duflow Modelling Studio, 2010), was used to get a better understanding of the functioning of the water management systems, to investigate whether it can be used as a tool to facility the discussions between the various organizations involved in the water management and to help them to make informed operational decisions.

Table 2 Organization of the water management in the Nickerie District, Surinam ((Ritzema, 2010).

Organization	Responsibilities
Water board OW-MCP	Wakay pumping station, Corantijn canal and the newly reclaimed MCP polder
Department of Public Works	Primary and secondary canal system including the inlet works, Clara pumping station and drainage sluices
Department of Agriculture and Fisheries	Water distributions between the polders, including the use of the pumping stations (when to start pumping etc.), part of the drainage system
Department of Spatial Planning	Major maintenance and rehabilitation works
Polder Water boards	Water management within the individual polders
District Commissioner	Coordination of the water management.

Discussion

The challenges in these studies were to match the implicit (or tacit) knowledge of the stakeholders with the explicit knowledge of the researchers in order to validate the problem analysis, to calibrate the models and to make informed decisions. A wide range of studies have addressed the role of stakeholders in research on sustainable development. In this discussion we will focus on the role of participatory modelling. We aimed to make the modelling more a process than a product. (Probst et al., 2003) suggest three prototypical approaches via this type of research, i.e. (i) the "transfer of technology approach"; (ii) farmers first, and; (iii) participatory learning and action research. These studies fit into the 3rd category: the research focus was on developing approaches for organisation and institution innovations through a mutual learning process. The role of the actors was clearly defined: local project staff was responsible for the project implementation and the interaction with the stakeholders and Alterra for guidance and advice. The procedures followed an iterative loop of action and reflection. Local Government organisations, including NGO's, performed an important advocacy role working with the farmers (both men and women) to add their voices and views to the decision-making process, the problem analysis, the proposed simulation options and finally the prioritisation of the improvement options. The local partners carried out the investigations and participatory monitoring programme, in close consultation and cooperation with the stakeholders.

The stakeholders, who represented individual farmers, other interest groups like women and agricultural organisations and public organisations at local, district or provincial level, were engaged from the beginning and had a final say in the problem analysis and the prioritisation of the improvement options. Some flexibility was built into the programme by planning the monitoring and modelling as parallel activities. As local project staff were engaged in both activities, fine-tuning between these two activities was relatively easy. Due to limited funding, Alterra could only provide backstopping periodically. Communication via the internet, however, proved to be a powerful method for overcoming these shortcomings. (Potential) conflicts occur at many levels, e.g. between rice and non-rice farmers, between upstream and downstream farmers, between farmers and village (built-up areas), between farmers and fishermen, between farmers and operators of structures, gates, pumping stations, etc. Based on experiences from a similar studies, Alterra staff realised that in such (potential) conflict-loaded situations, it was important that next to their role as a provider of scientific knowledge their role should be neutral, in the first place not looking for solutions but more in the role of a mediator.

The capacity to mobilise and use scientific knowledge is an essential component to promote sustainable development (Cash et al., 2003). The participatory modelling approach was selected for two reasons. Firstly, simulation models are a useful tool for increasing and sharing knowledge and understanding complex irrigation and drainage systems as found in the study areas. Secondly, simulation can be used to predict the impacts of improvement options. The selection of the model was based on the initial problem analysis and the proposed intervention options. We selected a model that is commercially available at a reasonable cost. Tailor-made training was organised to familiarise the local staff with the model and the participatory research approach. The training followed the principles of learning by doing; after an introduction of the model, the remaining time was spent by the local staff setting up the model for the study areas. After the training, the involved staff members were able to assess the type of input data needed for the calibrations. In follow-up missions, the next steps in the modelling process, i.e. simulation of improvement options, were tackled.

The levels of participation can be assessed by using the IAP2 Spectrum method of Public Participation (International Association for Public Participation, 2007). The IAP2 spectrum recognises five levels of public participation, from level 1 "*Inform*", via level 2 "*Consult*", level 3 "*Involve*" and level 4 "*Collaborate*" to level 5 "*Empower*". Although, these research studies have characteristics of all levels, the focus was on level 4. Stakeholders collaborated in the problem analysis, the pre-drainage investigations, the monitoring programme and the prioritisation of the improvement options, but they had no authority to make the final decisions: the end-product had to be approved by the local governments.

The capacity development approach is very similar to the knowledge-creating process of Nonaka (Figure 3). The pre-drainage investigations and tailor-made training sessions addressed the internalisation or learning phase. The applied research activities were in the socialisation or sharing knowledge phase. The use of the newly developed knowledge to develop improvement options was characteristic of the externalisation or knowledge-encoding phase, and the dissemination of this new/updated knowledge through the development of guidelines was in the combination or synthesis phase. A strict distinction between the activities and the phases is not possible as the knowledge-creating process is in principle a never-ending loop. For example, pre-drainage investigations and the applied research activities in farmers' fields also include elements of internalisation, externalisation and combination. The PLA Workshops also had elements of internalisation and socialisation as they link tacit and explicit knowledge. For the researchers they were an effective tool for updating their knowledge of the water management systems in the study areas. To make this type of capacity development processes successful, it is essential to bring stakeholders and scientists with different backgrounds together. To discuss tentative results of the research activities proved to be an effective tool integrating explicit and tacit knowledge. A prerequisite is that the participants are stimulated to bring in their own experiences (tacit knowledge) and that the researchers are capable of linking this knowledge to the explicit knowledge they present and to their own tacit knowledge. Local NGO's played a crucial role by stimulating the process of working together they created a sense of community and mutual trust.

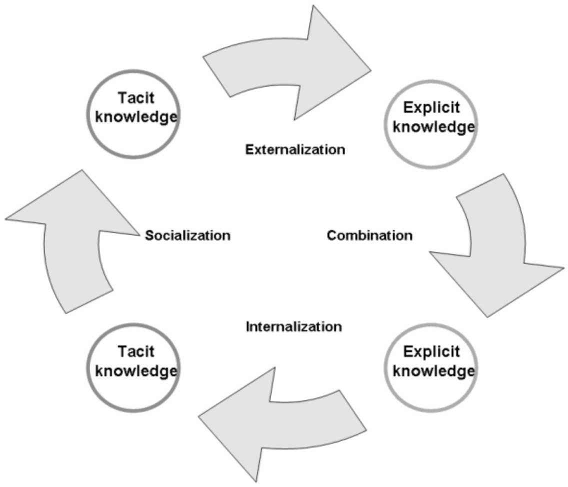

Figure 3 The knowledge creating process (after (Nonaka and Takeuchi, 1995).

In the step-wise participatory approach, all three elements of capacity development that form the base of IWRM were addressed. Local staff was not only trained in model activities but also in the other aspects of collaborative research. The PLA workshops were a good example of "learning by doing": under the guidance of local staff, the participants improved their ability to communicate and exchange information and knowledge in a participatory way, moving from "teaching" to "facilitating" in development issues. The participation of stakeholders in the problem analysis, pre-drainage investigation and prioritisation of the improvement options can be considered a major step in the institutional development. Finally, the guidelines prepared by the projects and endorsed by the stakeholders helped to create an enabling environment.

Lessons learned

There are three categories of lessons that we can draw from this study: lessons related to the theoretical perspective, lessons on the role of the various actors and lessons on the effectiveness of the applied methodology. The main lessons learned can be summarised as follows:

Theoretical perspective

- Collaborate research should be treated as a process. The step-wise approach as formulated in the guidelines probably needs adjustments when it is used in other areas, each with its own specific technical and social-economic conditions. According to Voinov and Brown Gaddis (2008) there is a clear similarity with the open source paradigm in computer science, when software is a product of joint efforts of a distributed group of players. Ideally the process should continue, as it is a valuable asset for future decisions and conflict resolutions.
- In such complex systems as found in many tidal areas, results can have a certain degree of uncertainty. To deal with this uncertainty, the research process should be flexible: there should be the possibility of making adjustments after consultation with the stakeholders.
- The stakeholders know best which scenarios can be selected to address a certain problem. Local people are invariably the best source of knowledge and wisdom about their surroundings (Lueder Cammann et al., 2004)). Many of them have prestige, responsibilities and/or influence in the community. Engaging the stakeholders in the selection of simulation options will lead to the development of more innovative solutions.

Role of actors

- The role of the research team is important in the social process, although they are the provider of the scientific knowledge, they should realise that their role as scientists is as a neutral mediator.
- The selection of stakeholders is of course an important issue. Rapid rural appraisals are an effective method to plan all these stakeholders.
- The level of confidence stakeholders have in modelling results is not so much related to the level of detail but much more whether they recognise the (simulated) effects of certain interventions. By discussing the effects of past events, i.e. extreme rainfall events or the effects of closing certain gates or sluices,

stakeholders gained confidence in the model because the simulations matched their experiences and observations. By discussing these events the stakeholders started to realise that isolated interventions only benefit some of the stakeholders and have negative repercussions on others.

- The planners benefit because they can use the location-specific knowledge of the stakeholders to develop their models.
- Both the planners and stakeholders acquire a better understanding of the location-specific problems (both physical and institutional) and their interrelated complexity.

Research methodology

- Selection of the model should be based on the knowledge, available data and priorities of the stakeholders and not on the preferences of the research team.
- Lack of long-term data records that may seriously limit the usefulness of simulation models can be complemented by linking the tacit and location-specific knowledge of the stakeholders to the explicit knowledge of the researchers.
- Discussing model simulations of the existing conditions with stakeholders and matching the results with the stakeholder's views and experiences proved to be a useful tool (i) to validate the model; (ii) to create mutual understanding of complex problems; (iii) to show that each intervention has its beneficiaries and victims, and; (iv) to achieve consensus on the need for an integrated approach.
- Collaborative research tools, such as participatory modelling and participatory monitoring programmes, are excellent ways of creating new knowledge from existing knowledge by sharing experiences (the so-called socialisation phase in the knowledge creating process).

Conclusions

Collaborative research studies were conducted in tidal polder areas in India, Vietnam and Suriname to gain a better understanding of the complex water management systems; to assess the effects of various improvement measures and to come to an agreement with the stakeholders on the outlines of an integrated approach. The challenges were to tackle the hydrological and social complexities, i.e. the large variety of hydrological functions, the many interests of different stakeholders and the lack of long-term data records. To achieve these goals, an approach was adopted that contained elements of the principles of participatory modelling, IWRM and PLA. The advantage of this approach is that, without an expensive and time-consuming data collection programme, a shared vision building and acting on emerging environmental issues could be initiated. Based upon existing data, stakeholder consultations and a quick reconnaissance survey for additional data, a hydrological model was built of the irrigation and drainage system. The model was calibrated using data collected during the participatory monitoring programme. This data was a mix of explicit information (maps, records etc.) and local specific knowledge of the stakeholders. For validation, simulations of the existing system were matched with the stakeholders' experiences. After calibration, the model was used to simulate the effects of proposed improvement measures as formulated by the stakeholders. Discussing model simulations with the stakeholders proved helpful in overcoming potential conflicts between stakeholders. Furthermore, by discussing the simulations the stakeholders started to realise that interventions would not necessarily satisfy all parties: each intervention has its beneficiaries and victims.

The obtained results and observations support the following hypothesis: a situation in which "researchers know that model input is partly based on assumptions, and stakeholders understand that their own knowledge is an important contribution", is more productive for environmental planning than a situation in which "researchers exactly understand the model input, but stakeholders do not believe that their own knowledge has been taken seriously".

The studies have shown that the current collaborative research theories can be effectively used in practice. It should be realised, however, that the theory should only provide the framework; flexibility is needed to allow for local-specific conditions both with respect to the physical environment and the social-economic setting. Only by applying existing theories, can the adequacy of the theoretical perspective be enhanced. We recommend that future research in this area should focus on the reduction of quantitative uncertainties in simulation results by including tacit knowledge in the process of input data compilation and plausibility checks. However, further research should also quantify whether the presented approach, despite the uncertainties, will give the same results compared with a traditional model validation and scenario-building process.

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