Interdisciplinary research and transdisciplinary processes for environmental management under different socio-natural conditions

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Abstract

Interdisciplinary research and transdisciplinary processes as part of environmental management respond to the increasing complexity of socio-natural changes in recent decades. Two similar studies of eutrophication in raw water reservoirs for drinking water production in Norway and China are used to discuss interdisciplinary research and transdisciplinary processes organised through the DPSIR framework (drivers, pressures, states, impacts, and responses) as instruments for environmental management. The conclusion is that interdisciplinary research and transdisciplinary processes can enhance the understanding of complex socio-natural processes under distinctly different institutional systems. The DPSIR framework was not necessary for achieving the desired result.

Keywords:

Environmental management; eutrophication; farming; interdisciplinary research; transdisciplinary processes; China; Norway.

Introduction

The globe is subject to increasing pressures on both earth system variables (e.g. terrestrial biosphere degradation, leaching of nitrogen to coastal zones, and ocean acidification) and socio-political variables (e.g. increasing (urban) population, primary energy use, fertiliser use, and water use) [1]. Environmental management has become increasingly wicked. This is not just the case for coping with global warming, but also for local problems like eutrophication. *Wicked* here means that environmental challenges are fuzzy and unstable; characterized by social complexity and shared responsibility; embedded in historical contingency and systemic interconnectedness; and inseparable from deeper issues of values, social justice, and power [2]. From another angle [3] it is argued that society is fuelling processes that are changing fundamental system dynamics. This emerging society of fundamental uncertainties is referred to as the "risk society", but perhaps more correctly is a society of fundamental "uncertainties". Increasing degrees of uncertainty with mounting stakes for involved parties apparently opens up the arena for lay actors and non-scientific knowledge [4]. This is also making the issue of bridging of different types of knowledge important, across different communities and social groups [5].

This development suggests that a 'post-normal' science has emerged [6], where facts and values have to be brought into a unified conception of problem solving. The complexity of today's environmental problems demands a closer cooperation between disciplines. There needs to be dialogue between actors in the interfaces between sciences and society, and politics. There have been calls for linking (scientific) knowledge and decision-making, thereby giving rise to a demand for interdisciplinary research involving natural and social science disciplines, and transdisciplinary processes involving science and policy stakeholders [7]. With transdisciplinary processes we mean interaction, collaboration, and perhaps cooperation between scientific disciplines and non-academic stakeholders, to integrate scientific and other types of knowledge as bases for policy-making. The belief is that organising knowledge processes in this way will facilitate effective decision-making and implementation of adequate measures for achieving policy goals; the management of socio-natural processes and resources.

How interdisciplinary research and transdisciplinary processes are organized will depend on the structure of institutional regimes. Western literature on environmental management and policies has argued in favour of multi-level governance and network learning [8]. Transformative adaptation is considered necessary for coping with the complexity of changing socio-natural processes, especially linked to climate changes but also other environmental challenges [9]. It is held that a change in the culture of thinking is necessary, not just iterative changes in infrastructure, land-use and physical conditions. The scientific literature brings the discussion on and combination of hierarchy, network, and market as principles for governing and actual governance types onto the table [10].

There is awareness of change in the structure and operation of the science–knowledge–policy nexus. Nevertheless, existing conditions are not easily restructured owing to inertia and path dependent lock-ins. For instance, interdisciplinary research confronts increasing specialisation and contradictory theoretical approaches. Furthermore, scientific knowledge may not agree with lay knowledge, perhaps leading to disputes rather than a compromise and consensus. Governmental bureaucracies may not easily comply with multi-level network governance. There is thus a need for discussion of variables in the emerging science–knowledge–policy system.

This paper offers a *comparative analysis of two eutrophication studies* conducted in China and in Norway. Both studies were inter- and transdisciplinary. They included several natural and social science disciplines: biology, chemistry, geology and hydrology, economics, human geography, political science, resource management and sociology. Moreover, the two cases allow for comparing experiences from two different institutional systems: China conventionally considered top-down and authoritarian and Norway conventionally considered bottom-up and democratic. The two projects applied the DPSIR-framework of drivers, pressures, states, impacts, and responses [11] for analysing eutrophication processes, with feedback loops from responses and potentially from earlier stages of the chain. In this paper we will:

i) Critically discuss interdisciplinary research and transdisciplinary processes as part of environmental management, focussing on knowledge production policy-making.

ii) Critically discuss the usefulness of the DPSIR-framework for transdisciplinary processes and environmental management in China and Norway.

Materials and methods

This article draws on two concluded research projects, Eutropia (RCN: 190028) in Norway and SinoTropia in China (RCN: 209687), both communicated through scientific papers (see Annex 1). Thus, the materials and methods of this article comprise those of the two previous projects and the analysis of this article. Only a brief outline describing relevant aspects of the study sites and analytical approach will be given since detailed description of material and methods appears in the scientific papers listed in Annex 1. Although interdisciplinary, the gathering and analyses of basic scientific data were disciplinary. The presentation below is structured accordingly.

The Yuqiao watershed (~436 km^2), in north-eastern China (Figure 1), provides water to the raw water reservoir for Tianjin municipality (Tianjin city) and Hebei province. The region has a sub-humid continental monsoonal climate. The approximately 130,000 people that reside within the study area have agriculture and husbandry as their main livelihood. During the decade leading up to the SinoTropia project (2011–14) the land-use of the watershed of Yuqiao reservoir was significantly changed by large-scale conversion of wasteland to agricultural purpose, along with intensified irrigation and cultivation reflecting the rapid growth of agriculture. The lowland and plains was used for growing staple crops, rotating between summer maize and winter wheat, or for vegetable farming. The hilly and mountainous areas were predominantly used for growing either fruits (orchards) or timber (forest). Eutrophication of Yuqiao reservoir had accelerated through excessive Phosphorous (P) loading from the land-use practices.

The Morsa or Vansjø-Hobøl catchment (~ 690 km^2) is located in South Eastern Norway (Figure 2). Boreal forest (including bogs) (85%) and agriculture (15%) are the predominant land-use forms. Approx. 90% of the catchment is below the marine limit [.[1]] Lake Vansjø covers an area of 36 km^2, and from its outlet drains into the eastern side of the Oslo fiord through Moss town. The lake is the drinking water source for more than 60,000 people around Moss which also is the largest municipality of the watershed, with a little more than 30,000 inhabitants. The smallest municipalities are Hobøl and Våler (approx. 5000 inhabitants), situated at the northern and south-eastern part of the watershed, respectively. Lake Vansjø is a recreational and leisure area for people living in Moss and the surrounding region, as well as a biodiversity rich area.

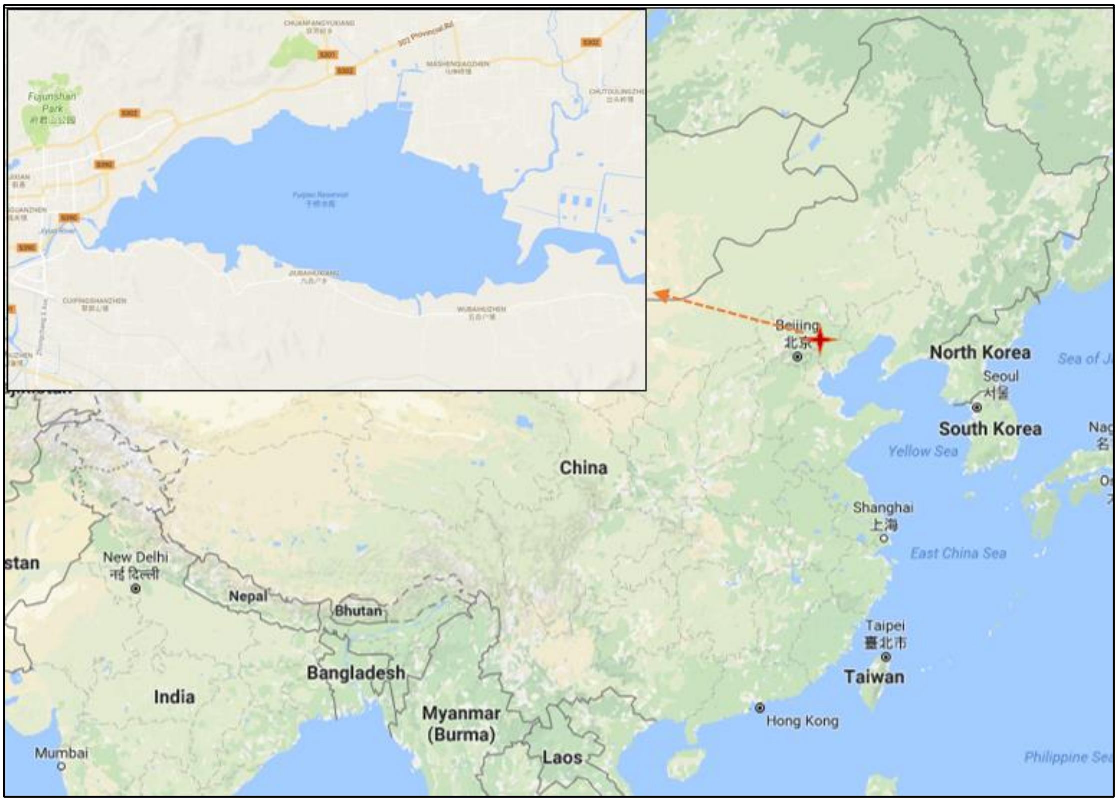

Figure 1 The Yuqiao reservoir

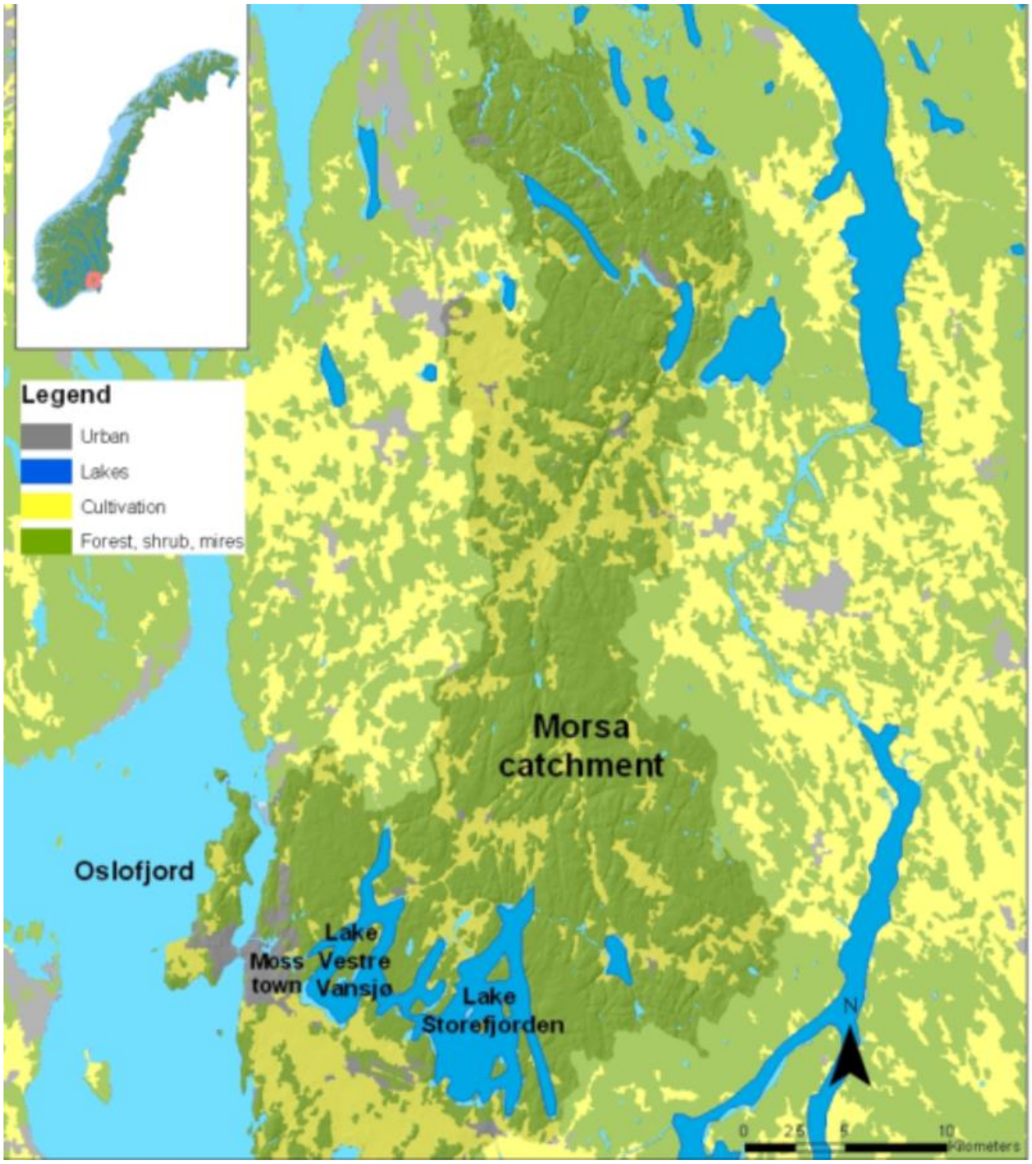

Figure 2 The Morsa Watershed (dark green area)

As to the social science part, document studies, interviews, and questionnaires were applied. They comprised both qualitative and quantitative methods. The *Eutropia*[2] project included semi-structured interviews with 23 farmers. The selection of farmers included farms of different size and location, and type and form of production; as well as farmers of different age and local engagement (role models or not). The interview guide included questions under the headings of general background of being farmer; on farming practices; farmers' and farming related networks; the issue of reducing use and loss of phosphorus; information and knowledge on positive and negative effects of phosphorus; and collaboration and cooperation within the Morsa watershed. Furthermore, 22 respondents engaged in the management of the watershed were also interviewed; including mayors and municipal officers from municipalities within the Morsa watershed area as well as government professionals at the county level and the state county governors. The interview guide for the management officers included questions under the headings of use of the main lake in the watershed and measures taken to improve the water quality; scientific information sources and knowledge on conditions in water courses and the lake; experiences with the Morsa watershed cooperation; the governance system; and the role of and actions taken by farmers. For both the interviews of farmers and watershed management, questions were reformulated during the interviews in order to receive better responses. For the interviews with farmers, all except one were recorded and transcribed[3]. For the interviews with respondents engaged in the watershed management, all except four were recorded and transcribed[4]. In addition, minutes and case handling documents from watershed board meetings for the period 2000 to 2010 were provided and used in the analysis[5].

The SinoTropia project included a survey comprising 545 farmers in 11 different villages[6]. The villages were selected to include different types and forms of production and location in the watershed. The attendance of respondents was voluntary bottom-up but restricted to about 50 from each village, with more than 50 from large villages and less than 50 from smaller villages. The survey included questions under the headings of environmental challenges; environmental attitudes and values; access to and pollution of water; farming motives and challenges; place attachment; information sources and knowledge on farming and the environment; farming practices; knowledge about and use of phosphorus/fertilizers and actions taken; and background variables on respondents. The statistical package of IBM SPSS Version 22 was used for factor analyses creating composite variables to be used together with other variables in multi-variate linear and categorical regression analyses. After the survey, interviews with 41 farmers were conducted[7]. The interview guide included questions under the headings of general background of being a farmer; on the social milieu of local farmers; local farmers' cognition and evaluation regarding the built and natural environment within this area; regular farming practices and productions; and the social relations and networks of local farmers. The interviews were recorded and transcribed. In addition, two focus group interviews with village leaders were conducted[8]. More specifically, in this article we are drawing on the experience gained from the Eutropia and SinoTropia projects related to the above outlined research questions, as well as relevant scientific articles and books.

Results and discussions

The Norwegian case

Cultural eutrophication was already in the 1950s being observed in the Morsa watershed, becoming a policy issue in the 1990s because of its increasing presence in the watershed, and especially in the Lake Vansjø. The deteriorating development was linked to population growth and intensive agriculture. Policy concerns and the initiative of seven municipalities located in the watershed sparked the establishment of the Morsa project in 1999, administratively embedded at the County Governors' Office[9] of Østfold. The project was granted funds from the Ministry of Environment and considered a pilot for watershed management, and headed by a project leader given the task of formulating and introducing measures curbing the detrimental development and restoring good drinking water quality.

The highest concentration of total P in Vansjø since the monitoring there commenced in 1975 was recorded in year 2000. This was an exceptionally wet year comprising a large flood. This also roughly coincided with an on average highest level of algae. Since then the total P and algal blooms have levelled off or slightly declined, although the concentrations of bioavailable P have continued to increase along with the water colour.

The considerably worsened conditions in Lake Vansjø at the dawn of the new century required action. A watershed board consisting of mayors from the municipalities of the watershed, together with representatives of civil society organisations, counties and county governor's office was established[10]. During the first decade the focus was on agriculture, with the introduction of both mandatory and voluntary measures: mandatory use of mineral fertilizers with less P content; imposed changes in agricultural practices like minimal autumn tillage, avoiding ploughing on land prone to erosion as well as across water ways in the fields; and establishing physical barriers like vegetated buffer strips adjacent to streams cutting through agricultural fields, and construction of wetland ponds adsorbing bioavailable P and catching silt containing P. Later, home based systems for treatment of sewage (also including leisure homes) not connected to the municipal sewage system were introduced.

Designing and implementing measures were achieved by bringing together different actors and bridging different interests in taking joint efforts aiming at reducing leaching of phosphorus to water streams, brooks, rivers, and eventually to Lake Vansjø [12]. Discussing the Morsa case on the basis of four principles of multi-level water governance (management on a bioregional scale, polycentric governance, public participation, and an experimental approach) [10], as part of the Eutropia project, researchers concluded that “the relative success of Morsa relates to a complex of factors, including openness of practices and active involvement of key actors, strong but including leadership, and a knowledge based ‘hybrid’ type of multi-level network combining horizontal and vertical network governance.” For the purpose of the current study, elaborating on the processes leading to the conclusions drawn by these two authors provides some instructive lessons.

The Morsa project, and later Morsa Watershed Board, has been strongly science driven, initiating research and using results as a basis for designing measures, including presenting findings and recommendations for the watershed board and grass roots meetings with e.g. farmers. Mayors would take part in the discussions at the board, supporting measures and thereby committing themselves to follow up on the measures in their municipalities. Yet there were conflicts, even some threatening to derail the watershed cooperation. From the very start an employee of the County Governors’ Office of Østfold who had previously worked on eutrophication but who was replaced by the new project manager, was very critical and went public with his criticism, eventually provoking the county governor to state support for the project manager. In addition, the Minister of Environment visited the area and expressed strong support for the Morsa project.

But, the employee was engaged in local policy making at the municipal level, and formed an alliance with representatives of two other municipalities intending to terminate the watershed cooperation. This effort was partly stopped by a research report undermining his professional argument of Lake Vansjø being "self-fertilizing" and partly counteracted politically, when all municipalities joined in support of the Vansjø project.

The success of the Vansjø project depended on convincing farmers to take voluntary actions and in a good manner carry out mandatory actions. In addition to economic compensation[11], farmers' actions were achieved by convincing and recruiting well respected local farmers (role models) to act as forerunners in introducing changes in farming practices, thus persuading others by example. Since Vansjø was used by the public for recreation and as a raw water source for the Moss city, there was a socio-economic argument to facilitate a change in attitudes. For instance, everyone can notice if some farmers are doing autumn tilling close to brooks, rivers, and lakes. The collective pressure for complying may turn out as strong, and indeed, one of the sceptical farmers explained during the interview that he was taking a number of actions just to preserve his reputation among other farmers and others in the local community.

Illustrating the perceived success of the Morsa project, the use of phosphorus fertilizer fell by half from 2004 to 2007[13], indicating that some measures had been paying off. Yet despite this reduction, after almost ten years of taking actions, Lake Vansjø had not been brought back to the identified "good ecological status." The eastern, main basin of the lake showed no clear reduction in total P levels, and the western section, with more severe eutrophication, had just had a slight recovery since the devastating flood in year 2000 [14]. The question arose: Had the spending over the last couple of decades amounting to about 125 million Eu been in vain? There was a perceived need for more profound studies of socio-natural processes, hence the Eutropia project.

There are many confounding factors that may be causing the lack in amelioration [15], one of which is climate change [16], with more frequent and heavy precipitation [17] resulting in increased runoff particulate bound P from agricultural sites [18]. Another important factor is likely the decline in acid rain. During the 1970s and 1980s acid rain over southern Scandinavia caused high concentrations of labile Al (Ali) in headwater streams and low leaching of Dissolved Natural Organic Matter (DNOM) into the aquatic environment. Abating the acid rain problem is today an environmental success story, returning the levels of the Ali back to low background levels and with increased leaching of DNOM. It is hypothesised that the loss of Ali has resulted in less co-precipitation of bioavailable P downstream in agricultural areas [15]. In addition, the increased flux of DNOM has brought attention to the role of the background flux of P [19]. The main natural transport mechanism of P from forested watersheds to surface waters is by DNOM. In Lake Vansjø, the background flux accounts for about 40% of the total P flux to the lake [20] since a large part of the catchment is forested and below the marine limit. It is thus hypothesized that the decreased leaching of Ali and increase in DNOM since the 1980s has caused an increased mobility of P – thereby disguising the effect of abatement actions. It is thus fair to postulate that without the abatement actions the conditions in Lake Vansjø would have been much worse today [15].

The question then was whether attitudes among farmers owing to a lack of results had turned more sceptical, resulting in less willingness to take actions. Although concerns and questions about what was going on were put forward by interviewees, the basic attitudes had changed surprisingly little. This was surprising because farmers complying with mandatory and voluntary measures experienced reduced income. On the other hand, there were several reasons for the continuing compliance and support. Most farmers expressed a clear understanding and agreed with society's demand for farming not to pollute drinking water sources. Furthermore, some measures made sense agro-environmentally, as e.g. reduced phosphorus content in fertilizers and avoiding soil erosion. As underlined by farmers: no need to pour phosphorus onto the fields when it doesn't stay there and there are no benefits to be gained from their best soil ending up in Lake Vansjø through erosion.

The Agricultural Advisory and Experimental Society (a type of farming extension service) played an important role in facilitating changes. The agency organized experiments and presented their results at farm meetings, making information–learning–knowledge networks. The information provided by the Experimental Society was generally trusted by farmers.

Nevertheless, important nuances were disclosed by looking into the cases of reduced phosphorus content and minimal autumn tillage of the soil. The measure of reducing P content was proven to work and farmers had no objections to follow the recommendations, although the change broke fundamentally with what they had been taught at agricultural schools. This was the case in spite of mineral fertilizer with lower content of phosphorus being more expensive[12].

On the other hand, not doing autumn tillage was far more contested because many of the farmers did not manage to achieve the results propagated from tests made at science run test fields even though better harrowing machinery compensated somewhat for less autumn tillage. Moreover, there were concerns over increasing problems with fungal toxins as a consequence of less tillage. Even so, most farmers agreed to do less autumn tillage. Similarly, the erosion zones, with restrictions on tillage in zones with a slope above a certain limit, led to frustration for farmers. This was especially the case when farmers, with their local knowledge and experience, did not agree that there was any risk of soil loss into the water system. The problem of erosion zones was one of accuracy in determining slope and distance to water ways[13]. Farmers know their fields well from knowledge gained from their own farming practices. Measures running counter to these experiences are bound to face (some) resistance. Apparently unjustifiable measures, impeding a farmer's ability to achieve high outputs, will easily spark protests and non-compliance or poor compliance.

In short, the Eutropia study revealed an interaction between scientifically produced agro-environmental knowledge and lay knowledge within the frames of an institutional system exhibiting both network and hierarchy: an interaction between site specific, contextual knowledge gained through practising farming and general scientifically produced knowledge. These interactions may produce dialogue and cooperation leading to innovative practices, or conflicts impeding changes aiming at improving the environment.

The straw that breaks the camel's back, harming support for taking the prescribed mitigation actions, is usually a combination of doubts about the effects of and the inconveniences caused by the measures. The study, through its interdisciplinary structure, could reveal the socio-natural processes counteracting the effects of the abatement and mitigation actions taken by farmers. This provided grounds for concluding that the eutrophication of Lake Vansjø would have been worse without those implemented actions, thereby neutralising a possible source of discontent.

Although the usefulness of interdisciplinary research and transdisciplinary processes is confirmed, it is important to elaborate on the how and why of both, starting with the interdisciplinary dimension. *Firstly,* Eutropia was organised with disciplines successively feeding each other (the relay model), with interviews conducted in the third and finalised in the beginning of the fourth and final year. Although natural science contributed to social science by commenting on the interview guides, social scientists doing the interviews were not sufficiently embedded in the work of natural science. This meant some shortcomings regarding the understanding of the work conducted by different disciplines. *Secondly,* the project was science based and not systemically integrating representatives of local, lay knowledge, but the natural scientists would interact with local farmers during fieldwork (collecting soil and water samples). In regard to the social science, interview guides were science based, but interviews with both members of the watershed board and farmers brought local knowledge to the table, making it part of the analysis. Fundamentally, the project was empirically based and so built on local, lay knowledge, but the starting and ending points, the frame, were science.

The administrative leader of the Morsa project (watershed board) was member of a reference group for the project, thus bringing the transdisciplinary dimension into the project, both local knowledge and policy-making. Furthermore, policy makers and professionals in government agencies were invited to communication events in which they participated and contributed. During a stakeholder's day at the final conference of the project, both the chairman, who was mayor in one of the municipalities, as well as the administrative leader of the Morsa watershed board expressed the view that the project was relevant and useful for local stakeholders.

The relay character of the interdisciplinary research may have something to do with using the DPSIR-framework (Figure 3) as an organising framework for the project. The (apparent) stepwise character of the DPSIR invites organising the research as a relay. Moreover, a type of relay is necessary in projects like Eutropia.

Thorough insight and understanding of the human activity is required in order to reveal and understand the main drivers and pressures governing differences in water quality in highly anthropogenic influenced systems, such as the studied agricultural sites. Natural scientists may be experts on tapping into state-of-the-environment monitoring data, but lack basic skills needed to acquire necessary data regarding demographics, infrastructure and agricultural activities, including best management practices. Moreover, insight into stakeholder's knowledge gaps and thus research needs requires the ability to ask the right questions. This is best achieved through an interdisciplinary approach, combining expert insight into the stakeholder's situation with knowledge of the biogeochemical processes governing the environmental responses to changes in anthropogenic pressures.

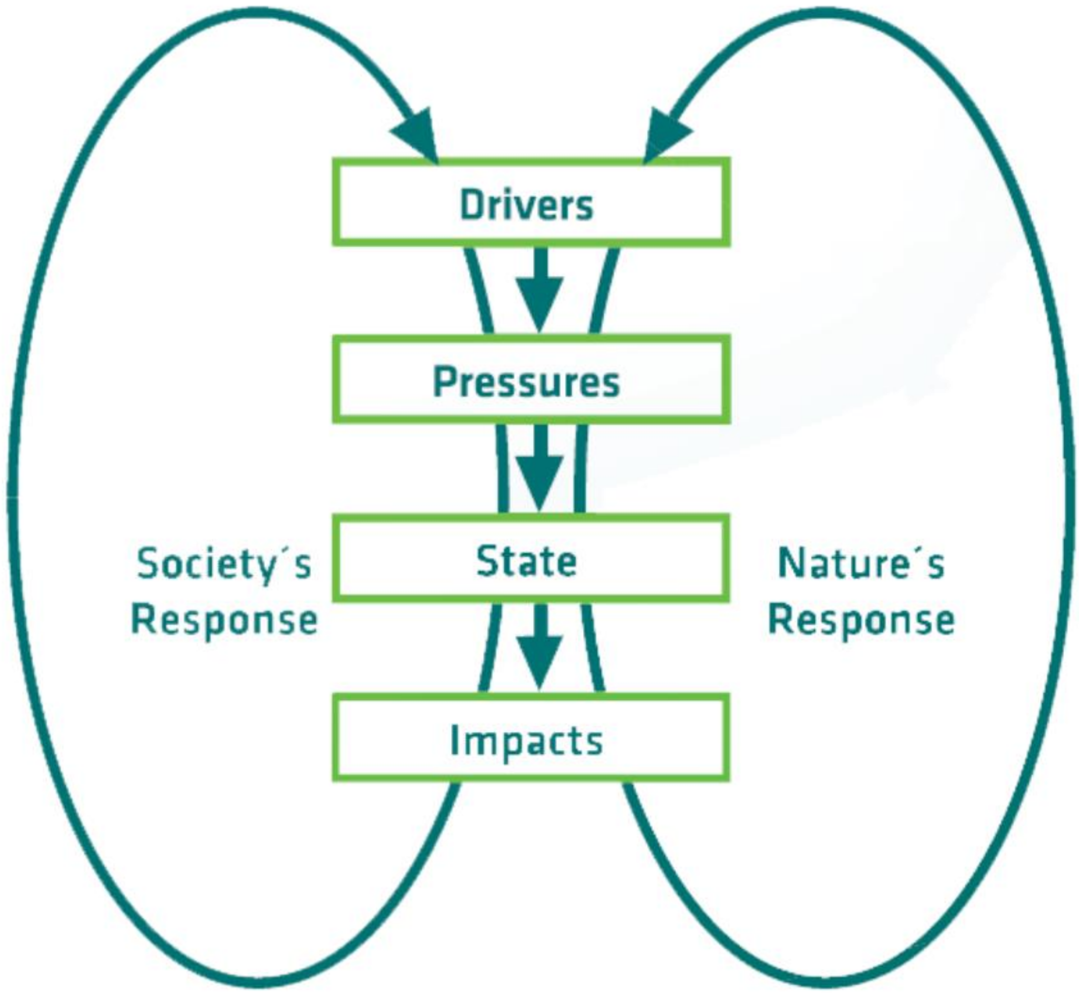

Figure 3 The DPSIR framework [11].

It is thus necessary to allow for and even facilitate the flow of information between the different parts of the project, also across the natural and social science divide, ahead of any definitive “takeover of the relay baton”, thereby guarding against failures and improving the overall performance of the research output and outcome. As indicated by Figure 3, information flows are part of the DPSIR framework through the indicated feedback loops.

The Chinese case

Based on the Eutropia experience adjustments were made for the SinoTropia project, embedding social science into the work from the very start. Accordingly, social scientists participated in preparatory natural science fieldtrips; planning of research tasks was done at meetings involving all disciplines. Interdisciplinary research across the natural–social divide was thus strengthened, at least among Norwegian researchers. In spite of top level support for interdisciplinary research on the Chinese side, it proved a much harder task to have Chinese participants engaging in this type of research. Notwithstanding this reluctance on the Chinese side[14], data gathering and the interaction between local, lay and global, scientific knowledge was similar to what is described above for the Eutropia project, but there are contextual differences.

The environment of Yuqiao watershed has during centuries, even millennia, been widely transformed by socio-natural processes, with a strong human pressure on nature [21 - 24]. Until recent decades this demanded meticulously collecting and returning organic matter to the soil to ensure the desired output. After the acceleration of production and hence use of mineral fertilizers in China from the mid-1970s, returning organic material to the soil gradually waned, concomitantly changing soil conditions.

Application of excessive amounts of inorganic P fertilizer has been a general practice in this region. But, the local soils have low phosphorus sorption capacity. This forces local farmers to apply inorganic fertilizers several times a year. Calculated in regard to agricultural land the total P loading is more than an order of magnitude greater than in Norway. The total phosphorus concentration in the soils exceeded their capacity, and they became oversaturated with phosphorus. There was a high concentration of bioavailable phosphate in the soil water. In addition, because of excessive livestock breeding and lack of sewage treatment, a large amount of animal dung and domestic sewage were disposed of either in heaps on wasteland or directly into the drainage channels. The land around the reservoir has a compact clay layer below the plough layer, rendering the soil profile practically impermeable for water. The soil quickly becomes saturated during rain events, leading to rapid surface flow. This gives rise to soil erosion and flushing of the manure and sewage dumped on wastelands, as well as fertilizers applied in excess to the fields. The resulting eutrophication in the Yuqiao drinking water reservoir (the raw water source for 6.5 million people) causes severe algal blooms (Microcystis sp.) during the summer and autumn.

Attempting to abate the increasing eutrophication of Yuqiao reservoir, the local government previously had issued massive abatement action plans, including displacement of about 28 000 residents around Yuqiao reservoir, transforming fish ponds adjacent to the reservoir to wetlands, and an ecological restoration program in the mountain area by converting orchards and timberland to natural forest.

Although practising farming in a socio-natural transformed environment, the farmers in the Yuqiao watershed were found to be more inclined to support a New Ecological Paradigm than a Dominant Social Paradigm worldview, but many farmers had mixed attitudes and might go in one or the other direction [25]. Farmers reported a fairly broad range of information and instruction sources for farming and the use of fertilizers [26], indicating a wide knowledge base. Moreover, farmers are taking both production and environmental actions, although typically some categories of farmers are more active than others: e.g. local members of the Communist Party and those considering themselves to have good farming competence; that is, there is a group of potential local role models [27].

On the other hand, researching farmers' reaction to measures taken to mitigate and abate leaching of phosphorus into the reservoir [28] found that the hierarchical way of governing may erode and distort the function of environmental policies and pollution control methods, as they were practised in this region. The absence of local residents from the decision-making process about measures for curbing eutrophication in the reservoir led to distrust of the government. The governmental "no use, no pollution" environmental protection logic applied in this region vastly reduced the reservoir's usefulness to local residents. The result turned out to be largely the opposite of the intended one, that is, the formation of "no use, no protection" logic among farmers. In particular the measure of fencing the whole reservoir, barring local residents from using the reservoir for e.g. fishing, annoyed the local residents.

Further, the erosion of traditional rules of mutual supervision at the grass-roots level contributed to a deterioration of pro-environmental actions. In essence, the combination of a dominant top-down decision-making process, the weakened sense of local belonging among local residents, and the ambiguous economic position of farming facilitated behaviour countering governmental measures, thereby making environmental policies and planning contradictory. Eventually this thwarted the policy aim of securing an end to eutrophication and the restoration of a good quality of water in Yuqiao reservoir [29].

This brings environmental management and transdisciplinary dimensions into focus, together with the overall governance system. The SinoTropia project brought together Chinese[15] and Norwegian[16] natural and social science institutes, as well as different disciplines within natural and social science; e.g. chemistry, biology, geology, hydrology, human geography, sociology, and economics. The natural science part cooperated with local village leaders and others in collecting samples from soil, creeks, rivers, and the reservoir. For the social science part, the team established cooperation with a village leader who then assisted in organising surveys in the selected villages, as well as detailed interviews with farmers and focus group discussions with local village leaders.

Results from the study were provided to village leaders, the true grass-roots level of China's governance system. The team, both natural science and social science researchers, had meetings with the county level Environmental Protection Bureau, discussing different features of the study. Results from the study were discussed at a final conference in Beijing on March 24, 2015. The stakeholders attending the conference included the Ministry of Agriculture and Tianjin Environmental Protection Bureau, as well as the Chinese Academy of Environmental Sciences, concluding that the results from the project had high relevance for policy-making and science. Thus, the project interacted with representatives of public authorities from the grass-roots level of villages, via county and municipality (equivalent to province) to the national. The importance of interacting with local residents was essential.

What has happened since the SinoTropia project commenced? In general, knowledge and understanding regarding nutrient management generated from the SinoTropia project have been applied in the planning process of a new local Ji county pollution control plan for the reservoir. To get a more detailed picture, in autumn 2017 we went to Yuqiao, met with the village leader assisting during the project, and visited different places in the area. This revealed that several measures have been taken and the most central ones for this study are: (i) the pigs, chickens etc. have been removed from the area near to the reservoir, and farmers have turned to e.g. plants used for making traditional Chinese medicine, as well as certain types of vegetables and fruits, removing manure and also, at least for some, halving the use of mineral fertilizers; (ii) pipelines for tap water into homes and waste water/sewage out and to centralized treatment are under construction (paid by Tianjin municipality), thereby avoiding the dumping of black water; (iii) fencing of the reservoir, eradicating fish ponds, and establishing wetlands reducing leaching of P to the reservoir; (iv) although some farmers are still adding excessive quantities of mineral fertilizers to their small plots of farmland, the village leader indicated that a more careful use is emerging; and (iv) facilitating new economic activities for farmers, e.g. tourism (flower farms and organized boat trips on the lake) and organic production of e.g. fruit, and some fishing in the reservoir continues, but this is now restricted.

We cannot tell whether the SinoTropia project has affected the making of these measures, but several are in accordance with findings and suggestions provided by the project, e.g. dealing with manure and sewage, the establishment of wetlands. It is notable that several measures have been introduced in a top-down manner, with local village leaders left trying to make the best deal for residents, e.g. ending husbandry and venturing into alternative productions, and negotiating compensation for e.g. displaced farmer households, etc. On the other hand, local farmers and residents participated in the SinoTropia project; they contributed to the conclusions and suggestions provided by the project. For farmers to be able to earn money from ferrying visitors on a trip onto the lake, and to have the right also of catching fish for sale to food outlets offsets anger at the restricted access to the lake.

The role of inter/transdisciplinary research and processes and the DPSIR framework

It appears reasonable to say that interdisciplinary research has enhanced the knowledge on eutrophication. As the two projects show, interdisciplinary research can make wicked problems of environmental management less wicked, thereby providing the basis for designing policy measures and environmental management.

The usefulness of the DPSIR framework is more ambiguous. It has been criticised for favouring environmental management of a preservationist–conservation type [30] and not facilitating communication between researchers and stakeholders/policy makers, or being able to deal with the multiple attitudes among stakeholders and the general public. Our experience has been different. The stepwise character of the framework may be seen as favouring a traditional approach of science providing input to policy making which results in actions, and subsequently responses are acting on drivers. The authors do not consider the science–policy–action–response–drivers chain to be necessary. Instead, interaction among different stakeholders may easily be integrated under and appear at different stages of the umbrella of a DPSIR framework, with its relatively broadly defined stages. Moreover, DPSIR is said to fail when it is used to study macro scale outcomes but not when it is applied to local cases [31] which was the scale of the projects reported here. On the other hand, though of limited significance, the DPSIR framework did not play any decisive role in relation to the interdisciplinary research and transdisciplinary processes in either project. Potentially, the path of “drivers–pressures–states–impacts–responses” thinking may influence outcomes, but the interaction and combination of disciplinary perspectives in analysing processes and outcomes facilitated by this conceptual framework were far more important.

The projects have shown that two very similar versions of interdisciplinary research were capable of laying the basis for conducting policy relevant analyses under different institutional settings. The two versions of transdisciplinary processes differed more but still, common elements worked in both settings. This indicates that interdisciplinary research and transdisciplinary processes may combine with environmental management under different institutional settings. Nevertheless, we also see that some recent policy measures have been introduced in a top-down manner, although the SinoTropia project to some degree provided a channel for bottom-up information before the top-down policy making.

Two issues are important in this respect: how systems of interdisciplinary research and transdisciplinary processes are integrated in environmental policies and management; and whether and how inter- and transdisciplinary research and processes may help improve results of policies and measures. Any conclusive answer to the second issue would demand holding a range of factors constant – which may be beyond what is feasible, and definitely beyond what is feasible in this article. Therefore, we focus our discussion on the first issue, before briefly discussing aspects of the second issue.

As underlined in the introduction, recent scholarship has argued in favour of multilevel network governance as a strategy for better coping with environmental challenges of the coming decades, and perhaps centuries. Interdisciplinary research and transdisciplinary processes can align well with multilevel network governance, and our claim is that this applies for China and Norway, the first conventionally considered top-down authoritarian and the second more bottom-up democratic. Some may object that the Chinese system cannot foster multi-level network governance. But the Chinese system is less top-down authoritarian and the Norwegian system less bottom-up democratic than the conventional story tells. Nevertheless, there are of course differences in the two versions of multi-level network governance. An instructive example of this is that although measures annoying farmers are introduced in both countries and provoking non-compliance or poor compliance, it seems that the interaction with farmers in the Norwegian case has facilitated more and better farmer compliance than in the Chinese case study. It should be added that this is a much simpler task in Norway than China because there is a far greater number of farmers in China.

Although important success factors of the Norwegian case, like the use of farmer role models and the Agricultural Advisory and Experimental Society, may well be replicated in China, it may also be the case that a stronger and more developed bottom-up component in Norway contributed to better farmer compliance. The question whether a stronger bottom-up component is possible under the Chinese system emerges. Recent studies of the governance system in China have brought to light a more pronounced role of bottom-up actors, seen by various authors as e.g. adaptive governance [32]; policy learning and experiments under hierarchy [33]; project governance [34, 35]; and consultative authoritarianism [36]. The integration of the grass-roots level, as e.g. farmers, into multi-level network governance is also found in China but it may still be much less general and widespread in China than in Norway. What is termed bottom-up in China may pertain to actors above the grass-roots level of our study, e.g. the county level.

We contend, however, that China can, within the existing institutional system, make the grass-roots level (farmers) more integrated in decision making, and thus develop a more systemic multi-level network governance of farming and the environment. As noted above [10], the Norwegian system also has a clear top-down component, indicating that the core issue is the balance between bottom-up and top-down governing, as well as hierarchy and network.

This discussion also relates to the role of science in the mix of interdisciplinary research and transdisciplinary processes. Eutropia and SinoTropia both had a strong science component which may better align with the Chinese system than with systems where stakeholders like e.g. local lay knowledge, NGOs, business organisations, policy think tanks, and policy-makers and governmental bureaucracies are assigned a larger or dominant role. On the other hand, if non-science stakeholders are granted a too strong position and the role and value of science is reduced, it is an open question whether interdisciplinary research can play a significant role in transdisciplinary processes. The approach favoured by the two projects was one of incorporating local lay knowledge as part of the empirical basis for scientific analyses.

The second issue identified above was whether and how interdisciplinary research and transdisciplinary processes may help improve results of policies and measures. What one may argue is that the use of a common framework for integrating different natural and social science disciplines enhanced our ability to reveal context-dependent processes that are central to policy-making and ultimately outcomes at the local scale in both countries. It is hard to conceive how this could have been achieved in projects just focusing on either natural or social aspects. For instance, knowledge on the poor content of organic material in the soil in the Chinese case and high content of iron in the Norwegian case are clearly important for understanding why local farmers have used an excess of fertilizers. In both the Chinese and Norwegian case, the importance of deep understanding of the local–global processes stood out. Moreover, it was evident that the significance of these processes was context-dependent. Although interdisciplinary research in both cases is shown to provide important results, outcomes may differ significantly which is to be expected.

Conclusions

The two projects confirm that interdisciplinary research and transdisciplinary processes improve the environmental management in handling the complexity and wickedness of current and emerging socio-natural conditions. This applies both under the Chinese and Norwegian institutional system, but the stronger bottom-up character of the Norwegian case seems to facilitate a stronger compliance by local farmers than is apparent in China. There is scope for improvement on the Chinese side by strengthening the involvement of local role models and doers, e.g. farmers with good farming competence and grass-roots members of the Party [27].

Interdisciplinary research for environmental management should aim to bring scholars from different disciplines together from the very start, also across the natural–social science divide. For instance, social science should from the very start take part in the preparatory work within the natural science disciplines and natural science should contribute to e.g. formulation of questions for surveys. This means working in parallel, thereby ensuring that the right questions are posed and addressed by both the natural and social sciences.

Transdisciplinary processes should be organised on the terms of science, or else science runs the risk of becoming hostage of vested interests. Local lay knowledge should be part of the empirical basis both for natural and social science. Similarly, policy-making may provide input for research and being part of the empirical basis but should abstain from meddling with choice of scientific theories and methods, and analyses and results – a principle that currently is contested. Transdisciplinary processes linked to interdisciplinary research can bring interactions between science and non-scientific actors into well-defined procedures.

Nevertheless, hydro-biogeochemical models used to make predictions of effects of future changes based on scenarios and planned abatement actions in Norway are not generally applicable in China as the main governing processes differ. Moreover, the greater number of Chinese farmers and a more complicated governing structure make any transdisciplinary process more complicated. Any wholesale transfer of Norwegian systemic solutions is not viable. General principles have to be applied in context. Socio-natural processes, of which environmental management is part, differ. It is the claim of this article that interdisciplinary research and transdisciplinary processes can provide a deeper understanding of actual socio-natural processes.

Applying a DPSIR-approach fits with, but is not critical for, interdisciplinary research and transdisciplinary processes, and hence, neither for environmental management. DPSIR is a frame for guiding and organising the thinking about socio-natural processes, with feedback loops centre stage. There may very well be interdisciplinary research without DPSIR but DPSIR without interdisciplinary research is futile.

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Disclosure statement
No potential conflict of interest was reported by the authors.

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Annex 1 Scientific papers published under the projects of Eutropia and SinoTropia

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Lukawska-Matuszewska, K., Vogt, R.D., and Xie, R., 2013, Phosphorus pools and internal loading in a eutrophic lake with gradients in sediment geochemistry created by land use in the watershed, *Hydrobiologia*, 713(1), 183–197.

Mohr, C.W., 2017, *The Role of Natural Organic Matter and Phosphorus in a Changing Environment*, Department of Chemistry, Univeristy of Oslo.

Ojwando, W.O., 2014, *Monitoring of phosphorous fractions – Understanding the hydrogeochemical processes governing mobilization and transfer of phosphorous in an agricultural watershed in north-eastern China*, Department of Chemistry, University of Oslo.

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Orderud, G.I., Vogt, R.D., Andersen, T. and Luo. J., 2015, Explaining and understanding environmental actions in Chinese agriculture: the case of Yuqiao watershed of Tianjin municipality, *International Journal of Sustainable Development & World Ecology*, 22(6), 496–509.

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Parekh, N., 2012, *Assessment of phosphorus fractions in streams draining different land use and development of new monitoring method*, Department of Chemistry, University of Oslo.

Pettersen, E., 2014 *Soil phosphorus pools and their relation to land-use and soil physiochemical properties – A case study of an agricultural watershed in north-eastern China.*, Department of Chemistry, University of Oslo.

Røyset, O., Vogt, R.D., Mohr, C.W. and Parekh, N., 2014, *Sampling of dissolved inorganic (DIP) and organic phosphorus (DOP) compounds in natural water by Diffusive Gradients in Thin Films (DGT)*, NIVA Report 6590-2013, (Oslo, Norway: NIVA).

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Zhou, B., 2016, *Assessments through field studies, experiments and modelling of potential risk for phosphorus loss from an agricultural watershed*, Department of Chemistry, University of Oslo.

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[1] The highest preserved shoreline of the Holocene Epoch.

[2] In addition to interviews, the project also included an economic modelling based on Bayesian theory. This is not presented here since it is not used in the current article.

[3] The respondents were asked beforehand whether they allowed recording or not. All except one agreed to recording of the interview. G.I. Orderud was taking part in all and S. Holen was taking part in nine of the 23 interviews.

[4] The 18 that were recorded and transcribed were conducted by G.I. Orderud, and the four others were conducted by J. Naustdalslid. The reason for not recording and transcribing was a preference for taking notes during interviews.

[5] These documents were analysed by J. Naustdalslid.

[6] The survey was overseen by the responsible researcher (G.I. Orderud) and carried out with the help of four graduate students from the Nankai University (Tianjin). J. Luo (Chinese Academy of Sciences) organized the survey and J. Wang (Nankai University) was present on the first day.

[7] The interviews were conducted by three graduate students from the Nankai University (Tianjin) – R. Li, L. Shi, and H. Tan, under the guidance of J. Luo (Chinese Academy of Social Sciences).

[8] The focus group interviews were conducted by J. Luo and J. Shu (Chinese Academy of Social Sciences).

[9] The county governor's office is the representative of the central government at the regional level, monitoring, guiding, and controlling activities and actions at the local level.

[10] The members are the 11 municipalities of the watershed (Enebakk, Ski, Vestby, Äs, Frogn, Spydeberg, Hoböl, Väler, Moss, Rygge and Räde) represented by their mayors (voting power), the County Governors of Östfold and of Oslo and Akershus, the Counties of Östfold and of Akershus, The Norwegian Water Resources and Energy Directorate, and the Norwegian Food Safety Authority. In addition representatives of Oslo municipality, the Farmers' Union of Östfold and of Akershus, the Association of Nature and Leisure, MOVAR, Vansjö Property Owners' Association, and Moss User Rights' Association all have the right to attend meetings.

[11] Agricultural production in Norway is strongly regulated, with annual negotiations between representatives of farmers' organisations and the central government, with the Parliament voting on the results; that is, both the overall allocation of funds and its structure.

[12] The dominant producer of mineral fertilizers had to develop a new production line for providing a type with less phosphorus and was reluctant to do so.

[13] The map basis did not have the necessary granularity and actual classification work may not have been sufficiently detailed. The map basis is being improved by digital topographical scanning with two points per square metre as the standard, but with options for more points in prioritized areas.

[14] Interdisciplinary papers on the Chinese case have been written and published, by social scientists from both countries, but the natural scientists have been Norwegians.

[15] Research Centre for Eco-environmental Sciences (RCEES) under the Chinese Academy of Sciences, Tianjin Research Academy of Environmental Sciences (TAES), Institute of Urban and Environmental Studies (IJUES) under the Chinese Academy of Social Sciences.

[16] Department of Chemistry and Department of Biology at the University of Oslo (UiO); Norwegian Institute for Water Research (NIVA); and Norwegian Institute of Urban and Regional Research (NIBR).