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An alternative approach for socio–hydrology: case study research

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Abstract. This paper argues for an alternative approach for socio–hydrology: detailed case study research. Currently, the dominant approach in socio–hydrology is developing coupled human–water models. With very few exceptions, these models treat society as one actor or as a group of individual actors and do not include management structures and processes. Moreover, there is a shortage of data to calibrate and validate the models. Detailed case studies of individual river basins can be of help in these respects. They can result in a more complete understanding of how society interacts with hydrology and can help to identify new data sources. In addition, they can offer more levers for management and facilitate interdisciplinary cooperation. Two questions should be central: which human activities have had a significant impact on the hydrology of the case study area, and which factors can explain these activities? To give an idea of what a socio–hydrological case study may look like and what its potential benefits are, this paper presents a short case study of the Dommel Basin in the Netherlands and Belgium and compares this with a typical socio–hydrological model. The paper concludes that there is room for different approaches in socio–hydrology. However, given the limited attention they currently get, more attention should be paid to developing detailed case studies.

1 Introduction

Suppose you are interested in how river basins and human society interact and evolve together. And suppose you are interested especially in the Great Ouse Basin in the east of England. How would you study this basin? One option would be to set up a large interdisciplinary research project that studies the topography and geology of the basin, the formation of peat soils since 6000 BC, the first human interventions, the 17th Century drainage works, the resulting peat shrinkage and wastage, the subsequent water management works, the changing governance structure to undertake and finance these works, the changing economy of the basin, and the changing influence of agricultural lobbies (e.g. Godwin, 1978; Darby, 1983; Richardson et al., 1978; Hall and Coles, 1994; Sheail, 2002; Purseglove, 2015; Mostert, 2017). This would involve extensive literature search and a lot of field work and archival research.

Another option would be to model the co–evolution of water and society in the Great Ouse Basin. Using insights from previous research on this basin and other comparable basins, a coupled human–water model could be developed, which could then be calibrated and validated in order to simulate past and predict future developments. Alternatively, the coupled model could be used as an exploratory toy model to generate possible explanations and identify possible future developments.

In socio–hydrology the most popular option currently is to develop coupled models. In this paper I argue for more detailed case study research. To give an idea of what a socio–hydrological case study may look like and what its benefits can be, I will present a short case study of the Dommel Basin in the Netherlands and Belgium and compare this with a typical socio–hydrological model. In the concluding section I will discuss which of the two options is best and whether they are really different or complement each other. But first I will briefly review the state–of–the–art in socio–hydrology, focusing on how society is included in the different socio–ecological models.

2. Socio–hydrology

The term socio–hydrology was coined in 2012 by three well–known hydrologists (Sivapalan et al., 2012). They defined socio–hydrology as “a new science of people and water” that aims at “understanding the dynamics and co–evolution of coupled human–water system” (Sivapalan et al., 2012, 1271). Socio–hydrology treats people as an endogenous part of the water cycle. It studies not only the impact of people on water, but also of water on people (e.g. Pande and Sivapalan, 2016). This would result in better understanding of long–term developments, better long–term predictions and better support for water management than for instance scenario–based approaches that do not consider hydrological constraints.

The dominant approach in socio–hydrology is developing coupled human–water models. The number of these models is slowly increasing. The issues modelled include flooding (Di Baldassarre et al., 2013, 2017; Viglione et al., 2014; Grames et al., 2015; Yu et al., 2017; Girons Lopez et al., 2017; Barendrecht et al., 2017), water quality management (Chang et al., 2014), reservoir operation (Garcia, 2016), water supply (Srinivasan, 2015; Ali et al., 2017), groundwater abstraction (Noël and Cai, 2017), subsistence farming (Pande and Savenije, 2016), the shift from water resources development and control to protection and restoration (Van Emmerik et al., 2014; Elshafei et al., 2014; Chen et al., 2016), and the collapse of civilisations (Kuil et al., 2016).

With very few exceptions, these studies model society as one actor (e.g. Elshafei et al., 2014; Van Emmerik et al., 2014; Viglione et al., 2014; Grames et al., 2016) or as a group of individual actors (e.g. Pande and Savenije, 2016; Noël and Cai, 2017). Management structures and decision–making processes are rarely modelled. Yet, in practice it makes a big difference whether decisions are taken at the basin level, at the local or at the national level; which interests are involved and which not; who will benefit and who will have to pay; and whether there is strong sense of community or not (see Mostert, 2015, 2017). The importance of these issues is recognised in the socio–hydrological literature, but this is rarely reflected in the coupled models that have been made. A very interesting exception is the toy model by Yu et al. (2017), which analyses the issue why farmers in the polders in Bangladesh are willing to make voluntary contributions to the upkeep of the flood defences, even though it seems economically rational for them to free–ride on the efforts of others.

Despite their simplifications, most socio–ecological models can mimic patterns that can be observed in reality. This could be because the models include many variables for which no data are available and consequently have many degrees of freedom (Troy et al., 2015). It could also be because the variables and processes not included did not vary a lot in the area and period modelled and consequently can reasonably be ignored (cf. Garcia et al., 2016). Or it could be a combination of both. In any case, the validity of the models outside of the area and period modelled is unclear and predictions based on them are highly uncertain.

Socio–hydrological systems cannot be modelled exhaustively, but it is important to include the most influential variables and processes (cf. Garcia et al., 2016). What these are depends, first, on the issue of interest, which in turn depends on the disciplinary background of the researchers and the political and policy context (Lane, 2014). Secondly, they depend on the area and period studied. Societal response to hydrological change may be limited when costs have to be made upstream but the benefits are downstream and when costs are individual but benefits collective. Response will be bigger when appropriate institutional arrangements are in place (e.g. Ostrom, 1990; Brondizio et al., 2009) and when there are strong collective values (Yu et al., 2017; Mostert, 2017). However, such arrangements and values will not be present everywhere and always. They have to be developed and maintained. Moreover, as conditions change, they may no longer function satisfactory and may need to be changed or replaced or else may collapse (e.g. Mostert, 2012).[1] To complicate matters, these changes may be triggered by hydrological factors, such as droughts and floods, but also by factors that are not or only weakly connected with hydrology, such as population growth, increasing levels of education, technological development and political changes.

The socio–hydrology literature contains several recommendations for future research. A first one is public participation (Lane, 2014; Sivapalan and Blöschl, 2015; Srinivasan et al., 2017). Public participation can be a means to obtain data from the public, to educate them, and to promote buy–in of model results and subsequent decisions. In addition, it can be a means to involve the public in the modelling itself and give them control over what to model exactly and what (policy relevant) assumptions to use.

Another recommendation is to start modelling with clearly defining objectives and to include only the most influential variables and processes given these objectives. This would prevent overly complex models and promote transparency (Garcia et al., 2016). A quite different recommendation is to move beyond the scale of individual river basins and include more variables and processes, such as international trade and climate change (Pande and Sivapalan, 2016; Srinivasan et al., 2017). All else being equal, this would result in more complex models.

[1] I will leave aside the question whether institutional arrangements can be designed (e.g. Ostrom 2005) or develop in practice (e.g. Cleaver 2002). The answer depends on whether one defines institutions as explicit agreements and enactments, or as types of practices. Moreover, it is not an either–or issue. To have any effect, agreements and enactments need be taken up in practice and become part of that practice. They may be used for purposes that differ from what they have been designed for (Cleaver 2002), but they can still have a large impact on practice.

A general recommendation is to collect and use more data (e.g. Troy et al., 2015; Blair and Buytaert, 2016). This is essential for calibration and validation and for preventing overfitting. Calibration and validation may be less important for exploratory toy models that do not aim to simulate specific systems accurately, but to capture essential processes and feedbacks, generate possible explanations and explore possible future developments (e.g. Thompson et al., 2013; Di Baldassarre et al., 2015, 2017; Yu et al., 2017). Still, toy models need data too, at least qualitative data, to check how realistic they are.

3. The alternative

Before adopting any recommendation for improving the current socio–hydrological models, it is good to look whether there are alternative approaches. One alternative is a specific form of case study research. It involves detailed research of the long–term developments in individual river basins or other hydrologically relevant units, such as a lake basin or an aquifer area. It addresses two central questions:

1) Which human activities have had a significant impact on the hydrology of the area? and

2) Which factors can explain these activities?

The human activities can include all activities that change land use, water use or water flows, such as deforestation, surface and groundwater water abstraction, field drainage, dredging, river regulation, hydropower generation and flood protection. These activities could be identified by hydrologists in cooperation with historians and social scientists. The latter are familiar with sources not often used by hydrologists, such as historical monographs, archival sources, newspaper articles and old maps (Zlinszky and Timár, 2013). For determining the impact of the different activities modelling can be useful, but the models do not need to be coupled: the activities identified can be included as external forcing factors. Depending on the area and period covered, the involvement of soil scientists, ecologists and river morphologists may be useful as well.

To explain the different activities, a sound understanding of how a society functions and what role water plays in this is needed. This requires insights from disciplines such as political science, (institutional) economics, law, sociology and anthropology. A first question to address is who are the major actors? In general terms these are the main individuals, groups and organizations that use the land and water, regulate land and water use, or construct and maintain the water management infrastructure. Further questions that can be addressed include which interests are represented in water management and how is it financed? Moreover, what are the values and perceptions of the major actors and how do these evolve? Are there conflicts of interests between different actors or sub–areas, such as city versus countryside, upstream versus downstream, or flood–prone areas versus higher grounds? How do the different actors interact? Is there a sense of community and an open dialogue, or is there a lot of political manoeuvring? How important is water for the economy in the area? And how much control do the actors have over external factors that affect the area's hydrology?

These are just some questions that may help to explain the different activities: there may be more. The trick, or "art" (cf. Savenije, 2009), is to zoom in on those factors that have the biggest explanatory power in the specific case. To achieve sufficient detail, it is advisable to focus on one or two important activities. In addition, one could use an existing theory to guide research and help interpretation, such as the theory on common pool resources management (e.g. Ostrom, 1990; Araral, 2014). However, this is quite tricky as many theories tend to be one–sided and focus one or a few factors only. Consequently, their explanatory power may differ from case to case and one should always keep an open eye for explanatory factors that do not fit the theory.

As in all case study research, the selection of cases is crucial (Yin, 1989; Mollinga and Gondhalekar, 2014). There are several options. If one is interested in the shift from water resources development and control to protection and restoration, one can select a typical example of this phenomenon to explore what important variables and processes may play a role. If there is already quite a lot of information on this phenomenon, one could select a case either to replicate previous research or to complement it, e.g. if all previous cases studies were about small watersheds in North America, one could select another small watershed in North America or a large river basin from another continent. If there is a theory that seems applicable, one could select a case that is critical for testing the theory, e.g. one that prima facie seems to falsify it. Practical considerations such as data availability and accessibility should play a role as well. If there is enough time to conduct multiple case studies, one could adopt a most different or a most similar design. A most different design involves selecting cases that are as different as possible, to cover as much of the diversity in the population of cases. In a most similar design, the cases are as similar as possible and differ in one important respect only, for instance they all have a similar size, population and level of economic development, but the type of water governance differs. This is a good design for isolating the effect of an individual factor, in this example water governance.

4. The Dommel Basin

To give a better idea of this alternative approach and its potential benefits, I will present a concrete case: the basin of the Dommel River. The Dommel River has its source in Belgium and then flows into the Netherlands, where it discharges into the river Meuse. The basin area is circa 1,700 km2, 200 km2 in Belgium and 1,500 km2 in the Netherlands. From 1875 onwards river regulation works were undertaken on the Dutch part of the Dommel to increase the discharge capacity and reduce flooding. From 1990 onwards, however, these works were replaced by river restoration projects (Roeffen, 1963; Didderen et al., 2009).

The Dommel basin is a typical example of the shift from development and control to protection and restoration. Using the socio–hydrological model of the Kissemee basin in Florida (Chen et al., 2016) as an example, it would be possible to explain this shift in terms of "community sensitivity". If community sensitivity is low, people prefer to develop or control the environment, and if it is high, they prefer to protect or restore it. Community sensitivity depends negatively on the memory of flooding – the bigger and more recent the flood, the lower community sensitivity – and positively on the degree of environmental degradation – the more degradation, the higher community sensitivity. Flooding and environmental degradation in turn depend on the regulation and restoration works, as well as on external drivers such as precipitation.

As in the Kissemee model, it would be possible to distinguish between different groups of people with different community sensitivities, such as people in flood prone areas and people living on higher grounds, and then calculate community sensitivity as a weighted average of the sensitivities of these groups. Using a limited number of equations, a coupled human–water model could be constructed that explains the decision to regulate or restore. Given the number of parameters – six in the Kissemee model – and the limited availability of societal data, it should be possible to achieve a reasonable fit. Moreover, it would probably be possible to validate the model to some extent by collecting newspaper articles that discuss either flooding issues – mostly prior to 1990 – or restoration – after 1990 (cf. Elshafei et al., 2015). This could indicate a change in community sensitivity – or it could simply reflect the different types of projects being discussed.

As it is, I have not made a socio–hydrological model. Instead, I have made a start with a case study on the Dommel Basin: I have read one monograph on the basin (Anonymous, 1963) and combined this information with my background knowledge of Dutch water management and water governance. This explained why flooding had become problematic in the first place. First, there were complaints that the water mills on the Dommel maintained a too high water level. Moreover, in the 1840s 4,000 ha of water meadows were constructed upstream in Belgium. These were flooded in winter with Calcium and mineral rich Meuse water, imported via a newly constructed shipping canal, to improve fertility of the soil. In spring, however, the surplus water was discharged onto the Dommel. Furthermore, in the late 19th and early 20th Century large tracts of heath and moorland in the basin were turned into forest and agricultural land (see Fig.1). This was seen as increasing flooding. The change in land use was made possible by the introduction of artificial fertilisers, which removed the need for sheep manure and therefore for the heath to graze the sheep.

To facilitate the river regulation works, the Dutch Province of North–Brabant set up a regional water board that could execute the work and tax the landowners in the basin. This took seven years, from 1856 to 1863. Following, it took another 12 years to finalise the plans and agree on financial contributions from the State and the Province.

By 1990, when the restoration works started, the situation had changed drastically. The population of the basin had increased a lot and they had more free time. Consequently, the recreational and landscape values of the Dommel had increased in importance. Moreover, in 1950 the water board had become responsible for sewage treatment. As a result representation on the board had been broadened to include citizens and industry; before only the land owners were represented (cf. Mostert, 2016). In addition, in 1916–1923 a new shipping canal was cut through the basin, the Wilhelmina Canal. This canal could also be used for draining the upper basin, thus reducing the load on the lower Dommel. And finally, in the mid–1980s a new national policy, called "integrated water management", had been introduced, which emphasised the ecological aspects of water systems (Ministerie van Verkeer en Waterstaat, 1985, 1989). This new policy had been triggered by the controversy on the closure of the Eastern Scheldt estuary more to the west in the 1970s. This controversy in turn can be explained by the growing environmental awareness in the Netherlands since the late 1960s and the limited flexibility of the State Water Management Agency at the time (Disco, 2002; Mostert, 2006).

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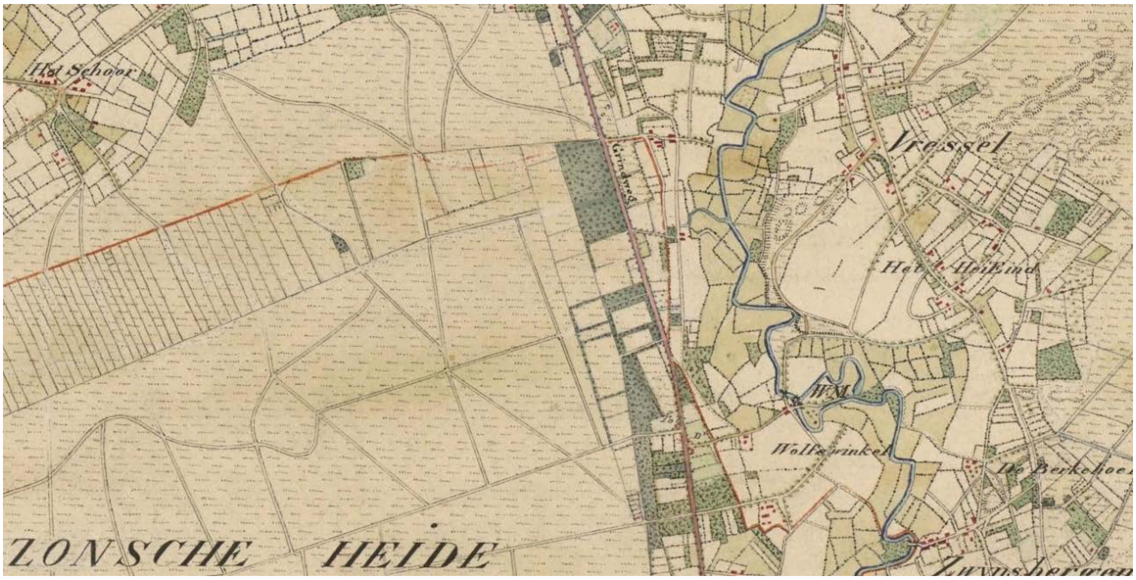

Figure 1: Part of the Dommel Basin in 1837, showing meadows along the river (light green), arable land (white) and large tracts of heath ("heide"). The Zonsche Heide is now mostly arable land, with forests and new residential areas in the south. "WM" indicates a water mill. (National Archives, topographical map of the area around Boxtel and Sint Oedenrode (detail), toegang 4.TOPO, inv. nr 9.169)

All these developments can be studied in much more detail. First, it would be interesting to model the impact of the land use changes and the river regulation works on the extent and frequency of flooding. Moreover, the social and economic changes and the changing governance arrangements in the basin can be described in more detail. And finally, individual decision–making processes, concerning for instance the establishment of the water board and the first restoration project, can be analysed in detail. Sources that can be used include the following:

- old land use surveys
- census data
- old topographical descriptions
- monographs on agriculture in the area
- project reports (feasibility studies, etc.)
- old water level data (e.g. in relation to the water mills)
- old laws and byelaws
- minutes of the provincial board
- minutes of the water board
- newspaper articles

Most of these sources are freely available at Brabants Historisch Informatie Centrum in the City of ‘s–Hertogenbosch and increasingly also online (older newspapers at www.delpher.nl, old maps at the Website of the National Archives www.gahetna.nl, etc.). Concerning more recent periods, additional data can be collected using the following methods:

- field surveys
- social surveys
- interviews
- direct observation
- gaming

5. Modelling versus case studies

How does socio–hydrological modelling and detailed case study research as proposed in this article compare? Which approach will improve our understanding of long–term developments most, which will result in the best predictions most and which can support policy best?

For improving understanding detailed case studies have many strong points. They allow for the use of all types of data, including qualitative data. They are flexible, allowing the researcher to move from hydrological issues to other issues and from the basin level to higher levels without having to develop a global model of everything. Unlike most models, they do not require that variables and relations are specified in advance and consequently they are more likely to reveal completely new mechanisms one did not think of before. Moreover, they do not require the assumption of stationarity. In fact, they are well suited to study how systems and system behaviour change, how for instance individuals and societies learn and why new management bodies are set up. Furthermore, case studies can go into much more detail than models and give detailed information on for instance decision–making structures and processes, political strategies, social relations and the distribution of costs and benefits. In addition, they can result in a better qualitative understanding of the issues at stake and can identify new sources of data, which can then be used for developing more realistic models and calibrating and validating these models. And last but not least, case studies offer good possibilities for cooperation with disciplines not used to (numerical) modelling, such as law and anthropology. For hydrologists interdisciplinary cooperation may imply losing some control (Wesselink et al., 2016), but the benefits are huge, provided one selects the right persons to cooperate with: those interested in hydrology and not using overly abstract jargon.

A potential problem of case studies is their generalisability: what can one conclude on the basis of one case study only? The answer is: not much. The solution is to select cases carefully, as discussed supra, and compare the results with previous research. In this way case studies can be used to test and further develop theory. Ideally, these theories should be flexible and adaptable to the specifics of the case, to ensure that they are both widely applicable and not too general.

Detailed case studies as proposed here are not good for making quantitative predictions. But models do not fare much better, at least not if by "prediction" we imply a minimum degree of certainty. For the short term this may be feasible, but in the long term too many factors may change that cannot be modelled properly (cf. Srinivasan et al., 2017). What models can do is to generate possible future developments or "scenarios", based on different assumptions concerning for instance climate change. These scenarios can then be used for developing robust and flexible adaptive strategies to cope with a broad range of possible futures (e.g. Haasnoot et al., 2013; Pahl–Wostl et al., 2008). Models can also be used to explore the possible effects of policy measures, such as an insurance system for flood damage (Grelot and Barreteau, 2012).

What detailed case studies can do is to improve our understanding of how unpredictable long–term developments are and how in the past societies have adapted to them. Moreover, since they can be much more detailed than models, they offer far more levers for management. Obviously, models that do not include management structures and processes cannot offer any guidance on these issues.

Finally, case studies may have intangible benefits as well. Arguably, increased mobility and trade have led to a de–localisation and de–materialisation of social life. Case histories of how society and hydrology have interacted and depend on each other may help to reconnect the social and the physical world and stimulate a sense of "watershed community" (Barham, 2001). And a minimum sense of community (or "social capital") is a precondition for effective river basin management as it mitigates conflicts of interests and facilitates cooperation (Mostert, 2017).

6. Discussion

So, which approach is better for socio–hydrology: developing coupled models or detailed case study research as described in this article? Before we can answer that question, it is necessary to revisit the aims of socio–hydrology and address the issue whether developing coupled models and detailed case studies are really different approaches.

Arguably, the central aim of socio–hydrology is better understanding of the human–water system because the other two aims of socio–hydrology, prediction and policy support, can only be realised if there is a good understanding. But "understanding" can mean different things. For me, understanding how my bicycle works means understanding how to operate it, but for a bicycle repair man it means understanding how to repair it. In socio–hydrology, understanding may mean quantitative understanding to enable precise predictions or scenarios. For this purpose developing coupled models is a good approach, preferably supported by detailed case study research. Understanding may also mean detailed qualitative understanding to support policy. For this purpose detailed case study research is a good approach, possibly supported by models, both coupled toy models and more classical models.

Since modelling and case study research can support each other, one might argue that they are not really different approaches, just different techniques that can be used in different phases of research. That would, however, be underestimating the differences. At the risk of overgeneralisation, we can say that quantitative approaches generally aim to identify commonalities and assume that empirical phenomena can be explained in terms of a limited number of general laws, processes or mechanisms. Case study research, on the other hand, focuses on the specifics of individual cases and tries to explain these in terms of a unique combination of factors. It tends to be very empirical. It starts with detailed description, guided by prior knowledge and interest, and then compares the results with other cases in order to identify differences and similarities and better understand the uniqueness of the individual cases. Modelling is usually more deductive and theoretical. The first step is to construct the model using hypothetic knowledge. Empirical data come in later to calibrate and validate the model, and not all models are calibrated and validated. The only exceptions are data–driven modelling, even though these use hypothetic knowledge too for selecting the relevant data, and to a lesser extent flexible conceptual models (Mount et al., 2016).

Modelling works best for systems that are relatively simple and stable. In socio–hydrology, however, we are interested in quite complex systems that evolve in time. This means that there is not one system to model, but a suite of related systems. Obviously, this complicates calibration and validation. A possible solution is to redefine the system to incorporate specific qualitative changes, but this would make the system modelled very complex. To cope with this complexity compromises are inevitable (Levins, 1966; Troy et al. 2015). One option is to sacrifice generality to realism and precision. This is effectively the strategy of demand–driven modelling. Another option is to sacrifice realism to generality and precision. This is what may happen if one makes models too complex to be calibrated properly or if one leaves out important processes in order to limit complexity. A third option is to sacrifice precision to realism and generality. Uncalibrated toy models fit in this strategy. But if one is willing to sacrifice precision, one can also think of detailed, qualitative case studies. As argued in the previous section and shown by the Dommel Basin case study, case studies have several advantages and can result in important new insights.

To conclude, there is no single best approach to achieve progress in socio–hydrology. All approaches have strong and weak points, and it also depends on what it is one wants to achieve. Yet, given the limited attention they currently get, I argue for more detailed case studies along the lines sketched in this article.

Competing interests. The author declares that he has no conflict of interests.

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