Locally embedded social movements and the science and technology system: A case study of the wetlands social movement in Bogotá[1]

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1. Introduction

Social movements are an important avenue through which civil society has historically expressed demands for social change in areas that are relevant to the science, technology and innovation system. However, research on how social movements can influence science and technology agendas are largely absent, not only from Schumpeterian framings of science, technology and innovation (STI) but are also left out of the equation in most accounts of civil society participation in science and technology governance. This may be because social movements, as opposed to other forms of so-called participation, are often associated with challenging power relations and can therefore be more difficult to dialogue with and control. Nevertheless, it is an important omission. Increasingly the priorities of science and technology policy need to reflect societal demands and social movements can represent a powerful and sophisticated civil society expression for social change. They can also be important in supporting the defence of the commons and provide agency behind what Hess has described as "undone" science i.e that science which tends be overlooked by the mainstream, not supported by multinationals and would otherwise not be heard or left incomplete (Frickel et al., 2010; Hess, 2015). From the industrial transitions literature there is also an increasing acknowledgement that transition processes will require deep changes in social processes within which social movements in certain areas such as environmental justice will be important (Geels & Schot, 2007)[2].

In this paper we turn the focus of social movements and the science and technology system outside of the global north and to Colombia, the location for this paper's case study. In Latin America not

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[2] Municipal and local authorities are often crucial in this process. Seyfang & Haxeltine (2012) point out that 83% of transition initiatives have begun the process to "build a bridge to local government" (2012: 39).

only are social movements more prevalent as an expression of societal demands for change, social movements also have a particularly strong tradition in academia. Unlike the European Universities, that were on the whole limited to the Humboldtian principles and traditions of science, the establishment of the university as an independent societal institution in Latin America was in addition forged through ideals of democratization and through its third mission to provide extension services to help deprived groups (Arocena, Göransson, & Sutz, 2017). This is often expressed in the regions in which university academics are embedded, which has often been interlaced with participation in social movements.

Building on these historic traditions, the purpose of this paper is to develop the discussion of the relationship of social movements and the science and technology system in two ways. Firstly, we bring in a geographical lens to the debate through a more in-depth discussion of place-based social movements. Geographers have long emphasized that territory and co-location of actors facilitates the building of relational local alliances and heterogeneous networks (Harvey, 2008; Warf, 2007). Place-based social movement and the networks that are formed is therefore an important feature of social movements that can overlap with how STI policy affects regions.

The paper also offers an approach for measurement techniques to represent changes that have taken place in social movements and R&D projects. This is an important contribution to a broader discussion of the pros and cons of using quantitative techniques and indicators available from new data sources to measure the relationships between mobilized publics, investments in science and technology and the linkages between the two. The above discussion takes place through an empirical study of a socio-environmental movement for the protection of Wetlands in Bogotá, Colombia. This allows us to incorporate some specific notions that link social movements to use of collective spaces.

2. STI social movements and place based analysis

Social movements are a particular expression of civil society where individuals and communities are brought together to create conditions for social change. The influence of science and technology agendas, practices and priorities requires an understanding of how the STI system engages both with the lay public but also with actors and organisations that are in subordinate positions. Reference to social movements are completely absent from economic and managerial innovation narratives that dominate many of the large multilateral organisations as well as national STI agencies. However, social movements feature more prominently in the Science and Technology Studies (STS) inspired literature, for example in grassroots innovation, where the concept of innovation is imbued with notions of social activism and community organising (Fressoli et al., 2014).

Hess (2016), whose contribution on the subject is the most clearly recognizable, pulls together experiences from a broad range of social movements to build a typology of social movements and that have influenced science and technology policy (table 1). For example science advocacy was particularly effective in the environmental breast cancer movement in the United States, whilst citizen science alliances have been a preferred mode of intervention in the anti-Dam movement in Brazil (McCormick, 2006).

	Motivation	Aim	Mobilizing structure	References
Scientific and intellectual movements	Dissatisfaction with research agendas	Reform research priorities	University departments	(Frickel 2004)
Scientific advocacy and activism	Reform a research field	Change public opinion and policy	Boundary organisations and scientific panels, covert advocacy, professional organisation	(Moore, 1996)
Citizen-science alliances	Challenge dominant paradigms	Respond to undone science needs of communities	Local communities, alliances	(McCormick, 2006)

Table 1: Typology of organisational forms of counterpublic knowledge (Hess, 2015)

A spatial analysis has the potential to strengthen this area because social pressures in the science and technology systems towards social transformations is essentially a political process that is inherently grounded in territorial spaces. Geographical proximity is by no means the only lens through which transformative is constructed. Nevertheless, co-location facilitates grassroots coalition building, alignment of views and construction of alliances between otherwise disparate groups and it is here that heterogeneous coalitions can be constructed (Harvey, 2008). These social relations, built through dense exchanges, can create identities (Kits 2000) and strengthen shared narratives, which is a point strongly emphasized by communicative theories (Habermas, 1987) that stress the importance of collective visions and sharing of histories (Tilly & Tarrow, 2007). These local movements and alliances are important, for we need to take our discussion out of the strictly scientific field of mobilization towards areas where scientific knowledge interacts with other knowledge of the mobilized publics (Hess, 2015) where scientists ally with ecological or other activists and look to alter research agendas (Smith, 2006).

A second reason for our focus on space and region is that differently positioned actors have distinct identities and experiences that influence their understanding of the world which emerge relationally through connections and interactions but are strongly influenced by spatial inequalities and unequal power relations (Crossley, 2010; della Porta & Diani, 2006). This means that, particularly in highly unequal contexts such as exist in Latin America, sensitivity to local realities is critical and needs to acknowledge the identities, perceptions, experiences and meanings of mobilized agents (Della Porta, Diani, & Routledge, 2015). We therefore need to combine an approach that incorporates both the idiosyncratic imaginaries created by actors that are co-located in social movements but also the uneven nature of these.

One important trend in the literature that can useful build bridges between space-based analysis and the STS literature, is the growing interest in STS studies and social movement studies (SMS) around policy making processes and actor agency roles (Hess, 2015). This means that civil society needs to be treated as an active rather than passive actor (Frickel et al., 2010) and questions of resource mobilization, collective action frames and coalitions need to be addressed as meanings that define and motivate action (Diani & McAdam, 2003; McAdam, 1999). An important space is thereby created whereby the agency of actors involved in social movements is attached to new metaphors such as entrepreneurship and construction, which opens up an important field of research around how for example community mobilization engenders processes of learning to overcome the limits imposed by the local conditions.

The importance of spaces therefore emerges as a milieu in which organisational forms and new meanings and alternatives are facilitated. A particularly useful approach that captures this idiosyncratic process of generation of local knowledge generation is the concept of bricolage. It emphasizes a mode of action based on actors' capacity to work with what is at hand to create novel combinations to overcome constrains (for example low local capabilities, fragmented agendas and unwillingness of policy makers and other actors in power to engage) (Garud & Kornoe, 2001; Faulconbridge, 2013; Boschma, et al 2017). Bricolage has been applied in different academic contexts, most notably entrepreneurship (Garud & Kornoe, 2001) to depict the way actors interact with their constraints to generate change. However, its relevance has not been lost in policy circles. Garud and Kornoe (2003) for example identified the continuous interaction between research centres in the development of turbines for wind energy generation and policy makers that allow new policy priorities to be shaped and define new standards and structure new calls for channelling funding of both research and entrepreneurial activity. The significance of social movements is that it combines specific connotations and notions of protest and societal challenge with the power to redirect science in society towards what Hess (2015) calls "undone science" i.e. that science which is often unfunded, incomplete or ignored but that civil society considers worthy of further research.

The advantage of this approach is that, unlike most studies of innovation that emphasize the conservative nature of firms, sunk costs and problems of lock-in, bricolage emphases the innovations in "shared collective spaces" by heterogeneous actors, which can lead to unpredictable outcomes (Baker, *et al* 2003; Altglas, 2014), although these are bounded by relational interactions in common spaces. These movements can facilitate the emergence of new resource arrangements, practices and policy oriented to address and generate socio-technical change (Garud & Kornoe, 2001, pg. 26). Participation of scientists, universities and research centres to bring in knowledge and technologies to create alternative understandings and solutions that may constitute potential solutions to current social demands (Garud & Kornoe, 2003; Boschma, *et al* 2017). This is relevant particularly in the case of urban water transitions, where interdisciplinary and cross disciplinary knowledge has been considered a key input for transition (Went, *et al 2015*). Social movements use those inputs and results to enrich narratives and substantiate more detailed demands for change and exert further pressure on policy. Moreover, increasing knowledge and reflection within territories can open opportunities for the emergence of new actors or institutions that are needed to facilitate the evolution towards a new socio-technical system (Bethelt & Glückler, 2005).

3. Research objectives and Methods

Two key features of social movements are their ability to construct new meanings (i.e. alternatives) and their organisational characteristics. New meanings in social movements have traditionally been seen through frame analysis which has been associated with for example Lubitow's (2013) study of frame amplification by providing scientific credibility to activist demands and cultural analysis that builds on the provision of narratives and relies on historical events and traditions as templates for action.

Our proposition builds on the above by highlighting how in place-based analysis unique heterogeneous organisational networks are part of the process of creation of new meanings because of the distinctive relations created. Place based analysis implies looking at the interaction processes between social movements and actors insert within the science and technology system in relational arenas. Actors can therefore be studied in terms of how they are positioned in a social space and through their relations and affiliations. This means focussing on how organisational changes and meanings interrelate in spaces. For this purpose, we pay particular attention to networks as a space for the reconfiguration of alliances. From a social movement perspective, social networks can be understood as resources for the articulation of alliances and coalitions across organisations and movements. At the same time, movements emerge through multiple types of ties and it is often the interplay between these that defines movement dynamics (Gould 1995, McAdam and Paulsen 1993, Diani 1995, Mische 2003, 2008). Over time the shape of the networks may change as structural holes are reduced and more bridges are created.

In this study, we use an empirical approach from place-based Social Network Analysis (SNA) to trace the salience of social movements in the science system. This is done firstly by tracing changes in the areas of interest for actors both within social movements and within relevant science and technology systems. Semantic network analysis allows us to identify main topics, agendas and controversies in order to represent messages as a network of objects, thereby narrowing the semantic gap between words and meaning (Van Atteveldt, 2008) and decoding some elements of the underlying coding system of the language.

Semantic network analysis allows us to construct semantic communities to understand the ways in which different actors work and come together (Habermas, 1984; Guimera & Amaral 2005; Newman, 2010; Wen et al., 2015) and can represent clusters working in distinct approaches to technology. These communities are represented by highly interconnected nodes that are less connected to nodes in other communities (Barabasi & Albert, 1999; Freeman, 2004; Newman, 2010). The identification of these communities network has crucial importance for finding configurations of actors working on new agendas (Wen et al., 2015) as expressed in new collaborations, controversies or in our case narratives (Callon, 1986; Vico Perez, 2013; van Alphen et al., 2010; Hellsmark et al., 2016).

We can detect communities through modularity, which is commonly related to small world networks (Newman, 2010). Small worlds represent networks in which the distances between nodes are very

short (most nodes can be reached by a small number of steps), which means that different voices are easier to hear. The idea of small worlds first arose from the findings that seemingly unrelated people are surprisingly close in social space (Milgram 1967). Short path lengths expose actors to new information because they connect them with different sources and nonlocal perspectives (Singh, 2005). Meanings may emerge as discourses of actors can involve agreements and divergences (tension) that are negotiated, turning speeches into common frames (Anderson, 2000). This permits collective action to work towards specific interests.

According to Fleming & Juda (2007) small-world properties can facilitate sharp transitions in the connectivity of a network, by allowing niches in the network to connect their ideas more easily with the system and facilitate creativity within communities (Watts, 1999; Hargadon 2003; Uzzi and Spiro 2006; Schilling and Phelps 2007). This can radically alter network dynamics because some actors can connect the central dynamic with niches and open the system to include new perspectives, practices and meanings. Interpretation of the changing network architecture can provide important insights into the nature of changing agendas of the social movements and R&D system. Finally, we use the most common metrics to analyse small world networks such as degree of sparsity, size of the biggest connected component, average distances among nodes clustering coefficient, and centrality measures (Albert, Jeong, & Barabási, 2000; Barabási & Albert, 1999; Watts & Strogatz, 1998).

4. Data collection and analysis

Data collection occurred in two different stages. In the first stage, two databases of social movements and investment in science and technology in the Bogotá wetlands were analysed using social network analysis methods to assess how social movements influence change in STI policy towards the defence of the socio-ecological systems[3] around the wetlands. A second stage consisted nine interviews with the participants and leaders of the social movement in the Bogotá wetland (see apnedix. This encompassed activists defending the socio-ecological system of Bogotá's wetlands, such as environmentalist activist, social leaders from The "Cow" wetland, a youth leader from Wetlands foundation, a leading scholar researcher on social movement of the wetlands protection and two former advisors to the District's Department of the Environment.

With respect to the network analysis, the first database is based on a compilation of news articles related to social movements and their actions over the last 40 years, which was compiled by the *Centro de Investigación y Educación Popular* (CINEP, by its Spanish acronym - Centre for Research and Popular Education). 113 news articles on social movements associated to wetlands in Bogotá and more broadly on water-related topics were collected from local and national journals/newspapers. Data on social movements in wetlands in Bogotá were classified according to date of publication, actors involved, synthesis of relevant news and exact location.

A second database was used that contains information on research and development and innovation projects funded by Colciencias, the Colombian administrative department of science, technology and

[3] Socio ecological systems are complex and adaptive relationships between social and ecological structures (Arnaiz-Schmitz, 2018). This concept allows us to understand the highly dynamics interaction of ecological and societal change such as society's biophysical structures, bio history and society-nature coevolution, or regulation, governance, and sustainability transitions (Fischer-Kowalski and Weisz, 2016)

innovation related to wetlands in Bogotá and water in Colombia within the last 20 years. This database consists of 79 records of R&D projects submitted by public and private institutions, although most of them come from universities and research institutions. Each project has information on the title, applicant institution(s), date of approval, country and municipality associated to main institution-author and characteristics of the project.

Networks from both databases are constituted by words (nodes) and their interactions (ties). Two words are linked if they were used by at least two actors. Words were standardized to a common word using the following criteria: plurals became singulars, adjectives and verbs were transformed to the nearest noun root, no gender-neutral nouns were homogenized to one gender, some synonyms were unified where there was no uncertain about their meaning, and conjunctions, adverbs, articles and pronouns were removed (Sowa, 2014).

Social network analysis was designed as a longitudinal analysis i.e. changes exhibited between sequential networks over defined period. Changes in the words used by certain actors over time is considered as evidence of change in topic over time. The key words were chosen from the summary of news pieces from the social movement database and the titles of the funded projects. In this way, databases were divided in four stages according to the time frame. Social networks in each stage include the records (either projects or news) for the lapse of time defined.

For every network built, we measured the modularity (trend towards the formation of communities or highly connected subgroups). This was carried out using Newman & Girvan (2004) algorithm, identifying inner structures into non-isolated words. All communities found were characterized in terms of the topics they encompassed. Networks were plotted using Gephi (Bastian et al, 2009) and node-coloured according to communities' structure. In addition, information derived from the interviews and secondary data allowed us to interpret the semantic networks and the communities. Figures 2 and 3 show the evolution of the social movements' network over a 40- year period and STI-projects in Bogotá wetlands over a 20-year period respectively. Subsequently we calculated metrics to find the small-world structure. In order to identify small world networks, we looked at the combination of short average path lengths L and relatively high clustering coefficients C. In addition, we calculated the degree and betwenness centrality to know the distribution of hubs.

5. Socio ecological system of Bogotá's wetlands

This section describes the elements that make up the competing framing of the Bogota wetlands and the role that social movements played in eventually consolidating the socio-ecological system view of the wetland. Figure 1 shows different representations of Bogotá wetlands. We distinguish one view that represents the developmental view of construction companies and some political actors, which see wetlands as marshes[4] hampering the progress and expansion of the city. As a local newspaper describes it "The marshes of the Savannah and, especially, those of the jurisdiction of the District of Bogotá, have traditionally been recognized as wasted lands or mosquito breeding places where the waters stagnate to produce bad odours. No one gives them their biological importance"

[4] These economic and political sectors use this word in a pejorative sense.

(El Tiempo, 1991). During the 1980s many public institutions thus saw wetlands as waste-water dumps.

The alternative view, espoused initially by sectors of civil society such as wetland's neighbours, environmental activists, youth activists and scholars by contrast framed the wetland as a socio-ecological system, a natural commons and an alternative to unfettered and unplanned urban growth. Thus the key feature of the socio-ecological view of Bogotá's wetlands is the integration of the biophysical systems and social systems (Young et al., 2006).

The initial social movements around the topics of the wetlands was associated with the environmental protection of the wetlands against its progressive environmental deterioration that included pollution, deforestation, the indiscriminate use of agrochemicals in agricultural activities, mining activity, the dumping of garbage and debris, industrialization and unplanned urbanization of river valleys and wetlands[5]. These concerns are revealed in figure 2 where the changing agenda in the evolution of social movements are shown over time. We see that between 1975 and 1994, social movements were focused on problems related to contamination of water and air primarily as a consequence of industry processes. We also see concerns about agriculture which reflects some urban-rural tensions as the city of Bogota begins to grow and conflicts arise over the use of the land on the edge of the urban areas.

However, socio-ecological systems possess essential spatial features i.e. they exist in 'spaces' with actors with idiosyncratic characteristics. Human geographers refer to 'territoriality' to describe how social and political power are organized and exercised over space (Brenner, Jessop, Jones, & Macleod, 2003). Thus, the social movement that arose around the Bogotá wetland was the expression of the ties of local people with their local area. As interviewee D comments:

'*I grew up very close to the wetland when Bogotá had rural areas rich in nature… The wetland was my neighbourhood… There was nature and healthy ecosystems… Then, we began to see how water was contaminated, how fauna died – birds, ducks, frogs- … how wetlands were destroyed'.*

The local ties extend to academics in the nearby Javeriana University:

'*I studied biology at the Javeriana University… some of my colleagues also lived close to wetlands… we used to share anecdotes from our childhood… during my studies, we did our academic practices in the wetlands… for instance, we analysed the water from wetlands in the laboratories to study the components… professors became interested in the study of wetlands' Interview with local environmental activist (interviewee D).*

[5] These factors were identified by interviews of actors from socio ecological system of Bogotá's wetlands.

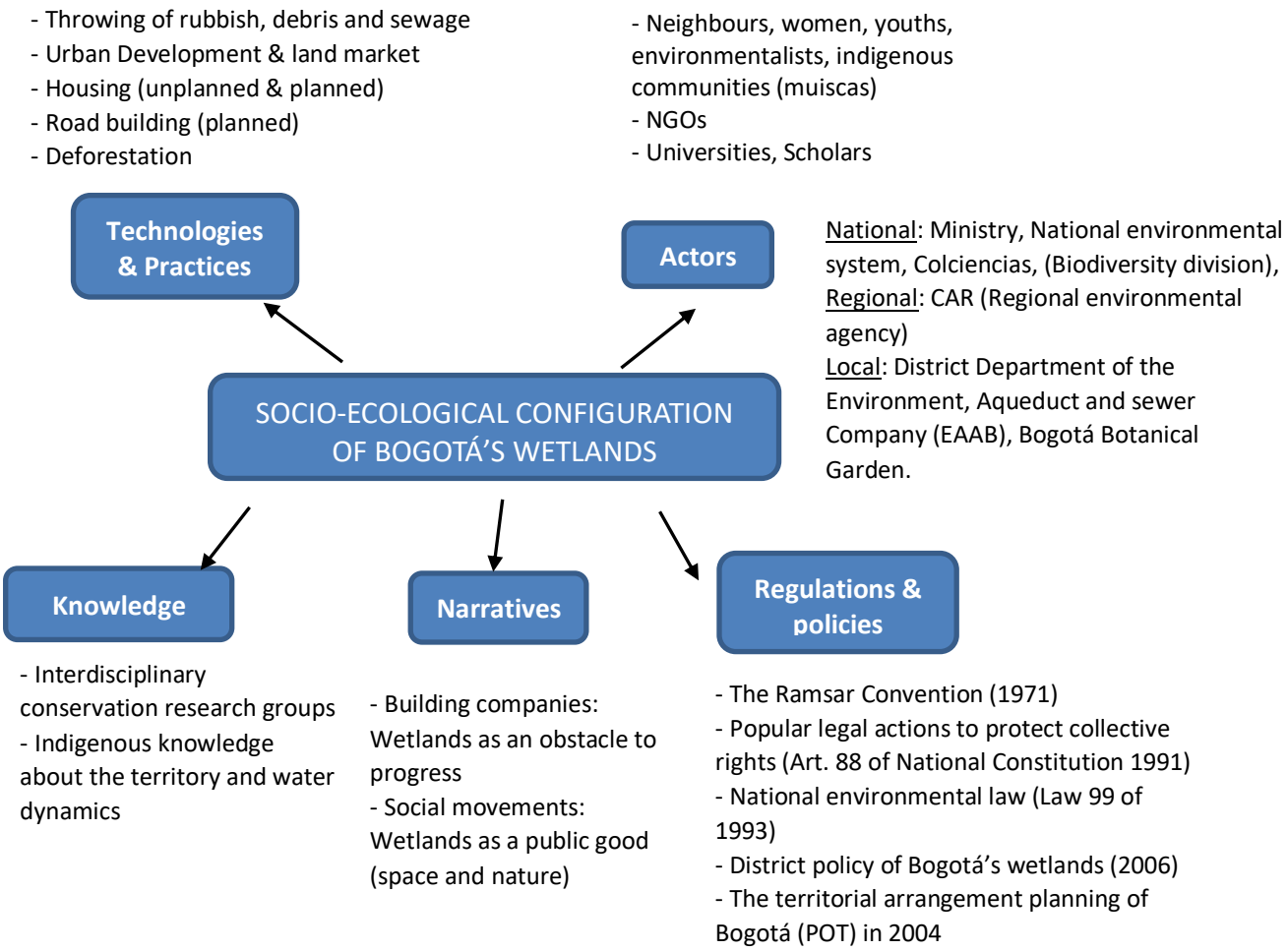

Figure 1. Elements from the socio-ecological configuration of Bogotá's wetlands based on Geels (2002)

The local history of the wetland changed dramatically in the period from 1985 to 1994, when armed conflict taking place in the country provoked a significant displacement of people from their territories to cities such as Bogotá. Illegal neighbourhoods were established near to Paloquemado market in the Centre of the city. In parallel, another major local social movement around water arose in the south-west of Bogotá. The increase in the cause of the Tunjuelito river caused major flooding with significant victims and damages. It was argued that the increase of legal and illegal industries had changed the course of the river. In response to this, some local actors built a social organization to protect their families from further risk of flooding. Figure 2 shows how social movements sprang up demanding public services such as aqueduct and sewage system. Thus, the arrival of thousands of people into new settlements near to the wetlands and the social movement that they created changed the narrative of the social movement incorporating questions of healthy lifestyles to the socio ecological narrative.

In the 1990s we see an increase in the number of social movements in the Bogotá wetlands and evidence of greater community awareness and specialisation over a more diverse range of topics (territory management, contamination, flooding) combining social, economic and political features

from neighbouring territories of the wetlands. Several factors explain this increased awareness. Among the main ones were a) the accelerated deterioration of wetlands due to the dumping of debris[6], b) pollution by sewage water and industry, c) the increase of diseases mainly in children. Neighbourhood movements organized in several areas of the city and networks emerged to promote a public agenda advocating the protection and conservation of wetlands[7]. Community actions began with delimitation of wetlands, clean-up, recovery and environmental education. Subsequently, the dialogue with the local government was formalized through the 'wetlands table'. This clearly represents a new organisational arrangement derived from the pressure exerted by the bricolage of social movement that create a new "collective space" to influence decision-making.

The breadth of the movement also reflects the heterogeneous nature of the network and therefore, the underlying relational and idiosyncratic elements of space. For instance, the social movement in the north of the city seeks to recover and preserve the ecology of the wetland around a narrative of ensuring public space and nature nearby their neighbourhoods. In the south of the city, where the new neighbourhoods increased exponentially, the narrative focuses on improving housing conditions and the provision of basic public services - electricity, sanitation, among others. The socio-economic conditions of these territories may explain the heterogeneity of the social movement. In the north of the city, upper-middle class families live in planned neighbourhoods, in contrast to those in the south, characterised by informal neighbourhoods, sometimes illegal and improvised by families who arrived in Bogotá fleeing the war in the rest of the country. Appendix 1 shows the map with the geographical distribution of wetlands across the city. However, as we will discuss, this heterogeneous alliance became crucial in consolidating the socio-ecological vision of the wetland over the developmental one and enabling the conditions for change.

Drawing on our earlier discussion of bricolage, a key feature of this heterogeneous alliance was how it innovated using resources from the technical and academic community at its disposal. Here we can identify an intervention by groups of academics and students who joined and assisted the social movement as part of a personal commitment with its demands, and a participation of scientists and academics as researchers funded by projects within the official STI system, that also responded to the demands of the social movements. Anecdotal and non-anecdotal evidence provides important insights to the importance of both forms of participation and the alliances that were formed between different groups. From the nearby Javeriana University, ecologists provided classroom lessons to reinforce the socio-ecological vision of the wetland. As a young leader of the Wetlands foundation commented:

'*We learned from German Galindo and Byron Calvachi (social leaders from wetlands social movement)… they taught and shared their experience through several courses in the Javeriana University' (interviewee F).*

[6] At the end of 1990's, about 500 dump trucks, per day, threw debris in the wetlands to fill them and develop housing projects (Figures from the Bogotá's wetland network).

[7] Some of these movements received international awards. This fact gave them greater visibility and more power of incidence in the formulation of local public policy. For instance, young leaders who promoted protection and recovery of the Tunjuelo river, received awards from the European Union award and from the Environmental Action Fund of United States (Los guardianes del Tunjuelo, El espectador 16 – 10 – 2009).

Academics from universities also provided technical-scientific support to the strategy used by the social movement to pressure the local authorities to change urban planning policies. Given the initial resistance of local authorities to attend their demands, the activists changed tactics and used the legislature route. The Colombian Constitution of 1991 introduced the "Popular Action", a legal mechanism that resembles a referendum, and can be used by communities to enforce compliance of their collective rights. Taking advantage of this constitutional mechanism, in 2000, the Community Action Board (CAB)[8] from Niza neighbourhood decided to hold a Popular Action against the Aqueduct and Sewage Company (EAAB) and its project of building a linear park in the environmental management and preservation area of Cordoba Wetland[9]. Local academics provided critical support to the social movement in this strategy by providing both legitimacy and technical support to the lawsuits in front of courts, such as environmental diagnoses, environmental management plans. In addition, international organizations and Canadian organization in particular gave financial support to universities to perform research on migratory birds that stopped in Bogotá wetlands when they migrate from South America to North America (Empresa de Acueducto y Alcantarillado de Bogotá (E.S.P) y Fundación Humedal la Conejera, 2012). Water analysis carried out in laboratories of Universities together with technical concepts developed by professors substantiated the demands and provided further back-up to the Popular Action. As a former advisor to the District Department of Environment comments:

'Communities from wetlands were well organised, they wrote academic documents, they planned the wetlands such as Jaboque, La Vaca, Cordoba, Juan Amarillo. They understood pretty well how wetlands worked; they knew where the sources of contamination were... They did environmental management plans without public institutions intervention… then when these institutions called them to design the public policy communities had the academic basics and gave all the inputs' (interviewee H)

Thus we can observe elements of bricolage such as the entrepreneurial behaviour of social movements as they experiment to overcome local barriers and mobilise resources and create agency to pressure local government for change. By means of a ruling of July 27 in 2001, the Administrative Court of Cundinamarca ruled in favour of the CAB Niza Sur, and the State Council confirmed the ruling. Subsequently in article 61 of Law 99 of 1993[10] a breakthrough legislation declared "to the Sabana of Bogotá, its high plateaus, waters, surrounding valleys, surrounding hills and mountainous systems to be of national ecological interest, whose priority destination will be agriculture and forestry'. Previously in 1998 Colombia had adopted the Ramsar Convention on socio ecological

[8] The Community Action Board (junta de acción comunal, in Spanish) is one form of community association and organization in which people with common characteristics (living in the same physical environment) are integrated.

[9] The popular action demanded 'To protect the collective right to have a healthy environment, the existence of an ecological balance, the management and rational use of natural resources to ensure their sustainable development, conservation, restoration or replacement; conservation of animal and plant species; and the protection of areas of ecological importance, the enjoyment of public space, the use and defence of public property and the defence of public patrimony' (Veredict 254 de 2001 Consejo de Estado).

[10] This is one of the pioneering and most important laws on environmental issues. It created the Ministry of the Environment, reordered the Public Sector in charge of managing and conserving of the environment and renewable natural resources, and organized the National Environmental System.

systems. Moreover, the expansion and strengthening of wetlands social movement boosted the reputation of its leaders who subsequently became directors of public institutions and influenced the protection of wetlands[11]. Clearly, the resources were found to the support the strategy of transformation and the legal route provided a mechanism to challenge the resistance of government officials and institutions and destabilise the developmental vision of wetlands.

Figure 3 show how the pattern ad topics of investment by Colciencias in topics related to Bogota wetland and its relationship to social movements. Initially this emerged also through actions of the courts. In the *La Conejera wetland judgment,* the judge ordered scientific studies to be undertaken regarding the environmental damage caused by construction and other activity. Collections of biological, physiochemistry and social information were orders by the judge related to this wetland in order to provide evidence for the popular action. This research was undertaken by different academics and students that were interested in protecting this wetland. Thus a legal mechanism was discovered to protect wetlands and other ecosystems in Colombia, which allowed the formal science system to support this alternative vision of the wetland.

Other actors then tried to replicate this process to protect other wetlands in Bogotá. These niches influenced the change of the environmental policy in Bogotá. When Conejera NGOs won the popular action, other social movements adopted Popular Action to pressure authorities to listen their demands. Thereafter, the wetlands board was created as a bridge to connect different initiatives throughout the city. This platform encouraged government actors to engage with the social actions. In enacting change and transformations, new institutions were created to fulfil new technology, policy or regulatory activities that were not present before. The knowledge and experience gained by actors involved within the process of enacting change is crucial in the establishment of a new institutional setting.

The effect of the social movement in reframing the socio-ecological system around the wetlands had profound implications. As government authorities introduced the measures for cleaning the wetland, a clash with some informal neighbourhoods built on the wetlands emerged near to Paloquemado, in the west-center of the city, in an attempt to remove the residents. These houses had been located on a wetland that had been clogged with garbage and waste. However, social organizations resisted and as a consequence, the local government carried out studies about the wetland social situation. This is represented in Figure 3 as “community monitoring. In the 2001-2005 period, we see the first indications of the STI system specifically funding social science research of the wetlands around “community monitoring” and highlights the growing awareness and dialogue with social movement, that emphasized aspects such as human health and its relationship to science. Figure 3 also exhibits evidence of social science and science researchers researching similar issues using common words, which suggests some synergies in their research. Moreover, the actors that undertook these studies had worked previously in la Conejera NGOs, which facilitated the interaction between government and social movement organisations. Eventually the neighbourhoods were legalized. The implementation of the wetland policy produced changes in the technologies used for management of water ecosystems in Bogotá. The monitoring of the natural and social conditions in Bogotá wetlands allowed the introduction of different instruments to collect

[11] ‘German Galindo became director of environment in the Aqueduct and sewer Company’

information related to water conditions (Table 2). Moreover, in La Conejera NGOs continued undertaking community monitoring in their wetlands.

Type of Technology	Technology used in Bogotá wetlands
There are technologies that provide sensors and information concerning the states of ecological systems.	The water monitoring includes filters, multiparameter, Ph indicators, climatological stations, geological stations, social observatory, geographic information system and sampling of fauna and flora.
Technological change stimulates economic growth and re-structuring of social development that impact upon multiple social-ecological systems.	Water management and the cleaning of water allow people to have a better health condition. It implies a reduction of the cost of public health care system. Specifically, acute respiratory diseases in children have been reduced.
Cleaner technology improves the efficiency with which material resources are harvested and transformed into valued outputs.	The policies related to reduce contamination in wetlands and the Bogotá river have implied to develop new technologies such as industrial filters and residential wastewater treatment. For instances, el Burro wetland was intervened with biofilters, treatment water machines and some infrastructure construction to improve its oxygen rate.
Technologies are being developed with the specific aim of repairing the environmental impacts of existing (technologically-mediated) activities	Some project to restore flora, fauna and water proprieties have been carried out by Bogotá Botanical Garden and the District Department of Environment. These technologies must be developed specifically for the wetlands conditions in Bogotá. For instance, Bogotá Savannah has a specific biodiversity and hydraulic conditions in its rivers and wetlands.
Governance strategies for promoting greater social-ecological systems resilience must consider technology choice, its patterns of use, and its control.	The actors tried to include projects related to regulation of using, cleaning and contamination water after the wetland policy started to rule. For instance, Bogotá Wetland Policy has a specific topic related to technology where COLCIENCIAS have to include programs for environmental education and social strategies.

Table 2. Technologies for monitoring wetlands in Bogotá. Souece: District policy of Bogotá's wetlands (2006), environmental management plans in Bogotá (Empresa de Acueducto y Alcantarillado de Bogotá (E.S.P) y Fundación Humedal la Conejera, 2012; Instituto de Estudios Ambientales (IDEA), 2007).

6. Analysis of social networks

In this section we conduct a more detailed analysis of the networks of the social movement and networks of scientists and their interrelations. Figure 2 and Table 3 shows that the number of actors and communities (modules) in the social movements increased from 1995, as did the interests these movements gained. Between 1975 and 1994 we found 5 communities, a small world network with short average path lengths and high clustering coefficient. The high clustering coefficient suggests a large community where different interests were expressed. The value of the clustering decreased significantly after 1994, while the path length increased progressively. We also found that density dropped through time windows, because new communities and words were integrated into the system. This suggests that as new themes and topics were taken up by the movement, they were not strongly connected with previous themes (Newman 2010).

Nevertheless, some words - water protection and social organization - play important intermediary roles by connecting new meanings that were developed in the communities. Protection of the Bogotá river is another important word connecting communities, which is important because wetlands allow different ecosystems to connect with the Bogotá river.

The semantic networks in the communities of STI research had a pronounced small world structure (Table 4; Figure 3) i.e. short average path lengths and relatively high clustering coefficients. The value of clustering centralization increased between 2000 and 2015, while average path length decreased at the same period. We also found that the value of the density increased significantly from 2011 to 2015. The significance of this result is that new themes were adopted by other research communities quickly, even when the number of nodes increased significantly in the 2011-2015 period. For example, the topic of water territories that reflects interest in how neighbourhoods interact with wetlands, which are associated with completely new actors in the research projects, can quickly influence the rest of the research systems. Potentially, it means that social movements can have an important influence in the R&D system. Here applied nature of the research within specific areas with researchers that are mostly co-located facilitated knowledge transfer and multidisciplinary work.

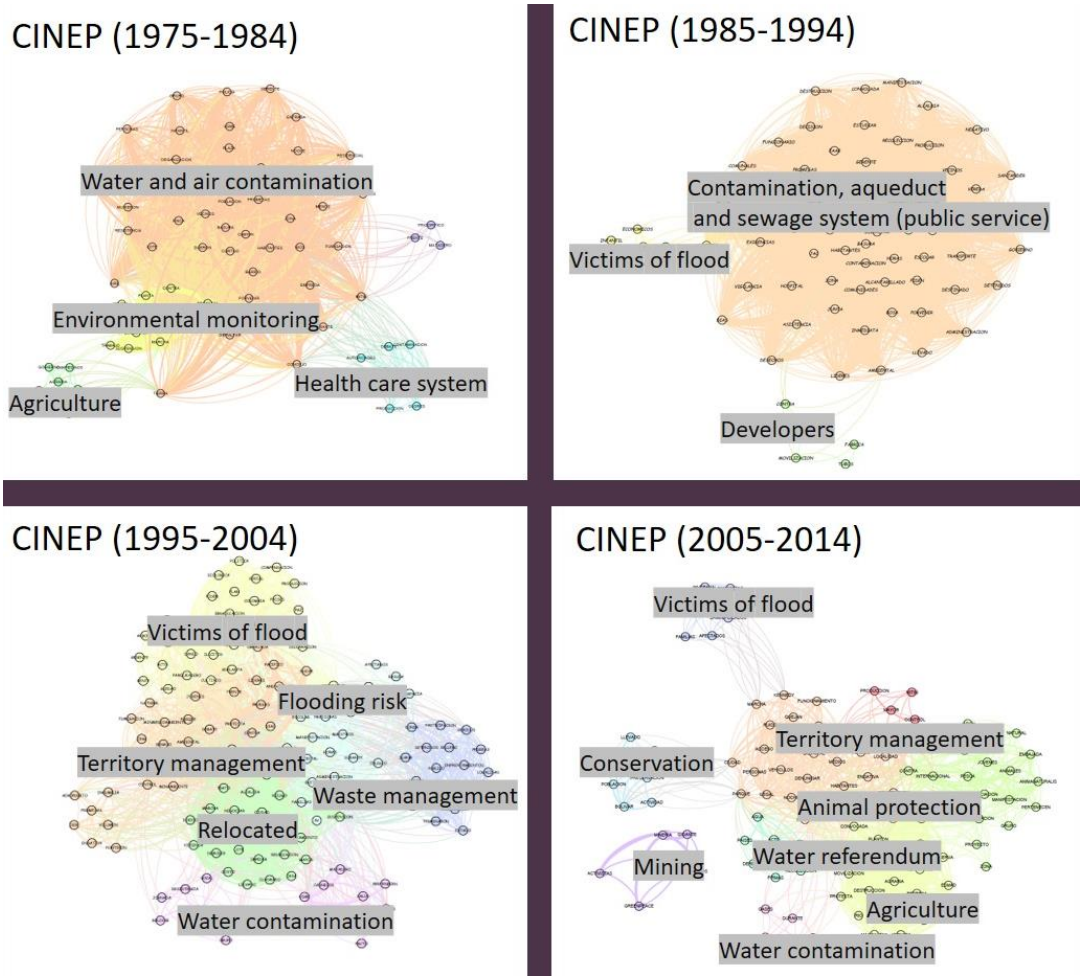

Figure 2. News related to social movements that had interested in wetlands in Bogotá. Two words are linked if they were used by a couple of actors. Colours represent communities that were characterized in terms of the topics that they encompassed. Derived from CINEP data base.

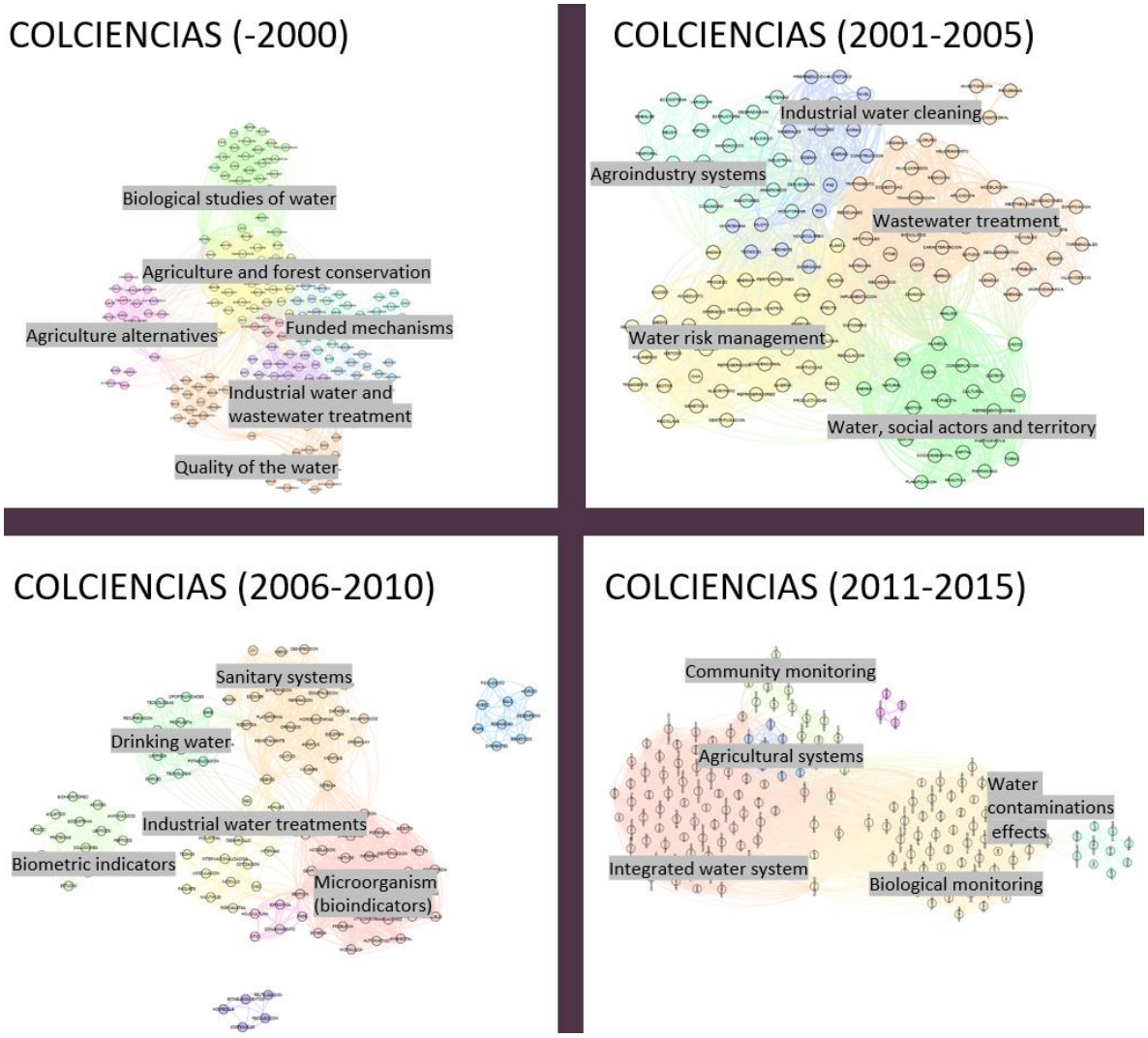

Figure 3. Projects funded by COLCIENCIAS. Two words are linked if they were used by a couple of actors. Colours represent communities of topics. Derived from Colciencias data base.

Time Windows	1975-1984	1985-1994	1995-2004	2005-2014
Node	76	76	143	105
Tie	1408	2119	1966	949
N Communities	5	3	5	9
Average Path Length (L)	1.563859649	1.3154386	1.882793263	2.02459677
Diameter (D)	3	4	3	3
Clustering Coefficient (C)	0.922996290	0.9913735	0.625596292	0.70326523
Density	0.494035080	0.7435088	0.193637349	0.17380952
Degree centralization	0.369009010	0.1949555	0.510688244	0.39133685
Betweenness Centralization	0.131236196	0.0701742	0.106423087	0.16183707

Table 3. Semantic networks metrics based on CINEP data base.

Time Windows	-2000	2001-2005	2006-2010	2011-2015
Node	190	150	125	171
Tie	2026	2243	1306	5072
N Communities	8	6	8	6
Average Path Length (L)	2.087051	1.9658166	1.806203044	1.717096663
Diameter (D)	4	3	3	3
Clustering Coefficient (C)	0.665961	0.7178507	0.792250298	0.885683699
Density	0.112838	0.2007159	0.168516129	0.348950808
Degree centralization	0.704098	0.4155632	0.533569368	0.59923425
Betweenness centralization	0.487894	0.1089305	0.224464216	0.210697058

Table 4. Semantic networks metrics based on COLCIENCIAS data base.

7. Conclusions

The socio-spatial component of the relationship between social movement and the science and technology system emerged around three principal points. First, the network of the social movement changed fundamentally with the arrival of displaced populations, the setting up of informal neighbourhoods and the social movements that emerged from this. In this process the understanding of the concept of a socio-ecological system changed and incorporated a broader narrative around cohabitation in the wetland area with vulnerable and displaced groups of residents.

Secondly, the academics and scientists were active participants in this transformation both as grassroots “out of hours” activists, providing advice and evidence to the Popular Action strategies and through formal research activities in projects funded by Colciencias. The embeddedness of scientists and technical specialists in the area provided in-depth knowledge, tailored solutions, and facilitated alliances with local authorities and provide the social movement science infrastructure (local university). The narrative was built from general concepts of socio-ecological systems but was tailored from local conditions.

Finally, analysis of the small world network using semantic networks of the social movement and science and technology projects of the wetlands suggests the science and technology system around the wetlands is able to quickly adopt new concepts and incorporate them. The example of how the challenge of introducing sustainable practices without forcible removal of residents by the science system was exemplary of the importance of implementing technologies in flexible and sensitive ways. Spatial proximity again may have played a part since the researchers in charge of these projects had participated in local NGO movements.

Locally embedded social movements, researchers and STI system and available resources were brought together to create the conditions to transform the socio-ecological system. Thus, a new narrative, actors, institutional setting, technologies, monitoring standards, uses and research agendas emerged to configure a new system. Social movements adopted an entrepreneurial role to overcome local constraints and use what was at hand to create a new resource environment. The distributed agency of the transformative process allowed different actors to contribute at different stages playing different roles, in some cases, shaping and supporting policy making. Continuous learning provided the bases for consolidated actions and change that enacted the consolidation of the new socio-ecological system.

The implications of this study for transformative innovation analysis is significant. Firstly, that they shine a light on methodologies of participation with the lay public. Social movements can represent a genuine and sophisticated expression of civil society demands for more socially and economically sustainable practices. They open democratic spaces by which ecological and human centred views can interact. On the other hand, scientists can open up spaces for communities that would otherwise be a closed policy process (McCormick, 2006). Working with social movement communities that are embedded in local territories can therefore enrich policy making by being sensitive to the needs of local populations and local environments and hence overcoming the often sceptical public perception of participation on social outcomes. Thus our study also supports the finding by Lubitow (2013) that scientists played a decisive role by partnering with activists to frame their issues to both the legal system and policy makers. In conclusion, social movements can act as an alert to policy makers of where to intervene in response to genuine civil society demands. The existence of big data can facilitate analysis of how social movements interact with local science and technology systems in different contextual environments and indicate areas to invest and strengthen.

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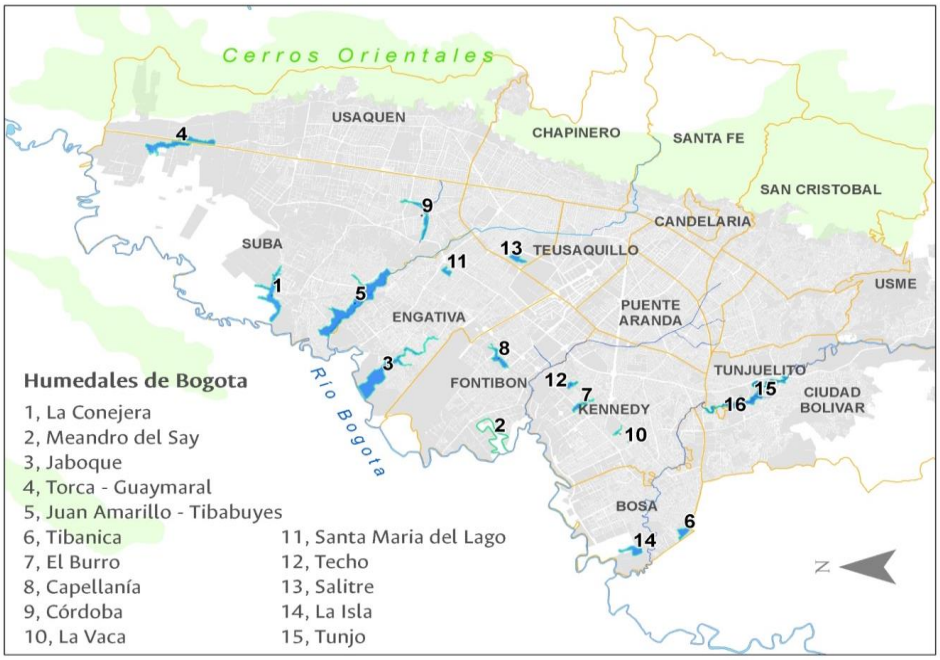
Appendix 1



Map of wetlands in Bogota

Appendix 2

Identifier	Role	Position
A	Social leader	Neighbour of The Cow Wetland
B	Social leader	Neighbour of The Cow Wetland
C	Social leader	Neighbour of Córdoba Wetland
D	Social leader	Environmental activist
E	Social leader and then director of Environmental department of Bogotá's Aqueduct and sewer Company	Neighbour of Córdoba Wetland
F	Youth leader	Leader in Wetlands foundation
G	Researcher on social movement of wetlands protection	Scholar
H	Local Government	Former advisor from District Department of the Environment
I	Local Government	Former advisor from District Department of the Environment

Detail of interviews