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Laurent Lespez, Mathieu Arnoux, Catherine Carré, Marie-Anne Germaine, Frédéric Gob, Evelyne Tales

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CONSIDER SUBURBAN STREAMS AS HYBRIDS: METHODOLOGICAL REFLEXION FROM THE PARISTREAMS PROJECT

Laurent Lespez, Université de Paris Est Créteil (UPEC), Créteil & Laboratoire de Géographie Physique CNRS-UMR 8591, Meudon, France

Mathieu Arnoux, Université de Paris & LIED CNRS, Paris, France

Catherine Carré, Université Paris1 Panthéon-Sorbonne & LADYSS CNRS, Paris, France

Marie-Anne Germaine, Université Paris Nanterre & LAVUE-CNRS, Geography, Nanterre, France,

Frederic Gob, Université Paris1 Panthéon-Sorbonne & Laboratoire de Géographie Physique CNRS-UMR 8591, Meudon & Paris, France

Evelyne Talès, INRAE, HYCAR, Antony, France

KEYWORDS

Urban Rivers, Fluvial system, Ecology, Hydrogeomorphology, Participation, Management

ABBREVIATIONS

ABSTRACT

Suburban streams often considered as our least restorable ecosystems but in fact constitute an important part of the hydrographic network in megalopolis and crucial environmental infrastructures for future urban development. Numerous studies have highlighted the dramatic hydrogeomorphological and ecological alterations due to the hydrological consequences of urban sprawl. Most often research focuses on the consequences of urban development but has not integrated ordinary practices and long-term river system management that have significantly reshaped existing rivers. Thus, we propose an interdisciplinary approach integrating the biophysical and social issues and different temporal and spatial scales in the Paris urban area. The PARISTREAMs project considers suburban streams as hybrids, i.e. as fragments of the socionature and proposes a holistic approach to develop a socio-ecological knowledge. The integration of palaeoenvironmental and historical research place the current restoration projects on a trajectory of the fluvial systems that is essential to understand the role of legacies (sediment, infrastructures, representations), that vary within an urban area, and to open the discussion on base line operation in a context of climate and metropolitan changes. Hydrogeomorphological (channel geometry), biological (macroinvertebrates, fish, riparian vegetation) studies and research on social practices and associated representations are required together, to determine the contemporary dynamics because the banks of these streams are subject to private ownership and to active management practices. The final objective is to propose a new hybrid methodology to have a holistic knowledge of suburban streams and to promote socioecological restoration according to their biophysical and social realities and the development of a renewed and shared river culture.

1 INTRODUCTION

The question of nature inside the city has now becomes a central issue. But, the emphasis is mainly on green spaces, urban agriculture and ecosystem services (Elmqvist et al., 2013; Francis et al., 2016) while riverscapes studies have been focused on the major waterways valued for their waterfronts (Macdonald, 2018) and the green and blue infrastructures they offer (Perrini & Sabbion, 2017). Meanwhile, small rivers (< 10m width, 2m deep), located outside of the city centre and the landmark places, not navigable, and subject to private ownership, have often remained in the backyard of the urban environmental project (Gray, 2016). However, the rise of environmental and hazard issues in metropolitan areas (floods, channel erosion, aquatic and riparian biodiversity, green and blue agenda) have triggered the development of specific investigations on urban rivers.

In the Paris urban area, suburban streams constitute the major part of the hydrographic network. Indeed, of the over 4 850 km of rivers that cross the Paris region, 475 km correspond to major rivers (Seine, Marne, Oise) while the streams of order 1 to 2 in the Strahler's classification constitute 72.4 % of the total. By 2015, only 18 % of these streams were classified as of good ecological status, leading to numerous restoration projects stimulated by the European Water Framework Directive. Although the issues of water quantity and quality are amply addressed, the environmental diagnosis of small urban streams often remains poorly understood. However, they are home to fauna and flora and constitute privileged places for reclaiming nature in cities and improving inhabitant's quality of life in the world's major and dense cities (Pitt, 2018). Therefore, the need to develop the socio-environmental research on suburban streams in the temperate western world is becoming increasingly crucial (Francis, 2014). The paper aims to demonstrate the hybrid nature of the current suburban streams and to propose a transdisciplinary approach integrating the biophysical and social dimensions and different temporal and spatial scales.

2 STATE OF THE ART

2.1. Urban streams are hybrid ecosystems that are not fully understood

Following the definition of urban stream syndrome (Walsh et al., 2005) there is a growing interest in order to disentangle which process mostly drives their evolution. Urbanisation changes the character of fluvial processes because of three main issues: (i) the increasing impervious areas, (ii) the installation of drainage systems and (iii) the channelization of streams for flood mitigation (Chin, 2006). This implies a cascade of consequences on several components of the hydrosystems: channel geometry (incision and widening), hydraulics, structure and composition of the bed substratum and biocenosis. The quantification and the prediction of such impacts is necessary to define the restoration objectives but remains a challenge because urban sprawl is discontinuous and multiform and because changes in biophysical processes occur at the same time as the city develops (Oudin et al., 2018). River managers usually refer to stable conditions from the recent past and often underestimate the consequences of urban sprawl when designing the restored river. Furthermore, aquatic biodiversity distribution in streams not only results from water quality but also from physical habitats shaped by flow regimes. These stream characteristics altogether are thus altered in the urban context leading to reduced diversity and density of biota and subsequent changes in community composition. However, in urban areas, the water quality is much more investigated than the hydrogeomorphology and the habitat. Meanwhile, habitat features, like riparian areas, could mitigate the impact of urbanisation on biodiversity by favoring species migration dynamics (Utz et al., 2016). Furthermore, the riparian vegetation is often considered for its role in ecological connectivity, rather than for its own biodiversity and dynamics. Collaboration between hydrogeomorphologists and biologists is also key to providing

efficient measures of restoration and to define hierarchical constraints exerted on streams (Roy et al., 2016).

The need for new research is highlighted particularly in Europe where the current functioning results, in part, from the recent urbanisation of the catchments but also because of the not-well-known legacy of a long-term biophysical alteration of streams by the development of medieval and modern societies (Schmitt et al., 2016; Vietz et al., 2016). Distinguishing the impact of urbanisation from more ancient alterations is still highly challenging. Indeed, long-term studies of small hydrosystems based on hydrogeomorphological, palaeoenvironmental, geoarchaeological and historical research have demonstrated their hybrid nature (Lespez et al., 2015; Lespez & Dufour, in press): i.e. “[ecosystem] that retains characteristics of the historic system but whose composition or function now lies outside the historic range of variability” (Francis, 2014). Geoarchaeology and environmental history have developed long term studies that articulate analysis of past biophysical functioning and social issues and have demonstrated that legacies continue to determine current river forms and functions (Wohl, 2015; Lespez et al., 2015; Brown et al., 2018). Complementary works demonstrate that the modern attachment to hydraulic structures, such as water mills, reveals a process of heritage enhancement by riverside populations that selects objects to which they confer value (Germaine & Barraud, 2013). Until now, long-term environmental studies on the trajectory of socio-ecosystems, mainly focused on the large rivers, and have demonstrated the co-evolution of the city and the river (Guillerme, 1983; Benoit et al., 2004; Winiwarter et al., 2013; Barles et al., 2015; Lestel & Carré, 2017). Accordingly, the current state of small rivers is partly an historical process during which they have been transformed to feed the city in energy, plant and food resources, long before being involved in the urbanisation process.

2.2. From amenities towards participative approaches in river restoration projects

Most scientific publications deplore that restoration projects remain too technical and highlight a “deficit model of public understanding” (Eden & Tunstall, 2006). These projects struggle to look beyond ecological objectives so as to take into account the needs of local communities and build a common project (Germaine & Barraud, 2013). Establishing a place for the sensory dimension and defining stakeholders’ scope in a more open manner encourages enlargement and avoids projects that are still too often monofunctional (Westling et al., 2014; Holifield & Schuelke, 2015; Zingraff-Hamed et al., 2017; Smardon et al., 2018). The concept of "social connectivity" proposed by Kondolf & Pinto (2017) can give additional understanding, exploring the relationship between public support for restoration operations and the physical relationship of local users of the river.

At the same time, citizens' initiatives are multiplying in favor of environmental issues. Local and resident participation has been identified as a way to promote empowerment and to prepare the ground for a more ambitious approach (EGEB, 2015). But if these participatory practices are of interest, too often participants are limited to discuss an already designed project or a narrow aspect of the project (Blatrix & Mery, 2019). Moreover, the organizers of these participatory processes rely more on scientific expertise (Bouleau et al., 2018) than on a territorialized environmental action. Thus, it seems essential to compare riverscapes and environmental projects located in different neighborhoods, regarding density and socio-cultural characteristics, because the challenge also deals with environmental justice issues (Holifield & Shuelke, 2015). The notion of hydrosocial cycle invites us to recognize water as a co-production of nature and societies (Linton & Budds, 2014). Rivers can be considered objects of “socionature” that are subject to power relations, especially in underprivileged districts. The interactions between the practices and expectations of local residents and populations, the biophysical dynamics and the ecological restoration objectives remain poorly understood (Ashmore, 2015; Flaminio et al., 2015; Gobster et al., 2016) even if the determining factor in restoring urban environments is often the benefit to the population. From a scientific point of view, even if the socio-ecological or socio-environmental approach is often mobilized, each approach of the river system has its own core of skills and favorite objects (Palmer et al., 2014). This explains why

holistic approaches to the restoration of urban streams remain exceptions. Furthermore, both science and politics are experiencing an important legitimacy crisis (Barthe et al., 2001). Participation appears as a solution to avoid conflicts and enhance public decision taking.

3 METHODS

We consider suburban streams as hybrids, i.e. as fragments of the socionature, and crucial environmental infrastructures in the perspective of future urban development.

3.1. Working Hypotheses

The PARISTREAMs project proposes a holistic approach to develop a socio-ecological knowledge based on 5 hypotheses:

- Because of their size, small urban rivers are an ideal living laboratory to promote a renewed and deeply integrative approach to river management issues.
- Because they are hybrid, the study of suburban streams requires a methodological innovation (Fig. 1) and justifies to promote a new approach to nature in cities.
- Situating restoration operations in an historical trajectory seems essential to understand the hydrosystem degradation and the role of legacies, to open the discussion on reference states and restoration goals and to anticipate future dynamics in a context of climate and metropolitan changes.
- A multi-scalar approach should highlight the role of the geographical contexts often neglected in urban areas by environmental management and restoration projects resulting from generic public policies.
- Researchers have a role to play in increasing the consideration of riverside populations for their environment. By sharing their research, they can promote river culture, which is a way to encourage participation of the local population. Symmetrically, they should reveal how residents view their daily living environment, which is a crucial element of their well-being, especially for the most disadvantaged.

Fig. 1 Morbras River: example of objects deserving a hybrid approach



3.2. Building a river Lab

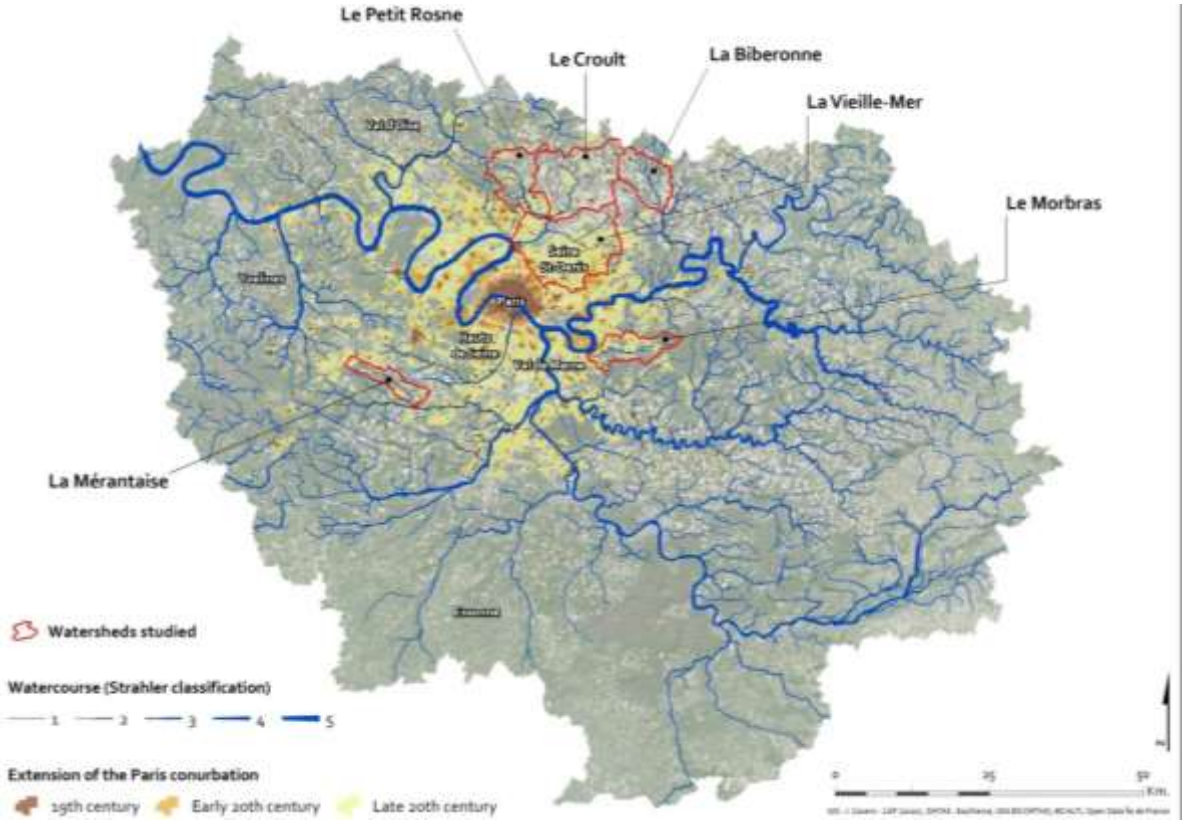
The living river Lab aims an equal acquisition of biophysical and social data and it is fruit of the collaboration between naturalists and social scientists. It involves 7 partners who are part of the PIREN-Seine program. The objective is also to share knowledge and experience by comparing the situation in the Paris urban area with metropolises across the Western world within other regulatory and socio-cultural contexts and micropolitical traditions. We focus on the experiences of co-construction of knowledge between scientific, managers and the local population (Smardon et al.,

2018). Projects in metropolitan regions were selected in the USA, thanks to the collaboration with US partners, in order to diversify the reference frameworks and to compare experiences involving a wide range of audiences (scientists and experts, institutions, associations, local residents) and articulating territorial projects in heavily urban areas that engage approaches to involve local residents and more particularly the most disadvantaged among them and make them actors in the promotion of the environment as a key element of their living conditions (Holifield & Schuelke, 2015; Druschke & Hychka, 2015). Furthermore, because of developing a participatory project in urban areas on environmental issues is a challenge and popularizing the environmental history of the rivers studied is a lever for mobilizing the local population, we also rely on the partnerships established over many years with managers and local associations in the Paris urban area. We have also developed a collaboration with Etats Généraux de l'eau à Bruxelles, a collective involving scientists and inhabitants, aiming to substitute the technical and commercial visions of water with a more ecological, shared and living perspective (Wantzen et al., 2016).

4 THE PARISTREAMS RESEARCH PROJECT PROPOSALS

The research proposes a multi-scale approach from local studies to international comparison. Detailed investigations are undertaken on 4 streams (Tab. 1, Fig. 2). They have been chosen to be representative of a wide variety of environments, distributed according to an urbanization gradient and different social contexts, from the Mérantaise and its largely privileged environment to the working-class district of the Croult and Petit Rosne. Those rivers are all run by intercommunal authorities that deal with the day-to-day management and undertake restoration operations (Tab. 1). From the diversity of these four catchments, our aim is to propose the first socio-ecological typology of small suburban streams for the Paris urban area.

Fig. 2: Map of the suburban streams studied



Tab. 1. Synthetic presentation of the suburban stream's studied

Stream	Dominant Land Use	Length, discharge & Specific power	Nuisances[1] IDH2	Intercommunal river authorities	Major targeted restoration projects
Biberonne	Cropland	12.5km Q=0.27 m^3/s 6<ω<18 W/m^2	Medium 0.4 to 0.6	SMHBB	River diversion (Moussy-Vieux, project) Enhancing straightened river channels & riparian vegetation (Moussy-Neuf, 2021-2023)
Mérantaise	Forest, Cropland	13.5km Q=0.18 m^3/s 6<ω< 20 W/m^2	Very low > 0.7	SIAVY & Nature Park of Chevreuse Valley	Restoring river channels & wetlands (Paris Sud University Campus, 2019-? & Chateaufort, project
Morbras	Urban	17km Q=0.34 m^3/s 10< ω<24 W/m^2	Low/medium 0.5 to 0.7	Great Paris Metropolis & SMAM	Restoring stream, wetlands & providing public access (Coq retention pond, 2021-?)
Vieille-Mer[2]	Urban	25km Q=0.29 m^3/s 4< ω<15 W/m^2	High < 0.4	Great Paris Metropolis & SIAH	River reopening downstream (project) Restoring streams, wetlands and providing public access (Vignois, 2019-? Goussainville, 2021-?)

[1]Sum of nuisances & Environmental pollution, Human development indicator (IAU, 2017), [2]It corresponds mainly to the Croult & Petit Rosne streams

4.1. Studying hybrid environments

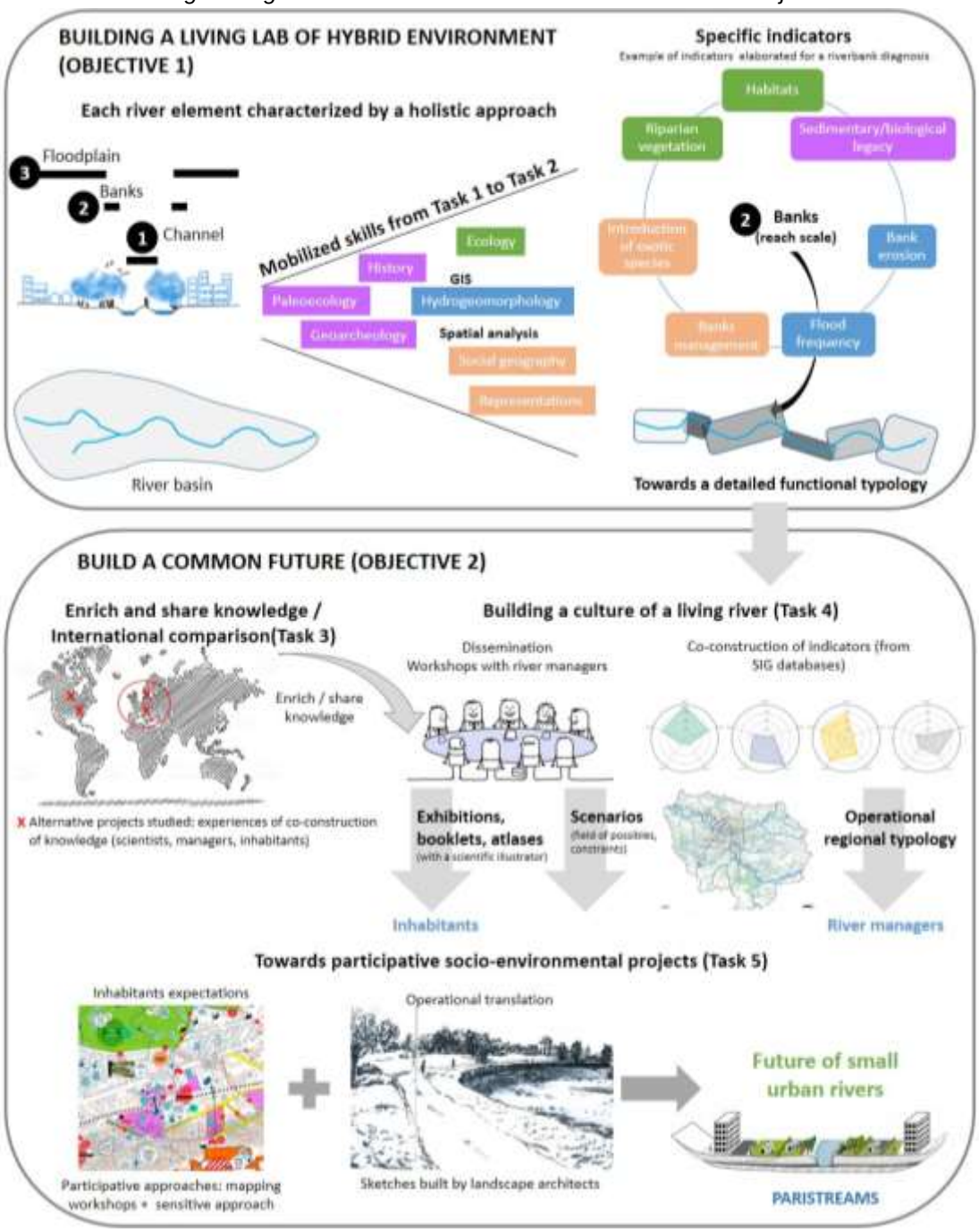
The diagnosis of the rivers' functioning integrates interactions between spontaneous and inherited biophysical processes and social practices of the rivers. To avoid the juxtaposition of social history, environmental trajectory and knowledge on current systems, our approach is based on the materiality of river landscapes in order to link approaches around a shared object.

To reconstruct the functional trajectories of small hydrosystems, we integrate paleoenvironmental and historical investigations (Task1)**.** The River Lab brings together expertise on hydrogeomorphology, paleoenvironment and geoarchaeology of the Paris basin (Pastre et al., 2003; Orth et al., 2004) and knowledge of ancient practices like hydraulic management, industrial revolution consequences and urban sprawl (Arnoux, 2008; Meybeck et al., 2018). Sedimentary archives are investigated by geophysical methods to implement sections made by core drillings to define the channel and floodplain changes during the last two millennia. Analyses are also focused on the cores preserving organic sediments and numerous bioindicators providing indications of vegetation cover changes. Diatom analyses assess the evolution of the trophic status related to changes in the catchment. The use of aeDNA to reconstruct palaeobiodiversity is much more innovative. DNA extracted from environmental sample provides information on many taxonomic groups (plants, mammals, fish) and thus allows assessment of plant and animal biodiversity changes (Taberlet et al., 2018). Developing the method of ancient environmental DNA will open up new perspectives for reconstituting biodiversity trajectories. The first palaeoenvironmental results obtained on the Mérantaise and Morbras streams confirm that the environmental changes from slightly altered to hybrid rivers is much older than the urban sprawl of the last two centuries and goes back at least two millennia. It encourages new field research to precise the geometry of the palaeochannels in order to get indications of the former river habitats and solid discharges.

Historical research based on medieval and modern sources decisively contributes to the understanding of the role of human practices in the river system changes observed. Although the areas under investigation have all been part of a homogeneous legal-political and technical-economic context for more than a millennium, each one nevertheless bears witness to a specific history within the very long-term development process of the Paris metropolitan area. The Croult, which has been the subject of major developments since Carolingian times, linked to the progressive construction of the city of Saint-Denis. Things were different for La Beuvronne and Le Morbras, which were linked in different ways to the grain production area located northeast of Paris. La Mérantaise, by its location on the edge of a forest massif, reveals the elements of a more recent history (12th-13th centuries), linked

to the expansion of Cistercian settlements and the establishment of the great feudal seigneuries. A first review of both local historical literature and the indexes of the national and departmental archives show that it is possible to follow the territories studied over at least six centuries, sometimes much more, and in particular to observe over this period of time the constitution and evolution of the milling system which has played a major role in the construction of streams. Finally, the data obtained by the two approaches will be cross-referenced to define the trajectories of each streams. The cross-analysis is deepened on several topics as the energy for example. Indeed, the balance between the energy mobilized by riverside societies and/or available for hydrogeomorphological processes is one of the fundamental keys to understanding the dynamics of streams since medieval times.

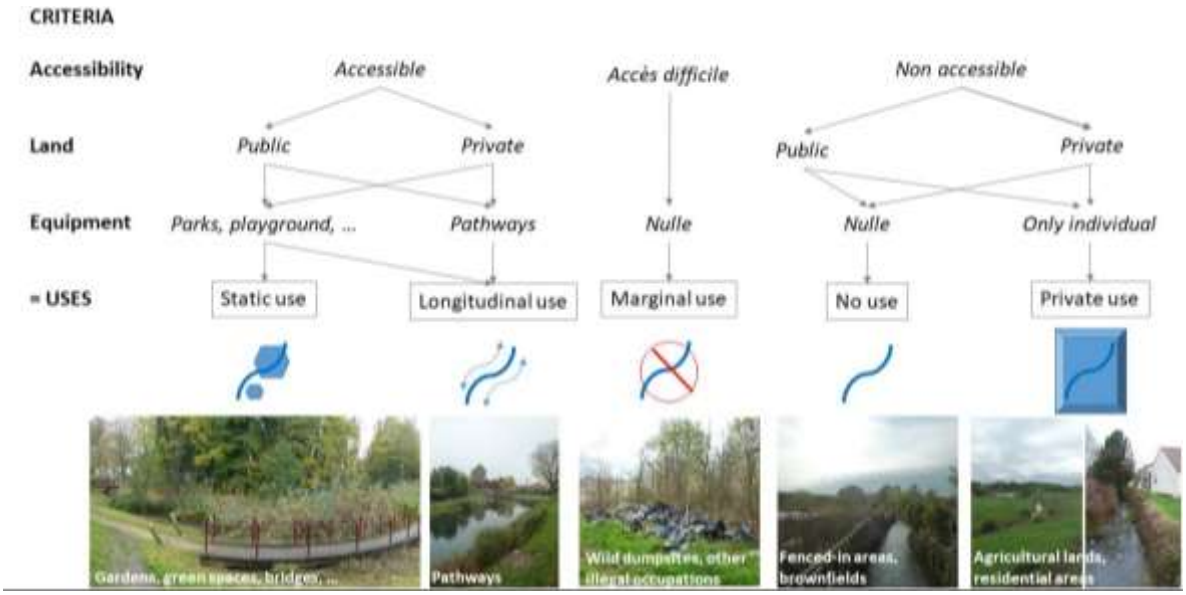
Fig. 3: Organization of the research in the Paristreams Project



Complementary methods are used to characterize the functioning of the hydro-geomorphological, ecological and social connectivity of streams (Task 2). Specific indicators summarizing that functioning are defined in order to build a functional typology. The small size of the watersheds allows us to favor a small-scale approach with high frequency measurements for the characterization of the channel, bank and floodplain either directly on the field or through very accurate remote sensing, i.e. Lidar images. On the 4 catchment areas, we characterize: (i) the hydromorphological characteristics, (ii) recent and older man-made features, (iii) the riparian vegetation. Hydromorphological characterization highlights the imbalances in their functioning and its magnitude is compared with the CARHYCE models (Gob et al., 2014), which propose a regional reference framework and make it possible to quantify the morphological alterations of rivers. Diagnosis of the aquatic biodiversity (macroinvertebrates, fish, algal biomass) result from both a structural and functional approach to identify trajectories even for rivers of poor ecological status (Talès et al., 2017). This biodiversity approach is coupled with the analysis of ecological functioning. The metabolism of watercourses is assessed by measurements of primary production. Indeed, algal biomass corresponds to autochthonous organic matter, one of the basic elements of the food web of running waters. The current trophic status of streams in the Ile-de-France region can be assessed and compared with the historical trophic status. Finally, the relationships between biodiversity and the ecological functioning of urban watercourses can be analyzed. The comparison of first results obtained with the regional model demonstrate that the studied streams are deeply altered morphologically, as expected, even if the timing on the alteration remain a matter of investigation (Jugie et al., 2018). But they also present a high longitudinal biological and morphological variability which highlight the necessity of small-scale investigations to avoid too general and simplistic approach of their functioning in the case of restoration project (De Milleville et al., submitted).

Finally, we mobilize social geography of the environment approaches. The analyses are based on the adaptation of the concept of social connectivity to small rivers and on an analysis of river management practices and residents representations. Describing the social connectivity is based on the characterization of the materiality of landscapes. This involves qualifying the spatial configuration of the river and their surroundings through different criteria, as this influences the relationships that riparians/users have with it (Fig. 4). In addition, river management are investigated to define how public authorities develop rivers and their banks (or not). Secondly, attention is focused on local residents who are often neglected by managers. As riverine owners are key-actors (e.g. choosing vegetation on private banks …) to understand biophysical dynamics, they are interviewed about their daily practices (bank management …) and knowledge to better understand how they participate in the functioning of suburban streams.

Fig. 4: Social connectivy applied to small urban rivers landscape



4.2. Towards the building of a common future

Firstly, the aim is to promote the culture of living rivers sharing knowledge with river managers and inhabitants. The results obtained will allow us to produce a combination of thematic indicators with the aim of a synthetic index. These more global descriptor will be then used in defining the reach organization along the streams and building a detailed socio-environmental functional typology for each stream studied. Practically, this will be achieved by sharing results with local river managers. Thus, we aim to contribute to the discussion on present restoration practices and to the definition of possible scenarios with river managers through projects that have been carried out first on four catchments but also in the Paris Region and abroad. The objective is also to disseminate results to a wide audience and to local inhabitants through exhibitions, booklets and web-documentary.

Secondly, we will promote participative socio-environmental projects. At the local scale, we will propose scenarios for restoring the quality of small suburban rivers taking into account river managers' constraints and inhabitants' expectations. To implement this participative approach and enlarge the debate on the future of rivers, we will develop new innovative methods to capture the sensitive dimension of people's relationship to the river. Participatory mapping workshops will help residents to share their knowledge together and with scientists. We will organize collective walks with inhabitants to record the observation in a collaborative map to formalize their understanding on the diversity of river environments. Such an approach has been implemented with success in Belgium (EGEB, 2015) or Barcelona. In parallel, a time of collective construction will be implemented during a visit to the river using intertexting method developed within LADYSS lab. Based on text messages exchanged during the walk about individual sensory experiences of the river, the aim is to produce collective narratives on the river materiality experience. These will provide a common basis for subsequent work with landscape designers, managers and researchers. Finally, a workshop will be conducted with landscape designers will help to reveal and give shape to participants' expectations, focusing on specific landscape motifs, which are the intermediaries between daily life and the ecological dimension of the river.

Conclusions

The project will result in promoting a socio-ecological approaches in urban environments and of neglected urban streams. Articulating fundamental research with operational projects is crucial for disseminating results and contributing to a better appropriation of the issues of river restoration. Sharing results of academic research with river managers and local people is a real challenge for

which we will develop local workshops and specific documentation to a wide audience. More generally, we promote inhabitants' involvement by considering the ecological project as an opportunity to bring populations closer to their daily living environment because it is a crucial element of their well-being, especially the most vulnerable.

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