Reducing the imperviousness of urban soils: a greener way of managing runoff that can be tricky to implement in Southern France

Christelle Gramaglia, Christian Salles, Marie-George Tournoud

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Abstract

Urban pavements, which help to maintain streets clean and secure, generate large amounts of runoff that aggravate flooding and degrade the quality of surface water. In the context of ecological and climatic crisis, they also contribute to creating heat islands in cities - as well as hindering biodiversity. So greening cities must be encouraged.

Our article evokes the situation of Montpellier - Méditerranée Metropolis (Montpellier 3M, Southern France) which is experiencing one of the strongest demographic and urban growth in France. It raises the question of the impact of increasing construction on the quality of water in small and fragile coastal catchment areas by the Mediterranean. It also questions local public policies in an attempt to identify the brakes and levers on the greening actions for the effective management of runoff water, encouraged by legislation: de-paving, setting up rain gardens, returning to permeable urban soils as well as encouraging the development of vegetated roofs.

To do so, we mobilise empirical material collected during a sociological survey - in addition to hydrological and chemical measurements. Our aim was to provide information on a wide range of stakeholders' perspectives which is needed if blue-green infrastructure are to be

adapted to local contexts, so that they are both efficient and judged as legitimate solutions (O'Donnel et al. 2021). Our reflection suggests ways to democratically think about the dismantling of modern coating infrastructures, to slow down urban water flows, and thus improve the habitability of Southern European cities in a context of climate and ecological crisis.

Keywords: hydrosociology; runoff ; water quality; urban greening ; depaving

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« *The more we pave, the more we make soils impervious, the more important the problem of water recovery and circulation is* ». Alain Dupont, industrialist interviewed by the philosopher François Dagognet, Cahiers de Médiologie, 1996.

Introduction

It is said that the King of France, Philippe Auguste, who was bothered by the water and miasma that stagnated in the streets of Paris, ordered their paving as early as the 12th century. Although various materials and techniques were tested over time, responding to issues of safety, durability of pavements (but also carriages) and hygiene, it was not until 1838 that the first trials of bituminous coatings took place - also in Paris (Holley 2003). Efforts in this field intensified after the Second World War with the development of new, more resistant bituminous mixes - based on hydrocarbons, minerals, and then synthetic additives - with a background of strong demand from automobile clubs for the development of road infrastructures (Harismendy 1999).

The advantage of bitumen over other road surfaces (paving stones for instance) is that it is less expensive and less noisy even in heavy traffic. It is also binder, adhesive and waterproof, which means that it does not slip too much when the road is wet. It was for all these reasons, rather than to prevent the erection of barricades as during the student demonstrations of 1968, that the Paris council decided, in 1976, to

cover its main boulevards with bitumen. Since then, most French urban soils have been paved and made impervious (as well as some roofs - for waterproofing reasons). Pedestrian or recreational areas, such as schoolyards, are not exempt from bitumen. This is comparable to the situation in the USA where 90% of pavements are bitumen (Holley 2003).

However, the very qualities that have made bitumen such a modern material, which makes it possible to walk or drive 'dry' in all weathers, are posing new problems in the current ecological crisis (McGrane 2016). Not only does it accumulate heat during heatwaves, which are exacerbated by climate change, but it deprives cities of much-needed water in times of drought. It also encourages flooding by speeding up the flow of rainwater into rivers. A lesser-known phenomenon, it also allows pollutants carried from roadways, such as tyre residues and hydrocarbons, to be washed out and concentrate in runoff (Rio 2019). Thus, demographic growth and urban expansion, which go hand in hand with massive soil imperviousness, are disrupting hydrological and ecological cycles in cities at levels that are still very little studied - even though compensatory measures, with less impact on hydrological cycles, were made compulsory in France as early as 1990 for all new urbanisation projects (e.g. storm basins) and later with the European Water Framework Directive (WFD).

In different parts of the world, voices are also raising in the sustainability sciences and architecture to promote further less harmful green-blue infrastructures (Ghofrani, Sposito, Faggian 2017;

Garda 2019; Pochodyla, Glinska-Lewczuk, Jaszczak 2021). This is the case in China, where the idea of the sponge city has been widely developed in response to the construction of new metropolises and neighbourhoods (Guan, Wang, Xiao 2021). There are also citizens' initiatives to 'depave' soils at the local level in Belgium following the *General assemby of Water* in Brussels (Zitouni 2013) or in North America, e.g. under the impetus of the NGOs *Depave Paradise* (USA and English speaking Canada) and *Sous les pavés* (Québec). In France, despite scientific recommendations and institutional incentives, actions in this domain remain very limited. They are confined to schoolyards and car parks under municipal ruling. This is particularly true of Mediterranean towns, which have not only inherited an urban history that is as long as it is mineral (old town centres) but are also experiencing high demographic growth because of the attraction of the sun and the coastline[1]. We wanted to use a specific case study to understand what could help or hinder the adoption of greener solutions in these specific regions - compared with what is being done further North, for instance in Portland (USA), Rotterdam (The Netherlands) or Newcastle (UK) - see O'Donnell et al. 2021.

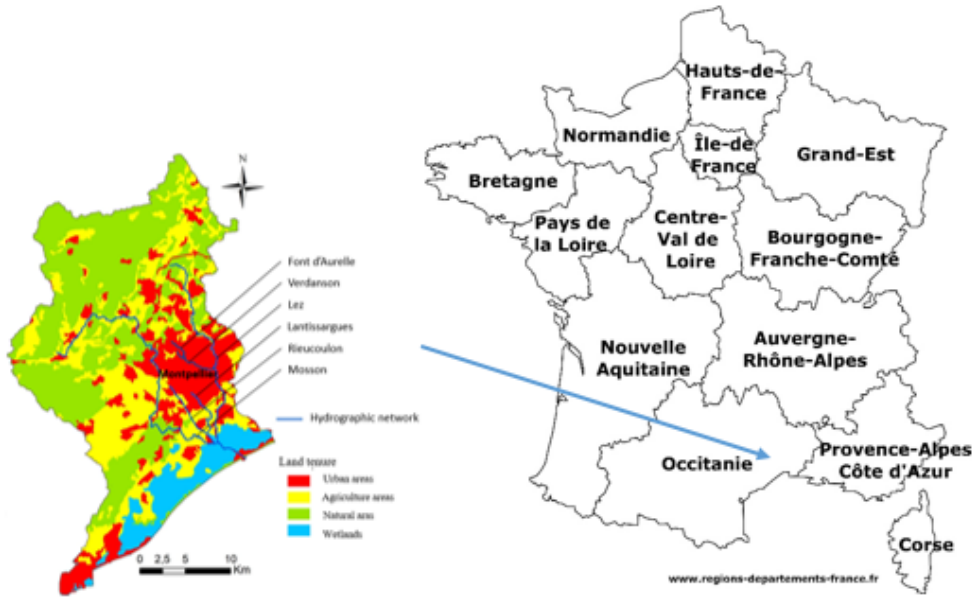
Our paper reports on interdisciplinary research conducted on the quality of runoff washing the impervious areas of Montpellier Méditerrannée Metropolis (Montpellier 3M), in the South of France, and on the technical and social obstacles as well as levers to the

[1] The coastline explains why many Mediterranean cities have, for a very long time, been more oriented towards the sea than towards their inner streams and rivers. This is the case of Montpellier, Marseille and Perpignan (Romain 2014).

adoption of urban greening methods that help runoff infiltration. This multidisciplinary research shed light on debates that will undoubtedly intensify in the future with the recurrence of extreme climatic events, particularly in the Mediterranean context. Our objective is to complete the range of hydrosociological research (Wesselink, Kooy, Warner 2017), rather focused on quantity issues (flooding or drought), to reconnect urban hydrology issues with water quality issues, land occupation, planning and social practices that condition the future of the water cycle in cities.

1. Case-Study, material and method

Montpellier 3M, located in the South of France on the Mediterranean coast, is a very attractive urban area. Composed of 31 municipalities (including Montpellier city), it has 427,500 inhabitants, with an annual growth rate of over 1% (slightly down in recent years), which is double that of comparable metropolises, according to the French National Institute for Statistics (INSEE, 2019). While Montpellier city itself concentrates two-thirds of the population, it should be noted that the outlying municipalities, such as *Juvignac* and Le *Crès*, experienced a much more exceptional growth rate of 4% over the period 2006-2011 (INSEE 2019). The national authorities note that between 2009 and 2018, an average of 33 million square metres of land were artificially developed in the region - mainly to build homes (DREAL 2020).



Map of Montpellier 3M and its rivers and streams (Source : Rio 2020)

Although all new buildings built in recent decades should, in principle, be connected to a separate sewer system, it should be noted that this is not the case in the older town centre. So 7% of homes are connected to the historic combined sewer system (Montpellier city). Part of the rainwater therefore goes to the metropolitan wastewater treatment plants, of which the main one, *Maera*, is under public control since 2023. This plant is currently being renovated. Its treatment capacity has to be increased as it is still sufficient in normal times (despite the rapid growth of the population) and overflows with untreated water during rainy episodes of a month's return period.

Furthermore, the six rivers crossing Montpellier 3M urban area (*Font d'Aurelle*, *Verdanson*, *Lez*, *Lantissargues*, *Rieucoulon* and *Mosson* - see

map above) do not have the same flow rates nor the same carrying capacity. While the *Lez* and *Mosson* rivers, the largest ones, enjoy a privileged status and retain part of their natural course, although lined with old and new hydraulic works, the bed of the *Verdanson*, as it flows through the city, has been partly sealed by concrete and even covered for some reaches. It is a favourite place for street artists and skaters who play along its banks during its long dry periods. The smallest rivers *Font d'Aurelle*, *Lantissargues* and *Rieucoulon* have either been culverted, walled up or simply made invisible. They occasionally reappear during intense storms, which cause them to burst their banks, forcing the closure of certain traffic routes. For instance, for the period 1994-2018 the inter-annual rainfall in Montpellier area was 669 mm (from 320 to 1149 mm - SD 199 mm) with 97 rainy days on average. However, there is a preponderance of light or heavy rainfall, with an increase in the intensity of extreme events over the recent period, which do not favour infiltration and the filling of the soil and subsoil with water.

These specific features motivated our questioning on the impact of the increasing artificialisation on the quality of the runoff that reaches the local rivers, especially as a significant part of the artificialised surfaces are also made impervious. We know that building materials and road coatings alter the natural water cycle in the city, some more than others. Rain is indeed a problem for modern urban areas where everything has been done to get rid of runoff as quickly as possible via a complex network of gullies, drains and pipes - first to clean up the city in the interests of health and safety. Let’s remember that in the

1830s, Montpellier city was twice hit by cholera epidemics – with the consequence that it was one of the first French city to implement a sewage system (Jeanjean 2020). At the same time, the impacts of these infrastructural changes have been little studied. Some researchers have focused on drinking and wastewater management infrastructure, while others have focused on the natural urban water cycle. The two types of approach remain poorly articulated - and not very interested in runoff issues. However, it is now known that this way of dealing with rainwater in the city, accelerating its transformation into runoff that we will try to get rid of, has major consequences (McGrane 2016). Each intervention on the soil has an impact on its capacity to capture or store rain, necessarily increasing the risk of flooding in the case of widespread impervious areas. Beyond these quantitative problems, numerous data now make it possible to assess the impacts on water quality. Intense runoff enhances the washing out of the contaminants present in the urban space, from pesticides to hydrocarbons, metal residues and synthetic compounds, increasing the stormwater pollution before it reaches the natural environment. In Montpellier city, Rio (2020) reported large quantities of bacteria indicative of faecal contamination, metallic trace elements such as zinc and copper, but also organotins and PAHs in high quantities, above the environmental quality standards for some, during high water periods (compared to low water periods), more particularly in the *Verdanson* river (Rio, 2019). Aujoulat et al. (2021) also pointed out several drug residues downstream from the city's hospitals, the largest of which are built on the *very* same catchment.

Rio's thesis work (2020) consisted of hydrological and chemical measurements, seeking to understand the risks that urbanisation, coupled with soil artificialisation and imperviousness, posed to the quality of surface water, particularly the vulnerable and remarkable lagoons and wetlands located on the coast downstream from Montpellier 3M. She completed her work with a sociological survey. The aim was to anchor the models to be built in the field so that they could provide relevant information about a given situation – in response to critiques which often target the off-ground nature and normativity of many models (Viveiros de Castro 2019). This took place in two stages - in the framework of a collective approach. 24 long semi-directive interviews were conducted, first with scientists and institutional actors (State services, managers, municipal officials, and technical services) in charge of water in the Metropolis, then with sports and environmental associations and neighbourhood committees. The aim was double: (1) to gather information on urban planning and soil artificialisation, on runoff management techniques in terms of theirs performances in reducing runoff volume and improving stormwater quality, (2) to design local scenarios of urban development which would be used as input data in the models of urban hydrology to predict the level of stormwater quality according to the evolution of land uses.

The interviews, which lasted between 30 minutes and two hours, were all transcribed word by word before being coded and analysed in relation to the different themes identified during the survey, namely the degree of knowledge of the stakes of runoff and then of the quality

234 of water in connection with runoff, the sensitivity to the risk of
235 flooding, the role of territorial planning tools, the capacity to define
236 alternative greening techniques, the interest for new practices in this
237 matter, according to the constraints, and the key-elements to be taken
238 into account in the construction of possible contrasting scenarios of
239 territorial development. All of this, in relation to the sociological
240 profile of the interviewees. This work was followed by the organisation
241 of a focus group or collective interview which allowed the project team
242 to present its hydrological, chemical, and sociological results for
243 discussion. An external professional, in charge of the urban greening
244 policy in Lyon, another pioneering metropolis in this field, was also
245 invited to provide points of comparison.

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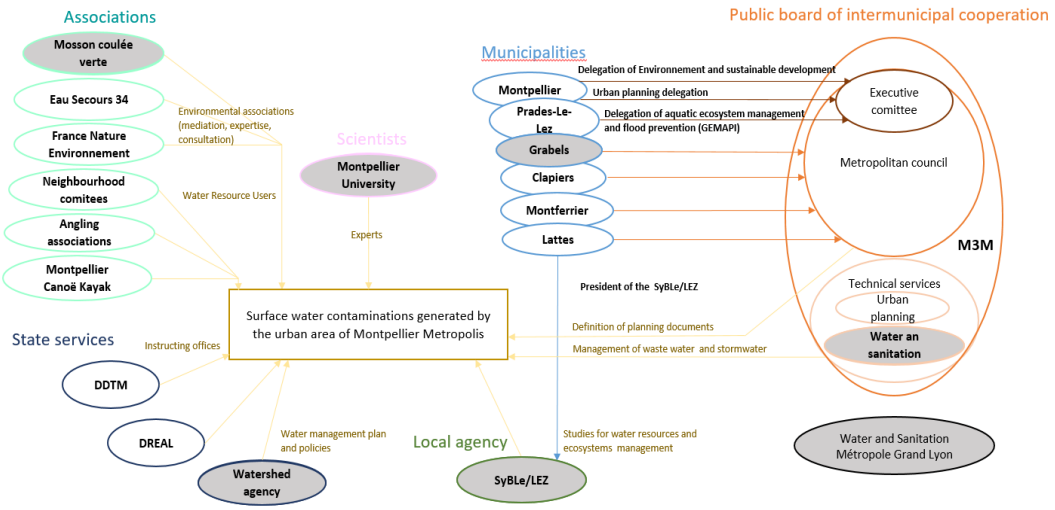

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Table 1: List of interviewees with their relation to the issue to be addressed. The actors outlined in grey took part in the focus group (Source: Rio 2020)

The event, which took place on 12 June 2019 over a period of 3 hours, brought together 4 scientists (the authors of this article) and 8 stakeholders from the region, including representatives of the Rhone-Mediterranean-Corsica Water Agency (RMC WA), the local river management board, an elected official, and a member of a citizen association. The participation rate was lower than expected. 20 people had initially been invited (some had been interviewed and yet had expressed interest) but due to unavailability and other pressing matters, they did not all show up. We took this into account in our analyses. The focus group was filmed, reviewed, and also discussed by the authors. This enabled us to validate some of our hypotheses, forged after the initial interviews and field observations, while nuancing others.

Unlike quantitative methods, qualitative surveys do not derive their scientific validity from the number of interviews conducted or the representative nature of their samples. The aim is not to produce statistics, but rather to analyse the content of the discourse of the actors encountered by comparing them. In this case, the diversity of the profiles of the interviewees is a better guarantee of quality. Samples such as ours are composed according to the themes dealt with. It is necessary to target the social actors concerned, for example,

representatives of administrations, professionals, and associations in the field, and then to proceed by the snowball technique to identify other people likely to bring complementary or contrasting points of view. The sample is complete when a saturation effect occurs: the discourses end up overlapping - or else, as happened to us, when the people declare that they are unfamiliar with the subject under investigation and are not able to discuss it. The analysis can therefore begin based on the transcribed and coded interviews, but also of the observations recorded during the survey. The aim is to make sense of the testimonies in order to reconstruct the viewpoints of the actors - which are characterised and illustrated through the presentation of selected quotes. We proceeded in this way, inductively, to draw from our data and their triangulation some arguments presented below.

2. Results

a- Concerns about floods come first

As explained here above, Montpellier 3M is subject to rare, but intense and violent rainfall events called *Cévenol* episodes since they occur on the foothills of the *Massif Central*, at the edge of the Mediterranean (Jacques 2016). They usually happen in autumn and are caused by vortices of different altitudes, followed by upward but stationary motions that cause large rainfall heights in a short time (more than 100 mm in less than half a day). Even if the metropolis did not experience the same catastrophic flooding problems as Nimes in

October 1988, we underline that it suffers quite regularly from floods of its main rivers swollen by abundant rainfall. This is notably what happened in September 2014, when 260 mm of rain fell in 4 hours (Bouvier et al., 2018). This exceptional event, of a centennial type, generated significant damage. Roads were cut off and thousands of people had to be evacuated.

In this context, it is not surprising that the persons we interviewed, especially those who were in decision-making positions at the time of this major *Cévenol* episode, stated that flooding was their main concern. An elected official from a small commune of the Metropole, for example, stated:

"*Floods, we have them every year. It's something you live and feel, not something you see in a schoolbook or that is explained to you... We have all had to deal with floods at some point*".

This quote shows that we are both in the register of familiarity with the event, which confers a certain experience, and the emotional. Heavy or even extreme rainfall recurs periodically. Elected officials are inevitably confronted with their consequences. They are responsible for ensuring the safety of their constituents, in coordination with the public emergency services, in the event of a weather warning. They are also the ones who organise, after the event, the aid and the restoration of local infrastructures - and request recognition of the state of natural disaster to obtain financial and technical support. This emergency character, with damage to property and persons, explains

why flooding is given priority. The consequence is that water quality problems, which are less acute, take second place. Moreover, their chronicity makes them less immediately perceptible (Erikson 1994). Their effects are often deferred in time within a perimeter that is difficult to delimit - unlike floods. Everything contributes to delaying their inclusion on the political agenda.

Another elected official confirmed that "*when you deal with floods, you don't deal with water quality*". Both for reasons of mandate, but also for lack of time and concern. As Comby et al. (2019) explained about the Lyon Metropolis, the presence of micropollutants in runoff is not identified as an environmental or health problem neither by the elected officials not by the municipality technical services. In Montpellier, the management of runoff itself, to limit overflow and flooding, has only started to be considered seriously after the 2014 event as the same technical services had to work on a Flood prevention plan – and still few respondents, especially among elected officials and the public, believe that urban runoff and overflow from stormwater systems is the cause of flooding in areas far from rivers. As far as the inhabitants are concerned, they are not informed at all about quality issues. They are concerned about the risk of flooding, originating from rivers, and its immediately perceptible emergency character. There is no clear social demand on qualitative issues - apart from pressure from a few associations with an expertise in this domain.

A regional representative of the RMC WA confirms this focus on flooding, which prevents other urban water problems from being considered and taken care of, with perspective. This is particularly the case in Montpellier where the *Verdanson* bed in the city centre is concrete or masonry – and sometimes entirely covered. After the 2014 floods, some of these structures were washed away, but they were quickly reinstalled. Without legal constraints or political support, the incentives to green the city by national institutions such as the French biodiversity agency (OFB) and the RMC WA have little effect. The alternatives, for managing runoff, are overshadowed by considerations in terms of securing the city against flooding, which borrow from the modernist register of rapid water drainage and protection by dykes, all the more so since the legislation in this area is not binding, especially for already developed areas. This has been confirmed to us on many occasions by the managers in charge of water and aquatic environments in the catchment area of the *Lez-Mosson* rivers – as shown below.

"*So, the regional water management plan says things but does not impose them. For new facilities, it can make requests, but to go back to the existing, that's another thing! We tried to instil these ideas in the Territorial Coherence Scheme* (SCOT - a land planning document that commits local authorities – authors' comment)*, but each time we were shut down. Today, the Metropolis is about flooding. That's all we see. It should change its vision and open up... But it's not necessarily easy*"!

The consequence is that change depends mostly on the goodwill of local political actors, who also face pressing demands for accommodating newcomers.

b- The constraint of housing inhabitants.

The tone is much more critical when the representatives of angling and environmental associations are questioned. They castigate local urban policies that maintain "unsustainable" urban growth, which leads to new constructions. For citizens with expert knowledge of water and aquatic environments, there is both an inconsistency between the prioritisation of flooding problems and the numerous authorisations given to developers to build and extend the Montpellier 3M – as expressed by a local fisher – representative of an association in charge of the protection of aquatic environments.

> "*On the one hand, we fight against floods and on the other hand, we do nothing to fight upstream, by preventing the extension of impervious soils*..." (angler).

This contradiction has several origins. First of all, it stems from the desire to make Montpellier 3M grow to rank among the main French metropolises - a policy that was notably deployed under the municipality of Georges Frêche (in office from 1977 to 2004) with several major urban planning projects, for example, the central Antigone neighbourhood (1980's). The attractiveness of the

metropolis, located very close to the Mediterranean seashore, makes its elected officials proud because it gives them power and prestige. They maintain it at the same time as well as they carry its burden because it forces them to complete the range of public facilities and services available. As demographic pressure remains high, it is necessary to reduce the pressure on the real estate supply by launching new construction programmes in neighbourhoods that replace wooded areas (*Malbosc* neighbourhood in the North – 2000's) and wetlands (*Grisette-Ovalie* and *Port Marianne* neighbourhoods in the South – 2010's and 2020's). Recently, demographic growth has been particularly strong in the smaller towns of the Montpellier 3M, which have launched their own urban development programmes, leading to the construction of further new neighbourhoods with blocks of flats and villas.

For some associative actors, as shown below, the causes of this rush are not only attributable to elected officials focussing on the need to house families of newcomers in the Montpellier city and the surrounding municipalities, but also to outdated ways of seeing and analysing the situation, particularly within the technical services, which engineers could not be aware of the new methods and techniques of green urban planning.

"*The problem is the discrepancy between the display and, I would say, the will of the municipality services. And then the will of the elected representatives! There is a gulf. In other words, the elected officials are not ready... Have you seen the new districts how they are made? It's all*

mineral. The city is completely mineralised. They reproduce Paris with its pavements. Its concrete... In the law, it is clearly stated that they must preserve the landscape... Urbanisation that considers the wetlands and preserves their functionalities, including protection against flooding... But, not at all! In fact, their objective is to fit people in somewhere and then that's it. In their minds, they must solve the problem of housing people and then they'll see... Instead of avoiding paving directly... The problem we encounter is the upgrading of officials who date and never question themselves. ".

The recent controversy over the construction of the new *Mogère* train station in a flood zone in the South of Montpellier 3M - a former agricultural area, has fuelled mistrust. The associations that proposed other developments (for instance the extension of the existing station in the city centre), more respectful of the natural constraints of the site and of biodiversity, but were not heard, expressed a certain amount of anger at the time of our investigation. According to them, runoff issues are not handled efficiently – although they can generate more damage than overflowing rivers. The Metropolis' planning choices, which favour urban sprawl, artificialisation and the paving of new areas, are denounced. Whether on the part of the elected officials, these claims are swept aside in view of the social and economic issues at stake. Bad choices are systematically attributed to the political majorities previously in place. On the contrary, they underline efforts to create new green spaces in the city.

c- Confusion between mandatory compensation and depaving.

However, our questions on the urban growth of the Montpellier 3M and the resulting problems on runoff and water quality have provoked many reactions. The elected officials and public service engineers know what the legal requirements are. They quoted the prescriptions intended to retain rainwater on the plots. Among these prescriptions, included in the local urban development plan, is, for instance, a maximum imperviousness coefficient that varies according to the sectors at stake, applicable to new constructions or building extensions. It also applies to demands for individual building permits, as explained by an elected official of a city located North of Montpellier 3M.

"*In the case of building permits, it is ensured that there is a certain percentage of soil surface that remains pervious. I don't know if it's 20 or 25% of the plot, you can find it there in the regulations… at least 25% of the plot that must not be concreted, paved, or built on, of course. This is precisely to ensure a certain permeability*".

In any case, as soon as the size of the impervious surfaces are changed, compensatory measures are planned to limit runoff. In addition to dykes (which are protection measures but not compensation ones), the interviewees cited the storm basins and ditches of which they were aware or which they have specifically worked on. A representative of a neighbourhood association even stated:

"*When Georges Frêche took over the region, that's when they started making retention basins and protection dykes*" (RepresNeighbourColl1).

These compensatory infrastructures have been legally mandatory since 1992 for any new construction project. The oldest are mostly fenced off and closed to the public. The most recent are immediately noticeable in the new neighbourhoods of the metropolis, where they are intertwined with the buildings. They are now designed as green spaces, likely to store rainwater and to offer additional amenities to city dwellers (they can be turned into dog runs, children's playgrounds, or sports fields, for instance). Elected officials are often proud to cite these achievements as the example below illustrates.

"We created an open storm basin for retaining water which can be used as a playground. It's planted with trees. When it rains, water is stored. This is a good example of a construction in the city center made for perviousness ».

Without constituting depaving actions, retention basins and ditches are spontaneously associated with "policies in favour of perviousness", since they help to avoid too much concrete or bitumen in the city and may favour infiltration of runoff. Consequently, some elected representatives argued that they had already "*done a lot to limit imperviousness*" by complying strictly with the regulations. Their knowledge of alternative or greener rainwater management techniques seems to be limited. There was even a certain amount of confusion regarding the available options and their capacities. The

other infrastructures most frequently cited, apart from storm basins and ditches, were public parks, vegetated roofs being unanimously dismissed as unsuitable to the Mediterranean climate. The quote from an elected official below is evidence of this. "*We have a motto, it's a development zone* (ZAC in French- authors' note), *a park. This is what we do everywhere, what we did at the former military school, what we did at the new* St Roch *neighbourhood, what we're going to do at* Cambaceres *[…] it's obviously to preserve everything that is... And for rainwater, each time, we calculate on each ZAC: first we make the networks, we plant, and we create retention basins. That's what's important*!"

This orientation is confirmed by the technical services of the metropolis. Like engineers and technicians of government agencies, they insist on compensation and management of rainwater at source. Their positions (and aspirations) were even bolder during the focus group (in which only one elected official was involved) than during the interviews. There was a kind of reinforcement effect of the statements, encouraged by a low presence of the political actors. The claim of this manager of the *Lez/Mosson* watershed attests to their ambitions and efforts.

"*In the framework of urban renewal, in fact everything that has been excessively concreted, everywhere where there are a lot of pavements, car parks, we try to optimise these sectors by removing the concrete and creating green areas... It's written into the Regional water management plan...*".

In fact, recently, localized actions have also been carried out, thanks to fundings from the RMC WA to depave schoolyards in Montpellier 3M. The first tests were launched in 2021. The main argument in favour of this works was however more to fight against urban heat islands and to restore biodiversity. It is worth noting that French public schoolyards are mostly covered with concrete or bitumen, and sometimes partially covered with a rubber coating to cushion the falls of the youngest. A few trees provide some shade, even if their roots are embedded in artificial materials (Pandelle, Le Roux 2021). Children have very limited contact with the natural elements. In Montpellier 3M , where temperatures already exceed 28°C at the end of June and beginning of July, these artificial zones contribute to increasing temperatures. Since municipalities manage school buildings and there are financial incentives for re-greening, choices are done to start where it easier, in small spaces and with spatially limited issues. Depaving in other parts of the city, however, raises other questions and problems.

d- Other obstacles and levers.

The main obstacle identified by all those interviewed, and in particular by the elected officials, is the financial and salary cost for installing and maintaining permeable infrastructure – once we had specifically mentioned them (during the interviews and the focus group).

"*The cost of management is terrifying, especially if it's small green spaces scattered all over the place. By the time the guys get there, come back, it's a horror.*", said an elected official.

The costs are obviously difficult for municipalities to accept. Yet the interviewed also pointed out the strong constraints that the regulations impose on real estate developers who must apply the regulations - which means devoting part of the land they acquire, whether in urban renewal or new neighbourhoods, to the construction of storm drains and ditches or more. For them, this is a loss of earnings that can give rise to resistance as mentioned by another elected official:

"*It is excessively heavy and expensive because land in Montpellier 3M is not cheap! When you carry out a real estate operation and there is already a significant cost of land, of destruction, of restructuring, plus a lot of standards that are put in place to have a rather pretty city with quality architecture etc., and you tell the guy, whether he is a private individual or a developer, 'ah I forgot to tell you that on 10 to 15 % of impervious soils today, you will have to go back to perviousness'… In some places, it means attacking several layers of bitumen, perhaps digging out pollution!*"

The longer-term benefits of alternative or greener urban development methods and techniques (for the management of rainwater) are rarely highlighted - even if they are emphasised by the state services. Prescriptions in the domain are seen above all as an additional cost and a constraint that is poorly understood. In some cases, in heritage areas or areas where pollution is suspected, additional expenditure can be required, either to protect historical monuments and buildings or to rehabilitate land.

Moreover, while coating materials such as concrete and bitumen (or paving stones) can be installed by the road services for many years, and are easily cleaned by the cleaning services, alternatives require more attention. Pervious bitumen is costly and last less time. It tends to clog and requires maintenance (Denis, Pontille 2015). It makes underground networks repairing more expensive. For other pervious infrastructures it is not only necessary to mobilise the 'parks and gardens' department, but also to try to bring together services that often work in silos to collaborate because their professional cultures are not the same (Meilvang 2021). The road technicians, like those of the sanitation services, have always worked to evacuate rainwater as quickly as possible. They do not see water as a resource, but as a problem. Their way of doing things is the opposite of the way of the 'parks and gardens' department - which agents usually operate in dedicated spaces that they control and not in the permeable city, i.e. a hybrid of streets and greenery. As underlined by a State official, it is therefore necessary to develop new transversal approaches.

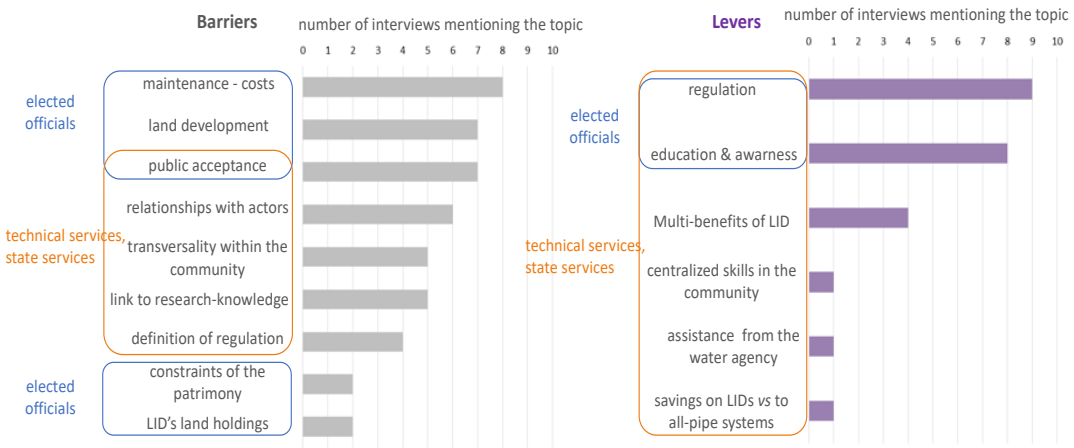
"*Sanitation is simple. There is a service that takes care of everything. As soon as you do with alternative techniques, it can be different with sanitation, road, and green space services. It is more difficult. The transversality within the municipalities is not completely acquired and it is necessary to work on it*".

There is a problem of both financial resources and human resources. The regular maintenance of a green and blue infrastructures requires

591 more staff, and staff trained in other methods and techniques that are
592 much less focused on one sector than previously. It is a question of
593 dealing with vegetation that must be pruned, with animal or plant
594 species that may proliferate, but also with changing states of matter,
595 for example, when it rains, mud may form. The predictability of
596 surfaces made homogeneous by a uniform impervious coating
597 disappears in favour of diversity and change. Municipalities not always
598 put the necessary funding into this because, as we have said, it is not
599 their priority and other risks may appear to be of greater interest to
600 them (flood control and the securing of public spaces). Yet large cities
601 like Montpellier 3M are already spending a lot of money on upgrading
602 their obsolete storm drainage networks - an effort that is largely
603 invisible and therefore difficult to promote.

604

605



606

607 Table 2: Barriers and levers for the development of alternative
608 techniques in interviews (Source: Rio 2020)

Among the other brakes and limits we have listed in Table 2, there are also the anticipated negative reactions of inhabitants. As mentioned, the French are used to cities where nature is entirely domesticated and even confined to strictly limited spaces inFrench style public parks and gardens as well as private gardens. Any irruption of alien animal or bloom of plants is viewed with suspicion. For example, the elected officials we met worried about unhappy constituents. They foresee that depaving more would induce the increase of complaints as they experienced with the ban of pesticides in public spaces. Alternative and greener approaches could then be seen as manifestations of neglect and dereliction.

"*Vegetation today in an urban environment is complicated to manage, it creates enormous tensions with our populations because as we no longer use phytosanitary products, and we don't have the means to pay guys to pull it out by hand, and we still haven't found the biological means to maintain it, people see trees growing everywhere, they say that we don't maintain the roads, that we don't maintain the pavements, 'what the hell is this mess'*!" (Elected official).

For this reason, all the interviewees indicated that educating the population is the solution to avoid such negative feedbacks. For a representative of the Montpellier 3M : "*we need to change mentalities*" to prepare the reception of new and lighter ecological infrastructures. To this, it would be necessary to add experiences of consultation in order not to remake the city for (or against) its

inhabitants, but with them. This would avoid frontal opposition. It could also lead to the emergence of preferences which should be considered. This is the conviction of an elected official of Montpellier 3M , also mayor of a small town to the North of the city, who has played an important role in the implementation of democratic local water policies.

"*Urban renewal requires much more consultation than urban development... It is normal if your living environment is modified under your windows*.

However, the neighbourhood associations we met still regretted being so little consulted. Most of the stakeholders had only partial information on the hydrological, chemical, social and political issues raised by rain and runoff. It was therefore difficult for them to envisage the greening of their city, with its democratic implications, especially as relations with local scholars were rather weak – compared to places like the Lyon Metropolis where there are intermediary actors who act as a link between scientists, decision-makers, and citizens.

3. Discussion

Our sociological survey was conducted in 2019, at the same time as we performed hydrological and chemical measurements in the *Verdanson* catchment area in the heart of Montpellier 3M. The results allowed us to develop several scenarios of population and urban growth to model the evolution of the quality of the stream in the

future - according to public policies (Rio et al. 2021). They also helped us to target and prioritise feasible depaving actions, which would have the most beneficial consequences in terms of decreasing the quantity of runoff and improving the quality of surface waters.

This action research aimed at solving a water-in-the city problem. However, we quickly realised that the technical knowledge we had produced would not be enough. The implementation of alternative or greener runoff management techniques does not only depend on the concrete enumeration of its advantages by a group of convinced scientists. It also requires political and social support to be implemented and work. For this reason, we took the time to analyse the interviews we had conducted for drawing the necessary lessons.

In particular, we noticed that the issue of river and stream quality, whatever the kind of contaminants found in urban settings, was not identified as a public problem in the sense that the sociologist Joseph Gusfield have given to this term (1984; Gilbert, Henry 2012): a phenomenon or issue that has been problematised in such a way as to be identified as a concern and, as such, taken on by institutions. This approach has the advantage of not suggesting that the issues are self-evident. On the contrary, it shows that they are socially constructed - remaining ignored until social actors not only take the trouble to investigate them, but also manage to have them publicly accepted as relevant and urgent to address. In our case, substantial efforts would be needed to raise awareness of the issues at stake: i.e. to make explicit the links between the water quality of runoff and the

683 degradation of the aquatic lagoon and marine environments located
684 downstream of Montpellier 3M. Indeed, the risk is great that these
685 coastal aquatic ecosystems do not meet the objectives set by the WFD,
686 in time. Long-term awareness-raising work, initially aimed at the
687 technical services of municipalities throughout the catchment area,
688 would be necessary so that concerns about flooding are correlated
689 with water quality problems in the city and its downstream coastal
690 waters. Other issues such as urban heat islands in paved areas or
691 biodiversity erosion could be connected to this. However, this
692 awareness raising could not be only informative. It should aim at
693 transforming professional and citizen cultures about nature in the city,
694 as, alternative rain management interventions refer to other
695 conceptions of urbanity. They also imply a hybridisation of knowledge
696 and know-how that is not only valid in Montpellier 3M but potentially
697 in other urban areas of Southern Europe. Our regional prism is all the
698 more relevant as it refers to comparable climatic conditions (extreme
699 weather events) and urban cultures.

700 In those areas where elected officials are slow to be convinced by
701 greener techniques for managing runoff, for all the reasons we have
702 seen, it would undoubtedly be possible to rely on the specialised
703 associations which have expertise in this field, and which appeared to
704 us as pioneers of the idea of a permeable city recently. It is a question
705 of setting up an integrated and concerted management of rainwater
706 to limit the flow of water, and by the way, to fight against flooding
707 together with dissemination of contaminants, but also to retain the
708 water necessary for the greening of the city. In Montpellier 3M , the

associations have expressed many expectations in this area. They also have a lot of proposals to make. We are not at all in the situation of those of Northern European and American cities where citizens' groups take the initiative to make the soil permeable again, by breaking up the concrete and bitumen of their streets. We remain within the French framework where these actions are the prerogative of the municipalities (or other competent local institutions). However, there is a good chance that these associations could relay the needs of the inhabitants and users or, conversely, serve as third-party mediators to explain certain decisions in favour of perviousness, – like it happened in 2021 in Milan or Parma, Italy, very recently (Ceci et al. 2023).

Efforts in terms of consultation would not be useless. During a recent field trip, we were able to interview an amateur on his way to his vegetable garden located in shared communal land near a new neighbourhood called *Malbosc*. We asked him about the dog run, which is a retention basin. He surprised us by answering that the site had been badly designed as it flooded every time it rained. This experience was repeated during a walk with a group of students from Montpellier University in a "rain garden" on the campus. Without explanation, the students saw nothing of the device designed to drain, thanks to a set of subtle slopes, the rainwater towards green spaces at the foot of the buildings.

These examples show us that alternative green methods and techniques are not immediately visible to those who have not learned

734 to see them. As a result, the devices concerned are unable to
735 demonstrate their ecological and social benefits. The only functions
736 that are apparent are often the possible disamenities associated with
737 the removal of impermeable coatings and the installation of pockets
738 of potentially proliferating nature in the city, as we have already
739 mentioned.Given the demographic and urban growth in Montpellier
740 3M , it is likely that storm basins, ditches, and urban parks (mandatory
741 compensatory measures) - or even the depaving of a few car parks and
742 schoolyards (main real greening interventions at this date) - will not be
743 enough to truly compensate for the future artificialisation of further
744 natural spaces. In this respect, this metropolis represents an extreme
745 case, with environmental, social and economic tensions, from which
746 to consider the development of depaving in other urban areas of the
747 Mediterranean.

748 Other more far-reaching and long-time actions must nevertheless be
749 considered to maintain the habitability of the areas concerned, both
750 in terms of their capacity to absorb increasingly rare and intense
751 rainfall, to limit the concentration of contaminants in runoff and to
752 avoid heat urban islands - all of which requires a balanced renaturation
753 of the city. The expected changes demand, however, what the
754 philosopher Alexandre Monnin calls: an art of destoration (2021), i.e.
755 methods and tools for thinking about the dismantling of modern
756 infrastructures, the drawbacks of which we can now see - even though
757 they appeared to be the markers of technical and social progress. How
758 can we get rid of the concrete and bitumen that cover our cities to the
759 point of depriving us of all contact with the natural elements of the

soil? How can we learn to do without their practicality? Without doubt, the ecological transition cannot be achieved by simple decree or the prescriptions of new technical standards. It has to be learnt and experienced collectively.

Conclusion

In 2019, the representatives of Montpellier 3M whom we interviewed spoke of a future greening plan for the city as the incentives of the RMC WA became more and more pressing. While ambitious plans have been announced since our survey, with the future depaving of larger portions of public spaces, clearly this plan does not yet exist. We have not been able to obtain a copy of it to check. Depaving is still included in the SCOT but without any more constraints than before. We note, however, that the Metropolis has hired, at the beginning of the winter of 2022, a project manager who main missions will be to promote depaving actions. During the last few years, things have accelerated, particularly under the influence of the summer intense heat waves and drought. The need to cope with this dramatic situation could open new possibilities. To rethink the place of water in the city and to green its management, new interdisciplinary research in urban hydrosociology will certainly be necessary - both to change organisational, professional and citizen cultures, but also to set to music the indispensable collaborations (Aimar 2023). Montpellier 3M, given its climatic specificities, will not become a “sponge city”. Neither will be Marseille (France) nor Naples (Italy). However, they could be

become metropoleses like Barcelona or Valencia, in Spain (Suleiman et al. 2020), where the pace of water has been significantly slowed down (Gies 2022), thanks to greener participative approaches of urbanism so living conditions are significantly improved with regard to future threats.

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References

Aimar, F. (2023). Limiting Soil Sealing and Depaving: Local Actions for Regenerating Public Spaces to Build Green Infrastructures. In *Green Infrastructure: Planning Strategies and Environmental Design* (pp. 127-137). Cham: Springer International Publishing.

Aujoulat, F., Ragot, R., Toubiana, M., Bancon-Montigny, C., Monfort, P., Salles, C., Masnou, A., Delpoux, S., Rio M., Tournoud, M.G., Marchand P., Jumas-Bilak, E., & Licznar-Fajardo, P. (2021). Antimicrobial Resistance in a Small Urban Mediterranean River: A Focus on Endemic Beta-Lactamases in Clinically Relevant Bacteria. Water, 13 (2010).

Brunet, P., Bouvier, C., & Neppel, L. (2018). Post-event survey of the 6-7th October 2014 flood in Montpellier-Grabels (Hérault, France): hydro-meteorological features and historical position of the event. *Physio-Géo*, *12*, 43-59.

Ceci, M., De Noia, I., Tedeschi, G., Caselli, B., & Zazzi, M. (2023). Soil de-sealing and participatory urban resilience actions: the "Green in Parma" case study. *UPLanD - Journal of Urban Planning, Landscape & Environmental Design*, *7*(2), 5-18

DREAL (2020). Etat des lieux de l'artificialisation des sols. Webdocument : https://www.occitanie.developpement-durable.gouv.fr/IMG/pdf/srgee_etat_des_lieux_vf.pdf

Garda, E. (2019). Let's get dirty! Le azioni di depaving dei suoli urbani per la multifunzionalità degli spazi sottoutilizzati. *Altre Modernità: Rivista di studi letterari e culturali*, (2), 164-178.

Ghofrani, Z., Sposito, V., & Faggian, R. (2017). A comprehensive review of blue-green infrastructure concepts. *International Journal of Environment and Sustainability*, *6*(1).

Gies, E. (2022). Smarter ways with water. *Nature*, *611*(7936), S12-S14.

Gilbert, C., & Henry, E. (2005). La définition des problèmes publics: entre publicité et discrétion. *Revue française de sociologie*, (1), 35-59.

Guan, X., Wang, J., & Xiao, F. (2021). Sponge city strategy and application of pavement materials in sponge city. *Journal of Cleaner Production*, *303*, 127022.

Gusfield, J. R. (1984). *The culture of public problems: Drinking-driving and the symbolic order*. University of Chicago Press.

Harismendy, P. (1999). Du caillou au bitume, le passage à la « route moderne »(1900-1936). In *Annales de Bretagne et des pays de l'Ouest* (Vol. 106, No. 3, pp. 105-128). Persée-Portail des revues scientifiques en SHS.

Holley, I. B. (2003). Blacktop: How asphalt paving came to the urban United States. *Technology and Culture*, *44*(4), 703-733.

INSEE (2019). Dossier complet commune de Montpellier.

Jacques, G. (2016). Les épisodes cévenols: Un aperçu historique. *La Météorologie*, *2016*(93), 50-57.

Jeanjean, A. (2000). Basses oeuvres. Ethnologie d'un réseau technique urbain: les égouts de Montpellier. *Annuaire des collectivités locales*, *20*(1), 633-640.

McGrane, S. J. (2016). Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. *Hydrological Sciences Journal*, *61*(13), 2295-2311.

Meilvang, M. L. (2021). From rain as risk to rain as resource: Professional and organizational changes in urban rainwater management. *Current Sociology*, *69*(7), 1034-1050.

Monnin, A. (2021). Planetary negative commons. *Multitudes*, *85*(4), 117-125.

Pandelle, L., & Le Roux, F. (2021). T'are ta gueule à la récré! Les cours d'école s' invitent chez les décideurs· ses. *Z: Revue itinérante d'enquête et de critique sociale*, (1), 152-157.

Pochodyła, E., Glińska-Lewczuk, K., & Jaszczak, A. (2021). Blue-green infrastructure as a new trend and an effective tool for water management in urban areas. *Landscape Online*, 92-92.

858 Rio, M. (2020). Flux de contaminants dans un bassin versant côtier
859 méditerranéen lors d'évènements pluvieux : quels bénéfices de la
860 désimperméabilisation des espaces urbanisés ? : étude à différentes
861 échelles sur la zone de Montpellier, Phd in water sciences, University of
862 Montpellier.

863 Rio, M., Salles, C., & Tournoud, M. G. (2021). Modelling the effects of
864 stormwater control measures on runoff volume and particulate load in
865 urban catchments. *Urban Water Journal*, *18*(2), 79-90.

866 Romain, F. (2014). L'imaginaire fluvial contemporain: un antidote urbain?.
867 Le cas du Lez vert à Montpellier et de la Têt à Perpignan. *Projets de paysage.*
868 *Revue scientifique sur la conception et l'aménagement de l'espace*, (10).

869 Viveiros de Castro, E. (2019). On models and examples: engineers and
870 bricoleurs in the Anthropocene. *Current Anthropology*, *60*(S20), S296-S308.

871 Wesselink, A., Kooy, M., & Warner, J. (2017). Socio-hydrology and
872 hydrosocial analysis: toward dialogues across disciplines. *Wiley*
873 *Interdisciplinary Reviews: Water*, *4*(2), e1196.

874 Zitouni, B. (2013). Asphalter ou désasphalter Bruxelles. Comment
875 l'hygiénisme du passé rencontre l'écologie politique d'aujourd'hui. *Revue de*
876 *l'Institut de Sociologie*, (83), 105-119.