

Contributions of Urban Political Ecology to sustainable drainage transitions*

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Abstract

This article aims to demonstrate how critical urban geography and Urban Political Ecology (UPE) can provide analytical tools to fully incorporate the social dimension in Sustainable Urban Drainage Systems (SUDS), overcoming geographical and depoliticized understandings of sustainable stormwater transitions. Through its socio-technical framework, Sustainability Transitions Theory (STT) has contributed significantly to the discourses around governance, infrastructure and management of the new stormwater paradigm *from hazard to resource*. However, the theory fails to recognise the complexities that geographical, historical and political dynamics introduce into this process, as questions arise regarding why, how and for whom stormwater becomes a resource. The article argues that UPE can offer insights into why and how drainage transitions may take place in specific contexts, considering aspects of sustainability, social equity, justice and democracy.

Keywords: stormwater sustainable transition; critical urban geography; socio-political analysis; socio-environmental analysis

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Resum. *Contribucions de l'ecologia política urbana a transicions de drenatge sostenibles*

Aquest article té com a objectiu reconèixer que la geografia urbana crítica i l'ecologia política urbana (EPU) poden proporcionar eines analítiques per incorporar completament la dimensió social als sistemes urbans de drenatge sostenible (SUD), superant les enteses ageogràfiques i despolititzades de les transicions sostenibles de les aigües pluvials. La teoria de les transicions de la sostenibilitat ha contribuït significativament, a través del seu marc sociotècnic, als discursos de governança, infraestructura i gestió del nou paradigma de les aigües pluvials *d'amenaça a recurs*. No obstant això, falla a l'hora de reconèixer les complexitats que les dinàmiques geogràfiques, històriques i polítiques introdueixen en aquest procés a mesura que sorgeixen preguntes sobre per què, com i per a qui les aigües pluvials es converteixen en un recurs. L'article sosté que l'EPU pot oferir informació sobre per què i com les transicions de drenatge poden tenir lloc en contextos específics, considerant aspectes de sostenibilitat, equitat social, justícia i democràcia.

Paraules clau: transició sostenible d'aigües pluvials; geografia urbana crítica; anàlisi socio-política; anàlisi socioambiental

Resumen. *Contribuciones de la ecología política urbana a las transiciones de drenaje sostenible*

Este artículo tiene como objetivo reconocer que la geografía urbana crítica y la ecología política urbana (UPE) pueden proporcionar herramientas analíticas para incorporar por completo la dimensión social a los sistemas urbanos de drenaje sostenible (SUD), superando los entendimientos ageográficos y despolitizados de las transiciones sostenibles de las aguas pluviales. La teoría de las transiciones de la sostenibilidad ha contribuido significativamente, a través de su marco sociotécnico, a los discursos de gobernanza, infraestructura y gestión del nuevo paradigma de las aguas pluviales *de amenaza a recurso*. Sin embargo, falla a la hora de reconocer las complejidades que las dinámicas geográficas, históricas y políticas introducen en este proceso a medida que surgen preguntas sobre por qué, cómo y para quién las aguas pluviales se convierten en un recurso. El artículo sostiene que la EPU puede ofrecer información sobre por qué y cómo las transiciones de drenaje pueden tener lugar en contextos específicos, considerando aspectos de sostenibilidad, equidad social, justicia y democracia.

Palabras clave: transición sostenible de aguas pluviales; geografía urbana crítica; análisis sociopolítico; análisis socioambiental

Résumé. *Contributions de l'Écologie Politique Urbaine aux transitions durables du drainage*

Cet article vise à reconnaître comment la géographie urbaine critique et l'Écologie Politique Urbaine (EPU) peuvent fournir des outils d'analyse pour intégrer pleinement la dimension sociale dans les Systèmes de Drainage Urbain Durable (SUDs), dépassant les compréhensions géographiques et dépolitisées des transitions d'utilisation durable des eaux de pluie. La théorie des transitions de durabilité a contribué de manière significative à travers son cadre sociotechnique aux discours de gouvernance, d'infrastructure et de gestion du nouveau paradigme des eaux pluviales *de la menace à la ressource*. Cependant, elle ne reconnaît pas les complexités que les dynamiques géographiques, historiques et politiques introduisent dans ce processus alors que des questions se posent sur pourquoi, comment et pour qui les eaux pluviales deviennent une ressource. L'article soutient que l'EPU peut fournir des informations sur pourquoi et comment les transitions de drainage peuvent avoir lieu dans des contextes spécifiques, en tenant compte des aspects de durabilité, d'équité sociale, de justice et de démocratie.

Mots-clés : transition durable des eaux pluviales ; géographie urbaine critique ; analyse sociopolitique ; analyse socio-environnementale

Summary

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 2. Analyzing stormwater transitions through the lens of Sustainability Transitions Theory (STT)
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1. Transitioning from risks to resources in stormwater management

Recent decades have been characterized worldwide by economic growth and urban development without much consideration for the environment (Loorbach and Shiroyama, 2016). Negative consequences such as overconsumption of natural resources, loss of biodiversity and climate change have been accompanied by economic crises and social tensions, especially in urban areas (Beling et al., 2018; Loorbach, 2007). While cities have grown significantly, basic urban infrastructures have not progressed accordingly, especially in the global South. Water supply and sanitation have become particularly problematic, with strong inequalities in access and affordability persisting mainly, but not only, in low-income countries (UNESCO, 2019; Zapana-Churata et al., 2021), while water privatization and commercialization – whereby water is conceived as a ‘merit good’ and a scarce commodity – is forcefully contested (Bakker, 2003). In sum, United Nations Sustainable Development Goal 6: (“Ensure availability and sustainable management of water and sanitation for all”) is advancing very slowly and, unless drastic changes are implemented, may not be achieved until 2050 (UNESCO, 2019).

In addition to water supply and sanitation, many cities in the global North are confronting another challenge: the increase in urban flooding, with adverse effects on development and welfare (Loorbach, 2007). Ninety per cent of natural disasters occurring in the world today are water related. Between 1995 and 2015, floods accounted for 43% of all documented natural disasters, affecting 2.3 billion people, killing 157,000, and causing economic losses of \$662 billion (UNESCO, 2019). The increase in urban flooding episodes shows the limits of traditional stormwater infrastructures based on ‘end of pipe’ solutions. These systems capture urban run-off and move it away from urban areas via large drainage networks, at high construction, operation and maintenance costs. During intense precipitation events, however, these infrastructures are prone to overflows causing floods and pollution (Perales-Momparler, 2015; Zhou, 2014). The increase in urban flooding is raising international awareness on the need to design and build more sustainable, adaptive and multi-functional stormwater systems (Porse, 2013), inspired by new perspectives on urban planning and landscape design that support water sensitive behaviours

adapted to climate change (Goulden et al., 2016) through mitigation, adaptation and resilience strategies (Scott et al., 2013).

This trend has been defined by Brown et al. (2009) as the transition from a 'water supply city' to a 'water sensitive city'. It encompasses six stages that represent distinct socio-technical moments that respond to socio-political drivers taking place at specific historical times. The first three stages are characterized by water supply access and security through centralized systems such as pipes and sewers that are the result of incremental developments of the existing water regime, while the second three, named respectively 'waterways', 'water cycle' and 'water sensitive city', are part of a broader paradigmatic shift away from pre-existing regimes (Brown et al., 2009). The final state of the transition, the 'water sensitive city', encapsulates a socio-technical reconfiguration guided by ecological equity and resilience to climate change in which stormwater is no longer considered a hazard but a resource (Chini et al., 2017; Saurí and Palau-Rof, 2017; Wong and Brown, 2009). This transition is achieved by means of multifunctional infrastructures and urban designs that reinforce water sensitive behaviours (Brown et al., 2009).

In recent years, new frameworks and agendas have emerged as part of long-term sustainability transitions in cities, and are receiving increasing attention in policy arenas (Chini et al., 2017; UNEP, 2011) and the social sciences (Markard et al., 2012). Following circular economy principles, and promoted in Europe by the EU Water Framework Directive (2000), Circular Economy Strategy (2015) and Green New Deal (2019), the umbrella concepts of Nature-based Solutions (NBS) and Green Infrastructures (GI) are becoming popular among scientific and professional experts. NBS and GI are measures that are deeply involved in the circular economy and have the capacity to conserve, restore or enhance natural or seminatural features (forests, wetlands, grasslands and agricultural lands) and processes for climate change mitigation, biodiversity, water quality, flood mitigation, coastal resilience, microclimate regulation and air quality (EC, 2020).

GI and NbS are applied in sustainable stormwater management in an attempt to integrate stormwater flows into the natural cycle of water (Cousins, 2018; Jones and Macdonald, 2006), thus promoting circularity in water systems (Nika et al., 2020). New drainage solutions are known by different names depending on geographical context: Water sensitive urban design in Australia, low impact urban development in New Zealand, low impact development in the United States of America, decentralized stormwater management in Germany, and sustainable urban drainage systems in the United Kingdom (Brown et al., 2013; Hoyer, et al., 2011). In this article the term Sustainable Urban Drainage Systems (SUDS) will be used to refer to these types of infrastructures. SUDS are said to provide integral solutions that bridge human-managed to nature-managed water systems, guided by circular economy principles (Nika et al., 2020). SUDS, in which stormwater is incorporated in the urban water cycle as a resource rather than a hazard, may take different forms, such as water retention ponds, green roofs, pervious pavements, infiltration basins, etc. (Andrés-Doménech et al.,

2021; Carlson et al., 2015; Perales-Momparler, 2015; Woods Ballard et al., 2015; Zhou, 2014).

Infrastructural changes such as those occurring in urban drainage have been theorized mainly through sustainability transitions studies, and play a significant role in the arena of the technical management of SUDS (Gimenez-Maranges et al., 2020a, 2020b). However, these studies present several limitations in terms of geographical, historical and political aspects, which underplay the role of uneven development and unequal power relations in the process. This paper aims to fill this gap by demonstrating how critical urban geography and Urban Political Ecology (UPE) can provide analytical tools to fully incorporate the social dimension in SUDS, in order to achieve a more nuanced and precise analysis of sustainable stormwater transitions in the urban arena.

The methodology used in this paper is based on the systematization of the literature on sustainable drainage transitions and urban water cycles, starting from key readings that define this literature. While several keywords have been used for narrowing the field mainly to geography and environmental studies, the specificity of the research – as it contemplates the very differentiated theories of UPE and STT – requires one to look at a very broad and diverse bibliography which does not fit easily into standard keywords, and which has evolved significantly in recent years. Recent publications have been especially considered, in order to obtain the most up-to-date snapshot of this subject of enquiry.

References used were identified through different online data bases such as *Elsevier SCOPUS*, *Google Scholar* and *Researchgate*, as well as academic and institutional repositories, and guided by key articles and reviews. The study also relies on grey literature, following the methodological approach of snowball sampling, as key readings unveil and expand references on STT and UPE in the water field. The literature examined is exhaustive. Hence, this article limits its scope to those papers that are interesting for the topic from a critical point of view, aiming to identify common ground as well as the limitations of both frameworks.

This article is structured in five parts. The next section introduces the approach of sustainability transitions as one possible solution to the persistent problems associated with unsustainable development (Happaerts, 2016). Transition theory helps us to understand the emergence of SUDS as socio-technical systems, under the logic of long-term, multi-dimensional, fundamental transformation processes whereby drainage infrastructures change towards more sustainable modes (Markard et al., 2012). Section 3 introduces the main concepts provided by UPE, especially regarding the role of social processes of power and control over urban drainage. Next, Section 4 presents the conversation between UPE and STT as a new research agenda that identifies why and how drainage transitions are taking place in specific contexts, considering aspects of sustainability, social equity, justice and democracy in transforming stormwater management processes into more just and environmentally sustainable practices. Last, Section 5 presents the conclusions of the paper.

2. Analyzing stormwater transitions through the lens of Sustainability Transitions Theory (STT)

The transition towards a water sensitive city can be theoretically approached from the multi-level perspective as a basic component of sustainability transitions studies. The multi-level perspective looks into long-term historical transitions from an evolutive angle and through the relationships of three different levels: niches, regimes and landscapes, corresponding to micro, meso and macro scales respectively (Geels, 2004).

In stormwater sustainable transitions, most urban experimentation has taken place in niches (micro scale) as loci for radical innovation (Geels, 2004; Khmara and Kronenberg, 2020), while the transition from niches to regimes proceeds more slowly, as it is aligned with broader sustainability objectives (Chini et al., 2017). Regimes are more stable levels, in which conventions, rules and norms are the dominant structures, cultures and practices guiding everyday life decisions of a specific society (Geels, 2004; Khmara and Kronenberg, 2020). Finally, landscapes, more difficult to change, are understood as the long-term, external developments that influence niches and regimes (Geels, 2004; Khmara and Kronenberg, 2020). Landscapes add pressures on the regime level and create opportunities for niches to evolve and contribute to changes in socio-technical regimes (Markard et al., 2012). The paradigm shift in urban drainage appears in all these three levels, by requiring the regulation of natural water processes with new infrastructures, different models of governance and the management of social behaviours with social rules such as policies and guidelines aligned to sustainability objectives (Franco-Torres et al., 2020).

2.1. *SUDS as socio-technical and multi-functional systems*

The study of stormwater infrastructure through the lens of sustainability transition acquires greater depth by merging technical, social and environmental dimensions. STT has adopted the concept of the socio-technical system to refer to different topics that may be experiencing transitions towards sustainability, such as food, transport, energy, health, education and water (Franco-Torres et al., 2020). These systems comprise not only networks of stakeholders and institutions but also physical infrastructures and knowledge (Geels, 2004; Markard et al., 2012), guiding humans towards finding a balance with their natural environment “based on principles of democracy, equity and justice” (Loorbach, 2007: 13). Management in this respect includes how resources are understood, planned, implemented, monitored and evaluated (Franco-Torres et al., 2020). In stormwater sustainable transitions, water is no longer a subject of hydrology, engineering and economic studies alone. Rather, it transcends traditional spheres of knowledge when approached from both technical and environmental perspectives at the same time, strengthening values such as sustainability, and changing social identities and behaviours (Franco-Torres et al., 2020).

Water infrastructures, which mediate relationships between society and H₂O (as the material dimension of water) (Franco-Torres et al., 2020; Linton and Budds, 2014) are increasingly adopting more sustainable and decentralized configurations (Monstadt, 2019). Along these lines, SUDS aim to achieve a balance between water quantity, water quality, amenity and biodiversity (Faram et al., 2010; Saurí and Palau-Rof, 2017; Zhou, 2014), creating multi-functional systems that, among other benefits, may absorb the effects of climate change through adaptation and mitigation, with the final objective of reducing urban run-off and flooding (Woods-Ballard et al., 2007; Gimenez-Maranges et al., 2020b). By (re)producing new socio-natures, SUDS can contribute to the integration and restoration of local ecosystems, as well as provide ecosystem services around water supply, flood protection, biodiversity, climatic regulation, recreation, aesthetic inspiration, opportunities for social interaction, stress reduction, environmental education and, above all, contributing to healthier and more liveable cities (Perales-Momparler, 2015).

Multifunctionality in SUDS implies positive impacts in natural, urban and economic arenas (Fratini et al., 2012; Lähde et al., 2019; Sañudo-Fontaneda and Robina-Ramírez, 2019; Zhou, 2013). While urban design based on these systems strengthens water-sensitive behaviours, it can also foster inter-generational equity and urban resilience (especially flood resilience) to climate change (Brown et al., 2009; Charlesworth, 2010; McClymont et al., 2020). Here, resilience is embodied in SUDS to the extent that these infrastructures capture stormwater as close as possible to its source, and preserve and recreate natural landscapes, while increasing pervious surfaces and turning stormwater into a resource (Capodaglio et al., 2016; Wong and Brown, 2009). This is considered of particular importance due to the increase of intensity and frequency in climate related hazards. Building resilient water communities will have a long-term effect on sustainable development (Capodaglio et al., 2016; Perales-Momparler, 2015).

Another notorious characteristic of these infrastructures is that they work as independent systems and do not require a central regime to operate (Dierkes et al., 2015), therefore reducing the dependence on large and expensive piped drainage systems (Carlson et al., 2015; Zhou et al., 2013). SUDS stand in opposition to the existing infrastructures, in which a central system concentrates resources under a top-down governance structure (Faram et al., 2010; Zhou et al., 2014), and can be developed at a variety of scales. Normally SUDS are implemented at the scale of neighbourhood or even lower scales (i.e., green roofs or vertical gardens).

To sum up, SUDS are infrastructures that not only have the practical objective of reducing floods, but also open new horizons as to how stormwater is captured, reused and perceived by society in bringing social benefits such as physical and mental health, recreation, beautification of open spaces, sense of community and social integration, equality, justice and cultural values (Franco-Torres et al., 2020).

2.2. The impact of SUDS on the reconfiguration of stormwater governance

Sustainability transitions research has emphasized the importance of shifts in social awareness and of understanding new ways of water governance in order to mainstream new system norms (Bos and Brown, 2012; Brown and Farrelly, 2009; Dhakal and Chevalier, 2017) over technical knowhow (Goulden et al., 2018). Governance here is understood as the structures and practices that allow stakeholders to achieve common goals (Franco-Torres et al., 2020).

The governance model of SUDS is a hybrid system based on existing schemes but at the same time responding to some of the flaws of these schemes. In particular, hierarchical governance models have been trapped by their highly vertical structure; market-oriented models have failed to fulfil social and environmental needs, leading to jurisdictional and institutional fragmentation (Brown, 2005); and networked structures have lacked accountability (van de Meene et al., 2011). Nevertheless, SUDS schemes attempt to take the administrative framework, political leadership and authority from the hierarchical approach; the flexibility of implementation that allows interdisciplinarity and collaboration, from the network scheme; and the efficiency in resource use and incentives for industry competition from the market view (van de Meene et al., 2011).

Due to the distributed structure of SUDS, governance and management responsibilities are more horizontally arranged compared to top-down traditional stormwater structures found at national and local levels (Carlson et al., 2015; Franco-Torres et al., 2020; Gimenez-Maranges et al., 2020b). SUDS can be applied at different scales, such as at neighbourhood scale (Sañudo-Fontaneda and Robina-Ramírez, 2019) by local actors (Charlesworth, et al., 2016; Dahlenburg et al., 2009). Moreover, by promoting diversity and new learning approaches (Franco-Torres et al., 2020; Goulden et al., 2018), SUDS embrace the participation of many stakeholders (Brown, 2005; Perales-Momparler, 2015; Porse, 2013) including government, service companies, water users, neighbourhood associations, academia, NGOs, research institutions, the media, and investors (Nóblega-Carriquiry et al., 2020; Perales-Momparler and Andrés-Doménech, 2016; Salomaa and Juhola, 2020). Some authors have defined this amalgam as ‘green self-governance’, with citizens, business and NGOs gaining autonomy and creating more bottom-up initiatives, while the State plays a facilitating role, contributing to the protection and management of green spaces and to the enhancement of social values (Mattijssen et al., 2017).

However, socio-institutional aspects in terms of both management (coherence between national, regional and local policies and regulations) and governance (distribution of responsibilities) challenge SUDS more than technical issues, and have slowed their implementation in different geographies (Brown and Farrelly, 2009; Jefferies and Duffy, 2015). There exists a reluctance to change old sewage practices (Brown and Farrelly, 2009; Gimenez-Maranges et al., 2020b; Matthews et al., 2015; Perales-Momparler, 2015), mainly from

the engineering and planning sector (O'Donnell et al., 2019), as well as a lack of confidence that new stakeholders (such as different experts and communities) will accept and support SUDS (Brown et al., 2009; Thorne et al., 2015), since it is not clear who is accountable in security and maintenance matters (Nóbrega-Carriquiry et al., 2020). In addition, the openness by which the new systems are defined may lead to numerous interpretations and endless negotiations (Cettner et al., 2014; Matthews et al., 2015) that may be in conflict with each other and can derive from hidden agendas. Lack of strategies to overcome such barriers abound (Brown and Farrelly, 2009), and flexibility is needed in order to come closer to the 'water-sensitive city' (Brown et al., 2009).

2.3. Sustainability transitions and SUDS: elucidating some research gaps

In the light of what has been presented in the previous section, STT constitutes an interesting lens to examine how transitions in stormwater management take place. After years of research and practice, transitions theory has helped us to understand that technologies are socially embedded in specific institutional (Brown and Clarke, 2007), spatial (Coenen et al., 2012; Truffer and Coenen, 2012) and governance contexts (Hodson et al., 2012). Recognizing the value of the more elaborated versions of STT in recent years, the next section attempts to highlight the research gaps that, from a critical geography perspective, may be identified and exposed.

2.3.1. A geographical understanding of sustainability transitions

STT has been criticized since its beginnings for its geographical naivety (Lawhon and Murphy, 2011; Markard et al., 2012) and misconception of the scales at which transitions occur (Coenen and Truffer, 2012; Coenen et al., 2012). Most sustainable transitions of stormwater have been studied in countries of the global North – where new paradigms were already in place – but the approach has rarely been used as an innovative tool in countries of the global South (Furlong, 2014). Even some geographical locations such as Eastern Europe and some Mediterranean regions have little coverage in the literature on SUDS and sustainable water transitions (Gimenez-Maranges et al., 2020a, 2020b). Hence, questions arise as to whether this theory is flexible enough to be applied in other contexts than the global North.

In STT, niches are seen as the principal locus for regime change (Furlong, 2014; Langhelle et al., 2019; Næss and Vogel, 2012) but only a few of them actually become successful, in what Happaerts (2016) calls a 'bottom-up bias'. This means that the phenomena of 'configurations that work' (where transitions emerge in niches and move to regime level and afterwards to landscape level) might not develop (Berkhout et al., 2005). In many cases the transition is top-down and not bottom-up (Gimenez-Maranges et al., 2020a), and might not conform to a unilineal, univalent and unidimensional structure (Berkhout et al., 2005). While in some contexts new and cutting-edge technologies may contribute to sustainable development, in others,

more traditional and already well-known technologies should be applied (Monstadt, 2019). This would be the case, for example, of stormwater harvesting with rain barrels, as used in certain regions (Furlong, 2014).

The multi-level perspective recognizes four general stages (pre-development, take-off, acceleration and stabilization) that theoretically describe the shifts from one socio-technical regime to another. However, transitions can be non-linear and messy, with drawbacks and lock-in periods (García Soler et al., 2018), offering more tensions to explore and involving more complex processes in which different socio-technical systems coexist (Furlong, 2014). Fuenfshilling and Truffer (2014) acknowledge that hard and soft stormwater infrastructures coexist in cities, and are likely do so in the future (see also Saurí and Palau-Rof, 2017).

In sum, there exists a general misconception of where transitions are taking place and at what – if any – geographical scale. While in some contexts, niches as sites of innovation can be the starting point, in others, existing infrastructures may work better, or even the coexistence of both may be seen as the best solution.

2.3.2. Depoliticized readings of transitions: What are the politics of SUDS?

Who benefits from them?

Infrastructures may appear neutral at first (Hodson et al., 2012) but at the moment of becoming functional their embeddedness in socio-political networks comes into focus (Finewood et al., 2019). Building on this argument, some of the questions arising are: “Where (with whom) does power reside in transition processes? How is power exercised in transition processes? Whose voices and narratives remain unheard? Which transitions are legitimate and how can this be assessed?” (Markard et al., 2012: 562). The change of a regime to more sustainable practices may have unforeseen consequences, as has happened with transportation systems that brought negative impacts to housing regimes due to gentrification (Lawhon and Murphy, 2011); or so-called green gentrification reflected in the increasing inequality of housing access that new green spaces produce in low-income neighbourhoods (Anguelovski et al., 2018; Shokry et al., 2020).

Finewood et al. (2019) sustain that the character of transitions is (at least initially) apolitical but goes on to fulfil different societal interests when some actors push harder for where they want the system to go or not, in what becomes a process of political judgement (Happaerts, 2016; Meadowcroft, 2009). STT lacks analysis of negotiation exercises and trade-offs around a common goal (Finewood, et al., 2019) and a deeper understanding of the power relations (and imbalances) that are at play in the design, implementation and governance of such transitions, and which produce winners and losers (Lawhon and Murphy, 2011; Markard et al., 2012). In its early stages, transition theory assigned little space to public participation and adopted a top-down approach (Berkhout et al., 2005; Gimenez-Maranges et al., 2020b; Hodson and Marvin, 2010; Meadowcroft, 2009). Often, the debates on SUDS were configured around professional technological knowledge (Gimenez-Maranges et al.,

2020a), while democratic and participatory processes of sustainability were left aside.

While STT elucidates the importance of policies in enabling transitions, less attention has been paid to the political circumstances that make the adoption of policies happen (or not), or to the way in which those policies are drafted (Meadowcroft, 2011). Furlong (2014) explains that niche experiments are fostered by economic growth and commercial development, in which the 'technical niche' can be reduced to a 'market niche'. Through the examination of policies, it becomes clear that the choice of a specific economic framing-based market dynamic will condition the scope of policy making (Aduet, 2014; Happaerts, 2016).

Even though socio-technical systems such as SUDS are inherently infused by power relations (García Soler et al., 2018; Linton and Budds, 2014), the politics behind those systems have been systematically neglected in STT (Hodson and Marvin, 2010; Markard et al., 2012). Technology has been at the core of transitions through the replacement of technological artifacts as a means to achieve sustainability (Gimenez-Maranges et al., 2020b; Karvonen, 2011; Meadowcroft, 2009; Shove and Walker, 2007), largely ignoring context-specific social and political-economic relations (Lawhon and Murphy, 2011). Similarly, how technology is embedded into society and what unexpected consequences it may bring (who uses it, who creates it and for what purposes) are issues not receiving sufficient attention by STT (Meadowcroft, 2009, 2011).

3. Insights on Sustainable Urban Drainage Systems (SUDS) from an Urban Political Ecology (UPE) perspective

In the light of the gaps in STT discussed above, UPE offers an alternative contribution to a more comprehensive understanding of SUDS. Studies of sustainability transitions have attracted the attention of geographers interested in identifying why (un)sustainable practices are happening at specific places (Chini et al., 2017), since what may appear just or sustainable at one scale may have a different outcome at another level (Heynen, 2013). Urban political ecologists look into sustainability not only as a form of ecological modernization but through a political lens that helps to understand new schemes of governance, citizenship and ways of confronting the problems of daily life (Karvonen, 2011). By examining the urbanization process through a political-ecological lens, the contradictory nature of socio-environmental changes is revealed, unveiling the conflicts that foster such changes (Swyngedouw et al., 2002).

The following subsection details how UPE may shed light on the conceptualization of stormwater as a constitutive part of the urban metabolism, and its relationships with the production of space. Debates on the neo-liberalization of the water cycle, largely developed by UPE, must also be taken into account when thinking about how SUDS are designed, implemented and managed.

3.1. Stormwater, the hydro-social cycle and urban metabolism

In UPE, the notion of urban metabolism is used to illustrate how economic, political and ecological processes shape environmental flows through the city and unevenly impact on different human and non-human actors (Cousins and Newell, 2015; Heynen et al., 2006; McKinnon et al., 2017; Swyngedouw and Heynen, 2003). The overlapping of material (flows) and social processes produce and reproduce urban spaces and socio-natures (Keil and Boudreau, 2006; McKinnon et al., 2017; Swyngedouw and Heynen, 2003). As Heynen et al. (2006) state: “In fact, it is exactly those “natural” metabolisms and transformations that become discursively, politically and economically mobilized and socially appropriated to produce environments that embody and reflect positions of social power” (p. 6). Therefore, the water cycle is determined by contextual political and economic flows, and this is why in sustainable stormwater management it is important to understand why actors in control can validate or dismiss decisions around stormwater (Cousins, 2017b; Finewood et al., 2019).

Water is a central flow in the urban metabolism (Cousins and Newell, 2015; Kaika, 2005; Swyngedouw, 2004) that not only mirrors technical, institutional and individual practices but also power and authority dynamics (Bakker, 2012). In that sense, a very useful concept that UPE water scholars have coined is that of the ‘hydro-social cycle’, whereby ‘water’ is not only seen as an object shaped by socio-economic and political processes, but also as an active agent that shapes social structures and relations. In this sense, Linton and Budds (2014) argue that ‘water’ and ‘society’ are internally related, meaning that water is not external to social relations, but encapsulates and expresses them. Zwartveen et al. (2017) understand that the governance of the hydro-social cycle is about politics, in the sense that whether different stakeholders can exercise influence derives from historical norms and hierarchies related to power. Hence, the way in which stormwater flows over time and space is also determined by institutions and discourses over the management of water.

The concept of urban metabolism is central for analyzing and understanding perspectives within urban sustainability that strive for more efficient and equitable consumption and production patterns in cities (Cousins and Newell, 2015). Delving into the relationships between technology, space, the materiality of H₂O and social structures through the flow of water can reveal tensions in the commodification of space and interactions between humans and technologies (Gandy, 2004).

3.2. Water and the social production of space

One of the pillars of UPE is that nature and society are mutually intertwined and constitutive of the urban space (Bakker, 2012). Urbanization processes are based on socio-spatial relations that produce ecological transformations (Heynen, et al., 2006). Urbanization is not only the product of a specific historical event where socio-environmental processes take place, but also the arena where changes in these processes occur (Swyngedouw et al., 2002). This

can be seen through the incorporation of blue and green infrastructures in stormwater management fostering relationships between natural, social and technical aspects (Karvonen, 2011).

Water encapsulates the intertwining of ‘nature’ and ‘society’ in the production of urban space. This is clearly illustrated by Gandy (2004) when he argues that “water implies a series of connectivities between the body and the city, between social and bio-physical systems, between the evolution of water networks and capital flows, and between the visible and invisible dimensions to urban space” (p. 374). In this way, the flow of water through urban space reveals the relationship between social and technological structures that are part of everyday life, and, at the same time, urban space represents the political and economic drive behind capitalist urbanization, as spatially uneven and as the product of social and cultural transformations (Gandy, 2004).

From another angle, Millington (2016) recognizes that stormwater’s green infrastructures can help us understand broader concerns of citizenship and belonging, since – as visible infrastructures – they are examples of activist practices in cities. The history of infrastructures reveals how a city is envisioned, structured and governed (Moss, 2020), and is vital for explaining the social, economic and geographical transformation of cities and urban forms through the years (Graham and Marvin, 1994). However, in the development of public space, SUDS and other ‘green’ drainage technologies are manifestations of political aspirations (Moss, 2020), and may exclude particular sectors of the population (Anand, 2017; Millington, 2016; Truelove, 2019) by generating a ‘cleansing’ process. As mentioned earlier, the development or renovation of urban neighbourhoods following on from environmental improvements and green spaces has sometimes led towards green gentrification (Anguelovski et al., 2018; Shokry et al., 2020), in which urban reconfiguration just follows (‘green’) business as usual, and reproduces uneven landscapes.

The diffusion of water technologies is closely linked with the development of the public sphere as an identifiable facet of the modern city. However, water infrastructures may also become a fragile dimension of urban space, revealing a number of tensions underlying the political and economic impetus behind capitalist urbanization as a geographically uneven and historically episodic process of social and cultural transformation (Gandy, 2004). The role of water in the social production of space departs from the idea that space is predicated upon a ‘system of relations’, meaning that spatial properties and objects in space cannot be conceived separately (Karvonen, 2011). UPE has helped show how nature is transformed in the city by looking into the social and ecological processes that can produce uneven development, in this case, uneven green spaces (McKinnon et al., 2017), such as with SUDS projects.

3.3. Neoliberalization and the decentralization of water governance

Following the same fate as other natural resources under capitalist urbanization, flows of water have always been linked to flows of capital (Swyngedouw,

2004, 2009). Recently, critical scholars analyzing the effect of neoliberalism on the natural world, and more specifically on water resources, have brought new insights into the ‘marketization’, privatization or commodification of water (Bakker, 2003, 2007; Furlong, 2010; Gandy, 2004), in what others have defined as ‘market environmentalism’ (Acevedo Guerrero, 2020).

Neoliberal views inspired the conceptualization of water as a commodity that needed to be managed efficiently through market mechanisms for both economic and environmental goals (Acevedo Guerrero, 2020; Matthews et al., 2015). Neoliberal approaches also addressed the importance of investing in cost-efficient water infrastructures (Acevedo Guerrero, 2020), reducing waste in the network and promoting public-private partnerships for water infrastructures which today constitute an important part of modern capital markets (Gandy, 2004). Last, neoliberalism in water practices aimed for what some have called ‘governance without government’, where the role of the state shifts from being a provider of services to a regulator, reconfiguring the governance of the resource, including the outsourcing of public functions not only to the private sector through private-sector participation or participation among other processes (see Bakker, 2003), but also to civil society, following decentralization of urban water governance (Zwarteveen et al., 2017). Such processes of decentralization – whereby civil society groups such as neighbourhood associations are granted responsibilities over the management of parts of the hydro-social cycle – draw a blurred line between processes of neoliberalization of water and more progressive reconfigurations of water governance following a commons perspective (Bakker, 2007; Domènech et al., 2011).

UPE scholars have shown the multiple contradictions behind the neoliberalization of urban water governance (Furlong, 2010), especially its poor results in terms of justice and equality (Swyngedouw and Kaika, 2008). While the so-called neoliberalization of the environment may have fostered more sustainable environments for some, at the same time it has caused environmental degradation for many others, and propagated socio-environmental conflicts in many geographies (Acevedo Guerrero, 2020; Obertreis, 2016).

While intuitively SUDS may open up new avenues of citizen engagement and decentralization of resource management, it might be the case that stormwater projects predicated upon the decentralization of water infrastructures are influenced by neo-liberalization principles (Cousins, 2018; Finewood et al., 2019; Newell and Cousins 2015). As UPE has been interested in the politics of urban metabolism, and more specifically of water infrastructures, and has thus shed light on some unexpected impacts of *a priori* transformative initiatives such as SUDS, this perspective would help in closing the gaps identified in transitions theory (Newell and Cousins, 2015; Obertreis, 2016).

3.4. Limitations of UPE on stormwater transitions

While urban political ecology may help resolve some of the limitations of transitions theory in spatial and power terms, and may foreground the broader

political economic space where SUDS are inserted, it is also important to acknowledge some of its limitations.

In UPE, water networks are conceived as socio-ecological systems (Monstadt, 2009), but some of the early work on urban water infrastructures (Gandy, 2004; Kaika, 2005; Swyngedouw, 2006) left behind several aspects of water networks as socio-technical systems. First, there is the issue of the material component of these networks. Industrial political ecology, examining social and political processes by quantifying and dematerializing resource stocks and flows of industrial ecosystems, life cycles and societal metabolisms (Newell and Cousins, 2015), has argued that UPE fails to acknowledge the politics of metabolic circulation in terms of material volumes. In this line of thought, Cousins (2016) speaks of 'volume control' in order to understand how techno-political interventions depend on the flow of resources that are captured, secured and circulate into, within and out of urban systems (Newell and Cousins, 2015). In other words, UPE remains unclear about how the mass, density or volume of urban metabolism shapes socio-material flows, and produces specific socio-ecological outcomes (Cousins, 2016).

Political ecology has also been criticized for its lack of outreach in terms of policy. Walker (2006), for example, asks where the policy in political ecology is, and takes issue with the practical side of UPE, as do many policy makers who remain sceptical of the approach. It has also been pointed out that political ecology shows little interaction with the public sphere or international research programs, remains inward-looking within academic debates, and while it is true that some political ecologists are also immersed in the policy world, they are usually the exception (Walker, 2006).

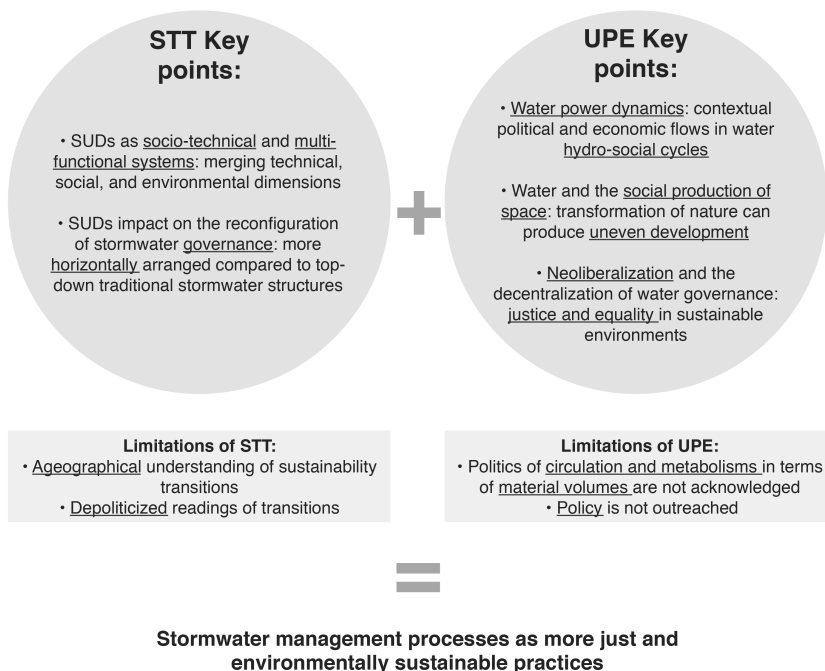
Current efforts in fully understanding the relationship between water and society should be directed towards incorporating various fields that would deepen the nature of sustainable stormwater's socio-technical systems, and the impact they have in shaping cities and their socio-ecological environments. This will provide new angles within fields of research by taking on board critical views that look into the direction of policy and institutional reform for optimizing urban metabolism (Monstadt, 2009).

By recognizing both the avenues and potentialities of STT and UPE to shed light on how stormwater is being reconsidered in cities, from being a risk to being a resource (Figure 1), the next section will attempt to build a dialogue between the two, laying out a shared research agenda around sustainable urban drainage transitions.

4. Sustainable urban drainage transitions: a research agenda

Sustainability transitions studies and UPE share common interests, as they are both conceptual frameworks that investigate the complex and multi-scalar factors that influence development processes and human environmental relations (Lawhon and Murphy, 2011). While they both aim to connect practices to broader scopes in social, economic and political aspects of resource and envi-

Figure 1. Summary of key points that STT and UPE can contribute to ensure more just and sustainable stormwater management practices



Source: own elaboration.

ronmental management (Lawhon and Murphy, 2011; Markard et al., 2012), they rarely interact. In fact, and with some exceptions (Cousins, 2017a-c, 2018; Karvonen, 2011), UPE has disconnected itself from the main discussions on sustainable drainage transitions.

Consequently, I propose a research agenda that attempts to look holistically into more salient new goals for SUDS, such as ecological sustainability, social welfare, and social and environmental justice emerging from the linkages between UPE and STT. The agenda is organized around three interconnected topics: citizen engagement in the development and implementation of SUDS; the unexpected impacts of SUDS on the urban fabric; and the political-economic dimension of SUDS.

4.1. *The role of citizens in the development and implementation of SUDS*

In contrast to traditional drainage systems, SUDS give space to new actors such as architects and landscape planners, as well as citizens associations (Nóblega-Carriquiry et al., 2020; Suleiman et al., 2019). Participation here is seen as essential to bring together skills, resources, knowledge, values, interests and

needs, and to provide transparency, trust, inclusiveness and equity (Franco-Torres et al., 2020). However, levels of participation can vary from being simply informative to performing an active role in decision-making. Participation, on the other hand, can be subsumed into neoliberal adaptive capacity and can contribute to the maintenance of the status quo (Whitehead, 2012). Only when open participation and voluntary association occurs are neoliberal biases exposed: “Climate change is reconfiguring urban politics and it is critical that neoliberal anticipatory elites are not able to exploit the urban future as a basis for controlling the metropolitan present” (Whitehead, 2012: 1364).

Against the backdrop of participation, there still exists institutional resistance to redistributing power to lay citizens or even to local expert knowledge (O’Donnell et al., 2019; Satorras et al., 2020). As an alternative, Satorras et al. (2020) look into the co-production of climate policy, understanding that under the urban resilience context, public participation may bring more democratic, knowledgeable and community-oriented debates. The concept of co-production, similar to collaborative governance or participatory planning, is not new in paying special attention to the production of knowledge and planning decisions, as well as to unveiling power asymmetries and political aspirations without falling into dichotomous traps (Satorras et al., 2020). This enables a more horizontal governance approach to sustainable drainage transitions, aiming even for self-governance, where civil society plays an important role in building, protecting and managing green spaces (Mattijssen et al., 2017).

In sustainability studies, the understanding of governance and of cultural systems and how they are structured is fundamental. Likewise, a robust understanding of ecological systems and how science and knowledge are produced is also critical (Pahl-Wostl et al., 2007). Social learning and co-production approaches can foster the inclusion of diverse actors into urban water policies, emphasizing the role of citizens in the production of knowledge and planning decisions, and consequently improving climate governance and community empowerment (Satorras et al., 2020).

4.2. The (un)expected urban impacts of SUDS

Transitions towards sustainable stormwater management attempt to incorporate stormwater into the water cycle, changing the ways people relate to drainage infrastructures (Larkin, 2013). Understanding the social and material relations bound up in infrastructures such as stormwater systems in terms of how they are used, governed, experienced and spatially understood is important, since in their material dimensions they act as enablers and constrainers of the urban form (Monstadt, 2019). In the past, society rarely interacted with underground drainage systems, but today, sustainable drainage can bridge social and environmental issues by understanding that natural and human systems work best together (Karvonen, 2011) towards a ‘water sensitive city’ (Brown et al., 2009). SUDS are therefore conduits to contemporary urbanism, as the visibility of green infrastructures has proved not only to bring back

political discussions about urban water management, but also to focus attention on the way society relates to the topic of sustainable water (Finewood et al., 2019; Karvonen, 2011; Moss, 2020).

Nevertheless, for whom, where and how water becomes a resource is much more complex, since incorporating new urban green spaces can also influence equity and environmental justice issues through displacement and gentrification (Anguelovski et al., 2018; Wolch et al., 2014). While urban greening brings significant benefits to cities, it may also cause and exacerbate inequitable outcomes (Wolch et al., 2014), including green gentrification. Anguelovski et al. (2018) refer to this as the 'urban greening orthodoxy' or one approach that focuses only on the positive health, ecological, social and cultural benefits of new green infrastructures, and leaves aside other important socio-spatial issues such as racial inequalities, social hierarchies and environmental privileges.

Geographers have developed an interest in exploring the socio-ecological role of parks, how they interact with the city fabric, and the challenge of incorporating 'green' elements and spaces into the city (Cousins and Newell, 2019) as they bring new understandings to how greening affects broader characteristics of the areas where they are implemented, such as household income, housing market trends and racial factors. In this vein, when public officials, planners and scholars refer to greening as a 'public good', they are actually veiling power dynamics and their unfair consequences (Anguelovski et al., 2018). Nevertheless, discourses around this topic are many, and authors such as Millington (2016) support the idea that, while ecological gentrification is an important issue to look into, it should also be acknowledged that for many citizens, open public space is part of a basic need within urban development, and should be pursued by public policies. Geographical analysis is of high importance since it identifies where transitions take place and understands why they develop where they do (Coenen et al., 2012; Hodson and Marvin, 2010; Lawhon and Murphy, 2011; Moss, 2014).

4.3. Political-economic aspect: power dynamics over SUDS

In order to acknowledge the uneven impacts of SUDS, it is important to identify who defines, plans and implements these systems, something that is usually left aside when studying decentralized water infrastructure. It is vital to understand not only who uses or benefits from SUDS, but also who controls these processes of urban metabolism and what type of influence stakeholders may have, since impacts will differ depending on the relationship between the public, private, and third sector spheres.

Power geometries shape access across different groups, and configure discourses around stormwater management, producing waterscapes with particular characteristics (Budds and Sultana, 2013; Loftus, 2009; Swyngedouw, 2009). When circulating through the city, water becomes a coproduced 'fluid medium' that can achieve social, economic, environmental, and/or political goals (Lawhon and Murphy, 2011). While some SUDS projects can be more

permeable and context-sensitive, such as the case of Bon Pastor in Barcelona, where citizen participation occurred at different levels (Nóbrega-Carriquiry et al., 2020), others may be less sensitive to local specificities, or may have a more hierarchical governance system, such as the so-called ‘sponge cities’ in China.

As stormwater is increasingly recognized as a resource, attention is now centred on investing in SUDS and thus providing more economic and ecological insurance for cities (Cousins, 2018). Throughout history, drainage and sanitation benefits, costs and risks have been distributed according to institutional and political-economic structures, often determined by class, religion, gender and ethnicity (Zwarteveen et al., 2017). Rolling out stormwater sustainable transition networks can reveal new and alternative governance transitions, such as community-led initiatives that follow ideas of degrowth (Coenen et al., 2012; Domènech et al., 2011), or decentralized and democratic water managements driven by more progressive and commons-oriented understanding of how water should circulate through the hydro-social cycle (Bakker, 2003). These structures critically consider the social processes and power relations through which knowledges and technologies are created (Lawhon and Murphy, 2011; Linton and Budds, 2014), and the effect these have on human-environmental relations and environmental values – such as humans and stormwater – by bringing insights into more democratic urban environmental politics (Heynen, 2013).

Political-economic issues around stormwater access and control are of extreme importance in discussing sustainable stormwater drainage, since deconstructing power relations reveals why alliances are formed, how decisions are made (Finewood et al., 2019; Lawhon and Murphy, 2011), who has influence on the understanding of SUDS, and how this determines citizen participation. Developing these conceptual languages might help us investigate

Figure 2. Research agenda proposed for sustainable urban drainage transitions. What to look into; why to look into it; and how to look into it

WHAT	WHY	HOW
The role of citizens in the development and implementation of SUDS	<ul style="list-style-type: none"> • New actors emerge such as architects, landscape planners and citizens associations, but levels of participation vary. • Participation can be subsumed into neoliberal adaptive capacity. • As an alternative to redistribute power to lay citizens. • To improve climate governance and community empowerment 	<ul style="list-style-type: none"> • Look into the levels of participation. • Be critical about the maintenance of the status quo. • Acknowledge co-production of climate policy. • Develop a critical understanding of ecological systems and how science and knowledge are produced.
The (un)expected urban impacts of SUDS	<ul style="list-style-type: none"> • In their material dimensions they act as enablers and constrainers of the urban form. • SUDS can also influence equity and environmental justice issues by displacement and gentrification. • It identifies where transitions take place and understands why they develop where they do. 	<ul style="list-style-type: none"> • Understand the social and material relations bound up (how they are used, governed, experienced and spatially understood). • Examine for whom, where and how water becomes a resource. • Develop geographical analysis.
The political-economic aspect: power dynamics over SUDS	<ul style="list-style-type: none"> • Impacts will differ depending on the relationship between the public, private, and society spheres. • Water becomes a coproduced ‘fluid medium’ that offers social, economic, environmental, and/or political goals. • It can reveal new and alternative governance transitions and help to identify inherited identities and social hierarchies. 	<ul style="list-style-type: none"> • Identify who defines, plans and implement SUDS. • Look into how power geometries shape access across different groups and configure discourses. • Unfold stormwater sustainable transition networks and investigate relations among stakeholders.

Source: own elaboration.

relations among stakeholders and to identify inherited identities and social hierarchies (Zwarteveen et al., 2017).

5. Conclusions

This paper has focused on sustainable drainage transitions from risks to resources through the emergence of SUDS. On the one hand, it has reviewed sustainability transitions research as a framework for understanding and analyzing urban drainage beyond the usually dominant technical dimension. It has attempted to show that STT has comprehensively explored the implications of stormwater drainage transition in terms of infrastructures as socio-technical systems, considering their management and governance dimensions.

On the other hand, the review has also argued that STT falls short in addressing current complexities of cities where stormwater transitions are taking place. UPE is introduced as a potential framework offering new perspectives into sustainable drainage transitions, mainly by bringing analysis of spatial, political, economic and social power dynamics into the equation.

Nevertheless, in policy-making terms, incorporating the critical insights developed by UPE in sustainable stormwater transitions will be challenging, since it implies that sustainability, social equity, justice, democracy and quality of life (Loorbach, 2007) must be adequately balanced in urban projects. This will involve broader efforts and a re-evaluation of values and standards of society in terms of cooperation, innovation, awareness and sensitivity to socio-environmental issues towards a more sustainable future (Loorbach, 2007). SUDS can contribute to this objective, since they have a relational component which reflects on how their materiality creates new spaces of social relations, towards the socially sensitive re-naturalization of cities.

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