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Research article

From conventional drainage to sustainable stormwater management: Beyond the technical challenges

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ABSTRACT

Countries and cities are increasingly recognizing the value of adopting Sustainable Stormwater Management (SSWM) goals and measures. SSWM serves multiple hydrological, ecological, social and economic goals and can replace substantial parts of conventional drainage infrastructure. Following international experience in the socio-technical nature of transitions in stormwater management, this research investigates how socio-institutional factors enable the transition from conventional to sustainable stormwater management over time. The research is based on analysing available relevant documents, semi-structured interviews and focus groups, all in a single country case study (Israel). We found significant changes in professional awareness and discourse, some advances in professional standards of work and changes to the regulative system, supporting infiltration practices in particular. We concluded that the three-pillared socio-institutional framework, composed of cultural-cognitive, normative and regulative changes, was insightful for mapping factors supporting transition from conventional drainage to SSWM. Elements within the three pillars can work simultaneously and synergistically to achieve widespread change. At the same time, while SSWM always strives to achieve multiple goals, the order of priority of the various goals may differ from place to place and may change over time. Thus the transition process across the socio-institutional pillars should be renewed if and when the priority of goals changes. The urban and regional planning system can play a crucial role in enhancing the transition process from conventional to sustainable stormwater management. These conclusions may be relevant to other localities and countries that are struggling with such transitions to sustainability.

1. Introduction

In the past few decades there has been growing awareness of the value of stormwater as a resource to be factored into urban development. This has been driven by various trends including rising populations and increased water demand, increased environmental awareness, risk of storm damage exacerbated by climate change, and growth in urban areas and related impervious surfaces. There has been a parallel emergence in many countries of more sustainable paradigms for urban stormwater management including Water-Sensitive Urban Design (WSUD) in Australia, Sustainable Urban Drainage Systems (SUDS) in Britain, and Low-Impact Development (LID) in North America (Fletcher et al., 2015). As opposed to conventional drainage approaches, which treat stormwater as a nuisance to be removed from the urban area as quickly as possible, the sustainable management of stormwater sees it as a multifunctional resource (Mitchell, 2006) with many potential benefits for society and the environment if managed wisely (Barbosa et al., 2012; Fletcher et al., 2015; Hering and Ingold, 2012; Makropoulos et al., 2008; Mitchell, 2006; Roy et al., 2008).

The implementation of Sustainable Stormwater Management involves measures at different scales, from urban and regional planning, where siting of different land uses can be determined according to topographical and hydrological conditions, down to construction of individual installations or best management practices (BMPs) (Carmon and Shamir, 2010). The latter are designed to retain, detain, convey and preserve stormwater flow, to encourage groundwater recharge, provide water for irrigation, reduce topsoil loss, and filter unwanted pollutants and sediments (Barbosa et al., 2012; Roy et al., 2008). Rainwater harvesting can also directly supplement domestic water supply for reuse and provide other

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benefits such as reducing pressure on downstream drainage and sewer systems and reducing the need to transport water (Han and Mun, 2011; Nguyen and Han, 2017).

Sustainable Stormwater Management is closely related to urban planning and landscape design. As Karvonen (2011) notes, "Where conventional stormwater management focuses on the symptoms of large stormwater volumes, source control goes to the root of the problem to address development patterns and impervious cover that create these large volumes of polluted water in the first place" (p.18). Connecting between integrated urban water management and spatial planning has been described as a means of providing a statutory basis for spatial water management, overcoming fragmented water governance (Mitchell, 2005) and shifting the field of water management from a largely technical domain to an issue with broader professional and social considerations (Wiering and Immink, 2006).

In this paper we use the term Sustainable Stormwater Management (hereafter SSWM) to denote an approach that incorporates these changes and departs from reliance on conventional urban drainage. The main elements of these different approaches are summarized in Table 1.

In many parts of the world there is evidence of a gradual transition from conventional to SSWM practice (Chouli et al., 2007; Dhakal and Chevalier, 2016; Ellis and Lundy, 2016; Ferguson et al., 2013; Han and Mun, 2011; Nguyen and Han, 2017) and reasons to increase and accelerate this shift. Yet, existing research has acknowledged that in addition to technical knowhow, widespread change towards SSWM requires social shifts in awareness, professional norms, and forms of governance (Bos and Brown, 2013; Brown and Farrelly, 2009; Carmon and Shamir, 2010; Dhakal and Chevalier, 2016; Sharma et al., 2016; Taylor and Fletcher, 2007; van de Meene et al., 2011). Examples of social changes contributing to SSWM have included the creation of new professional communities (Ferguson et al., 2013), inclusion of more actors and approaches in governance (van de Meene et al., 2011) and new public discourse and terminologies (Morison and Brown, 2011). The changes required for implementing SSWM have therefore been framed as socio-technical (Bos and Brown, 2013; Rogers et al., 2015), in line with approaches described within socio-technical transitions (Geels, 2011) and specifically sustainability transitions studies (Markard et al., 2012). As with the detailed transitions framework presented by Brown et al. (2009), this conceptualization emphasizes that water management includes social and cultural elements that change in tandem with technical developments as new practices take hold. Without social changes, new technologies and practices are unlikely to be widely introduced, as the existing social systems tend to privilege existing technologies. The existence, or absence, of various social parameters are therefore an indication as to whether conditions exist to bring about new approaches to stormwater management in practice (Rogers et al., 2015).

With a view to understanding how the uptake of Sustainable Stormwater Management may be increased, this paper places the transition to SSWM in the context of a broad socio-institutional framework (Ferguson et al., 2013) to consider the complex factors that may increase the adoption of SSWM goals and practices by practitioners. The analysis is carried out in a case study of a single country, the State of Israel. The research derives recommendations on how to encourage further uptake which may be relevant to other countries at various stages of a similar paradigm shift.

The goals of the research presented in this paper were:

(i) to study and understand the socio-institutional context affecting a transition from conventional drainage to Sustainable Stormwater Management (SSWM) in the case study of Israel;
(ii) to draw conclusions and provide recommendations on supporting greater implementation of SSWM for countries interested in sustainable development, including Israel.

2. Materials and methods

2.1. Study area

The case of Israel is of interest given that it has a history of awareness of drought, centralized water management and high capacity for control of water resources (Feitelson, 2005), yet management of stormwater as a resource is still an emerging field, which highlights the complexity of approaches to this water resource. In particular the case study depicts changing and varied approaches to stormwater use within a policy context that prioritizes water management and efficiency.

Awareness of SSWM has grown in Israel since the 1990s, with the development of the field of Water-sensitive Planning (Carmon and Shamir, 1997, 2010). Water-sensitive Planning emphasizes the multiple objectives of stormwater management and the benefits of integrating water considerations into urban and regional planning to achieve these (Carmon and Shamir, 2010). This approach was developed in response to Israel's decreasing natural water replenishment (OECD, 2011; Weinberger et al., 2011) that has been exacerbated by intensive development and increased impervious surface area, particularly in the coastal plain (Goldshleger et al., 2015; Shoshany and Goldshleger, 2002). Shamir and Carmon

Table 1
Characteristics of conventional urban drainage and SSWM – Sustainable Stormwater Management.

	Conventional urban drainage	Sustainable Stormwater Management (SSWM)
Attitude towards stormwater	to be controlled and removed; designed to handle extreme stormwater events	a valued resource for humans and nature; handling all stormwater events; living with water
Goals	avoid flooding; avoid sanitation risks, in cases with combined sewage infrastructure; reduce topsoil erosion	multiple goals: (i) water-related – increasing quantity, improving quality, flood mitigation and adaptation. (ii) ecological – protecting water-based ecosystems, reduced topsoil loss (iii) social – improving urban quality of life by supporting urban nature and water-based urban landscapes, reducing urban heat islands and creating recreational and educational opportunities (iv) economic – reducing infrastructure costs, increasing land value due to blue-green landscapes and attracting tourists
Measures	rapid removal of runoff (in urban areas) by constructed channels	slowed runoff conveyance; detention, retention and infiltration of runoff; biological and mechanical quality treatment; dynamic management of flood plains; integration with conventional drainage as needed
Professional roles and work process	drainage engineers work alone post land-use planning and architectural design	cooperation from initial stages between the various relevant professionals: urban planners, architects, drainage engineers, landscape architects, ecologists.

(1999) concluded that Water-sensitive Planning practices could have prevented a loss of 70 million cubic meters (mcm) of water per year to the coastal aquifer up to 1990, if implemented instead of conventional building practices. More recently, additional drivers for SSWM in Israel have been national stream restoration programs, which are reliant on stormwater quality and quantity, and the high economic costs of perennial flooding experienced in several urban areas. Mirroring findings elsewhere (Ferguson et al., 2013), there is a general consensus among researchers and practitioners that the implementation of SSWM in Israel lags behind available knowledge.

2.2. Theoretical background

One way to study the multi-faceted social factors which can support the transition to SSWM has been summarized by Ferguson et al. (2013) as an "enabling institutional context" (p.7310). Drawing on institutional theory (Scott, 1995) as a means of considering how social choices are shaped by the institutional environment (Hoffman, 1999), this framework considers three elements or 'pillars' which are theorized to shape change in organizations and fields. The first is cultural-cognitive factors, reflecting accepted beliefs and often unquestioned ways of doing things; the second, normative factors such as professional conduct, goals and leadership, which denote a moral and professional obligation; and the third, regulative factors based on regulatory and coercive mechanisms. Palthe (2014) differentiates between the categories by describing how they cause actors to *want* to change based on values and beliefs (cultural-cognitive); to feel they *ought* to change because of moral obligation or duty (normative); and to make them *have* to change because of legal obligation and coercion (regulative). Research in the field of urban planning specifically has also used Scott's (1995) three pillars to analyze changes within urban planning and policy (Granath, 2016). The urban planning field, as a professionally integrative field, includes elements from each pillar, such as regulative laws, statutory plans and policy documents; professional norms; and cultural-cognitive approaches such as discourse (ibid.).

While the three institutional categories or pillars are often presented and analyzed as independent entities within institutional theory, they can also be shown to be interrelated, with developments in one pillar leading to developments in another (Hoffman, 1999). Granath (2016) presents change processes as a continuum, from regulatory requirements that lead to normative (moralistic or duty-bound) processes and eventually to cultural-cognitive change, "taken-for-granted and thus unconsciously sustained" (p.84). This interrelation between the elements highlights the systemic nature of a paradigm shift, incorporating new attitudes, norms and regulations. This is relevant to the socio-technical shift needed for SSWM and any major shift towards sustainable development, and thus makes the institutional framework a useful tool to analyze the myriad factors within this change process.

2.3. Methods

We use a descriptive, country-based case study approach (Yin, 2009) to examine the socio-institutional factors affecting stormwater management in Israel. The data collection for the case study was based on multiple sources of evidence, used to understand the case, provide contextual detail, and ultimately describe the case, as suggested by Yin (2009).

We collected and analyzed relevant laws, regulations, national and local masterplans, policy documents produced by different agencies, research papers and professional guidance documents. On the basis of this initial mapping of relevant organizations and policy tools we identified potential interviewees. A dozen semi-structured interviews, including two by phone, were conducted with leading Israeli professionals involved in stormwater management in various capacities. At the national level the represented organizations included the Water Authority (part of the Ministry of National Infrastructure), the Ministry of Agriculture and Rural Development (responsible for drainage) and the Ministry of Construction and Housing. Interviews were also conducted with a Drainage Authority director (regional level) and municipalities. Interviewees represented a range of professions including hydrology, urban planning, landscape architecture and engineering. Additional interviewees were independent landscape architecture and engineering professionals who are active in sustainable stormwater management. The national-level organizations approached are responsible for national policies and programs; regional and municipal bodies are responsible for city-level and regional projects; individual professionals operated at the individual lot, neighbourhood and city-wide levels.

Interviewees were identified and selected using a snowball effect based on recommendations from other interviewees, with the aim of reaching knowledgeable individuals in each of the main agencies and professional areas involved in sustainable stormwater management. The interviews were conducted over the course of nine months from March to December 2016. Interviewees were asked about changes in professional approaches to stormwater management; the existence of regulation, policies and other guidelines affecting their work; their perspective on barriers to implementation of these tools; examples of BMPs - Best Management Practices being used; and suggestions for further implementation.

We also conducted three focus groups on urban stormwater management that focused on municipal-level experience and implementation in practice, as part of a workshop attended by local authority officials and planning and engineering consultants in March 2017. Each focus group numbered 8–10 participants including multiple representatives of 9 medium to large cities and engineering and planning consultants experienced in working with local authorities. We conducted a short survey on the institutional arrangements and stormwater management policy in different municipalities followed by guided discussions with the participants. Discussions were recorded and written protocols were prepared.

Following the three institutional 'pillars' of transition described in the theoretical background above, we organized and analyzed the findings according to three categories and sub-categories, outlined in Table 2 below. We arrived at a list of categories based on the institutional conditions we expected would support SSWM, according to existing literature (e.g. language and governance) as well as topics identified as central to the development of stormwater management in the Israeli literature (e.g. professional collaboration and planning policy) (Laster et al., 2009; Shamir and Carmon, 2007; Water Authority, State of Israel, 2012).

Given the emphasis in Israel on Water-sensitive Planning as an approach to SSWM, we looked in particular at the place of the urban and regional planning system in these changes and its impact on socio-institutional elements that enable or restrict a shift towards SSWM.

Data on regulative conditions such as laws and plans arose mostly from document analysis, supplemented by interviews. Data on normative changes were taken from professional guidance documents and also interviews and focus groups. Data on cultural-cognitive changes were drawn from interviews in relation to different stormwater management goals as well as from the approaches reflected in different research and policy documents. Notes and transcripts from individual interviews and focus groups

Table 2
Categories of socio-institutional framework.

Cultural-cognitive	Research and knowledge-generation
	Attitudes to stormwater as a resource; associated policy goals
	Awareness of sustainability and urban sustainability
Normative	Professional guidelines and guides
	Professional training in SSWM
	Professional norms presented in practice
Regulative	Relevant laws
	National masterplans and statutory outline plans
	Legal responsibility and governing bodies for water management at national and municipal levels

were manually coded to extract data on the different categories and these results were compiled into a narrative description according to the categories and sub-categories. We analyzed the data collected via interview and focus groups through thematic analysis (Braun and Clarke, 2006; Joffe and Yardley, 2004; Vaismoradi et al., 2013) in relation to cultural-cognitive and normative changes. In order to organize changes over time, the findings were separated into decades, starting from early research into Water-Sensitive Planning in the early 1990s to the present day.

The findings are presented in table form in the next section, followed by a more detailed narrative by category.

3. Results and discussion: the socio-institutional context for implementing SSWM in Israel

Many change factors were found in relation to stormwater management in Israel during the time period studied, as summarized in Table 3. Cultural-cognitive changes in both research and environmental awareness have been followed by changes in professional standards and norms and in tools used to govern and regulate stormwater management. Different emphases in stormwater management are also evident, with an initial focus on groundwater supply concerns and infiltration practices followed by later connections made between stormwater and broader ecological and landscape values. Regulation via the planning sphere advanced considerably between 2000 and 2010 while national legislation and governance arrangements on drainage and stormwater management are still in the process of being updated.

These changes are discussed in more detail in the following sections. For each group of factors, we present dominant changes found to be influencing SSWM in the country, and an assessment of progress and current limits. As is sometimes the case in qualitative research, this main section of the paper presents both findings and discussion.

3.1. Cultural-cognitive changes

3.1.1. Awareness and knowledge surrounding stormwater and sustainability

The challenge of drought in Israel and longstanding awareness of scarcity (Menahem, 1998) has supported the investigation of alternative sources of water. Starting in the 1990s, research began to be published in the Technion – Israel Institute of Technology and the Erosion Research Station of the Ministry of Agriculture that proposed goals for Water-sensitive Planning and policy recommendations in the context of Israel (Carmon et al., 1997; Carmon and Shamir, 1997; Kronaveter et al., 2001; Meiron-Pistiner et al., 1996). Later studies highlighted the relationship between development practices and stormwater quantity and quality in Israel (Asaf et al., 2004; Goldshleger et al., 2015). A special government investigative committee on management of the water sector gave clear recommendations in 2010 on exploitation of alternative sources, including building and planning practices to encourage infiltration of runoff.

In parallel there has been growing awareness of environmental degradation and sustainability issues in Israel over the past two to three decades. This has been expressed among other things in significant government decisions, such as the Strategic Plan for Sustainable Development in 2003, and rapid growth in the size and diversity of environmental non-governmental organizations (Tal et al., 2013). In the past decade in particular the topic of sustainability in the built environment has received greater attention. New government-backed voluntary 'green building' and 'green neighbourhood' standards establish environmental expectations for new developments, and include criteria for runoff conservation. A number of large construction companies have introduced

Table 3
Summary of socio-institutional changes in stormwater management in Israel over time and by socio-institutional 'pillar'.

	1990s and before	2000s	Since 2010
Cultural-cognitive	Strong public awareness of water scarcity since early days of the State	Drought periods (1999–2001, 2004–2011) strengthen interest in new water sources including, among other, stormwater conservation	Discourse of multi-goal stormwater management reaches wider circles of various professions as well as national and local decision makers; concentrates on infiltration into the ground
	Growing awareness of sustainable development including government decisions	Rising environmental awareness in Israel among decision makers and general public expressed for example by over 100 NGOs under "Life and Environment" umbrella organization	Research emphasizes ecological and environmental benefits of sustainable stormwater management and the central role of planning and landscape architecture in implementing SSWM
	Academic research into new modes of stormwater conservation emphasizing water quantity and infiltration to groundwater	Academic research emphasizes environmental, economic and social goals of stormwater management in addition to hydrological goals	Large-scale desalination in Israel reduces policy and professional imperative for investment in alternative freshwater sources
Normative		Landscape architects and a few drainage engineers adopt Sustainable Stormwater Management discourse and several practices, mainly via professional forums.	Landscape architects carry out projects on neighbourhood and urban scales integrating a range of practices of stormwater management
		Guidelines on water-sensitive planning and stormwater management issued by two of the six regional planning committees.	Drainage engineers prepare drainage appendices for large construction plans (as required by the National Outline Plan), beginning to integrate urban planning with stormwater management, but note the lack of professional best practice guidelines
		Ministry of Construction & Housing with other ministries published guide for practitioners on "runoff-conserving planning and construction" (2004) with emphasis on infiltration.	
Regulative		Water Corporations Law (2001) regulated and privatized city water and sewage management, making it more efficient, while stormwater remained a part of municipal responsibility.	National Masterplan for the Water Sector (2010) adopts some basic principles of SSWM
		National Outline Plans – the highest level of the planning system – adopted (2006&7): 34/B/3 on streams and drainage; 34/B/4 on water retention and infiltration for groundwater enrichment and protection.	Proposed revision to Drainage Law submitted to Parliament (2013); still under discussion; recognizes stormwater as a resource and its multiple goals

sustainable construction as a central component of their brand. Major cities have also become more active in establishing environmental policy commitments (Goulden et al., 2017) and integrating nature into the urban domain. These changes provide a supportive context for raising awareness of stormwater management as a component of urban sustainability, rather than solely a drainage issue, with a corresponding emphasis on integrated environmental, economic and social benefits. Yet the focus groups demonstrated that awareness of sustainability in general, and SSWM in particular, still varies between cities and different social groups.

Despite awareness of urban sustainability in general, there is low awareness of the potential role of urban stormwater BMPs in this. In terms of public opinion, reports from municipal representatives suggested that the public is wary of projects that involve retention of water, due to potential risks from standing water, such as mosquitoes and drowning. Surface water is still seen as a hazard. As Morison and Brown (2011) discuss, local-level policy commitment to stormwater management may be a phenomenon of "policies without publics" (p.84), where there is no direct interest in supporting stormwater BMPs because they are not seen as preventing harm to the city and its residents.

3.1.2. Changes in stormwater management definition and priorities

Studies of existing stormwater management projects as well as accounts from local authority officials show that professional practices mostly focus on infiltration at the micro (plot-scale) and meso (neighbourhood) level. This emphasis on groundwater replenishment reflects the research done in the 1990s in response to concerns over groundwater shortages (e.g. Katz et al., 2001). The recommendations and policies developed as a result have emphasized infiltration, including a permeable surfaces requirement within a national outline plan on water management (NOP 34/B, see section 3.3.2 below). Yet in more recent years, as interviews with Water Authority officials and researchers highlighted, the pollution of many parts of the coastal aquifer has raised doubts about the benefits and related costs of infiltrating surface water to the aquifer. Meanwhile we found that other stakeholders, particularly private professionals and some municipal representatives, emphasized other benefits of SSWM such as green infrastructure and flood mitigation as key drivers of their work.

There is a growing awareness and discourse, backed by academic research (Shamir and Carmon, 2007), in support of stormwater management to achieve broad economic, ecological, social and hydrological goals – what Mitchell (2006) describes as a "multifunctional" tool. Landscape-based stormwater projects are being developed in several cities and are driven by the landscape and ecological value derived from recreational parks with stormwater-based pools and flowing water and by increased flood resilience. According to one municipal landscape architect, the National Outline Plan requirement on permeable surface area (see section 3.3.2) was not considered relevant to their local environment or geological conditions, but they used the requirement, in the absence of any other, to ensure greater use of vegetation in local planning proposals. This suggests that there is an interest in regulation for SSWM that recognizes the multiple values of stormwater management and the different benefits for different municipalities, according to local characteristics of each place.

Another factor that has an impact on the adoption of SSWM is the recent and massive introduction of desalination into Israel. Following years of drought, a masterplan was created for rapid development of desalination infrastructure along Israel's coast (Feitelson and Rosenthal, 2012; Water Authority, n.d.). A succession of ten government decisions from 1999 to 2008 approved the establishment of desalination plants, rising from a single tender for 50 million cubic meters (mcm) capacity in 2000, to a decision in 2008 to produce 750 mcm by the year 2020. Desalinated water now accounts for approximately 50% of freshwater supply in the country (Water Authority, n.d.). The rapid development of desalinated water sources has reduced concerns over water supply that previously dominated national water policy. As a result there is less of a policy imperative to invest in alternative water sources (Teschner et al., 2013). As stated by a Water Authority official interviewed, decisions on water management are now routinely compared to the cost of desalination as a benchmark. This contrasts greatly with an era when groundwater quantity concerns were paramount, which drove early research into Water-sensitive Planning (Carmon and Shamir, 1997, 2010). As a result, while conserving natural water resources including aquifers is still a strategic goal, the promotion of SSWM will also need to rely on the acceptance of social and environmental goals that are not related to water supply, such as greening the urban area, improving urban microclimate, nurturing biodiversity and more.

Hence, while a cultural-cognitive shift towards SSWM has started taking root, the goals associated with SSWM are still shifting and expanding. Different professional groups who are expected to work together may not necessarily understand new water management paradigms in the same terms, as found by Wiering and Immink (2006) in relation to new discourses on 'accommodating water' in Dutch spatial planning. In our case, landscape architects were often given as examples of those driving stormwater management-based projects. This trend may lead to a greater number of landscape-based BMPs, but not to systemic changes in the planning process unless drainage engineers are also involved.

3.2. Normative changes

3.2.1. Professional standards

Formal changes supporting new professional norms can be seen from 2000 onwards, with guidelines adopted within the planning system. The Regional Planning Committee of the country's Central Region (one of six regions in the country) developed and adopted guidelines on water-sensitive planning in 2000, having witnessed conflicts between the Planning and Building Law and the Drainage Law (O. Cafri, pers. comm., 22.3.17). The Tel Aviv Regional Planning Committee also adopted such guidelines in 2004. Recommendations from the Ministry of Environmental Protection and from an inter-ministerial committee for "stormwater-conserving construction", established in the year 2000, led to the development of stormwater guidelines in other regional and local planning committees, with a particular focus on encouraging infiltration to replenish the coastal aquifer (Shamir and Carmon, 2007). In 2004 the Ministry of Construction and Housing together with the Ministries of Environmental Protection and of Agriculture published a professional guide to runoff-conserving construction, although according to an official involved at the time, little budgetary emphasis was placed on its dissemination. Subsequent to these guidelines, the adoption of the new National Outline Plans integrated SSWM more formally into the planning process.

3.2.2. Professional conduct

A change in the professional approach taken towards SSWM is seen within certain circles. Of particular note is a workshop for drainage authority employees which was established following the redrawing of drainage authority boundaries in 1996, to provide training on the responsibilities conveyed by drainage basin management. It emphasized the connection between stream restoration programs and stormwater management. From around the year 2000, after exposure to lectures and written material as part of the workshop program, there was a gradual change in terminology

among participants from “drainage” to “stormwater management”, and incorporation of sustainability terminology. Participation in the workshop's meetings has since extended to professionals and organizations beyond the drainage authorities, creating a broad informal professional network and new discourse which is apparent from interviews with individuals involved and written summaries from the workshop itself.

Accounts of projects that have implemented SSWM, collected via interviews with landscape architects and engineers working in different sectors, emphasized the role of individual professionals, such as engineers, landscape architects or municipal officials, who subscribed to a more sustainable approach to stormwater management. Such professionals recalled their insistence for stormwater management to be integrated into design and their unwillingness to take part in projects where drainage solutions would simply be calculated and added post-design. Awareness of the need for professional integration was said to be rising but was not considered to be a common approach. One landscape architect noted that the definition of landscape architecture isn't stabilized and is changing, increasingly being related to infrastructure as well as to the landscape.

A notable example of professional integration in practice is a stormwater management plan prepared in 2013 as an appendix to the Tel Aviv-Jaffa drainage masterplan (Tel Aviv-Yafo Municipality and Studio Urbanof, 2013), proposing landscape-based alternatives to additional drainage infrastructure. Another notable example is the development of the Gazelle Valley Park in Jerusalem, where local community participation combined with landscape redevelopment led to the inclusion of stormwater management as a central component of the park. A few websites of landscape architects and drainage professionals offer consultations based on SSWM, indicating its entry into more general professional conduct, yet mostly with an emphasis on infiltration. Finally, an emphasis on SSWM is hardly found in the academic educational programs in planning and engineering and the formal integration of SSWM into professional practice is still limited. It was noted in interviews that more professionals working in the field in Israel are needed and further academic professional training was highlighted as a recommendation for further implementation. Professional expertise among those evaluating plans in planning committees is seen as too limited and insufficient to critically evaluate the reports of consultants preparing expert opinions for planning applications. These consultants were therefore identified as a relevant targets for awareness-raising and training with regard to SSWM.

3.3. Regulative changes

3.3.1. The Drainage and Flood Prevention Law

The key regulative tool relating to stormwater management in Israel is the Drainage and Flood Protection Law dating from 1957. It presents a central barrier to change in stormwater management as it defines ‘drainage’ as the practice of managing surface water “that harms or may harm agriculture, public health, development of the country and the functioning of necessary services”. It also considers streams primarily as drainage conduits, with no consideration of the ecological and landscape value of the quantity and quality of water flow. A proposed amendment to the 1957 law contains major revisions, including a change in terminology from ‘drainage’ to ‘stormwater management’, recognition of the value of stormwater as a resource, awareness of the potential benefits of improved management of this resource, and steps to clarify the division of responsibility and funding between specific relevant authorities. However, the proposed amendment has been on the table of a Knesset (Israeli Parliament) committee since 2013, stalled by disagreements over the responsibilities of the Water Authority and the Ministry of Agriculture.

3.3.2. National Outline Plans and masterplans

A dominant statutory change supporting the basic idea of SSWM, principally the notion that stormwater is a resource and not only a hazard, was the addition in 2006–7 of two new National Outline Plans (NOPs), one related to stormwater and the other to rivers. The NOPs form the upper tier of Israel's highly centralized planning hierarchy, established by the 1965 Planning and Building Law, with nested plans and planning authorities at national, regional and local levels (Brachya, 1993). The Outline Plan on Streams and Drainage (NOP 34/B/3) guides planning in the proximity of streams to maintain them as viable drainage routes alongside nurturing their landscape and ecological functions. The second Outline Plan (NOP 34/B/4) sets out to create a planning framework for enriching and protecting groundwater, while reducing flood damage, via water retention and infiltration to aid the conservation and use of surface runoff. Its specific requirements focus mainly on infiltration of stormwater into the ground in order to enrich groundwater, at the individual plot level (requiring 15% permeable surface area on every plot) and at larger drainage installations outside the city. The plan also requires large development plans to include a drainage appendix which must be approved by the relevant regional drainage authority.

NOPs 34B/3 and 34B/4 were described by practitioners and public officials interviewed as a significant change, even a “revolution”, in policy that is gradually changing the attitude towards runoff and the practice of stormwater management. They create a formal connection between the Planning and Building Law and stormwater management. Respondents noted positively the steadily increasing numbers of plans sent to drainage authorities for approval as stipulated by the Outline Plan. However, existing research has shown that the implementation of NOP 34B/4 lags behind expectations because of a lack of enforcement (Geldman, 2012) and a lack of professional expertise in examining and implementing plans governed by the national outline plan (Laster et al., 2009). Regional planning committees may also opt to exempt plans from requiring the approval of drainage authorities.

A further regulative change is the Israel Masterplan for the national water sector prepared by the Water Authority in the Ministry of National Infrastructure (Water Authority, 2012), with one of its chapters devoted to stormwater management. It recommends that runoff be seen as a resource to be managed for a variety of goals, from flood protection and replenishment of groundwater to streams and ecosystem conservation. It draws on academic-professional study (Carmon and Shamir, 2011) and calls for a structural change in the national management of stormwater management, coordination of urban and basin-level runoff management via watershed-level master plans, multi-disciplinary work from the initial stage of each development plan, and alternative professional training. Yet, unlike the NOPs mentioned above, this masterplan is not a statutory plan and it does not have coercive power. It is categorized here as a regulative tool, but its main impacts are on awareness of the paradigm change (cultural-cognitive component) and on pushing towards changes in professional conduct and professional standards (normative component).

3.3.3. Governmental and municipal responsibility for water

The Israel Water Law determines that all the water in the country, above as well as below ground, is a public resource controlled by the state. The water sector in the country has been highly centralized, managed by the Water Authority (formerly, the Water Commissioner). This centralized control has enabled integrated management of water resources (Rubin et al., 2006), including construction of a national water carrier for distribution to

arid areas in the 1960s and county-wide desalination infrastructure in the early 2000s (Tal, 2006). Yet public ownership of all water in the country is a barrier for local entities wishing to infiltrate or extract water for stormwater management who need special permits to do so (Shamir and Carmon, 2007). It arose from interviews and focus groups with municipal representatives that the benefits of national infiltration requirements (such as those in the National Outline Plan) may not be matched by factors considered by local authorities. Infiltration requirements can conflict with local development pressures (for example increasing numbers of underground car parks in apartment buildings in densely populated urban centers) and current infiltration BMPs were reported to be problematic, often resulting in blockages. Meanwhile other municipalities expressed greater interest in other SSWM goals besides infiltration, such as supporting local vegetation and biodiversity.

There are significant barriers to coordinated management of stormwater at the regional level. Drainage basin authority borders were redrawn in 1996 from 26 regional administration areas to 11 authorities, based on river basins (Laster, 2012). While in principle this arrangement can support basin-based stormwater management, responsibility for drainage is vaguely divided between these regional drainage authorities and 'islands' of local authorities and municipalities responsible for urban drainage within them. The result is that coordination relies on goodwill cooperation between different authorities with different interests (Laster, 2012).

The requirement in NOP 34B to submit drainage appendices to drainage authorities for approval, for large new urban development plans, attempts to overcome this urban/rural fragmentation. The proposed amendments to the Drainage Law will also allocate broader responsibilities to the drainage authorities and require preparation of basin-based masterplans to coordinate stormwater management between municipal and rural authorities. Informants from national-level agencies noted that the drainage authorities could be a significant actor in promoting SSWM but several of them currently lack the professional leadership and resources to fulfil this role while a Drainage Authority representative noted that the proposed changes to the law were needed to provide the authorities with more tools.

Within municipal boundaries, the management of stormwater is also less organized than for other water resources. In 2001, the Water and Sewage Corporations Law was passed with the goal of increasing efficiency of water supply and wastewater management; it established a closed financial loop so that revenues from water provision could increase investment in water infrastructure (OECD, 2011). In all but two municipalities in the country, drainage was not included in the remit of the new corporations and it has continued to be managed by the municipality. A unique case is the city of Rishon LeZion, where stormwater management is handled by the water corporation, alongside water supply and wastewater treatment. This corporation manages artificial stormwater-fed lakes in the city, to enrich groundwater and provide a source of pumped irrigation water for neighbourhoods in the city, while the lakes serve as a popular recreation area with related commercial projects (for details see Shapira, 2018).

Due to the division between local, regional and national authorities for drainage and stormwater management, the municipal handling of drainage is disconnected from the national authorities responsible for research and policy such as the Ministry of Agriculture and Rural Development and the Water Authority. Stormwater management in relation to urban construction has no obvious "parent authority", as described by government officials. Changes in policy, approach and discourse evident at the national and regional levels, as already described here and below, have no formal channels of communication to the local level. A Drainage Authority representative expressed their responsibility as receiving the stormwater arriving from the city but without automatic ability to influence how much is produced. Furthermore, it arose from focus groups that the departments responsible for drainage vary widely between municipalities, making the potential paths for transition to more integrated management specific to each case. It was also noted that in many cases there is no clear urban stormwater policy, nor a department with the oversight and budget to bring about a change in policy.

4. Conclusions

The socio-institutional context for implementation of Sustainable Stormwater Management in Israel has changed substantially over the past twenty years. The main change is in awareness and discourse among relevant decision-makers and professionals, especially among landscape architects and also water engineers, with acceptance of the idea that stormwater is a resource and not only a hazard. The 1957 Drainage and Flood Prevention Law, which defined stormwater as harmful water, and is aligned with an agriculturally dominated approach (Feitelson, 2005; Menahem, 1998), is still in effect. Yet the revision to the law under discussion by the Israeli Parliament proposes to replace the term 'drainage' with stormwater management, and to exchange the negative definition of stormwater with recognition of its benefit to the water sector, public health and nature conservation. Moreover, the urban and regional planning system has adopted the basic idea that stormwater is a valuable resource and it has assisted the transition towards SSWM by including stormwater management stipulations at certain stages of the planning process. However, the transition is far from complete. Attitudes in favour of SSWM are common in only certain policy and professional circles and are limited by administrative barriers and low public awareness. Furthermore, in both new regulation and in practice, infiltration of stormwater for groundwater enrichment is the dominant approach, while adoption of broader goals and practices of SSWM are advancing far more slowly.

The emphasis on groundwater enrichment stems from a period when Israel suffered from severe water shortages and when its main source of water was its aquifers. In the 21st century, Israel's water sector has changed dramatically: five large desalination plants supply more than half of the country's drinking water and treated wastewater is the main source of water for agriculture. Accordingly, the order of priority of SSWM goals could be expected to change, with less of an emphasis on stormwater as a water source and more priority given to environmental, economic and social goals.

Our study showed that the three-pillared socio-institutional framework (Ferguson et al., 2013; Palthe, 2014; Scott, 1995) is valuable for understanding and mapping the non-technical factors that enable a transition to sustainability, including to SSWM. Moreover, the three pillars of cultural-cognitive, normative and regulative changes can work simultaneously and synergistically to make the transition happen, as was the case with the move towards groundwater enrichment. A basic conclusion of this study is that while SSWM strives to reach four categories of goals – hydrological, ecological, social and economic – the order of priority of the various goals differs from place to place and with time. When the priority given to different goals of SSWM changes, the transition process across the three pillars should be renewed, to bring about changes adapted to these new circumstances.

5. Policy implications

In addition to these analytical conclusions, several policy recommendations can be drawn from this study that may also be

relevant to other countries struggling with a transition from conventional drainage to Sustainable Stormwater Management.

To provide public legitimacy and a platform for changes to policy and practice, awareness of the many benefits associated with SSWM and the concept of stormwater as a multifunctional resource should reach all professional circles and all levels of government, as well as the wider public. Where public awareness is lacking, as was the case with this study, research into public attitudes towards stormwater management and to different installed Best Management Practices (BMPs) could help guide awareness-raising initiatives. Such cultural-cognitive changes are necessary as further implementation depends not only on guidelines and regulation from above but also on cooperation and public interest from below.

It is recommended that the urban and regional planning system be used to generate coordinated changes at all levels, from large scale land-use planning of a whole watershed to detailed plans of neighbourhoods and buildings. The planning system can provide a statutory basis for integrated action, despite water management being divided between different agencies and authorities. This recommendation is especially true for countries with strong planning systems, including those like Israel whose planning heritage was influenced by the centrality of the British planning system in the past. The research also demonstrated that when the planning system is used as an integrator, greater professional expertise and capacity-building on stormwater management may be needed for different bodies within the planning system to successfully fulfill this role.

Awareness and regulation cannot create the transition to SSWM without compatible changes in professional standards of work. The findings demonstrated the significant impact of committed SSWM professionals to changing work processes around them, and also highlighted the general need for greater professional expertise. This can be achieved with targeted professional training, including specialized courses and publication of SSWM guides for planners, landscape architects and drainage engineers. Drawing on the systemic institutional framework employed here, investment in training should also make professionals aware of "the limitations of their current socio-institutional context and operating environments", as argued by Brown and Farrelly (2009, p.845). Thus, rather than using professional training to tackle lack of expertise as an isolated barrier, this approach would raise awareness of the impact of the socio-institutional context on technical stormwater management practice, and could thus enable professionals to become advocates for systemic institutional change towards SSWM.

A further recommendation is to use incentives rather than punitive measures to encourage local authorities to move from conventional drainage to SSWM, such as direct subsidies to local authorities or private developers who use BMPs to detain, collect, infiltrate and reuse stormwater, combined with local purification where needed. The incentives and drivers for BMPs should be made clear and worthwhile to those who implement them, taking into account water ownership regulations and the division of responsibilities among national, regional and local authorities.

Lastly, we recommend increasing applied research, mainly in the form of monitored demonstration projects (see Mitchell (2006) for a discussion of Australian experience and Shapira (2018) for evaluation of Israeli projects). To further promote SSWM, evidence is needed, based on context-specific work, of the interconnections between SSWM measures and benefits to human beings and nature, including improved local quality of life (blue-green landscapes, better urban microclimate), reduced municipal expenses (on irrigation), and contribution to ecological goals. These are expected to draw together the various aspects of the socio-institutional changes we studied: to support the spreading of cultural awareness among decision-makers, professionals and irresolute residents; to have an impact on the design of norms and professional standards; and to provide necessary legitimacy for regulative changes.

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