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Who governs climate adaptation? Getting green roofs for stormwater retention off the ground

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Green roofs are an innovative solution for urban stormwater management. This paper examines governance arrangements for green roofs as a ‘no-regrets’ climate adaptation measure in five cities. We analysed who governs green roofs, why and with what outcome. Our results show that hierarchical and market arrangements co-exist in the various stages of the policy process. Cities with a higher prevalence of hierarchical arrangements have substantially higher implementation rates for green roofs. Although private sector involvement is crucial for raising efficiencies, a significant level of public responsibility taken by local governments appears to be salient for unleashing the potential of green roofs.

Keywords: climate adaptation; responsibilities; governance arrangements; green roofs; cities

1. Introduction

Adaptation to the impacts of climate change has gradually emerged as a new public policy field (Biesbroek *et al.* 2010, Preston *et al.* 2011). The governance of adaptation is inherently a multi-level challenge, requiring action from the global to the local level (Adger *et al.* 2005, Urwin and Jordan 2008). The local/regional level is particularly emphasised because of the spatial diversity of climate-induced risks and the belief that these risks should be dealt with by those directly affected, and because many adaptation solutions require changes in the physical environment, which is usually the responsibility of local/regional governments (e.g. Stjorbjörk 2007, Lundqvist and von Borgstede 2008, Biesbroek *et al.* 2009, Saavreda and Budd 2009). Urban areas are generally regarded as relatively vulnerable to the impacts of climate change because of their accumulation of social, cultural and financial capital, their common location in delta regions, and their already overburdened environments (e.g. Lindley *et al.* 2007, Carter 2011, Corfee-Morlot *et al.* 2011, Lankao and Qin 2011). Cities are more prone to surface water flooding from ever-increasing levels of impervious surfaces and decreasing levels of green space, and this is expected to be exacerbated by increased precipitation rates (Mees and Driessen 2011). Although increasing adaptation activity is being witnessed in Western cities (e.g. Tang *et al.* 2010, Carter 2011, Mees and

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Driessen 2011), in practice local government activities often come down to ‘no-regrets’ measures that serve multiple societal goals (Matzarakis and Endler 2010, Tompkins *et al.* 2010, Berrang-Ford *et al.* 2011, Runhaar *et al.* 2012).

Green roofs (also known as vegetation or living roofs) are an example of such a no-regrets adaptation measure, and have therefore become increasingly popular in European cities and more recently in North America (Oberndorfer *et al.* 2007, Dvorak and Volder 2010). They offer several public eco-system services (enhancing biodiversity, contributing to urban pollution abatement and better air quality, and mitigating the urban heat island effect), thereby contributing to overall urban sustainability. Green roofs are able to store rainwater and reduce surface water run-off and sewage overflows from increased precipitation rates (Oberndorfer *et al.* 2007).¹ They form an innovative alternative to more conventional stormwater measures such as sewage networks and drainage canals. Green roofs also deliver private benefits to property owners (e.g. energy savings, thermal comfort, aesthetics).²

Given the extent of private property, city governments need to involve the private sector to secure sufficient instalments of green roofs for stormwater retention purposes, in particular in areas where densities are high, (green) space is scarce and the capacity of the traditional sewage systems has reached its limits. Furthermore, involvement of the private sector might raise efficiency levels, as many economists and governance scholars assert (e.g. Lemos and Agrawal 2006, Baarsma *et al.* 2010). But what types of governance arrangements between public and private actors are actually employed to stimulate the uptake of green roofs? In this paper we address how the implementation of green roofs is governed in practice, by whom, for what reason, and with what outcome. The majority of articles touching upon the public-private divide in climate adaptation are conceptual, and tend to employ a theoretical-economic perspective (see for instance Berkhout 2005, Mendelsohn 2006, Stern 2007, Aakre and Rübhelke 2010a, Osberghaus *et al.* 2010). Our focus is on an empirical exploration and analysis of governance arrangements for climate adaptation. This is done through an in-depth comparative case study of five Western frontrunner cities active in green roof policies, but with different arrangements: Basel, Chicago, London, Rotterdam and Stuttgart. Our aim is to generate knowledge on the governance of adaptation as such, and specifically for green roofs as a popular no-regrets adaptation measure. In doing so we hope our findings will contribute to the environmental governance literature in general. While there is an ongoing scientific debate about the shift from government to governance, as well as its consequences, several empirical studies show that this shift does not necessarily occur in practice in all policy domains (Howlett *et al.* 2009, Weber *et al.* 2011, Driessen *et al.* 2012). Our empirical research will provide insights into whether such a shift actually occurs in green roof arrangements. The second section discusses the analytical framework used; the third section describes the research method and case selection. The fourth section gives a brief overview of the five case studies. The fifth section provides the results, while the final section discusses the main conclusions in light of the environmental governance literature.

2. Governance arrangements in theory

2.1. Environmental governance arrangements

Governance as a new way of steering has become a popular concept in social sciences. (Environmental) governance theorists and political scientists have

expressed their views on how the state, market and civil society should share responsibility for public issues. They agree that it concerns governing styles in which the boundaries between public and private sectors are blurred (Stoker 1998, p. 17). There appears to be a general consensus about the need for involvement of non-state actors in environmental governance. However, there is some debate about which governance modes or arrangements (both referring to some form of organisation between state and non-state actors) are feasible and effective in dealing with the complexity, uncertainty and ambiguity that characterise many environmental issues, including adaptation to climate change. In addition, there is debate about the normative consequences of these arrangements in terms of fairness, legitimacy, etc. On the one hand they are said to increase commitment to the implementation of environmental measures; on the other hand they are alleged to cause an implementation deficit because they lack authoritative power (e.g. Driessen and Glasbergen 2000, Lemos and Agrawal 2006). Likewise, they are believed to raise legitimacy and accountability because of the inclusion of a plurality of environmental values, while others believe they create a democratic deficit because of exclusive representations and the potential dominance of powerful interests (e.g. Bogason and Musso 2006, Lemos and Agrawal 2006, Juhola and Westerhof 2011).

Governance arrangements can range from top-down government on the one end of the scale to societal self-governance on the other end. Between these extremes, various configurations can be observed, referred to as hybrid (denoting various types of co-operation among the three spheres of state, market and civil society, cf. Lemos and Agrawal 2006) or interactive (denoting a more specific type of co-operation between public and private actors in the form of non-hierarchical policy networks, cf. Kjær 2004). Different classifications of ideal-typical governance arrangements along varying dimensions have been presented in literature (see e.g. Treib *et al.* 2007, Hysing 2009, Arnouts *et al.* 2012, Driessen *et al.* 2012). In line with several authors (Treib *et al.* 2007, Driessen *et al.* 2012), for this research we classify a governance arrangement according to (1) the division of responsibilities among state and non-state actors along the stages of the policy process (also denoted as the actor base/politics); (2) the steering strategy employed to guide actors (denoted as the institutional structure/polity); and (3) the policy instruments used to support adaptation action (denoted as the content/policy). We interpret *responsibilities* simply as tasks that an organisation or actor has, whether public, private or a public-private constellation, and for which it can be held accountable. Wherever this is instrumental for the analysis, we will make a distinction between self-initiated responsibilities (autonomously taken on by an actor), and mandated responsibilities (enforced through regulations). Concerning *steering strategies*, most governance scholars distinguish between hierarchical governance (or hierarchies, top-down government), interactive governance (or networks), and market governance (or self-governance) (see e.g. Thompson *et al.* 1991, Kjær 2004). Hierarchical governance arrangements tend to depend on chains of command and control with power as the medium of exchange. Public actors, i.e. government bodies at various levels and sectors, are responsible for policy making. Market arrangements apply prices as the medium of exchange. In this case the private sector regulates itself; private actors assume responsibility and initiate policy to regulate competition (and to pre-empt public policy). Interactive arrangements depend on dialogue, deliberation and collaboration between public and private stakeholders with trust and reciprocity as a medium of exchange (Kjær 2004). Here responsibility is more of a joint

public-private effort. Finally, we classify *policy instruments* according to legal, economic and communicative instruments, depending on the type of incentives used to influence behaviour; respectively, regulations (sticks), financial incentives (carrots), and information and education (sermons) (see e.g. Glasbergen 1992, Bemelmans-Videc *et al.* 1998). Each instrument type can be utilised for each steering strategy, although specific combinations often tend to go together (hierarchical steering and legal instruments; market steering and economic instruments; network steering and communicative instruments). We have used the above classifications to analyse the governance arrangements for green roofs (see Table 1). It is important to note that these arrangements are not static; they might vary per stage in the policy process from policy making, policy implementation, and policy evaluation to policy maintenance.

2.2. Rationales for governance arrangements

If we aim to explain why different governance arrangements emerge and dominate an environmental issue such as climate adaptation, we need to understand their underlying rationales. We assume that differences in governance arrangements are influenced by different rationales underlying the public-private divide. In other words, the decisions for public and/or private responsibilities are built upon different considerations underlying that decision. The dominance of one or a few considerations might have consequences for responsibility divisions among public and/or private actors and the chosen steering strategy and policy instruments. Inspired by the JEP (Juridical-Economic-Political) triangle of Nelissen (2002), which applies a multiple perspective for analysing governance arrangements, we have derived considerations from three scientific disciplines that have traditionally dealt with the public-private divide. The resulting competing juridical, economic and political considerations are portrayed in Figure 1.

The juridical perspective takes the influence of laws, regulations, principles and norms on the public-private divide as the focal point. Two key considerations have

Table 1. Ideal-typical governance arrangements and their key considerations.

Dimension	Hierarchical governance	Interactive governance	Market governance
Actor base	Predominantly public responsibilities	Shared responsibilities among public and private actors	Predominantly private responsibilities
Steering strategy	Predominantly hierarchical	Steering through policy networks	Predominantly through market steering
Policy instruments	All instruments (legal, economic and communicative); with preference for regulations	Mostly communicative instruments and negotiated agreements	Mostly economic and voluntary instruments
Considerations	Predominantly Securing adaptation action (as specification of effectiveness), Fairness and Rule of law	Predominantly Legitimacy, Accountability	Predominantly Efficiency

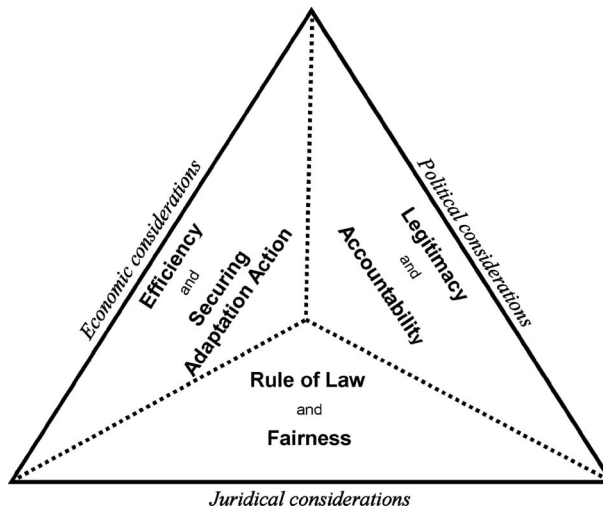


Figure 1. Considerations framework inspired by Nelissen (2002).

been derived: 'Rule of Law' and 'Fairness'. *Rule of law* is about conforming to extant law; about abiding by regulations to which the adaptation issue is subject (Driessen and Van Rijswick 2011). National regulations and constitutions often assign duties of care to public authorities, certainly in cases of national security, as is witnessed in many countries for flood management. *Fairness* relates to a reasonable distribution of costs, benefits, risks and responsibilities (Aakre and Rübhelke 2010b). In particular, a fair division of adaptation goods among beneficiaries is important, much more so than in mitigation from which everyone benefits. Fairness often leads to public responsibilities for a fair application of the precautionary principle (intergenerational equity) and compensation principle (spatial and socio-economic equity), to safeguard an equitable distribution of burden sharing in society (e.g. Eakin and Lemos 2006, Osberghaus *et al.* 2010).

The economic perspective sees the balance and distribution of costs and benefits as the main influence on the public-private divide (Mendelsohn 2006, Aakre and Rübhelke 2010a). The first economic consideration is 'Efficiency'. *Efficiency* is about the optimum allocation of scarce resources, about supplying an adaptation good at the lowest cost, and as such is a key rationale underlying economic policy instruments. This is based on the premise of economists that markets are generally more efficient in allocating scarce resources and in spurring innovations (e.g. Baarsma *et al.* 2010). The second economic consideration refers to effectiveness, which is about the attainment of pre-defined goals. For this research effectiveness is framed as '*Securing adaptation action*', which refers to the supply of sufficient levels of an adaptation good (in our case green roof instalments). In instances of market failure, governments might need to step in by providing the adaptation good themselves, or by stimulating private adaptation action (e.g. Berkhout 2005, Mendelsohn 2006, Aakre and Rübhelke 2010a).

The political perspective is based on trust and reciprocity to bridge the public-private divide (Adger *et al.* 2009, Hobson and Niemeyer 2011). It is represented by the considerations of 'Legitimacy' and 'Accountability'. *Legitimacy* is about the support of stakeholders and society at large for an adaptation goal, solution and the

decision-making process itself. This is based on the idea that a broadened democracy can be realised by involving different actors beyond the state³. In this view the social complexity of adaptation issues requires interactive arrangements through deliberative processes with the extensive participation of a wide range of stakeholders, including those affected by climate change (e.g. Hulme *et al.* 2007, Adger *et al.* 2009). *Accountability* is about clarity of responsibilities and transparency of information on the content and process of policy making. It requires transparency in decision-making processes and open access to, and sharing of, information among actors so that they can be held accountable; it might therefore require interactive governance arrangements, since networks are often claimed to foster communication, information and knowledge dissemination (e.g. Bogason and Musso 2006, Bodin and Crona 2009). The predominant considerations of the three ideal-typical governance arrangements are included in Table 1.

Of the six considerations, we expect ‘Securing adaptation action’ to be particularly relevant for green roof arrangements, owing to the occurrence of market failure (to link up with economic theorists). There is a considerable degree of uncertainty deterring private actors from installing green roofs. Uncertainty is generally acknowledged as a key barrier to effective adaptation action (Füssel 2007, Urwin and Jordan 2008, Biesbroek *et al.* 2009). With green roofs this uncertainty revolves around the limited knowledge of their properties, costs and monetised benefits, and hence uncertainties with respect to the returns on investments, given the upfront costs of installation. Green roofs thus represent a case of positive externality; those who implement them are generally unable to retrieve the benefits they generate for society as a whole. They require the stimulation of positive behaviour. Therefore, our hypothesis is that there will be some degree of public responsibility in order to provide sufficient levels of green roof instalments. Furthermore, we hypothesise that a hierarchical governance arrangement, which is able to employ more coercive steering by using legal instruments as a principal resource to guide adaptation action, will lead to higher levels of green roof installations (Glasbergen 1992).

3. Research method

We argue that a comparative case study approach is useful for our research, because the use of several cases helps us to explore and clarify differences in governance arrangements for climate adaptation, and provides greater weight to the conclusions (Pickvance 2001, Campbell 2003, Burnham *et al.* 2008). One common use of comparative analysis, as described by Pickvance (2001, p. 15) is “to examine a small number of empirical cases holistically to grasp the causal processes leading to observed similarities and differences”. The comparison among five cities allows us to find patterns of similarities and differences among governance arrangements for green roofs. The cities were strategically selected for a number of commonalities and one key difference. In terms of commonalities, first of all they face similar vulnerabilities to surface water flooding due to their high densities, and stormwater management has been a key reason for introducing a green roof policy (in addition to other policy objectives). Second, they are considered leaders in green roof implementation in their countries in terms of square metres realised, and/or in their ambition for green roof instalments (Taylor 2007, Brenneisen 2010, Carter and Fowler 2008, Carter 2011, Mees and Driessen 2011). Third, they have the authority to independently develop green roof policies in their jurisdictions. This means that

they have the freedom to initiate and develop green roof policies independently from national governments (although national regulations might support or stimulate local governments to develop policy). Finally, they are all Western democratic cities subject to similar neo-liberal tendencies in recent decades, albeit to different degrees. Therefore, responsibilities are often not set in stone and are rather diffuse in practice. The most relevant difference is that the cities vary in the types, duration and breadth of policy instruments used to promote the uptake of green roofs, a characteristic we were able to discover via desk research (see the fourth section for a brief overview). We assumed that these represented key differences in governance arrangements and their underlying considerations.

We used two methodological approaches as described by Urwin and Jordan (2008). What they denote as a 'top-down' perspective was conducted through a content analysis using various sources, such as official policy documents for green roofs and/or stormwater management, staff reports from local administrations, and non-peer-reviewed research reports on green roofs. These documents gave insight into rules and policies that give direction and set objectives that should lead to adaptive action on the ground. The content analysis also yielded insights into the formal responsibilities for local (rain) water management, and allowed us to scan the different policies employed, based upon which we made the final selection of case studies. This was complemented by a 'bottom-up' perspective, provided by conducting interviews with key public and private stakeholders in each city. This yielded additional insights into how policy goals are translated on the ground, by drawing upon the expertise and experience of these stakeholders. Furthermore, it generated knowledge with respect to the considerations underlying the governance arrangements. The interviews were conducted face-to-face with the exception of three, which were conducted by telephone. The interviews were recorded and transcribed. A stakeholder analysis was done to obtain an overview of the most relevant stakeholder types. Consequently respondents were recruited using the snowball technique; these consisted of representatives of policy officers in various public administration sectors (such as water and environmental management, and spatial planning), and of real estate companies/developers, housing corporations, architects, green roof industry associations, and finally green roof consultants and politicians (interviews with 58 respondents in total, see Table 2).⁴ We used a semi-structured interview guide which aimed to obtain insight into responsibilities and considerations via spontaneous expressions of the respondents, after which specific questions were addressed to verify and classify the considerations according to the framework. We deduced the dominant considerations from the responses of the interviewees based on our consolidated interpretations. There were no major

Table 2. Overview of respondents per city.

City	Public	Private
Basel	4	8
Chicago	7	4
London	7	4
Rotterdam	8	8
Stuttgart	5	3
Total	31	27

differences in answers obtained. Moreover, the results were validated with several key respondents via verification of case study reports, and via an interactive workshop in one city (Rotterdam).

4. Green roof policies of Basel, Chicago, London, Rotterdam and Stuttgart

Since the mid-1990s the Canton of Basel has employed several policies during consecutive periods of time to promote green roofs. Two large subsidy programmes were developed for green roofs; according to respondents, these seem to have brought down the costs of instalments, and served as a testing period for green roof suppliers and architects to gain experience in the field. The mandatory requirement for green roofs on new and renovated buildings through the local building code, which came into force in 2002, was accepted after this test period without major resistance and has been a major driving force for greening Basel's flat roofs ever since (Brenneisen 2010, BPG 2011). Current attention focuses on the quality of green roofs, in particular for biodiversity reasons; prescriptions require a minimum depth of substrate layer (of 10 cm) and a specific 'Basel mix' of soil and seeds, adapted for native plant species. Nevertheless, green roofs remain important for stormwater management, and hence a 50% reduction of stormwater charges is given if a property has a green roof.

The City of Chicago commenced its green roof policy in 2001, when the Mayor pushed for the installation of a demonstration roof on the City Hall. Green roofs are part of Chicago's Climate Change Action Plan for both stormwater and heat stress management (CCAP 2008). They are promoted through performance-based regulations for stormwater management, energy efficiency and landscaping (CECC 2008, CLO 2000, CSWO 2006), and through a mandatory requirement for all new buildings that receive city funding and that are subject to review (CSDP 2003). Direct financial incentives play a modest role in the adoption of green roofs in Chicago. There are indirect financial incentives: a density bonus (developers are allowed to build more units per square footage if their building has a green roof), and the Green Permit Program (CGPP 2010). The latter involves a fast-track permissions process and a fee reduction for developers if they install a green roof.

Compared to the other cities, London has a rather restrained policy. Since 2004 a green roof policy has been integrated into the Greater London Authority's London Plan, which encourages major developments to incorporate living roofs where feasible (LP 2008, p. 210). In practice this means that developers need to justify why they do not install green roofs. Local authorities have the authority to require green roofs as 'material consideration' in planning applications, which most tend to do on a case-by-case basis.

Since 2006 the City of Rotterdam has integrated targets and policies for green roofs as a stormwater management measure in three municipal strategy documents, and has agreed upon these targets with the regional water boards (RCV 2007, RWP 2007, RCP 2010). An incentive programme with substantial budgets available has been running since 2008; a subsidy of €30 per square metre is provided to businesses and citizens, which should cover about half of the installation costs. In support of this, a communication campaign was launched, as well as a demonstration roof which acts as a visitor centre.

Although in Stuttgart green roofs were installed throughout the twentieth century, actual green roof policy only came into existence in 1986. Stuttgart employs

a range of policy instruments to promote green roofs. First, based on the federal building code (FGBC 2011) German municipalities are authorised to make green roofs mandatory on all new builds with flat roofs via binding land-use plans, which Stuttgart in effect implements for those parts of the city subject to local development plans. In other areas green roofs on new buildings are stimulated via a density bonus for developers on a case-by-case basis. Second, green roofs on existing buildings are financially stimulated through a subsidy programme, which ran for 15 consecutive years until 2009, and through a 50% reduction of the stormwater fee. Third, both the public authorities and the green roof industry itself engage extensively in education and information campaigns to promote green roofs. See Table 3 for an overview of the policy mixes per city.

5. Governance arrangements in practice

5.1. Scope of green roof arrangements

Table 4 provides an overview of governance arrangements throughout the policy process and their underlying rationales for the five cities studied. It shows the common hierarchical and market governance arrangements co-existing in the cities. This reflects experiences in urban water management, which is dominated by combined approaches of hierarchical and market-based governance (van de Meene *et al.* 2011). Hierarchical arrangements are prevalent in each city in the early stages of the policy process: a wide adoption of the green roof technology among private actors does not happen autonomously, and hence local authorities aim to secure sufficient levels of adaptation action by initiating some form of green roof policy. This corresponds with our first hypothesis in the second section of the paper. Market arrangements as a form of self-regulation among private actors are more prevalent in the policy implementation, evaluation and maintenance stages, driven by the rationale of efficiency. With the exception of one city (Basel), interactive arrangements with joint responsibilities are lacking. A major difference across the cities is that, in Basel and Stuttgart, hierarchical arrangements with dominant public responsibilities, hierarchical steering and the utilisation of legal instruments are witnessed throughout the policy process. This is instigated by a stronger prevalence of the considerations of securing (adaptation) action and fairness. We will now explore the hierarchical, market and interactive arrangements identified in more detail, and will clarify them in terms of their underlying considerations.

5.1.1. Hierarchical arrangements

All five cities show hierarchical arrangements in the policy making stage. Public authorities have taken on the responsibility (self-initiated) for agenda setting, knowledge creation, initiation of green roof policies, and for target setting. This means that various municipal authorities from the five cities have these tasks in common.⁵ The prime motivation for this public responsibility is that local authorities want to ensure green roof installations are encouraged to secure adaptation action; without some form of government intervention, private actors will not take sufficient voluntary action. A second consideration of local authorities is fairness; the precautionary principle is taken into account in dealing with uncertainties regarding the impacts of increased precipitation rates for current and future generations. Rule of law is a third consideration, which has some bearing in three of the cities in

Table 3. Overview of policy mixes in the five case studies.

Policy instruments	Basel	Chicago	London	Rotterdam	Stuttgart
<i>Legal instruments (sticks)</i>					
Technology based regulation (e.g. building codes)	Green roofs are mandatory for every unused flat roof according to the building code of the Basel Canton (Par.72 of the Bau und Planungsgesetz since 2002); additional regulation prescribes quality standards	Mandatory green roofs for new buildings which receive city funding (Sustainable Development Policy since 2003)	No requirement, but based on the green roof policy in the London Plan developers should provide reasons for not installing a green roof for new developments (since 2004)	None	Mandatory for flat roofs on new buildings for areas with binding land-use plans (Federal Building Code; Local development Plans since 1986)
Performance based regulation (e.g. LEED)	None	Green roofs count as a measure for achieving targets for storm water retention, energy conservation and beautifying landscapes according to several ordinances of the Chicago Municipal Code (Stormwater Ordinance since 2007, Energy Conservation Code since 2002 and Landscape Ordinance since 2000)	None	None	None

(continued)

Table 3. (Continued).

Policy instruments	Basel	Chicago	London	Rotterdam	Stuttgart
<i>Economic instruments (carrots)</i>					
Direct financial	<p>1) 50% reduction of stormwater fee in case of a green roof</p> <p>2) Two subsidy programs: one in 1995/1996 of 0,8 mio Swfr. (20 Swfr/m² for all buildings), and one in 2005/2006 of 1,2 mio Swfr. (30–40 Swfr/m² only for existing buildings)</p>	<p>Limited budgets available through:</p> <p>1) Green Roof Grant Program 2005–2007</p> <p>2) Green Roof Improvement Fund 2006–2009</p> <p>3) Illinois Green Roof Grant Program 2009</p>	None	<p>Since 2008 to date a substantial budget of appr. 1 mio Euro/year is available through subsidy program for both new and existing buildings (30 Euros/m²)</p>	<p>1) Between 1986 and 2009 a modest budget was available for subsidizing green roofs not subject to the mandatory requirement</p> <p>2) Stormwater fee reduction</p>
Indirect financial	None	<p>1) Density bonus</p> <p>2) Expedited permit process: fast permitting & permit fee reduction (Green Permit Program since 2004)</p>	None	None	Density bonus on a case by case basis

(continued)

Table 3. (Continued).

Policy instruments	Basel	Chicago	London	Rotterdam	Stuttgart
<i>Communication instruments (sermons)</i> Information & education	1) Public promotion during the subsidy programs with a "best looking green roof contest" 2) Various public leaflets 3) Ongoing education & information through the Swiss Green Building Council, and development of a quality label for green roof suppliers	1) Public demonstration roof on city hall 2) Public Green Tech Resource Center as center for information to citizens	Ongoing education/information through living roofs.org (green roof consultancy)	1) Public demonstration roof combined with an information centre since 2010 2) Public communication campaign 2009–2011 (posters, leaflets) 3) Ongoing efforts of the green roof industry (association), among which development of quality standards	1) Various public demonstration roofs 2) Public "green hotline" and consultation 3) Various private partnerships and green roof industry engage in information and education programs, and development of quality standards/industry norms

Table 4. Overview of governance arrangements and their underlying considerations.

Actors	Considerations	Roles per stage	Rationale for considerations
<i>Hierarchical governance</i> Local authorities	Economic: Securing adaptation action	Policy making: agenda setting, knowledge creation & policy initiation Policy implementation: financing & implementation of green roofs	Lack of sufficient incentives for private actors to take water retention measures/install green roofs; uncertainty regarding climate effects, impacts and the cost-benefit ratio of green roofs Deficit of installments on privately owned buildings; showcasing green roofs on important city buildings; high upfront costs for private actors, refraining them from action
		Policy evaluation: quality control (Basel only)	Without quality control developers/green roof suppliers would cut costs on quality; a higher quality of substrate reduces maintenance costs later on
	Juridical: Fairness	Policy making: policy initiation & target setting	Uncertainty regarding the extent of urban flooding and effect of storm water measures encourages public actors to take the precautionary principle into account on behalf of present and future generations
		Policy evaluation: monitoring (all cities) & enforcement (Basel and Stuttgart)	Guarantee of a level playing field: no preferential treatment; the same burden for everyone (Basel and Stuttgart); those that receive benefits from public policy should maintain their end of the bargain (Chicago/Rotterdam)
	Political: Legitimacy	Policy making: knowledge creation & strategy making (Basel & Stuttgart)	Consultation processes with scientists, green roof suppliers, and consultants
	Juridical: Rule of law	Policy making: policy initiation (Basel, London, Rotterdam)	Acts that place duties for flood management on local authorities (Bundes Gewässerschutzgesetz 814:20 (art. 7); GLA Act 2007, Flood & Water management Act 2010, Dutch Water Act 2008)

(continued)

Table 4. (Continued).

Actors	Considerations	Roles per stage	Rationale for considerations
<i>Market governance</i> Green roof industry (individual/partnerships)	Economic: Efficiency	Throughout the policy process	Raising of awareness for, and knowledge of, green roofs. Creation and securing of market demand and customer satisfaction; innovation in green roofs to bring down their costs and raise their benefits
Property owners	Economic: Efficiency	Policy implementation: financing & implementation of green roofs Maintenance	Green roofs have many co-benefits, without which they would not be cost-effective; in Basel and Stuttgart cost levels are already optimal/mature market Maintenance clause as part of contract with green roof suppliers to earn additional money and for quality control; in Basel high quality standards at installation significantly reduce maintenance costs
Consultants/ecologists	Economic: Securing (biodiversity) action	Policy making: agenda setting & knowledge creation (Basel & London)	Through active lobbying and conducting research they managed to convince local authorities of the need to initiate green roof policy for biodiversity reasons
<i>Interactive governance</i> Schweizerische Fachvereinigung Gebäudebegrünung	Economic: Efficiency	Policy making: agenda setting; Policy implementation: info provision; Policy evaluation: quality labelling	Creation and securing of market demand and customer satisfaction; promotion of green roofs, with specific emphasis on quality guarantees. Currently a new SIA norm (no. 312) is developed for green roofs, as a strong national guideline for architects to conform to

Note: Unless specified the statements apply to all five cities.

initiating policy. National/federal Acts place duties of care for flood management on the local authorities of Basel, London and Rotterdam (so this is a case of mandated responsibility), and hence they might be held liable for flood damages and forced to provide compensation (BSG 1991, GLA 2007, WGW 2008, WW 2008, FWM 2010).

In all cities the (self-initiated) responsibility for strategy making also rests with these public authorities: they decide upon the use of green roofs as a measure for stormwater retention, and upon the type of policy instrument(s) introduced to promote the uptake of green roofs. However, the cities do differ in the types and breadth of instruments used. Basel and Stuttgart authorities employ the broadest mix: they use coercive regulations to make green roofs mandatory on new buildings, while simultaneously rewarding green roof installations with financial incentives (stormwater fee reduction and, in the past, also with subsidies). According to respondents, this combination of instruments has helped to make the regulation acceptable. Furthermore, in Basel the subsidies and information/education campaigns preceded the regulation, which also helped to break down resistance. Both cities have very strong ulterior environmental motives for adopting the regulation: biodiversity in Basel and air quality in Stuttgart. This made the consideration of securing (adaptation, biodiversity, clean air) action even more prevalent. By contrast, Chicago and Rotterdam mainly use voluntary instruments to induce private behaviour; financial incentives are complemented by communication and education. London is the most restrained, and mainly relies on communication instruments.

Consistent with their policies, Basel and Stuttgart show a hierarchical arrangement in the evaluation stage of the policy process; the local authorities take on responsibility for monitoring and controlling green roof installations. In Basel the *Stadtgärtnerei* (urban green department) checks the required architectural roof plan of each new or renovated building, and performs a physical inspection upon completion, taking the quality guidelines into account. In Stuttgart a building can (but does not need to) be inspected by the Department of Building Law. The main consideration for performing this task is fairness; since green roofs are mandatory, enforcement mechanisms have been put in place to guarantee a level playing field for all developers. In the other three cities the local authorities' responsibilities in the evaluation stage are limited due to administrative and financial constraints. They put some effort into keeping records of green roof installations and subsidies provided, but there is no physical check of actual instalments.

5.1.2. Market arrangements

Market arrangements are witnessed throughout the policy process, but they really dominate in the implementation and maintenance stages. Private actors engaged in green roofs are numerous, and can broadly be divided into those with primary commercial interests (consultants, architects, green roof suppliers, horticulturists), and property owners (developers, real estate companies and civilians).

In all cities the most active stakeholder group with high interests at stake is the green roof industry, which has taken on many responsibilities (self-initiated). They can operate individually, as an industry association, or in private partnerships with gardeners, landscapers, roof contractors and consultants, in order to bring together the expertise of different professions. In the policy-making stage they lobby to get green roofs on the agenda of local authorities, architects and the like, and they are

very active in research. In Stuttgart, for example, various private partnerships (such as the Green Roof Industry Association FBB, the German Gardener Association DDV, and the German Landscape Research, Development and Construction Society FLL) were instrumental as agenda-setters and knowledge brokers in advocating the adoption of green roofs. In the rest of the policy process the green roof industry's most prominent (self-initiated) responsibilities are in providing and distributing information regarding the beneficial properties of green roofs, and their cost-benefit ratios, in the actual installations, and finally in the maintenance of green roofs through guarantee clauses in purchase agreements. Steering happens autonomously through pricing and competition, and the instruments used are mainly communicative. In addition, some private regulation is also undertaken by the industry itself through the creation of quality standards and labels. Efficiency is the key consideration for local governments to leave these responsibilities with the green roof industry. Green roof suppliers have continuously sought for economies of scale, and have been driving down the prices for green roofs over the years, in particular in Basel and Stuttgart. They have realised substantial infrastructural efficiencies through innovations (e.g. pumps to blow substrates on the roof, development of light-weight and modular substrate systems). Furthermore, the industry has generated new products geared towards excellence in certain properties, such as special water retention roofs. In Chicago the industry is shifting attention to the revenue side of green roofs, by promoting them as urban roof top farms. As one respondent said: "green roofs can't be implemented on a broad scale unless they make financial sense" (green roof consultant in Chicago 2011).

Property owners are another important group of private actors. Since most urban property is in private hands, their responsibility is most pronounced in the financing and actual instalments of green roofs on their properties, and in the maintenance of these roofs. However, there are major differences in the levels of private responsibility depending on whether green roofs are legally mandatory or not. Property owners in Basel and Stuttgart have a mandated responsibility since they have to comply with regulation, while in the other three cities instalments of green roofs very much depend on the extent to which property owners themselves are willing to take on this responsibility. Those that do tend to be driven by motivations of sustainability, whether intrinsically or for strategic reasons to boost their green image. As one respondent put it "Green roofs are visible sustainability" (policy officer in Rotterdam 2011). Barriers for taking on private responsibility are mostly financial, as stated before. Furthermore, there is the issue of 'split incentive', which deters landlords/housing corporations from investing in green roofs since they are often unable to pass on these costs to their tenants.

Another group of private actors, which has been quite actively involved in the policy-making stage in every city, are green roof experts/consultants. For example, in both Basel and London, ecologists were instrumental in getting green roofs on the local political agenda. They managed to exert a sizeable influence on the spread of awareness for, and knowledge of, green roofs in and beyond their cities, and can be regarded as 'policy entrepreneurs'. In Basel this ecologist conducted extensive research, which ultimately led to the creation of the Basel mix, and to the adoption by the Basel authorities of quality guidelines in order to guarantee lasting durability of the roofs. In London the ecologist was heavily involved in

drawing up the policy in the London Plan, as well as in drawing up technical guidelines.

5.1.3. Interactive arrangements

The only prominent example of an interactive governance arrangement is the Swiss Green Building Association. This is a public-private partnership, which includes the Basel authorities, green roof suppliers and roof contractors. It has taken on responsibility for the promotion of green roofs in Switzerland, and for the development of quality standards. However, overall in all cities there is a lack of true joint public-private responsibility. In the early stages of the policy process the local authorities consulted the private sector, but the ultimate decisions regarding stormwater retention strategies and green roof policies remained in their hands. The extent of consultation does vary per city: in Basel and Stuttgart consultants, NGOs, economists and the industry were most actively involved. This was mainly meant to facilitate the practical implementation of the regulation and quality standards (not to co-decide). The consideration of legitimacy was the prime motivation of local authorities for seeking stakeholder input; it helped to reduce the resistance to the regulation. It is important to note that the political consideration of accountability was never mentioned as a motivation. When specifically addressed in the interviews, respondents would indicate that there was no real lack of transparency in responsibilities and decision-making processes, or a lack of access to information (although information from suppliers is not always trusted).

5.2. Evaluation of green roof arrangements

The previous section highlighted a key difference in governance arrangements among the cities. In Basel and Stuttgart we have seen a dominance of hierarchical arrangements, since there was a greater consideration for securing adaptation action. Given the importance of this consideration, we will now address the question of which arrangement is most effective in securing sufficient levels of adaptation action, thereby reducing vulnerability to increased levels and intensities of precipitation. We could only tentatively answer this question because of a lack of data related to retention capacities of green roofs, as well as to their spread across the cities. We assumed that the available data on the amounts of square metres installed, related to the population size and the eligible roof space, would at least give some indication of implementation levels for the green roof technology and serve as a proxy for the performance of the arrangement. Table 5 shows that the arrangements in Basel and Stuttgart are by far more advanced in green roof implementation; almost one-quarter of the eligible roof space has been greened, while in the other cities this percentage is still below 1%. This supports the hypothesis that a hierarchical arrangement with coercive steering through regulations would perform better in securing adaptation action. Nevertheless, our research also suggests that the combination of regulations and financial incentives is particularly fruitful; the incentive might make the regulation more legitimate. Moreover, the findings indicate towards a need for local authorities to take responsibility throughout the whole policy process, and in particular in the evaluation stage resulting from the regulation. The hypothesis might therefore be nuanced with the addition of this specific

Table 5. Implementation levels of the green roof technology.

Characteristic	Basel	Chicago	London	Rotterdam	Stuttgart
Policy since	1996	2003	2004	2008	1986
M ² installed by 2010	1,000,000	700,000	715,000	40,000	1,000,000
Inhabitants	170,000	3,000,000	7,800,000	600,000	600,000
M ² per capita	5.8824	0.2333	0.0917	0.0667	1.6667
% of eligible roof space covered	25%	<1%	<1%	<1%	22%
Average price/m ² in Euros for a common green roof	25–35	40–80	60–65	50–90	10–40

Sources: The amounts of installed square metres, percentages of eligible roof space and average price levels are indicative and mainly derived from information of respondents. For Basel and Stuttgart, additional sources could be used such as Brenneisen (2010), Green roofs.com, Travellerspoint.com

instrument mix, and the need for explicit public responsibility in the monitoring, controlling and enforcement of green roof installations.

While the dominance of hierarchical arrangements provides a potential explanation, three other factors appear to have contributed to the high levels of implementation in Basel and Stuttgart. First, both cities are well known for their favourable green political climate, which stimulates the adoption of sustainable solutions by residents. Second, both cities have had policies in place substantially earlier than in the other cities. These preceding policies helped to build know-how and experience in green roof technology. Third, this long experience might explain why price levels are much lower than in the other three cities (see Table 5). Perceptions of respondents in Basel and Stuttgart confirm this. When asked about critical success factors, respondents mention the mandatory requirement, the green political climate, the independent jurisdictional status, and (in Basel only) the perseverance of the green roof consultant in promoting green roofs with the local authorities. According to respondents the requirement has not met with any major resistance in Basel; there was some resistance in Stuttgart but this was not severe enough to deter the local authorities from introducing the requirement. In fact, when asked about alternative arrangements in their cities to boost green roof technology, several respondents in London and Rotterdam indicated that a mandatory requirement would be the best way forward. They preferred the regulation rather than, for example, a subsidy, exactly because it creates an equal playing field and because it creates certainty over a longer period of time. Through regulation, cities can make use of urban regeneration cycles, which will foster organic growth of green roofs over time.

6. Conclusion

Green roofs represent a short-term no-regrets climate adaptation measure. In addition to raising urban sustainability more generally, they are able to buffer (excessive) rainfall in densely built urban environments without consuming space. Given the dependence of local governments on the private sector for green roof instalments on private property, and against the background of shifts in governance arrangements from government to governance, this paper has addressed the question of what type of governance arrangements between public and private actors have been put in place to stimulate the uptake of green roofs, for what reason and with what outcome.

Our research reveals that hierarchical arrangements dominate in the early stages of the policy process, with responsibilities being taken on by local authorities to secure adaptation action, as was seen in all five cities. The theoretical-economic literature on the public-private divide in adaptation supports this finding. This body of literature states that public adaptation goods need public responsibility (Berkhout 2005, Mendelsohn 2006, Stern 2007, Aakre and Rübhelke 2010a, Osberghaus *et al.* 2010), either to provide that good directly or to develop policy that motivates private actors to provide that good (also referred to as “privately provided adaptation public goods” in Tompkins and Eakin 2012). We might conclude that green roofs essentially deliver a local public good, i.e. the provision of dry feet, clean air, biodiversity etc. Nevertheless, our findings also suggest *when* and in *what way* public responsibility is salient and effective. Based on the cases of Basel and Stuttgart, it appears that, for a wide adoption of the green roof technology, hierarchical arrangements are needed throughout the policy process: public responsibility is apparent in roles for local authorities in each stage, supported by a balanced policy mix that combines different policy instruments (in particular simultaneous use of economic and regulatory instruments) over certain periods of time (employing economic and communicative instruments prior to the introduction of regulation). The spread of the green roof technology in the other three cities is still in its infancy, suggesting that enhanced public responsibility might need to be considered. This is not to say that private responsibility does not matter. The results in all five cities clearly signal the added value of private involvement in raising efficiencies through innovation. In particular the green roof industry has been active in lowering prices and in raising the benefits of green roofs, so as to make them more accessible.

By concluding that a dominant public responsibility is both feasible and indispensable for getting green roofs off the ground, this research provides a nuanced view on the shift from government to governance. Several empirical studies on the governance of climate adaptation seem to hint in a similar direction; that the planning of adaptation is often government-led (e.g. Storbjörk 2007, Johnson and Priest 2008, Mees and Driessen 2011). A recent study on network arrangements of public and private actors for climate adaptation by Juhola and Westerhoff (2011) also hints towards the need for a (prominent) role for national governments in the co-ordination of adaptation efforts across policy levels and sectors. Furthermore, our research suggests that hierarchical arrangements have several positive spin-offs. The cases of Basel and Stuttgart show that they might raise fairness because they guarantee a level playing field for all, and raise accountability in terms of clarity of responsibilities. Finally, these cases suggest that hierarchical arrangements can also be perceived as legitimate (in terms of receiving societal support) as long as the process preceding the arrangement is characterised by extensive consultation of key stakeholders (also referred to as throughput legitimacy).

This is not to say that alternative types of arrangements might not be feasible and effective for other climate adaptation issues. Issues that require adaptation to be mainstreamed with other policy sectors (Adger *et al.* 2005, Biesbroek *et al.* 2010, Berrang-Ford *et al.* 2011) increase the need for co-operation and hence might require interactive governance arrangements. Likewise, one could imagine market-governance to be more prevalent in sectors whose financial performance is very dependent on an adequate and timely response to climate change and whose goods can be traded, such as the insurance, infrastructure and agricultural sectors (Mendelsohn 2006). In order to gain a more complete picture of the governance of adaptation, it

will be necessary to explore the feasibility and effectiveness of governance arrangements along the continuum from government to governance. Future research could help discern the scope of governance arrangements for adaptation themes, such as water safety, heat stress and fresh water supply, on various geographical scales. This could help verify or falsify the need for a dominant public arrangement for climate adaptation. The analytical framework presented in this paper has provided a useful classification of these arrangements according to four parameters: responsible actors, steering strategy, policy instruments and key underlying considerations. We encourage other researchers to apply our framework for furthering empirical studies of governance arrangements for climate adaptation.

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Notes

1. Various studies show that rainfall retention of green roofs ranges from around 30% to nearly 90%, depending on the depth and material of the substrate, the vegetation used and the slope of the roof (see e.g. van Woert *et al.* 2005, Mentens *et al.* 2006, Villarreal 2007).
2. Green roofs prolong the roof life (Wong *et al.* 2003, Kosareo and Ries 2007); insulate buildings from both heat and cold, thus reducing energy bills for heating in the winter and air conditioning in the summer (Wong *et al.* 2003, Sailor 2008); insulate against noise (van Renterghem and Botteldooren 2011); have higher (perceived) aesthetic values than a regular roof (White and Gatersleben 2011) and might therefore raise the value of a property.
3. In the (environmental) governance literature, deliberative network arrangements are claimed both to enhance and to reduce democratic values such as legitimacy and democracy (for a discussion see e.g. Bogason and Musso 2006, Lemos and Agrawal 2006, Juhola and Westerhoff 2011).
4. The supplementary materials (online only) consist of a detailed overview of the respondents and the interview guide.
5. In Chicago, primarily the Department of Zoning and Planning and the Mayor's office; in Rotterdam, primarily the departments of water management and of Rotterdam Climate Proof; in Stuttgart, primarily the department of Urban Planning. In Basel, the Canton authorities are the main public actor, in particular the 'Stadtgärtnerei' (the urban greening department); and in London the Greater London Authority, the Environment Agency and the planning departments of the 33 boroughs.

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