

Global governance principles for the sustainable development of groundwater resources

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Abstract A normative framework for the governance of groundwater is emerging at the global level. However, existing analyses have not comprehensively covered all the governance texts that have a bearing on transboundary groundwater resources or looked at them from the perspective of sustainable groundwater governance. Therefore, this paper responds to the questions: What are the global governance texts (including international laws) applicable to groundwater resources; to which forms of the resource do they apply; which principles have been included over time; and what are the implications for sustainable development of groundwater resources now and in the future? The analysis highlights key groundwater concepts, discusses twelve global groundwater governance texts and the thirty principles therein, classifies the principles into ideal–typical categories based on the sustainable development concept; and assesses the gaps and conflicts between the principles and texts. The paper has three key findings. First, groundwater governance is rapidly evolving and there are a number of principles available to promote sustainable development. Second, however, these collective principles do not adequately address (a) the link with all water resources; (b) the potential impact of climate change on water resources; and (c) the impact of trade on equitable sharing of groundwater and protection

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of groundwater-related ecosystems. Third, to the extent that this collection of principles can contribute to sustainable development, they are inconsistently included in the legally binding groundwater governance texts. Therefore, much progress is needed to ensure a global normative framework that can guide the sustainable governance of groundwater resources.

Keywords Groundwater governance · Transboundary aquifers · Sustainable development · Groundwater sustainability · International groundwater law · Law of transboundary aquifers · Principles for groundwater governance

Abbreviations

ECOSOC	United Nations Economic and Social Council
HRC	Human Rights Council
ICJ	International Court of Justice
ICWE	International Conference on Water and the Environment
IGRAC	International Groundwater Resources Assessment Centre
ILA	International Law Association
ILC	International Law Commission
IWRM	Integrated Water Resources Management
PCA	Permanent Court of Arbitration
SDGs	Sustainable Development Goals
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNGA	United Nations General Assembly
WCED	World Commission on Environment and Development

1 Introduction

Groundwater constitutes 98–99 % of the world's available freshwater resources (Margat and van der Gun 2013: p. 5). Nearly 600 groundwater resources traverse political boundaries (International Groundwater Resources Assessment Centre (IGRAC) 2015a, b), and an unknown number solely reside within country borders. Approximately, 25 % of humans rely on groundwater for their domestic needs (Machard de Gramont et al. 2011) and 50 % use it for potable water supply (Mechlem 2003). Groundwater supplies over 40 % of irrigation needs globally (Döll and Hoffmann-Dobrev 2012; Siebert et al. 2010), partly due to increased reliability of individual irrigation wells over public surface water distribution schemes (Shah 2009a). Additionally, groundwater makes up 50 % of municipal and 40 % of industrial water withdrawals (Zektser and Everett 2004); thereby catalyzing growth, development and poverty alleviation (Shah 2009b; Wijnen et al. 2012). However, many aquifers are in jeopardy due to poor governance (Llamas and Martínez-Santos 2005) and insufficient legal frameworks that lack consideration for hydrogeological complexities and/or socio-political, environmental and economic aspects.

The literature has analyzed individual treaties (Eckstein 2007; McCaffrey 2011; McIntyre 2006; McIntyre 2011) or a combination thereof (Dellapenna 2011; Eckstein and

Sindico 2014; Mechlem 2003). Several analyses relate to the six transboundary aquifers that have aquifer-specific legal mechanisms;¹ others to one or more of the 89 out of 196 countries that have groundwater regulations (IGRAC 2015a, b). However, no one has comprehensively assessed the norms in all relevant groundwater governance texts from the perspective of sustainable groundwater governance. Such an assessment becomes all the more relevant in the light of the recent entry into force of the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Watercourses Convention 1997); the opening of the United Nation Economic Commission for Europe Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE Convention 1992) to accession by all UN member states (see Sect. 3); and the September 2015 adoption of the Sustainable Development Goals by 193 UN member states (UN SDGs 2015). Hence, this paper addresses the questions: What global governance texts apply to groundwater resources; to which types of groundwater resources do they apply; which principles have been included over time; and what are the implications for sustainable development of groundwater resources now and in the future?

This paper treats sustainable development and Integrated Water Resources Management (IWRM) as overarching concepts, rather than single principles; although they are mentioned as principles in several governance texts.² Sustainable development “aims to meet the needs of present generations without compromising on the ability of future generations to meet their own needs” (WCED 1987: 43) and can be operationalized through legal principles (Fuentes 2002; Rieu-Clarke 2000). Groundwater sustainability implies the development and use of groundwater without causing unacceptable long-term environmental, economic or social consequences through integrated, adaptive and inclusive governance (Custodio 2002; Gleeson et al. 2012; Gleeson and VanderSteen 2010; Llamas et al. 1992). IWRM calls for coordinated management of water-related resources (Biswas 2004; Global Water Partnership 2002: 22); adaptive governance for dealing with the inherent uncertainties of the system; and inclusive governance to focus on the socio-ecological dimensions.

This paper explains key groundwater concepts (see Sect. 2), global groundwater governance texts (see Sect. 3), and assesses the principles that emerge from these texts in terms of social, environmental and economic dimensions of sustainable development (see Sect. 4); before drawing conclusions (see Sect. 5).

2 Groundwater: physical and political typologies

Groundwater is water that fully saturates the pores and cracks of the earth’s subsurface geology (Fitts 2002). It is primarily formed after percolating from the earth’s surface through the soil and into the underlying geological formation, but it may have also been trapped during geologic processes, such as sedimentation or volcanic activity. Depending on the geology below (e.g., sand, clay, gravel, fractured rock), groundwater can accumulate into a distinct formation called an aquifer and often flows slowly through the subsurface.

¹ These agreements are listed in Eckstein and Sindico’s (2014) publication. Since then, the Al-Sag/Al-Disi Aquifer Agreement (2015) was signed.

² Sustainable development is included as a principle in the UN Rio Declaration (1992), UNECE Convention (1992) and Protocol (1999) as “sustainable use,” ILA Berlin Rules (2004) as “sustainable use” and action agenda of the ICWE Dublin Statement (1992). IWRM is included in the ILA Seoul Rules (1986), UN Agenda 21 (1992), and ILA Berlin Rules (2004).

An aquifer is a permeable layer of underground rock, which is saturated with and capable of yielding groundwater (Fetter 2001; Fitts 2002). Sometimes a groundwater resource is only defined as an aquifer when it has yield sufficient for human use. Aquifers can be unconfined, where the water table occurs within the aquifer layer and the groundwater is in direct contact with the atmosphere through soil pores, or confined, where it is over- and underlain by a semi-permeable or impermeable layer (Fitts 2002; Margat and van der Gun 2013). A non-recharging aquifer, containing “fossil” groundwater, does not receive meaningful recharge on a human timescale. Political typologies of aquifers include national aquifers completely contained within state boundaries; national aquifers hydrologically linked with international watercourses; and transboundary aquifers shared by two or more states.

3 Evolution of groundwater governance texts at the global level

This section discusses global groundwater governance texts (see Table 1) in terms of the political and hydro(geo)logical typologies mentioned above (see Table 2). Scholars within the International Law Association (ILA) codified the principles for governing international rivers in the non-binding Helsinki Rules on the Uses of the Waters of International Rivers (ILA Helsinki Rules 1966). In Article II, an International Drainage Basins is defined as a “geographical area extending over two or more States...including surface and underground waters flowing to a common terminus.” This includes groundwater that is hydrologically connected to a transboundary surface water feature and flows toward a common point of discharge area.

In 1972, the world’s first environmental conference adopted the Declaration of the United Nations Conference on the Human Environment which addressed human–environment interactions and water resources (UN Stockholm Declaration 1972, Preamble, Principle 2). The UN’s first water conference adopted the Mar del Plata Action Plan and Recommendations (UN Mar del Plata Plan 1977) clarifying norms for water management and mentioning groundwater in relation to water supply for domestic and agricultural use.

In 1986, the ILA published its Seoul Rules on International Groundwaters (ILA Seoul Rules 1986), where these scholars already suggested focusing on aquifers, not groundwater. It went beyond the Helsinki Rules to include: “the waters of an aquifer that is intersected by the boundary between two or more States [...] *whether or not* the aquifer and its waters form surface waters part of a hydraulic system flowing into a common terminus” (Article I, emphasis added).

In 1992, at the second global environmental conference, the Brundtland Commission’s exploration of sustainable development (WCED 1987) and the UN Stockholm Declaration (1972) influenced the Rio Declaration on Environment and Development (UN Rio Declaration 1992) and the accompanying non-binding action plan, Agenda 21 (1992) (Dellapenna and Gupta 2009). The Rio Declaration contains 27 environmental governance principles some of which are further assessed here; Agenda 21 is highlighted where relevant. That same year, many countries and NGOs adopted the ICWE Dublin Statement on Water and Sustainable Development (ICWE Dublin Statement 1992) at the International Conference on Water and the Environment with four principles recognizing the finite nature of water, the need for participatory processes, the role of women, and water as an economic good.

In the same year, the UN Economic Commission for Europe adopted the regional, Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE 1992). It covers “ground waters...which mark, cross or are located on boundaries between two or more States” (UNECE 1992: Art. 1.1). Its Protocol on Water and Health (UNECE 1999) focuses on protecting human health and well-being through

water management. In 2013, amendments allowing all UN member states to accede to it entered into force (UNECE 2003)—making it global. In 2014, the UNECE adopted Model Provisions on Transboundary Groundwater Management, which “provide practical guidance” and “offer assistance” to the parties in creating agreements for the sustainable use, management and protection of groundwater (UNECE 2014: p. 3, para. 9). These Provisions apply both to groundwater and the geological formation containing the groundwater, subtly shifting from groundwater to aquifer.

In 1997, the UN member states adopted the UN Watercourses Convention (1997), culminating a 30-year process led by the UN’s International Law Commission (ILC). It entered into force in 2014 and is binding for its parties. This Convention applies to international watercourses defined as a “system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus [...] parts of which are situated in different States” (UN Watercourses Convention 1997, Article 2a). It focuses on surface water systems and some connected groundwater resources. There is debate as to whether it applies to two situations: first, where an aquifer hydrologically links two surface water bodies with different termini and second where a confined aquifer is linked to an unconfined aquifer or surface water body but would still constitute distinct systems rather than a “unitary whole” (Mechlem 2003). This issue is being gradually clarified by legal experts. However, the UN Watercourses Convention does not cover aquifers that lack hydrologic connection to surface water.

This gap was addressed in the ILC’s non-binding Berlin Rules on Water Resources (ILA Berlin Rules 2004), which updated its Helsinki Rules. The ILA Berlin Rules proposes that states apply the rules to transboundary and national resources, “as appropriate” (ILA 2004b: Article 1.2; Dellapenna 2011) and are controversial as a result (Bogdanovic et al. 2004). Nevertheless, its contents contribute to normative developments in groundwater governance.

The UN ILC prepared the Draft Articles on the Law of Transboundary Aquifers (ILC Draft Articles 2008) in response to the gap in scope of the UN Watercourses Convention and the developments in the ILA Berlin Rules. The Draft Articles define an aquifer as “a permeable water-bearing geological formation underlain by a less permeable layer and the water contained in the saturated zone of the formation” and include all aquifers where its “parts ... are situated in different States” (ILC Draft Articles 2008: Art. 2a, 2c). Although thrice reviewed by UN member states, delegates still disagree about whether the Draft Articles should be a declaration of principles, an international framework convention, or remain a non-legally binding document. Consequently, it is a provisional agenda item for the UNGA’s 71st session in September 2016.

The UN Human Rights Commission and UNGA adopted resolutions on the human right to water and sanitation in 2010, not only advancing rights-based approaches to (ground)water governance, but also having implications for the use and development of all groundwater resources (UN HRC 2010; UNGA 2010). In September 2015, the UN member states adopted the SDGs, which calls for the sustainable management of all fresh water resources. It implicitly includes groundwater, but does not apply any principles specifically to it.

Thus, the evolution of global groundwater governance texts has been nonlinear, influenced by developments in different fora, and is rapidly accelerating (see Table 1). This evolution has resulted in texts defining and including groundwater differently in their scopes (see Table 2). Only the Berlin Rules and Draft Articles explicitly define an aquifer and mention “layers of geological strata” (Article 3.2 in ILA 2004) and “aquifer systems” respectively (Eckstein 2007; ILC 2008). The Helsinki Rules and UN Watercourses Convention are ambiguous with respect to the types of links between ground and surface water, including multilayered aquifer systems.

Table 1 Status and ratifications of governance texts applicable to groundwater resources

Text	Date	Legal status	Ratifying parties		
ILA Helsinki Rules	1966	Academic list of rules, non-binding	Not applicable		
UN Stockholm Declaration	1972	Adopted by states, non-binding rules	Not applicable		
UN Mar del Plata Action Plan	1977	Adopted by states, non-binding rules	Not applicable		
ILA Seoul Rules	1986	Academic list of rules, non-binding	Not applicable		
ICWE Dublin Statement	1992	Adopted, non-binding principles	Not applicable		
UN Rio Declaration	1992	Adopted, non-binding declaration	Not applicable		
UNECE Convention	1992	Ratified, in-force treaty	Albania Austria Azerbaijan Belarus Belgium Bosnia and Herzegovina Bulgaria Croatia Czech Rep Denmark Estonia E.U. Finland Latvia	Liechtenstein Lithuania France Germany Greece Hungary Italy Kazakhstan Luxembourg Netherlands Norway Poland Portugal Republic of Moldova	Romania Russia Serbia Slovakia Slovenia Spain Sweden Switzerland Turkmenistan Ukraine U.K. Uzbekistan
UN Watercourses Convention	1997	Ratified, in-force treaty	Benin Burkina Faso Chad Côte d'Ivoire Denmark Finland France Germany Greece Guinea-Bissau Hungary Iraq Ireland	Italy Jordan Lebanon Libya Luxembourg Montenegro Morocco Namibia Netherlands Niger Nigeria Norway Palestine	Paraguay Portugal Qatar South Africa Spain Sweden Syria Tunisia U.K. Uzbekistan Venezuela Viet Nam Yemen
UNECE Protocol	1999	Ratified, in-force protocol to treaty	Albania Azerbaijan Belarus Belgium Bosnia and Herzegovina Croatia Czech Republic Estonia Finland	France Germany Hungary Latvia Lithuania Luxembourg Netherlands Norway Moldova Portugal	Romania Russia Serbia Slovakia Spain Switzerland Ukraine
ILA Berlin Rules	2004	Academic list of rules, non-binding	Not applicable		
ILC Draft Articles	2008	Awaiting adoption by states	Not applicable		
UN HRC; UNGA	2010	Adopted, non-binding resolutions	Not applicable		

Table 2 Governance texts and types of groundwater addressed

Text	Scope/definition	Types(s) of groundwater		
		Included	Excluded	Ambiguous
ILA Helsinki Rules	International Drainage Basins: Watershed limits of system of waters, including surface and underground waters, flowing into a common terminus	<ul style="list-style-type: none"> • Groundwater from unconfined aquifers, recharging and discharging in basin • Groundwater from unconfined aquifers, only discharging in basin • Groundwater in unconfined aquifers, which is the common terminus of a watercourse 	<ul style="list-style-type: none"> • Groundwater in unconfined aquifers, only recharging in basin • Groundwater in confined, non-recharging aquifers 	<ul style="list-style-type: none"> • Groundwater linking multiple surface water bodies with different termini • Distinct groundwater systems with links to surface water • Multilayer aquifer systems
UN Mar del Plata	Shared waters	Transboundary groundwater resources implicitly	–	–
ILA Seoul Rules	<ul style="list-style-type: none"> • An aquifer that contributes water to, or receives water from, surface waters of an international basin that constitutes part of an international basin for the purposes of the Helsinki Rules • An aquifer intersected by the boundary between two or more States that does not contribute water to, or receive water from, surface waters of an International Drainage Basin constitutes an International Drainage Basin for the purposes of the Helsinki Rules 	All transboundary aquifers	Groundwater outside an aquifer	–
ICWE Dublin Statement	All waters	All groundwater implicitly	–	–
UNECE Convention and Protocol	Transboundary Surface and Groundwater: Any surface or ground waters that mark, cross or are located on boundaries between two or more States	All transboundary groundwater ^a	–	–

Table 2 continued

Text	Scope/definition	Types(s) of groundwater		
		Included	Excluded	Ambiguous
UN Watercourses Convention	International Watercourses: A system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus	<ul style="list-style-type: none"> Groundwater from unconfined aquifers, recharging and discharging in a basin Groundwater from unconfined aquifers, only discharging in a basin Groundwater in unconfined aquifers, which is the common terminus of a watercourse All transboundary aquifers National aquifers, as appropriate 	<ul style="list-style-type: none"> Groundwater in unconfined aquifers, only recharging in a basin Groundwater in confined, non-recharging aquifers 	<ul style="list-style-type: none"> Groundwater linking multiple surface water bodies with different termini Distinct groundwater systems with links to surface water Multilayer aquifer systems
ILA Berlin Rules	Water of International Drainage Basins and all waters, including all aquifers where “aquifer” means a subsurface layer or layers of geological strata of sufficient porosity and permeability to allow either a flow of or the withdrawal of usable quantities of groundwater	<ul style="list-style-type: none"> All transboundary aquifers National aquifers, as appropriate 	–	–
ILC Draft Articles	Transboundary aquifers and aquifer systems where: <ul style="list-style-type: none"> “Aquifer” means a permeable water-bearing geological formation underlain by a less permeable layer and the water contained in the saturated zone of the formation; “Aquifer system” means a series of two or more aquifers that are hydraulically connected 	All transboundary aquifers and aquifer systems	Groundwater outside an aquifer	–
UN HRC/UNGA	All waters	All groundwater implicitly	–	–

The UN Stockholm Declaration and UN Rio Declaration are not included here because their scope is not specific to water

^a The UNECE Model Provisions also include the geologic formation containing and allowing flow of groundwater

4 Principles, rights and measures applicable to groundwater

4.1 Principles applicable to groundwater and their classification

The twelve key groundwater governance texts discussed above include thirty principles, rights and measures (hereafter called “principles”) as explained in Table 3. These principles are categorized into the environmental, social and economic dimensions of sustainable development with an additional general governance category. Although some principles cross multiple dimensions, each principle is given a primary designation. These principles have emerged from different historical stimuli and range in the degree to which they are considered legally binding or have attained customary status in international law. The analysis below focuses on the content of these principles, their inclusion in groundwater governance texts (illustrated in tables), and their ability to contribute to sustainable development. All tables in this paper list the principles in alphabetical order; there is no implicit prioritization in their listing.

Figure 1 shows that an increasing number of principles have been integrated into global groundwater governance texts over time. These texts have evolved from including an average of six legal principles prior to 1992, to more than twelve principles from 1992 onwards, indicating an increased sophistication in the global groundwater governance regime. Yet this progression has also led to gaps and conflicts in *how and when* these principles are included in governance texts.

4.2 General principles applicable to groundwater

Table 4 shows which governance texts have adopted the general principles of transboundary governance. These principles support sustainable development of transboundary groundwater resources by providing a foundation for cooperative and peaceful interaction between states.

The principles of cooperation, peaceful resolution of disputes and information exchange are also considered customary law (McCaffrey 1987)—i.e. “the collection of international behavioral regularities that nations over time come to view as binding on them as a matter of law” (Goldsmith and Posner 1998: 1116). Since 1972 most agreements require states to cooperate with respect to transboundary waters and to resolve disputes peacefully (PCA 1910), as codified in relation to water (ILA Helsinki Rules 1966: Art. II) and institutionalized in the UN Watercourses Convention (1997). Most agreements and codifications since 1977 call on riparian/aquifer states to exchange relevant water information and data (see UNECE 1992, Art. 11).

A fundamental principle of international law is state sovereignty (UN Charter 1945; UNGA 1963). Historically, states have claimed sovereignty (e.g., absolute territorial sovereignty and absolute integrity of state territory) over water resources within their territory and used it to opt in and out of international agreements, affecting interstate cooperation. Consequently, the applicability of the sovereignty principle to (ground)water resources has been the subject of debate (Dellapenna 2011; Eckstein and Sindico 2014; Eckstein 2007, 2011; McCaffrey 2009, 2011; Yamada 2011). Sovereign control over territorial resources, subject to not causing harm to others, was included in the Stockholm, Mar del Plata and Rio Declarations. However, it was excluded from all scholarly codifications and laws on international waters since then, until the 2008 ILC Draft Articles (see

Table 3 Simple explanations of principles/rights from groundwater governance texts**General: Riparian/aquifer states shall/should/must/may**

Exchange of information	Share relevant information with each other
Obligation to cooperate	Engage cooperatively with each other and act in good faith
Peaceful resolution of disputes	Settle disputes peacefully through negotiation, conciliation, mediation, consultation of good offices, arbitration and/or tribunal
Sovereignty	Do what they wish within their territories (within limits)
Primarily social	
Common but differentiated responsibilities and respective capabilities	Share obligations based on their responsibility for causing the problem and their ability to address the problem
<i>Equitable and reasonable use</i>	<i>Share transboundary waters based on each other's conditions and contexts</i>
<i>Human right to sanitation^a</i>	<i>Ensure that all humans have a right to access improved and safe sanitation facilities</i>
<i>Human right to water^a</i>	<i>Ensure that all humans have a right to access improved and clean water sources</i>
Prior informed consent	Inform and receive the consent of other states (or individuals) for activities that may affect them
<i>No priority of use</i>	<i>Recognize there is no inherent priority of uses for water; however, special attention may be given to vital human needs</i>
Public access to information	Provide the public access to information collected, procedures followed and decisions made by their governments
Public participation	Encourage the participation of the public or stakeholders in decision-making processes
Rights of women, youth and indigenous peoples	Account for the rights of individuals/groups in its decision-making process
Primarily environmental	
<i>Basin as unit of management^b</i>	<i>Use the water basin or watercourse as unit for policy-making and implementation</i>
Best available technology/technique	Use the best technology/techniques available to reduce environmental harm
<i>Conjunctive use and management</i>	<i>Account for hydrological relationships between surface and groundwater resources in management and policy decisions</i>
Environmental Impact Assessment	Require project developers to assess potential (transboundary) impacts
Monitoring	Monitor groundwater quality and quantity
No significant harm	Not cause harm to other states; this limits the sovereign rights of a state
<i>Notification of accidents</i>	<i>Notify other potentially impacted states following an accident (e.g., industrial spills)</i>
<i>Notification of emergency situations</i>	<i>Notify other potentially impacted states during emergencies (e.g., droughts or floods)</i>
<i>Notification of planned measures</i>	<i>Notify other possibly impacted states of plans with potential (transboundary) impacts</i>
Pollution prevention	Take measures to prevent pollution
Precautionary principle	Take precautionary action to prevent irreversible harm even when there is inconclusive scientific evidence on cause and effect

Table 3 continued

Protection and preservation of ecosystems	Take measures to protect and preserve ecosystems
<i>Protection of recharge and discharge zones^b</i>	<i>Take measures to protect groundwater discharge and recharge zones</i>
Subsidiarity	Take action at the lowest appropriate level of governance
Primarily economic	
Open international economic system	Not adopt actions that could affect the principles of international trade
Polluter pays	Require that polluters internalize the costs of pollution
<i>Water as an economic good</i>	<i>Recognize water has an economic value and should be considered an economic good</i>

Principles in italics are specifically applicable to water resources

^a Although the human right to water and sanitation is a composite right in the UN General Assembly’s text on the subject, it is separated here because most texts assessed do so

^b Also included as principles here because they are strong starting points for water governance

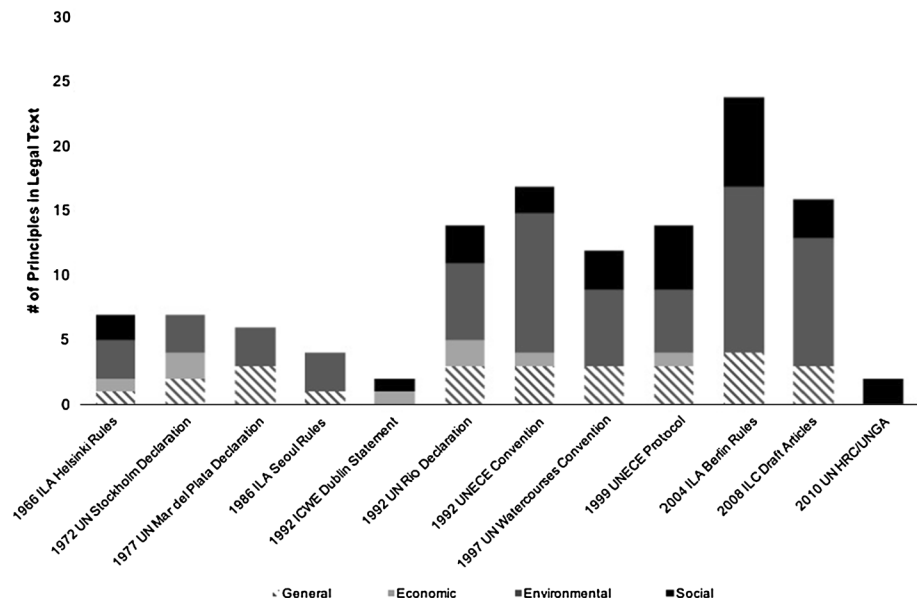


Fig. 1 Types of principles/rights in global governance texts

Article 3). Legal commentaries on the ILC Draft Articles indicate that countries wanted groundwater resources to be treated like other “similar” underground resources such as oil and gas (Eckstein 2007; ILC 2004). Some argue this reverses decades of progress in international water law (McCaffrey 2011; McIntyre 2011; Tanzi 2011). Others say sovereignty is “balanced” by the provisions on equitable and reasonable use of water, not causing significant harm to others, and the obligation to cooperate in managing

Table 4 General principles in global governance texts applicable to groundwater resources

	IL/A Helsinki Rules	1966	UN Stockholm Declaration	1972	UN Mar del Plata Declaration	1977	IL/A Seoul Rules	1986	ICWE Dublin Statement	1992	UN Rio Declaration	1992	UNECE Convention	1992	UN Watercourses Convention	1997	UNECE Protocol on Water and Health	1999	IL/A Berlin Rules	2004	ILC Draft Articles	2008	UNHCR/ UNGA	2010
Exchange of information			✓		✓		✓			✓			✓		✓		✓		✓					✓
Obligation to cooperate			✓		✓					✓			✓		✓		✓		✓					✓
Peaceful resolution of disputes	✓										✓		✓		✓				✓					
Sovereignty			✓		✓					✓							✓		✓ ^a					✓

^a "State" means a sovereign state or a regional economic integration organization, there is no further reference to sovereignty with respect to water

transboundary aquifers (Eckstein 2007; Sindico 2011; Stephan 2011; Yamada 2011). Nevertheless, inclusion of the sovereignty principle could affect the achievement of sustainable development if used to avoid implementation of other groundwater governance principles.

4.3 Social principles applicable to groundwater

Table 5 shows the extent to which the nine identified social principles have been included in groundwater governance texts.

Internationally, there is no clear pattern of an increasing use of social principles or consistency between the applications of social principles in relation to groundwater governance, possibly because of tensions among the principles. While the principle of common but differentiated responsibility and respective capability of states is included in the Rio Declaration, this principle is not included in groundwater-specific texts. Doing so would mean that countries would also have to implement the other principles in accordance with their respective responsibilities and capabilities. This would have added additional factors to the existing list of factors included in the Watercourses Convention to determine how water can be shared equitably and reasonably.³

Similarly, the principle that there is no priority of use of water can potentially counter the human right to water and sanitation. With the exception of the ILA Berlin Rules (2004), agreements either choose the principle of no priority of use or the human right to water. The UN Watercourses Convention (1997: Art. 10) does not recognize a priority in water uses. The right to water and sanitation is included in UNHRC (2010) and UNGA (2010); the Berlin Rules (2004: Art 17) recognizes only the human right to water and the UNECE Protocol (1998: Art 6) implicitly recognizes state responsibility in this respect. This implies inconsistent rules (Obani and Gupta 2014), especially if the customary status of this right is contested (Bluemel 2004; UN ECOSOC 2003; Gleick 1998; Gupta et al. 2010; McCaffrey 1992; McIntyre 2012; Ziganshina 2008).

The remaining principles are interdependent and could collectively contribute to the social dimension of sustainable development. The rights of women, youth and indigenous peoples are elaborated in human rights law but not included in any legally binding groundwater governance text. The principle of prior informed consent supports the fulfillment of these rights and is framed as “express consent” in the governance texts. It is included in the ILA Berlin Rules (2004: Art 10) and placed within the context of notification of planned measures in the UN Watercourses Convention (1997: Art 3.4, 14(b)) and the ILC Draft Articles (2004: Art 9). The participation principle has been included in the UN Rio Declaration (1992: Principle 10), ICWE Dublin Statement (1992: Principle 2), UNECE Protocol (Arts. 5, 6, 16) and alluded to in the scholarly ILA Berlin Rules (2004: Arts. 4, 17, 20). Public access to information is only arranged in the UNECE Convention (1992: Art. 16) and Protocol (1997: Art 5(i)).

The combination of these social rights is critical for sustainable development. Yet, as can be seen, they have been included sporadically in the groundwater governance texts. In fulfilling these social principles, the potential impacts to the ecological sustainability of groundwater must also be considered.

³ This principle is suggested in the scholarly Helsinki Rules and included in the Watercourses Convention (1997: Art. 5 and 6), the UNECE Convention (although not elaborated) and Draft Articles (2008: Art. 4, 5).

Table 5 Social principles in global governance texts applicable to groundwater resources

	IL-A Helsinki Rules	1966	1972	1977	1986	1992	1992	1992	1992	1992	1997	1999	2004	2008	2010
	IL-A Stockholm Declaration	UN Mar del Plata Declaration	IL-A Seoul Rules	ICWE Dublin Statement	UN Rio Declaration	UNECE Convention	UNECE Convention	UN Watercourses Convention	UNECE Protocol on Water and Health	2004	2008	2010	ILC Draft Articles	UNHRC/ UNGA	
Common but differentiated responsibilities and respective capabilities							✓								
Equitable and reasonable use	✓					✓		✓		✓			✓		
Human right to sanitation									✓ ^a						✓
Human right to water									✓ ^a	✓					✓
No priority of use	✓									✓ ^b			✓ ^b		
Prior informed consent										✓ ^c			✓ ^d		✓ ^e
Public access to information							✓		✓						
Public participation				✓					✓				✓ ^e		
Rights of women, youth, and indigenous peoples							✓						✓		

^a Not framed as right, but as a state responsibility

^b These documents adopt the principle of no priority of use, but give vital human needs attention

^c Framed within procedures of notification of planned measures

^d Called “expressed” consent

^e Including that of women, youth and indigenous peoples

4.4 Environmental principles applicable groundwater

Table 6 illustrates how environmental principles are included in groundwater governance. These fourteen principles facilitate sustainable development through (a) resource-based management (b) principles on preventing harm (including over-exploitation and pollution prevention) and (c) notification procedures. The principle of basin management requires that hydrological rather than administrative units are used for groundwater management. Using this principle also facilitates subsidiarity (management at the lowest appropriate level) and conjunctive use and management when groundwater is appropriately included in the scope. However, these principles are hardly used. They are also limited because at the global level, groundwater resources outside of transboundary aquifers/basins are not fully included in the scope. This presents a practical challenge since politics is a function of administrative units not aquifers and river basins.

Several environmental principles depend on and/or support each other. The principle of no significant harm has been included in all global groundwater governance texts since the UN Watercourses Convention in 1997. This principle would prevent states from significantly impacting other aquifer states and would require them to implement pollution prevention principles to maintain groundwater quality and prevent over-abstraction throughout the transboundary aquifer. Use of best available technologies and resource monitoring would support these efforts. While technologies could reduce contaminant loads in water recharging to aquifers or remediate contaminated resources, the principle is only included in two texts—the UNECE Convention (1992: Art. 3) and the ILC Berlin Rules (2004: Art. 27)—as well as in the groundwater protection activities of Agenda 21 (1992). Monitoring, which is also critical to pollution prevention, has been included in half global groundwater governance texts since the 1977 Mar del Plata Declaration and pollution prevention in slightly more. However, in practice there is a lack of aquifer-specific data regarding the quality and quantity of groundwater. Thus, the precautionary principle is highly relevant and the legal approach to management should include measures that protect the resource from over-exploitation or irreparable contamination. Yet, it is not included in the UN Watercourses Convention (1997) and only included for pollution in the ILC Draft Articles (2008). Consequently, many aquifers/basin states may lack the practical and legal means to prevent significant harm to groundwater resources, especially because no environmental principles explicitly deal with over-abstraction.

Planned actions, such as diverting a watercourse that recharges an aquifer or abstracting groundwater during mining, may impact the state of the groundwater resource. The principle of notification of planned measures would require that states potentially affected by the projects receive advanced notification. States are also obliged to notify other aquifer states during emergencies such as droughts or accidents such as industrial spills. Each of these notification principles is included in most texts from 1992 onwards. Conducting environmental impact assessments, as included in the UNECE Convention (1992: Art. 3h) and ILC Berlin Rules (2004: Art 29) and suggested as a means of consultation in the UN Watercourses Convention (1997: Art. 12), and the ILC Draft Articles (2008: Art.15), would allow countries to account for any potentially significant harm that a project may cause to groundwater. The obligation to conduct environmental impact assessments might soon become a customary law obligation (ICJ Pulp Mills case 2010: para. 204; Eckstein and Sindico 2014). This indicates a convergence with regard to notification and impact assessment procedures in groundwater governance, which is further supported by the general principles of cooperation and information exchange. In general, the large number

Table 6 Environmental principles in global governance texts applicable to groundwater resources

	ILA Helsinki Rules 1966	UN Stockholm Declaration 1972	UN Mar del Plata Declaration 1977	ILA Seoul Rules 1986	ICWE Dublin Statement 1992	UN Rio Declaration 1992	UNECE Convention 1992	UN Watercourses Convention 1997	UNECE Protocol on Water and Health 1999	ILA Berlin Rules 2004	ILC Draft Articles 2008	UNHRC/ UNGA 2010
Aquifer/Basin as management unit	✓			✓			✓	✓		✓		✓
Best available technology/ techniques							✓			✓		
Conjunctive use and management				✓						✓		
Environmental impact assessment						✓	✓			✓		✓ ^a
Monitoring			✓	✓ ^c			✓			✓ ^d	✓	✓
No significant harm		✓				✓ ^e	✓ ^f	✓	✓	✓	✓	✓
Notification of accidents							✓ ^g		✓ ^h	✓		✓
Notification of emergency situations							✓			✓ ^h		✓
Notification of planned measures	✓						✓			✓		✓
Pollution prevention	✓	✓	✓	✓			✓			✓		✓

Table 6 continued

	ILA Helsinki Rules	1966	UN Stockholm Declaration	1972	UN Mar del Plata Declaration	1977	ILA Seoul Rules	1986	ICWE Dublin Statement	1992	UN Rio Declaration	1992	UNECE Convention	1992	UN Watercourses Convention	1997	UNECE Protocol on Water and Health	1999	ILA Berlin Rules	2004	ILC Draft Articles	2008	UNHRC/ UNGA	2010	
Precautionary principle										✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	
Protection and preservation of ecosystems			✓							✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	
Protection of recharge and discharge zones																									✓
Subsidiarity																									✓

^a Not obliged; can be requested
^b Emergencies and accidents called "extreme conditions"
^c "Data collection" and monitoring is done at the request of other watercourse states
^d Framed as duty to acquire data
^e Framed as not causing damage beyond harmful limits
^f Falls under definition of "transboundary impact"
^g Both emergencies and accidents called "critical situations"
^h Specific to outbreaks of disease
ⁱ Only for pollution
^j Uses "environment" not "ecosystem"

of environmental principles being discussed would suggest that if comprehensively adopted and implemented in legally binding agreements, the resource would be well-protected. However, true sustainability may be compromised by a lack of principles designed to cope with climate change.

4.5 Economic principles applicable to groundwater

Table 7 illustrates how the three identified economic principles are included in groundwater governance.

The polluter pays principle requires polluters to internalize the costs of pollution. It is the most-included economic principle, although still appearing sporadically in governance texts. Interestingly it is not always paired with principles for preventing pollution/harm or protecting ecosystems, principles which it supports. Since many products traded internationally use groundwater in their production processes, the principle of promoting an open international economic system is important in groundwater governance. It facilitates economic growth by ensuring that environmental trade policies are non-discriminatory and do not constitute a “disguised restriction on international trade” (Rio Declaration: Principle 12). The principle of water as an economic good was promoted by the ICWE Dublin Statement (1992: Principle 4) and is given significant attention within IWRM through water pricing and cost recovery mechanisms (Rogers et al. 1998; Savenije and van der Zaag 2002; Solanes et al. 1999) as applied by funding agencies.

Although water as an economic good and maintaining an open international system are not addressed in the global water governance texts (see Table 7), these principles are implemented *de facto* in trade regimes leading to increasing demand for water intensive products (Vörösmarty et al. 2015) and through “market environmentalism” which passes on economic and environmental costs to water users (Bakker 2007). In other words, the costs of these activities are simultaneously incorporated in water prices but excluded from prices of groundwater intensive products across the world, possibly shifting financial burdens to countries and affecting implementation of rights-based approaches and ecosystems protection.

5 Conclusions and recommendations

This paper assessed twelve key international groundwater governance texts (see Table 1) using a normative framework of thirty principles categorized according to the dimensions of sustainable development (Table 3). The assessment has shown that, for the most part, the principles necessary to achieve sustainable groundwater governance are present in the framework, but are not necessarily included in the formal legally binding documents applicable to groundwater. This leads us to three overarching conclusions.

First, groundwater governance has evolved rapidly in the last 25 years and includes an increasing number of principles (see Fig. 1). This is a positive trend in that collectively these principles could potentially promote sustainable development and use of groundwater resources.

Second, however, the framework of these collective principles does not adequately address (a) the link with all water resources including other groundwater resources; (b) the potential impact of climate change on water resources; and (c) the impact of trade on equitable sharing between regions and protection of groundwater-related ecosystems.

Table 7 Economic principles in global governance texts applicable to groundwater resources

Year	IL/A Helsinki Rules	UN Stockholm Declaration	UN Mar del Plata Declaration	IL/A Seoul Rules	ICWE Dublin Statement	UN Rio Declaration	UNECE Convention	UN Watercourses Convention	UNECE Protocol on Water and Health	IL/A Berlin Rules	ILC Draft Articles	UNHRC/ UNGA
	1966	1972	1977	1986	1992	1992	1992	1997	1999	2004	2008	2010
Open international economic system						✓						
Polluter pays ^a	✓					✓	✓		✓			
Water as an economic good				✓								

^a Often expressed as “compensation” not payment

Third, to the extent that this collection of principles can contribute to sustainable development, they are inconsistently included in the legally binding groundwater governance texts (Tables 4, 5, 6, 7). Ideally, one would have expected that the legally binding texts would have included all the different relevant principles. However, (a) the scope and definitions of groundwater resources are inconsistently defined in the governance texts; (b) principles are inconsistently presented—for example using “expressed” consent rather than prior informed consent; or water as an economic good versus water as a human right; (c) critical principles such as the precautionary principle or protection of human rights are excluded from the legally binding texts; and last but not least (d) there is disagreement regarding how exactly sovereignty should be treated in groundwater governance texts. While limited sovereignty is more consistent with sustainable use of resources, where these resources are seen as limited in quantity and critical for state security, countries may use sovereignty to justify non-cooperation with others.

Hence, a normative framework for sustainable groundwater governance, which supports the global SDG agenda requires that groundwater governance texts (a) use a common terminology that is rooted either in the state-of-the art hydrogeology or legal norms, as appropriate; (b) include definitions and scope that recognize the duality of groundwater being both part of and apart from the contemporary hydrologic cycle, thus including aquifer of all types whether non-recharging, layered, or linked to surface water; (c) include norms presently underrepresented in legally binding texts; (d) reconcile tensions between principles; (e) elaborate best practices for well-accepted principles that are most challenging to implement; and (f) introduce principles or mechanisms to cope with the effects of trade and climate change. Further research on economic aspects of global groundwater governance and the relationship between the global framework and domestic rules and rights would greatly support such an endeavor.

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