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Integrating landscape and water-resources planning with focus on sustainability

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Abstract

The global freshwater crisis demands new forms of action if further environmental and social impacts are to be avoided. Traditional sectoral and technologically based approaches have proven to be ineffective in addressing this crisis, since they disregard the multiple and complex roles of water in the landscape, and subsequently the need for cooperation across the many sectors involved in water-resources planning and management, including institutions and citizens. As an invisible resource, groundwater has been particularly affected by the traditional sectoral approach. Moving towards sustainability demands integration at multiple levels (e.g. land–water, social–natural, surface–underground), which in turn calls for transdisciplinarity between academic disciplines (including sciences and humanities), practitioners and

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stakeholders. In this paper we argue that land and water-resources planning and management paradigms are converging in this direction. However there is room (and interest) for further convergence under a landscape-ecology-based approach. In order to proceed with this convergence several barriers must be overcome: the lack of a common approach and language, a tradition of disciplinary approaches that is hard to change, the higher demands of transdisciplinary (in terms of complexity, resources and time) when compared to the traditional disciplinary approaches, etc. We argue that applying landscape ecology and the sustainable landscape-planning framework can contribute to solve several inherent shortcomings of the current water-resources planning paradigm, including lack of integration of related subjects (such as land use) and the need for transdisciplinarity. This paper outlines a course of research that will contribute to an operational method for sustainable integrated (ground)water-resource planning.
Keywords: integrated water-resources management; groundwater; sustainable landscape planning; landscape ecology; transdisciplinarity; integrative approaches

Introduction

Maintaining or restoring clean freshwater is a key element in achieving sustainability: it is vital for the survival and functioning of ecosystems and human societies (Naiman and Turner 2000; Jønch-Clausen and Fugl 2001; Falkenmark 2003). Moreover, freshwater is a landscape integrator (Naiman and Turner 2000; France 2002), both in space and in time. The flows associated with freshwater (matter, energy, organisms, information) and their related physical, chemical and biological processes result in chorological relations between all landscape components (natural and cultural, aquatic and terrestrial, surface and underground etc.) (Van Buuren and Kerkstra 1993; GWP TAC 2000; Falkenmark 2003). Freshwater also shapes the landscape components themselves by significantly affecting the characteristics and patterns of ecosystems (relief, soil, biotic communities) and human societies (demography, culture, economy) as well as their change through time (Naiman, Magnuson and Firth 1998; Duda and El-Ashry 2000). Thus freshwater significantly influences the characteristics and evolution of the landscape, as defined under the transdisciplinary landscape concept proposed by Tress and Tress (2001).

The global water crisis that began in the 20th century threatens to worsen in the future. Its magnitude is revealed by some alarming numbers: billions of people lack access to safe drinking water and sanitation and suffer from water-related diseases; half the world’s rivers and lakes are polluted (Serageldin 1999); groundwater resources face widespread depletion, salinization and pollution (Shah et al. 2000). Pressure on water resources, water-stressed human populations and ecosystems and water-related conflicts will continue to increase in the future (Duda and El-Ashry 2000; GWP TAC 2000; Naiman and Turner 2000).

Traditional sectoral water-planning and -management practices have proven to be ineffective to prevent or solve the water crisis since they don’t account for water’s inherent interrelatedness with other landscape components and issues (Duda and El-Ashry 2000; GWP TAC 2000; Baron et al. 2002; Falkenmark 2003). This is particularly true for groundwater, as an ‘invisible resource’. Consequently there is little cooperation between the different sectors resulting in a lack of the much needed concerted efforts and actions. We concur with Duda and El-Ashry (2000) and Baron et al. (2002) when they argue about sectoral approaches being insufficient to pursue the goal of sustainable development set at the Rio Summit in 1992, and that new planning and management approaches are required. Moreover we argue that these new approaches must integrate all issues and perspectives related to water and hence be transdisciplinary.

Transdisciplinarity occurs in "(…) projects that integrate both academic researchers from different unrelated disciplines and user-groups participants to reach a common goal" (Tress et al. 2003, p. 10). Hence transdisciplinarity is built on the dialogue and boundary-crossing between scientists from different knowledge areas, i.e. interdisciplinarity (Pickett, Burch and Grove 1999), plus some more intervenients: planners, decision-makers and stakeholders in general. To improve the flow of information between these several actors effectively, transdisciplinarity requires that participants share a common language. Regarding this issue some evolution is taking place. Although with slightly different meanings there are already some key concepts shared by both landscape ecologists and planners, such as land use and land cover, or spatial structure and pattern (Antrop 2001), therefore related with the spatial dimension of the landscape. Some authors argue that the spatial dimension of landscape is the appropriate platform for integration of different areas of knowledge and between science and planning. From a transdisciplinary perspective planning would also benefit if a common approach would be available to support such a combined effort towards shared goals (Ahern 1999aa; Fry 2001).

Transdisciplinary approaches can improve planning and management of natural resources in several ways: (i) by providing better scientific information to planners and decision-makers. By promoting the combined work of different disciplines transdisciplinarity provides new insights, adding new kinds of information to the traditional, disciplinary one; (ii) by reducing conflicts and reducing uncertainty in implementation. By empowering stakeholders and sharing responsibility within the planning process, it is more likely that the outcome will be agreed upon (Vasconcelos 2001); (iii) by increasing applicability of academic research focused by society's needs, concerns and perspectives (Ahern 1999aa; Fry 2001) and (iv) by improving efficiency of the planning process through reduction of unnecessary revisions. Often plans need to be revised according to citizens' legitimate contributions to increase the success of plan implementations. Additionally management can also gain from citizens' adhesion to plans' recommendations by involving them in monitoring activities. Under a strategic planning approach collaborative design can be applied to the definition and evaluation of alternative scenarios, where stakeholders participate actively in defining different sets of guidelines for implementing scenarios and criteria to evaluate them (Botequilha Leitão and Ahern 2002).

However, the application of transdisciplinarity faces barriers of different types, e.g. (i) strong disciplinary tradition, sometimes with long-established approaches and jargons (Fry 2001), (ii) lack of a common approach (Turner and Carpenter 1999; Tress and Tress 2001), (iii) difficulties to integrate qualitative and quantitative research methods, which is one the major gaps between natural sciences and humanities (Fry 2001), (iv) added difficulties in publishing in international referred publications, which are typically discipline-orientated (Fry 2001; Pickett, Burch and Grove 1999), (v) slower advances due to increased complexity of the approach and the higher number of participants when compared with traditional disciplinary approaches (Turner and Carpenter 1999), (vi) institutional setting, which is in general not favourable to transdisciplinary approaches. Nevertheless there are already good examples of transdisciplinary projects for instance in landscape studies (Botequilha Leitão et al. 2001; Tress et al. 2001), and watershed planning (Ahern, Desmond and LARP Studio IV students 1999).

Integrative approaches to water-resources planning are under development. However, difficulties in practice are being reported by several authors. These problems seem to be in line with the above-mentioned barriers to transdisciplinarity: e.g. it is necessary to clarify what to integrate and especially how (Jønch-Clausen and Fugl 2001; Biswas 2004), the ecological and water communities need to cooperate more and better, the public and the decision-makers require more information on scientific issues, institutions responsible for water issues are not adapted to integrative approaches and generally disregard the ecological component of their activity (Falkenmark 2003). In this paper we argue that the integration of (sustainable) land-use and water-resources planning in a landscape context can contribute to overcome these difficulties. We also argue that landscape ecology and the sustainable landscape-planning framework as proposed by Botequilha Leitão (2001) and Botequilha Leitão and Ahern (2002) are useful as a framework to assist this integration.

The research from which this chapter draws focuses on determining the relationship(s) between landscape structure and groundwater and on using these relationships as a basis for developing planning strategies and tools for (more) sustainable water use and (more) sustainable landscapes.

Paradigm evolution

Thomas Kuhn defined scientific paradigm as a "constellation of achievements – concepts, values, techniques, etc. – shared by a scientific community and used by that community to define legitimate problems and solutions" (Kuhn 1962). Paradigms are useful as models to understand and explain certain aspects of reality (Saraiva 1999, p. 25). Capra (1996) expands the concept of scientific to social paradigm, which provides a useful tool to analyse the evolution of attitudes, values and perceptions, and ways the community organizes itself. We will use such a framework to analyse the evolution of concepts, values and approaches for water resources and land planning and management.

Water-resources planning and management paradigm evolution

Saraiva (1999) identified four main evolutionary stages of the water-resources planning and management paradigm: (i) harmony: human activities adapt to natural rhythms; (ii) domination: humans try to tame water through technology; (iii) degradation: ecosystems become degraded due to human interventions and (iv) sustainability: humans search for a "development that meets the needs of the present without compromising the ability of the future to meet its own needs" (World Commission on Environment and Development 1987, p. 43).

The harmony stage began with the first human settlements. Humans introduced minor changes into the natural systems in order to use water resources. Moreover humans adapted their lifestyles and habits to the natural hydrological cycles (such as flooding or droughts) which they could not control (Saraiva 1999). Traditional cultural landscapes such as the Montado in Alentejo, Portugal, are examples of that harmonious integration between humans and nature (Pinto-Correia 2000).

The domination stage began in the 17th - 18th centuries (Table 1) with the intense development of hydraulics and hydrology. It accomplished the regulation of river flows through the construction of channels, dams etc. These works increased the benefits derived from water resources and minimized the inconveniences and hazards to human life and property (Saraiva 1999; Gleick 2000). In the 20th century as technologies grew more powerful, so did the interventions in water resources. Large multipurpose hydraulic projects began to be implemented in the 1930s aiming at domestic consumption, irrigation and energy production (Saraiva 1999; Duda and El-Ashry 2000; Gleick 2000).

The degradation stage has its roots in the 1960s (Table 1). Awareness of negative environmental and social consequences of the prevailing development concept increased (Duda and El-Ashry 2000; Gleick 2000). Environmental legislation was enacted in the USA and later in the EU to protect natural resources including water (Botequilha Leitão and Ahern 2002). This kind of reactive environmental planning resulted primarily in sectoral, mitigative measures.

The sustainability stage emerged in the 1990s (Table 1) with the recognition that mitigation wasn't enough to address the global water crisis and that a proactive approach to water-resource management was needed. This stage led to the emergence of the integrated water-resources management (IWRM) approach. The guiding principles of IWRM were stated at the International Conference on Water and the Environment held in Dublin in 1992. These principles contributed significantly to the Agenda-21 recommendations adopted at the Rio de Janeiro Conference later in 1992. Since then these principles have been restated and elaborated in major international conferences, such as the World Water Forums or the World Summit on Sustainable Development held in Johannesburg in 2002 (GWP TAC 2000; Jønch-Clausen 2004).

According to GWP TAC (2000, p. 22) "IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". It promotes a holistic approach to water resources and integration at various levels (Table 1). It emphasizes the need for transdisciplinarity (GWP TAC 2000; Falkenmark 2003). Under this approach watersheds and aquifers can be regarded as landscapes and are considered appropriate management units for integrative approaches (Duda and El-Ashry 2000; GWP TAC 2000).

IWRM principles are beginning to be applied throughout the world (e.g. river-basin management in the USA and the EU: France, Germany, The Netherlands, Portugal, England and Wales) (Pavlikakis and Tsihrintzis 2000). They underlie the EU Water Framework Directive (2000/60/CE). However, application of IWRM has been criticized for: (i) its modest degree of integration of the relevant sectors with the 'water sector' (e.g. land management is often absent) (Duda and El-Ashry 2000); (ii) its emphasis on economic issues (Falkenmark 2003); and (iii) paying little attention to ecosystems as providers of water resources and other goods and services (Radif 1999).

Ecosystem management is currently being integrated into IWRM in order to overcome these and other faults (Radif 1999) (Table 1). It was given more attention after 1991, with many USA agencies applying it to natural-resources management (Pavlikakis and Tsihrintzis 2000). Ecosystem management focuses first on the goal of maintaining the proper functioning of ecosystems, which are viewed as life-support systems for human societies. Its dynamic pattern-process vision of nature arises from its scientific foundations where landscape ecology plays a pivotal role (Botequilha Leitão and Ahern 2002).

Table 1. Compared evolution of paradigms in water-resources planning and management and land planning.

Legend: from (--) to (++) growing degree of importance of an objective at given stage; from white to black: transition from one principle to its opposite

Timeline			Water-resources planning and management												
			Objectives				Principles								
		Paradigm					Lack of integration of landscape components								
			Economic growth / Production	Human safety and health	Social welfare	Ecological systems preservation	Groundwater / surface water	Water / land	Human / natural zones	Resource-focused approach	Point / linear vision of water resources	Sectoral approach (Water sector)	Rigid planning	Top-down planning approach	Single-purpose planning
19th century		**Domination**	+	++	+	--									
	1900		++	++	+	--									
	1940														
20th century	1950														
	1960					-									
	1970	**Degradation**	++	++	++	+									
	1980														
	1990	**Sustainability** *IWRM**	++	++	++	++									
21st century		*EM***	++	++	++	++									
			Simultaneous and integrated concern with all aspects: **Sustainability**				Integration within and among all components - Holism			Systems approach	Spatial approach	Interdisciplinarity	Adaptive management	Public participation	Multipurpose planning

*Integrated Water Resource Management
**Ecosystem Management

Table 1 (continued)

	Land planning									
	Objectives				**Principles**					
Paradigm	Economic growth / Production	Human safety and health	Social welfare	Ecological-systems preservation	Lack integration of landscape components	Basic sciences (earth and biological)	Sectoral approach / knowledge fragmentation	Rigid planning	Top-down planning approach	Single-purpose zoning
Early urban planning (applied at cities)	++	++	+	+						
Urban planning	++	++	+	--						
Urban planning **Landscape planning** (applied to the countryside)	++	++	++	++						
SLP*** (in cities and countryside)	++	++	++	++						
	Simultaneous and integrated concern with all aspects: **Sustainability**				Holism	Landscape ecology	Transdisciplinarity	Adaptive management	Public participation	Land multifunctionality

***Sustainable Landscape Planning

The groundwater sub-sector of water-resources planning has been slow in evolving towards a sustainable approach, despite some recent progress in this field. This may be due to: (i) this resource not being traditionally planned or managed but simply extracted by any land owner with small-scale technology and (ii) its 'invisibility' and that of its connections with other landscape components that delayed the evidence of its degradation and all related impacts (economic and social besides environmental) (Kemper 2004).

Although there is a growing consensus as to the need to apply ecosystem management to IWRM, an operational method for IWRM is yet to be developed (Nakamura 2003). Such a method should be able to address the gaps of IWRM (the ones above identified and others) by promoting:

- the integration of water in the context of the landscape: surface and groundwater integration in the context of the hydrological cycle and land–water integration;
- transdisciplinarity: effective communication among scientific disciplines and between scientists, planners and managers, and stakeholders) while working towards a common goal. This implies addressing a long list of barriers such as those earlier referred in section 1;
- the reform of traditional sectoral institutions as to enable them to respond effectively to the challenges such levels of integration pose and hence to promote better governance, i.e. "the political, administrative, economic and social systems that exist to manage water resources and services" (Vasconcelos 2001; Baron et al. 2002; Falkenmark 2003; GWP 2003, tool B1.01). For instance, the introduction of transdisciplinarity in the planning process requires the creation of new fora, such as public workshops or meetings, that can promote effective communication between all participants (Vasconcelos 2001). Also the bureaucratic pathways of decision-making must change in order to accommodate sharing of power, e.g., between different public institutions. "Conflicting laws, duplication or lack of clarity of mandates for different organizations and jurisdiction of different tiers of authority – local, sub-regional, national and, increasingly, international" must be identified and eliminated.

Nevertheless there are already examples of successful application of transdisciplinarity to (ground)water-resources planning and management, e.g. Neufeld (2000), Scholz et al. (2000) and Ferreira et al. (2003).

Land-planning paradigm evolution

The ecological and holistic principles emerged in the transition from the 17th to the 18th century with Alexander von Humboldt and others, who perceived and studied the landscape as a whole (Tress and Tress 2001). In the 18th and 19th centuries, land planning was restricted to cities and focused on public health in addition to economic interests and aesthetics (Ndubisi 1997; Magalhães 2001) (Table 1). The industrial revolution increased natural-resources exploitation, urban growth and pollution. Innovative approaches were developed to solve the problems raised by industrialization. They tried to bring ecological processes into the city in order to improve the quality of life of urban dwellers. Several pioneering ideas and projects, e.g. 'garden cities', 'green belts' and park systems (e.g. the 'Emerald Necklace' in Boston, USA) were developed by Ebenezer Howard, Patrick Geddes and Frederick Olmsted, amongst others (Ndubisi 1997; Magalhães 2001).

A different paradigm emerged in the 20th century, from the 1920s on (Table 1), that disregarded the integrative approach introduced by the earlier visionaries. After

World War I (and more so after World War II) it was urgent to rebuild the infrastructure to support rapidly growing cities (Magalhães 2001; Botequilha Leitão and Ahern 2002). As modernism became the cultural paradigm it was believed that only cities required planning since the rural activities and uses were compatible with the environment and conservation of natural systems (Roberts and Roberts 1984). Providing a healthy environment for urbanites was pursued by functional separation – housing was zoned away from polluting activities – and was not allocated according to ecological principles. Simultaneously generalist and integrative (including ecological) thinking lost all influence to specialization and analytical thinking (Magalhães 2001).

In the 1960s the scope of planning was expanded into the countryside (Table 1). Ecological principles began to be woven back into planning as a result of an increased environmental awareness motivated by general environmental degradation and increasing urban sprawl into the countryside (Roberts and Roberts 1984; Ndubisi 1997). A new landscape-focused approach emerged, based on theory developed earlier, which was also explicitly ecology-based (Ndubisi 1997). However landscape and urban planning were generally developed independently.

Subsequently the growing complexity and intertwining of environmental problems was recognized (Ndubisi 1997) and practical approaches to deal with it began being sought. A planning movement that regards the landscape as a complex and multidimensional (natural, cultural, spatial, mental etc.) entity, evolving towards integration and transdisciplinarity, has been proposed by several authors, particularly Naveh and Lieberman (1995) and Tress and Tress (2001; 2003). Several disciplines converged to a common paradigm with sustainability as the overarching goal. Principles and guidelines from these disciplines (including ecosystem management) were 'filtered' from a significant body of research and literature by Botequilha Leitão (2001) and Botequilha Leitão and Ahern (2002), which produced a new and useful transdisciplinary synthesis of planning methods, arguably labelling it as *sustainable landscape planning* (Table 1). More than a rigid method, sustainable landscape planning encapsulates a set of principles, guidelines to integrate landscape ecology into planning and tools (a horizontal perspective), and provides a planning structure of five planning phases (a vertical perspective).

The sustainable landscape-planning framework's main purpose is to provide a common planning framework applicable to all spatial planning activities. It has landscape ecology as its core scientific foundation. It constitutes an integration platform for a wide array of scientific knowledge that shares a spatial dimension and a landscape approach, including natural and social sciences and humanities. It also provides links between science, planning, management and stakeholders (Botequilha Leitão 2001). A caveat is in order. The concept of sustainable land planning proposed under this framework differs slightly from some earlier literature (Senes and Toccolini 1998; Treu et al. 2000). In very general terms the latter uses an operational model that evaluates sustainability based on the concept of carrying capacity of different land uses under different situations. The sustainable landscape-planning framework (Botequilha Leitão and Ahern 2002) refers to sustainability under a more conceptual perspective by considering (i) the integrity of ecological systems as the basis for all human development; (ii) advocating for indispensable integration of the human component; and (iii) promoting the integration of social sciences and humanities.

Landscape ecology is a meta- or transdisciplinary science (Naveh and Liebermann 1995; Zonneveld 1995; Botequilha Leitão and Ahern 2002). It can provide the scientific basis for integrating land and water planning. Landscape ecology focuses on the link between pattern and process, i.e. how the landscape's spatial configuration integrates with ecological processes (Botequilha Leitão and Ahern 2002). Landscape ecology focuses on the landscape (watershed or aquifer) as a particularly appropriate planning unit that relates with the scale of human perception (Nassauer 1995; Ahern 1999bb).

Application of integrative and transdisciplinary landscape-planning methods is still at its infancy. The challenge is to make these concepts operational in spite of their complexity (Tress and Tress 2001; 2003), e.g. how landscape-ecology principles and tools (i.e. metrics) support better, more sustainable water-resource planning and management. In order for integration and transdisciplinarity becoming operational concepts within the scope of water-resources planning and management several issues must be addressed. First of all the need for integrative approaches must become widely accepted, as sectoral tradition is still very strong within many water-resources communities. Agreement on a common approach to water-resources planning and management is also required, as well as an institutional setting that makes it feasible. The development of a common language is also indispensable for this goal. In practice this implies that scientists should develop their research focused on the needs of the planning process, and (water) planners and managers should improve their literacy in science, particularly in landscape science. However if success is to be attained these issues require that due consideration is given to the expectations of intervenients (scientists, policy-makers, end users, etc.), that training is provided to intervenients on the new approach, and that evaluation of the process is done in order to improve the approach (Tress et al. 2003).

Discussion

The preceding analysis and Table 1 describe the convergence of paradigms of water-resources planning and management and land planning under the goal of sustainability. Both paradigms followed a similar evolution: sectoral, technical, top-down approaches with little or no consideration for ecological principles gave way to sustainable approaches with ecological, economic, social and cultural concerns. The current paradigms cite sustainability in their goals and adopt principles such as systems theory, holism, adaptive planning, public participation etc. (Table 1). Both recognize the multidimensionality of their subjects – land and water – and their inter-relationships in the wider context of the landscape. Hence the two paradigms also recognize the need for integration and transdisciplinary approaches in order to address effectively the multidimensional issues they are presented with. In practice these approaches refer to the close and interactive collaboration between different academic disciplines (natural and social sciences as well as humanities), practitioners and the public in the research and planning processes (Tress et al. 2003).

However, there are differences between the paradigms: the holistic and transdisciplinary landscape approach is much less developed in water-resources planning and management than in land planning. The latter is inherently spatially-oriented and has a longer tradition in integrating ecological concerns while water-resources planning and management is still very sectoral by definition and in practice still remains attached to its traditional technologically-based approach to river management that focuses solely on water bodies themselves, e.g. rivers and channels, instead of the watershed / landscape as a whole (GWP TAC 2000).

A convergence or integration of water-resources planning and management and land planning under the common goal of sustainability can bring several benefits to both fields and to landscape planning as a whole. As mentioned earlier, water and land are intrinsically connected within the landscape. Therefore, a single meta-framework integrating water-resources planning and management and land planning would be truer to the spirit and intention of sustainability that the current paradigms are already trying to convey. It could help as a common ground for communication between knowledge areas and between scientists, planners and the public, leading to shared visions, goals, methods and ultimately to transdisciplinarity in implementation and equity of results. Such a meta-framework should include hydrology, hydrogeology and landscape ecology as core disciplines, while also integrating geology, soil science, sociology, psychology, history, computer science and modelling, etc., under an overall landscape-planning framework. Its strategies (methodological and spatial) should be adapted to local characteristics, such as is already prescribed in IWRM (GWP TAC 2000). For operational reasons they could be compiled in a toolbox similar to the one that Global Water Partnership has built for IWRM (GWP 2003). An example of spatial strategy that could be part of this toolbox is the framework method proposed by Van Buuren and Kerkstra (1993).

Proposal

We argue that landscape ecology and the sustainable landscape-planning framework are adequate approaches to improve the current water-resources planning and management paradigm (the IWRM approach) and become the foundation for the meta-framework earlier mentioned. They can address its earlier mentioned shortcomings by improving integration and transdisciplinarity. In particular they can address its deficits of ecological vision, of land–water and surface–groundwater integration and of integration of a spatial component in IWRM. Also they can contribute to achieve a common planning method that can be shared by all actors with intervention in the water planning and management process. Thus they can contribute to a more sustainable surface and groundwater planning and management and consequently to more sustainable landscapes.

Landscape ecology and the sustainable landscape-planning framework are ecologically driven. Therefore they are particularly well suited to balance the ecological component with the economic and social ones within the IWRM context. It can provide linkages with other sciences such as social ecology and ecological economics (Grove and Burch 1997), and humanities such as landscape history (Marcucci 2000).

Landscape ecology can provide some insights about ecological phenomena, e.g. spatial configuration of land uses and/or ecosystems, which in turn influence water-resources variables and phenomena, both in terms of its quality and quantity (e.g. Ferreira et al. 2003).

Landscape ecology and the sustainable landscape-planning framework's explicit spatial approach can contribute to understand better the reciprocal relationships between landscape ecological processes and water-resources quality and quantity. Each discipline views the world in a different way, biased by its own scientific background, either hydrology, hydrogeology (water, abiotic-component driven) or ecology (until recently very much biologically orientated). The new insights provided by such an integrative approach as the one proposed can help change the understanding of the world as seen by each discipline, to establish new relationships between once unrelated or poorly related variables or components, and thus to advance their own discipline-based theoretical principles and research methods, close the gaps between different scientific disciplines, and achieve true interdisciplinarity. Consequently they can point to innovative solutions to water issues that, in principle, would not emerge from each own, separated and compartmentalized scientific area.

Landscape ecology and the sustainable landscape-planning framework can provide a method for planning and management of water resources in the landscape context. They can therefore contribute to transdisciplinarity in water-resources planning and management by providing a common platform that can integrate the work of all intervenients in the process.

Landscape ecology includes tools that can help put the holistic, systems vision into practice. For instance landscape metrics are useful to describe landscape-spatial patterns in a quantitative fashion (Botequilha Leitão and Ahern 2002). Through their spatially-structural approach metrics can be used to study the relationships between land uses, ecosystems, aquatic features and thus with water quality and quantity. Landscape composition and pattern becomes the common denominator by which the condition of one resource type (e.g. streams) can be compared to another (e.g. farmland or suburban areas). Metrics can therefore contribute decisively to integration and transdisciplinarity in water-resources planning and management. Public participation / collaborative design can also contribute to this goal and are part of the sustainable landscape-planning framework's toolbox.

This research intends to contribute to the improvement of IWRM as well as to landscape research, within the above-discussed scope. It intends to integrate sustainable groundwater and land planning by applying landscape ecology and the sustainable landscape-planning framework. Its goal is to contribute to more informed land-use decision-making processes regarding (ground)water resources. The main research questions to be addressed are: How does landscape structure influence the quality and the quantity of groundwater? What landscape areas are essential to maintain or restore groundwater systems? How can these areas be protected in a sustainable socio-economic context?

In order to address these questions the sustainable landscape-planning framework will be adapted to include spatially-explicit hydrogeological models describing (ground)water flows and quality. The landscape will be analysed for spatial and non-spatial relationships between landscape structure, associated human activities and practices and the quantity and quality of groundwater (e.g. what land uses and practices are related to groundwater contamination and over-extraction? Does their location in the landscape influence their impacts on groundwater?). Statistical tools (e.g. principal-component analysis) will be used on hydrogeological models' outputs and landscape metrics to determine these relationships and their significance. Alternative planning scenarios will be built in order to assess the consequences of different planning solutions. GIS software will be used as an integration platform for all spatial data and results (Botequilha Leitão and Ahern 2002). An operational model will be defined based on the relationships determined and will include operational criteria for delimiting groundwater-protection areas and management practices for human activities in those areas. These intend to guarantee the preservation of processes that are essential for the sustainable maintenance of groundwater systems.

Crossing disciplinary boundaries will be indispensable to this operational model and will constitute also one of its main challenges. Hydrogeology, landscape ecology, landscape planning, landscape history, computer science and stakeholder participation will be used to describe, understand and plan the relationship between local human society and the landscape, focusing on (ground)water.

Other issues and questions can be raised when pursuing inter- and transdisciplinary research, such as the one in this chapter draws from: (i) need for increasing ecological and landscape literacy (Lubchenco et al. 1991; Ahern, Desmond and LARP Studio IV students 1999; Hill and Johnson 1999; Spirn 2003) both of water-resources planners and managers, and decision-makers and citizens; (ii) need for improving communication flow between science and planning. Scientists might lack understanding of the kinds of decisions planners/designers have to make. In consequence ecological models often lack understanding, spatial context, alternative approaches/scenarios that could be useful to water-resources planners and managers. Frequently traditional science fails to answer key policy questions in a usable form: moreover scientific descriptions of landscape ecologists and artistic, intuitive approaches of landscape designers are not always compatible; (iii) need for improving integration of social sciences, answering such questions as "how are humans involved in the ecology of the landscape?" (Grove and Burch 1997; Ahern 1999aa) and "how can cultural landscapes dependent on human disturbance related to historic land uses be maintained?", as reported by Botequilha Leitão (2001); (iv) resource-management projects often fail to provide for double-loop learning or adaptive strategies (Light, Gunderson and Holling 1995); and (v) publication of interdisciplinary research is often impaired by disciplinary territories in most leading journals (Pickett, Burch and Grove 1999).

So what can be done to address these issues? Ahern (Ahern 1999aa) provides some answers such as: (i) landscape ecologists and landscape architects/planners can jointly write handbooks to facilitate better communication of existing principles, such as the one which one of the authors is currently working on (Botequilha Leitão et al. in prep.); (ii) reference studies should be developed for presentation (e.g. Ferreira et al. 2003); (iii) development of operational tools by landscape ecologists to be used by practitioners relating to landscape patterns with natural processes (e.g. wildlife, disturbance regimes); (iv) cooperation is needed in research projects that have landscape ecologists and landscape architects/planners working together, where the key questions are asked together – joint site visits prompt thoughtful decisions bridging the gaps (Ahern, Desmond and LARP Studio IV students 1999); (v) encouragement of students and practitioners of both disciplines to broaden their knowledge in studying the other discipline; (vi) social scientists need to recognize spatial implications, such as represented by the research developed by the Long-Term Ecological Research – Baltimore Team in urban ecosystems (Grove and Burch 1997; Grimm et al. 2000; Grove, Hinson and Northrop 2003); (vii) to compensate for potential biases against interdisciplinary research (Pickett, Burch and Grove 1999, p. 306) one way is for "a journal, a professional society, or an entire science to have a vision for the value, the role, and needs of a successful interdisciplinary research", and enforce it.

In line with the principle of interdependence presented by McHarg and Steiner (1998) and Capra (Capra 1996), everything is connected within the landscape – functions and processes and people. Water has a decisive role as a connecting agent. In turn the spatial dimension has a key role as the medium where all landscape linkages take place and develop. Hence water must be seen, planned and managed in this context, i.e. in a spatial, integrative and transdisciplinary fashion. This is the challenge we face today and to which this chapter intends to contribute.

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