

Systems Thinking and Transdisciplinary Approach for Sustainable Groundwater Management

You think that because you understand 'one' that you must therefore understand 'two'

because one and one make two. But you forget that you must also understand 'and'.

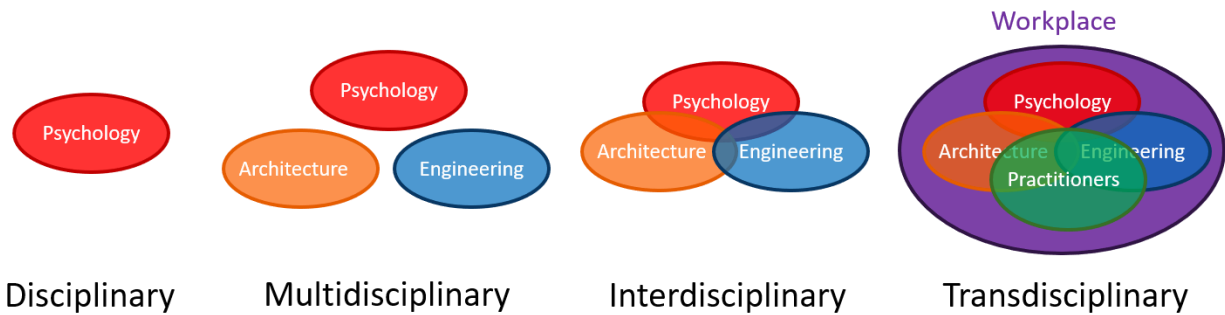
-Sufi Teaching Story (Meadows, 2008)

Dursun Yıldız

Director

Hydropolitics Academy

dursunyildiz001@gmail.com



SUMMARY

Social norms direct resource management paradigms. The transition from the current free use or utilitarian resource management paradigms to a sustainable management paradigm will be hindered or advanced depending on societal value perspectives. How resources are managed change with changing perceptions of value, which in turn change with improved knowledge of management options and a deeper understanding of the consequences for the environment, economy, and society. Therefore, the evaluation of community attitudes and expectations with regards to resource management, and the mapping of divergent interests, barriers and stakeholder conflicts, remains imperative to sustainable development (1,2).

A system is an interconnected set of elements that is coherently organized in a way that achieves something. A key principle of systems is that they are comprised of "elements" or components

If a transition towards a sustainable management paradigm is taking place, we would expect there to be measurable improvements in both social engagement and ecological health. In other words, policy changes alone do not seem to have successfully translated into management improvements so far. It may be suggested that the lack of transdisciplinary understanding of the roles of values and ecological identity in resource management is thwarting the shift in paradigms.

Keywords: System thinking, Groundwater management, Transdisciplinary, Interdisciplinary water management

1. Introduction

The world around us is comprised of systems - organizational systems, business systems, political systems, family systems, inter-personal systems, biological systems, economic systems - the list goes on. This audiobook, written by an experienced systems thinker and consultant, helps the reader develop an appreciation of the nature of systems - what they comprise of, how they function, how they sustain and organize themselves and what they influence and are influenced by. With this knowledge, people and organizations can obtain a greater understanding of themselves and can develop the ability to identify the structure of problems and make interventions with far greater skill and precision.

The system concept is one of the modern approaches to complex phenomena, whose focus is on the whole, though it is made up of components. A system does not exist in a vacuum. It functions in an environment involving other systems.

System thinking is not new. The principles of system thinking have been known and adopted for thousands of years. We can count on Leonardo da Vinci, Isaac Newton, Charles Darwin and Albert Einstein as famous system thinkers.

All of us have been system thinkers all our life. In our life, many things are systems. For instance; our own body is a perfect example of a system comprising a digestive system, immune system, etc. Systems are all around us.

Paradigms: the mindset out of which the system's goals, structure, rules, delays, parameters - arises. Paradigms are the sources of the system's functions: to achieve sustainable water management, **a new sustainable resource management paradigm** must be developed that

- (i) promotes a shift by the creation of new locally defined visions for ecologically sustainable urban water management;
- (ii) promotes water as the agent needed for urban consumers to reconnect with the ecosystem services they rely upon for survival;
- (iii) recognize the mauri of water, restore kaitiakitanga of local iwi (mana whenua and tangata whenua); and
- (iv) allows the inclusion of „the middle term“, giving water simultaneously both exchange (use) and utility (non-use) value.

Goals: the purpose of the system and function of the system. The goals of a sustainable water management framework would include avoiding future costs by reinvesting and restoring natural capital stocks, avoiding ecological degradation, full cost allocation, and full participation from stakeholders; recognizing that water use is a means to an end, thus the supply stream should match the end-use, to get more from less, and minimize waste.

2. Definition of a System

A system is an interconnected set of elements that is coherently organized in a way that achieves something. A key principle of systems is that they are comprised of “elements” or components. Hence your car for example has an ignition system, fuel system and braking system. These components can work alongside each other or they can be contained or embedded within each other.

Within an organization, the fact that these various elements also operate independently means that there needs to be a flow of information up and down as well as across. This also suggests that there needs to be a certain amount of coordination across the elements as well as overall management and control of each element to ensure that they operate together in some sensible way

2.1. System Thinking

“The whole is greater than the sum of its parts”

This idea is a key principle of system thinking. That means that when elements of a system come together and interact in some way, something else emerges from the interaction of those elements that were not present in the elements themselves. This can be defined as the principles of “emergence”

Therefore system thinking can be defined as a way of understanding the world that emphasizes the relationships among a system's parts rather than the parts themselves. This approach can give us clues as to why what we expected to happen didn't happen and what we need to do at the right level of the system itself to achieve the outcome we want. We can count on “elements, interconnections, interrelationships and emergence “ as some of the core principles of system thinking

D. Meadows provides the above definition in his study on “Thinking in Systems - A Primer” (3). The definition contends that a system is more than the sum of its parts, that a system consists of elements and the relationships between them, and that it has a purpose, it achieves something. Various generalized system types can be used to assess a real-life system based on the stocks, flows and presence of feedback loops.

Systems theory now underlies most approaches to the advancement of sustainable development: from theoretical discourses such as game theory, organization theory, and the learning organization, to management models (ecosystem management models, integrated catchment management models, The Natural Step framework, etc.).

Conventional water policies are generally steered towards the lowest cost and highest profits, theoretically achieving the allocation of water to the highest value use. Policies also generally consider the cost of supply and value of demand in the pricing of goods and services. However, ecosystems, and their contributions to both the supply and demand side of the equation, are frequently ignored. Systems thinking requires that ecosystem should be taken into account as water infrastructure which provides freshwater resources. A transdisciplinary framework must consider risks posed by changing climates to the natural and built infrastructure.

3. Overview of Disciplinary Concepts

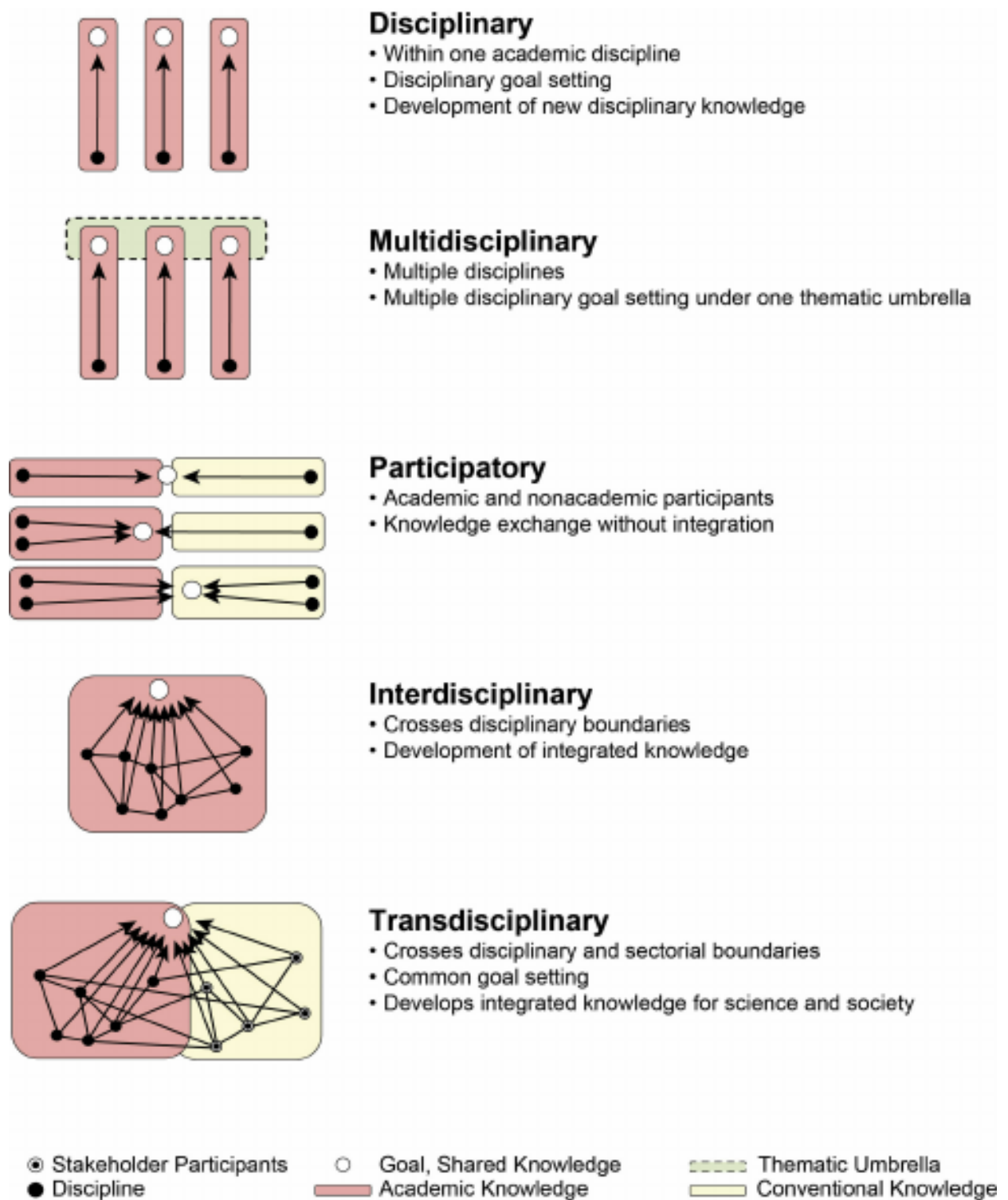


Figure 1. Graphical representation of the concepts of disciplinary, multidisciplinary, participatory, interdisciplinary, and transdisciplinary research. Redrawn from Tress et al. (5).

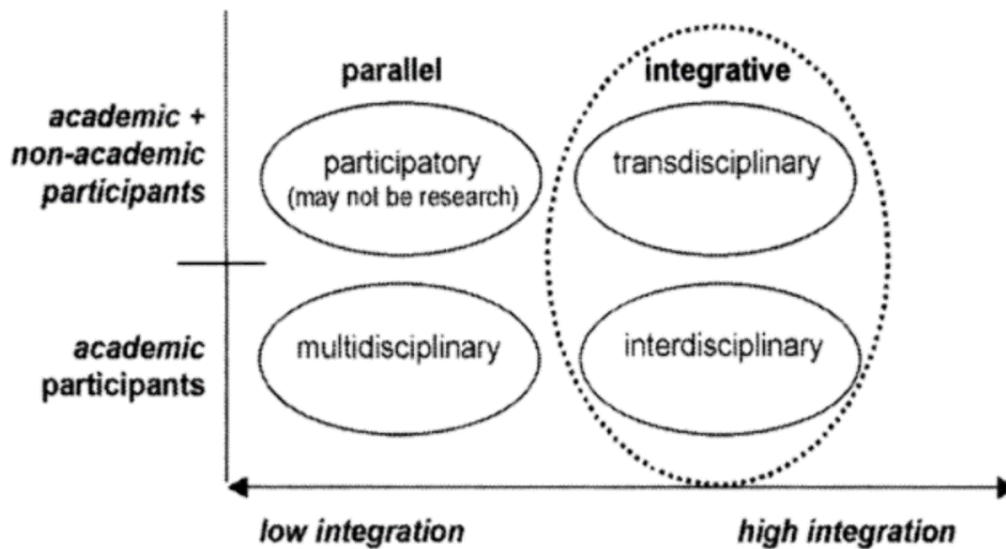


Figure 2. Degrees of integration and stakeholder involvement in integrative and non-integrative approaches (6).

As shown in Figure 1 multidisciplinary approaches use the perspectives of a number of different disciplines with no necessary overlap, and interdisciplinary approaches use the methods and theories of one discipline to inform others. However, the goal of transdisciplinarity is to move beyond the limits of the disciplines and provide new ways of organizing knowledge and modes of thinking (7). The last category, typically termed transdisciplinary, has been promoted as uniquely capable of and perhaps necessary for addressing society's most complex and difficult problems, such as those affecting interacting human and natural systems at different types of scale, i.e., time, space, and human institutions (8). Conceptually, transdisciplinarity extends beyond interdisciplinary integration to involve non-academic stakeholders to address the gap that can exist between research and practical application by collaboratively generating knowledge (9).

Degrees of integration and stakeholder involvement in integrative and non-integrative approaches are given in Figure 2. The inter-disciplinary and trans-disciplinary approach is in the circle of high integration.

3.1.What is a Transdisciplinary Approach?

The water management approach should not only include natural science but also incorporate social science such as food and livelihood security, valuation of water, different institutional aspects, politics and governance. Trans-disciplinary approach producing new knowledge including engineers along with social, political and economic experts and supplement the scientific knowledge. Political wisdom is also required in this region to solve the conflict by the interdisciplinary knowledge base (10).

The trans-disciplinary approach covers Co-design of research agenda Co-production knowledge and Co-dissemination of the results with societal stakeholders such as governmental agencies, funders, industries, NGOs, and civil society.

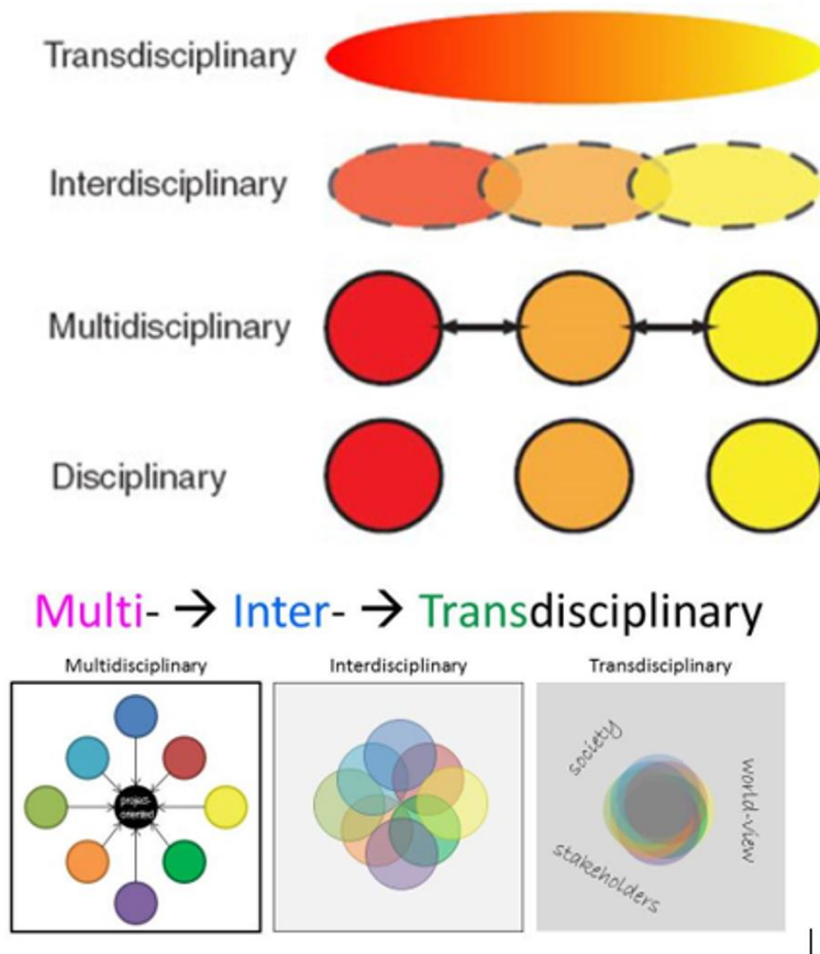


Figure 3. Multi-inter and transdisciplinary concepts (11).

A transdisciplinary approach to management integrates expertise and experience from several different and related professional disciplines Figure 3. With a truly transdisciplinary team, the typical boundaries of each professional discipline tend to disappear. Instead, each professional develops a working knowledge of their co-workers' areas of expertise and discipline. Ultimately, the common goal – exceptional treatment progress – is achieved through the collaborative, transdisciplinary team.

One of the important elements of transdisciplinary work is that it is problem-based and so concerned with the practical applications of knowledge in the real world where issues tend to be multifaceted and call for multiple analytical perspectives (12).

3.2. A transdisciplinary approach to groundwater management

The river basin management approach is accepted by most experts as indispensable to sustainable water management. As Rauhen and Teixeira mentioned in their article (13) that “These initiatives usually require an interdisciplinary and transdisciplinary approach to achieve relevant and wide-ranging targets, due to the magnitude and nature of socioeconomic

and environmental problems”. They also argued in the article that “ social participation has accepted by some countries as a key element in their national water resources policy”.It. comprises a transdisciplinary movement in itself, as it incorporates local knowledge, expectations and potential into the decision-making process that aims to achieve sustainable and long-lasting solutions to water management problems(13).

A transdisciplinary framework needs to be cost-effective, socially acceptable, with transparent responsibilities and accountabilities. Transdisciplinary activities include problem definition, problem representation and problem-solving (15).

The most appropriate approach to policy analysis in a transdisciplinary framework is through system dynamics modeling. System dynamics models the dynamics and interactions of populations, ecological and economic systems using feedback loops (16,17).

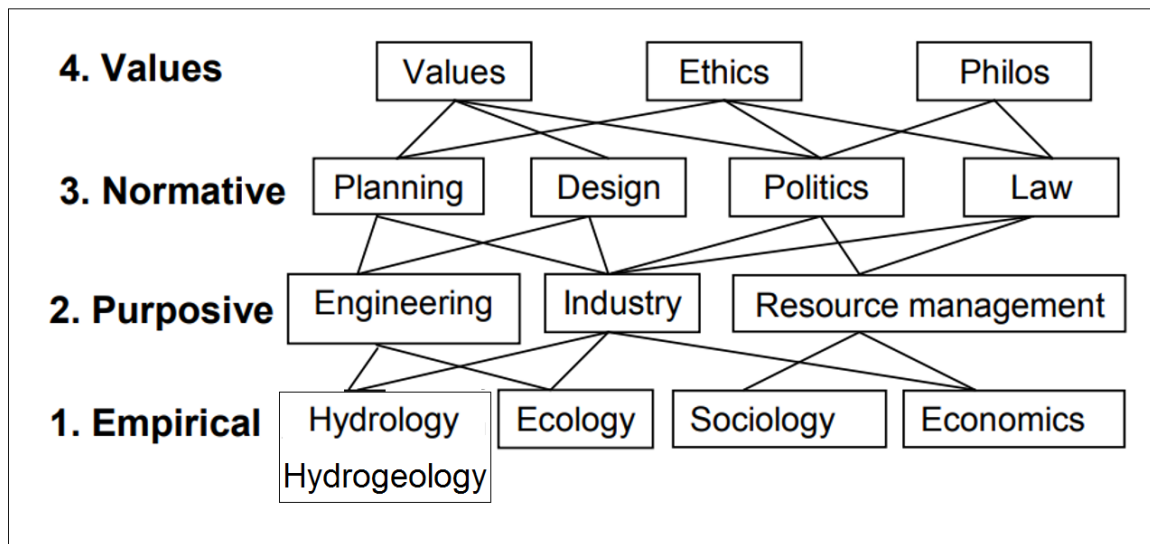


Figure 4. A Transdisciplinary framework for groundwater management (Adapted from (4)).

Figure 4 shows this transdisciplinary framework for the groundwater management sector including components at four cognitive levels and illustrates the broad range of management fields that need to be included (as opposed to consulting with) as stakeholders in a holistic water management system

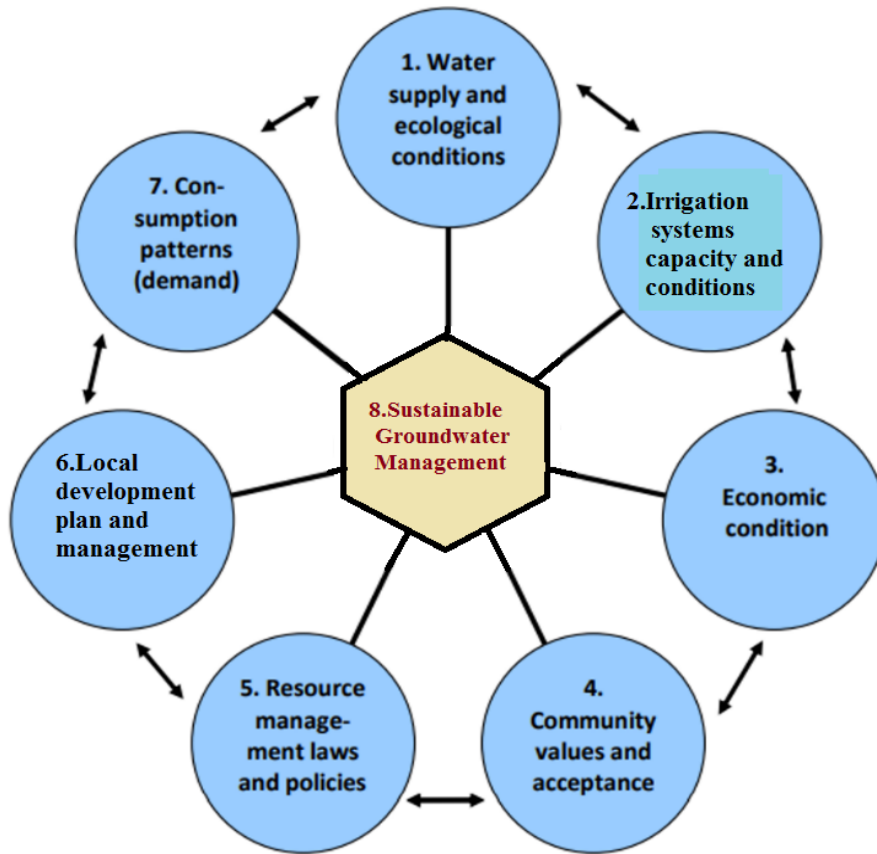


Figure 5. The Groundwater System. (1-4) are system preconditions. These all influence (5) resource management paradigms, which in turn influence (6) Local planning and development, and finally influencing consumption patterns. Influences may flow both ways and also across to other elements. Number (8) represents the overall state and/or desired outcomes. (Adapted from 4)

The Groundwater system is influenced by resource management paradigms, which in turn influence local planning, development and consumption patterns. (Figure 5).

Groundwater management is considered a typical object of the transdisciplinary approach. This is due to the establishing of environmental standards, appropriate solutions and the implementation of technology and problem solving requiring joint problem solving between science, technology, and society.

One approach to policy analysis in a transdisciplinary framework is the use of system dynamics modeling. System dynamics models the interactions of population, ecological and economic systems using feedback loops [18].

3.3.What is the benefits of using a transdisciplinary approach

The benefits of using a transdisciplinary approach to

- Assess current and alternative water management,

- Investment and pricing policies include the capacity to couple choice modeling with system dynamic modeling,
- Allowing consumers to visualize the consequences of management options aiding in assigning value to behavioral changes.

Transdisciplinary water management framework (19).

In very broad terms it may consist of two components:

- **a pathway for reform and**
- **a schedule of assessments.**

First and foremost, a pathway for reform must be developed to serve as a guiding document in the initial reform process, but also to evolve as each phase will stake out the direction for the next phase. The pathway, based on the recommended points of leverage described above, would consist of the following „phases“ (19).

- (1) **Transition;** establishment of a transitional panel responsible for creating a sustainable management paradigm, by setting the goals and creating the rules;
- (2) **Water authority;** the establishment of local water boards, to be in charge of administering funds, scheduling system dynamic modeling workshops, establish adaptive management and learning-organization principles;
- (3) **Assessment;** collecting empirical information from across the sectors, and conducting assessments as needed to build understanding;
- (4) **Consultative;** the communication of findings from the assessment phase to stakeholders;
- (5) **Initiation;** the finalization of strategies and initiation of new management regimes;
- (6) **Project development** / operational; making changes to the stock-and flow structures, buffers, information flows and tweaking the numbers;
- (7) **Monitoring** / reassessment; following adaptive management principles, measuring successes or failures; and
- (8) **Revision;** adjustment of goals, re-election of the water authority, revising strategies.

4.Conclusions

The management approach should not only include natural science but also incorporate social science such as food and livelihood security, valuation of water, different institutional aspects, politics and governance. Trans-disciplinary approach producing new knowledge including engineers along with social, political and economic experts and supplement the scientific knowledge. Political wisdom is also required in this region to solve the conflict by the interdisciplinary knowledge base.

A transdisciplinary framework would need a water authority working alongside local governments, representing stakeholder groups and adhering to the principles of co-management, adaptive management, and learning organizations; and an enhanced dialogue across management fields and with the community using system dynamics modeling.

If sustainability is a goal for groundwater management a transdisciplinary approach and a systems perspective are required. The pathway towards sustainable water management would move through several phases, each phase of development designed to evaluate the system leverage points

A transdisciplinary groundwater management framework with a systems perspective would need to at least entail the pathway of reform, and suggestions items outlined in this article.,

The benefit the understanding of the ecological, economic and social systems of groundwater management, with cross-sector and cross-institutional input. We can list the items under eight categories (Ecosystem services and natural infrastructure; stocks and flows; built infrastructure; stakeholder attitudes; community participation; value and price analysis; demand management; and ecologically sustainable water management strategy.

Each category requires a risk analysis to understand uncertainty related to that aspect, and a component for an investment

5. References

- [1] Craig, J. & Mitchell, N. (2000) Managing the matrix: realigning paradigms toward sustainability. Conservation in production environments: managing the matrix (eds J. Craig, N. Mitchell & D. Saunders), Surrey Beatty & Sons PTY Ltd, Chipping Norton. pp. 26-34
- [2] Tacconi, L. (2000) Biodiversity and ecological economics: participatory approaches to resources management. Earthscan Publications Ltd, London. Tacconi, L. (2000) Biodiversity and ecological economics: participatory approaches to resources management. Earthscan Publications Ltd, London.
- [3] Meadows. H.D. 2008 “Thinking in Systems” London . Sterling VA
- [4] Kviberg K.2008 “Value and price: a transdisciplinary approach to urban water management” WIT Transactions on Ecology and the Environment, Vol 108, © 2008 WIT Press
- [5] Tress, G., B. Tress, and G. Fry. 2004. Clarifying integrative research concepts in landscape ecology. Landscape Ecology 20:479-493. <http://dx.doi.org/10.1007/s10980-004-3290-4>
- [6] Bärbel Tress, Barbel Tress, Gunther Tres, Gary Fry, Paul Opdam 2006 From Landscape Research to Landscape Planning: Aspects of Integration ... From Landscape Research to Landscape Planning: Aspects of Integration ..Springer Science & Business Media, 2006 –
- [7] Blassnigg, M. and M. Punt (2013). Transdisciplinarity: Challenges, Approaches and Opportunities at the Cusp of History. Transtechnology Research, Plymouth University.
- [8] Hammond, R. A., and L. Dube. 2012. A systems science perspective and transdisciplinary models for food and nutrition security. Proceedings of the National Academy of Sciences of the United States of America 109:12356-12363. <http://dx.doi.org/10.1073/pnas.0913003109>

- [9] Lyall, C., L. Meagher, and A. Bruce. 2014. A rose by any other name? Transdisciplinarity in the context of UK research policy. *Futures* 65:150-162.
<http://dx.doi.org/10.1016/j.futures.2014.08.00>
- [10] Bandyopadhyay, J. 2006. Integrated water systems management in South Asia: A framework for research. Centre for Development and Environment Policy.
- [11] -http://www.nature.com/nchembio/journal/v4/n9/_gtab/nchembio0908-511F1.html
- [12] Philip C. McCarty, Eve Darian-SmithPhilip C. 2017” Global Studies and Transdisciplinary Scholarship”May 9, 2017, |Volume10 |Issue31. available from <https://www.21global.ucsb.edu/global-e/may-2017/global-studies-and-transdisciplinary-scholarship>
- [13] Rauen B.W and Teixeira C.E. 2015 “ Inter-and trans-disciplinary research in shared river basin management” *Water Practice and Technology* (2015) Volume:10 (4): 720-724.
<https://doi.org/10.2166/wpt.2015.088>
- [14] Nicolescu, B., The transdisciplinary evolution of the university condition for sustainable development, *Universities' Responsibility to Society*, Centre International de Recherches et d'Etudes Transdisciplinaires (CIRET): Bangkok, 1997.
- [15]-Sholtz, R.W., Mieg, H.A. & Oswald, J.E., Transdisciplinarity in groundwater management- towards mutual learning of science and society. *Water, Air, and Soil Pollution*, 123, pp. 477-487, 2000.
- [16]-Forrester, J. W. (1994b). System dynamics, system thinking and soft OR. *System Dynamics Review*, 10(2), 245–256.
- [17]- Forrester, J. W. (1996). Road map 1: System Dynamics and K-12 teachers. Cambridge,
- [18] Forrester, J.W., 1995 Counterintuitive behavior of system dynamics. *Technology Review*, **73**(3), pp. 52-68.
- [19] Kviberg Karen Creagh, 2010 Value and Price: A Transdisciplinary Approach To Ecologically Sustainable Urban Water ManagementThesis submitted in partial fulfillment of the requirements of the degree of Doctor of Philosophy School of Environment, Faculty of Science University of Auckland January 2010

Biography



Dursun Yıldız is a hydropolitics expert and Director of the Hydropolitics Academy Association located in Ankara-Turkey. He is a civil engineer and used to be Deputy Director at State Hydraulic Works in Turkey; completed hydro informatics post graduate course at the IHE in Delft, Technical training program in USBR-USA and a master degree in Hydropolitics at the Hacettepe University-Turkey. He has over 5 years of teaching experience in some Turkish Universities and now works as head of his own Hydro Energy & Strategy consulting company located in Ankara. He has published several international articles and 13 Books. He received the Most

Successful Researcher Award on International Water Issues from the Turkish Agricultural Association in 2008 and the Central Union of Irrigation Cooperatives in 2016.

(Received: 9 Feb. 2019 Accepted: 22 March 2019)