

Assessing traditional irrigation systems in data scarcity conditions, a proposal for a methodological approach.

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Introduction - interpreting traditional irrigation

Traditional irrigation represent one of the oldest and **most efficient forms of human adaptation to cultivate in harsh and arid environments**, they are spread worldwide and five principal interpretation keys can be pointed out:

- ▶ the systems are autopoietic and **water collection is in equilibrium with the water availability**, thus not impoverishing the available resources;
- ▶ **irrigation efficiency is greater**, with respect to other conventional irrigation techniques practiced in conditions of water abundance;
- ▶ the adaptivity of traditional farming is, to some extent, contributed to by the concurrent use of principal and ancillary water collection techniques;
- ▶ **they are structurally linked to the roots and to the culture of local communities**, thus contributing to the local cultural identity;
- ▶ the long-term observation of the climate and of the environment, which underlies both the traditional culture and the irrigation techniques, builds a meaningful **capacity of risk mitigation based on reconnaissance of the hazards**.

Barontini, S., Boselli, V., Louki, A., et al. (2017). **Bridging Mediterranean cultures in the International Year of Soils 2015: a documentary exhibition on irrigation techniques in water scarcity conditions.** *Hydrology Research*, 48(3), 789-801.

Introduction - characterizing the research on traditional irrigation

Research on traditional irrigation techniques often observes some recurring issues to be addressed:

- ▶ it is **site specific** and field observation is needed;
- ▶ it is **intrinsically multidisciplinary and multifaceted** and requires a continuous dialogue between different disciplines;
- ▶ it is often **aimed at the dynamic conservation of traditional knowledge** and its integration with contemporary knowledge;
- ▶ it is **often carried out in marginal areas** of the world which often are more vulnerable, poorer and marginalized and which consequently suffer from a lack of interest in monitoring environmental and social variables, properly. **Therefore it often suffers from data scarcity.**
- ▶ By virtue of the characteristics listed above, it presents the need for a strong **integration of qualitative and quantitative assessments.**

Introduction - problems arising studying traditional irrigation

- ▶ How and why was a certain irrigation technique selected?
- ▶ How and why has the technique that we study transformed, the production systems, the landscape, the ecosystem and the culture of the place?
- ▶ Which aspects of traditional irrigation techniques are valid for **climate change adaptation strategies**? How can we improve it and **integrate them with contemporary techniques**?
- ▶ What are the **dynamics that are driving the adoption or abandonment of a traditional irrigation technique**? What are the dynamics that modify or adapt this technique?
- ▶ Can I use considerations on the historical and archaeological evolution of traditional irrigation systems to **corroborate or falsify reconstructions on the historical, social, political, climatic and environmental evolution of the place**?

Methodology - introducing system dynamics

The introduction highlighted how research on traditional irrigation is configured as a study of strictly interconnected socio-ecological systems.

Moreover, many of the research objectives are focused on answering questions relating to the evolutionary dynamics of such systems, most of the time configuring the problem as a System Dynamics (SD) problem.

The study of SD suggests that an SD behavior is controlled by feedback loop structures that can provide a potentially useful conceptual framework in the assessment of non-linear complex feedbacks, such as the ones arising from a tightly coupled social-ecological system.

Senge, P. M. (2014) *The Fifth Discipline Fieldbook: Strategies and Tools for Building a Learning Organization*; Crown Business: New York, NY, USA.

Richardson, G.P. (1991) *Feedback Thought in Social Science and Systems Theory*; University of Pennsylvania: Philadelphia, PA, USA.

SD is a methodology born in the industrial sector to map and improve production processes, therefore, applied and adapted to the study of traditional irrigation, it is already aimed at offering decision-making tools and analysis of the evolution of processes.

Methodology - modelling process

Modeling a complex system by means of SD can be seen as an iterative process, following the enumerated steps.

1. A global schematization of the dynamics on the basis of a selected literature review on similar cases, a general observation of the ecosystem to be modeled and experience.
2. The first schematization should address the data collection and analysis process.
3. In the light of the data collected and analyzed, the robustness of original schematization can be verified and, if necessary, reformulated and enlarged to better represent the case study and the dynamics to be investigated.
4. Again, if qualitative or quantitative data is needed to investigate some dynamics, a new data collection campaign must be carried out and consequently iterating the process from point 3 until the dynamics observed and the model represented are self-consistent.

A self-consistency of the model can be seen as its validation.

Mirchi, A., Madani, K., Watkins, D., Ahmad, S. (2012) *Synthesis of system dynamics tools for holistic conceptualization of water resources problems*. *Water Resour. Manag.*, 26, 2421-2442

Methodology - exemplary bibliography on SD and water resources

Martínez-Fernández, J., Esteve-Selma, M.A., Calvo-Sendín, J.F. **(2000)** Environmental and socioeconomic interactions in the evolution of traditional irrigated lands: A dynamic system model. *Hum. Ecol.*, 28, 279-299.

Shahbazbegian, M.R., Turton, A., Mousavi Shafaei, S.M. **(2016)** Hydropolitical Self-Organization theory; system dynamics to analyse hydropolitics of Helmand transboundary river. *Water Policy*, 18, 1088-1119.

Tenza, A., Gutiérrez Pérez, I., Martínez-Fernández, J., Arregui Giménez, A. **(2017)** Understanding the decline and resilience loss of a long-lived social-ecological system: Insights from system dynamics. *Ecol. Soc.*, 22, 15.

Di Baldassarre, G., Wanders, N., Agha Kouchak, A., Kuil, L., Rangelcroft, S., Veldkamp, T. I. E., Garcia, M., van Oel, P. R., Breinl, K., Van Loon, A. F. **(2018)** Water shortages worsened by reservoir effects. *Nat. Sustain.* 1, 617-622.

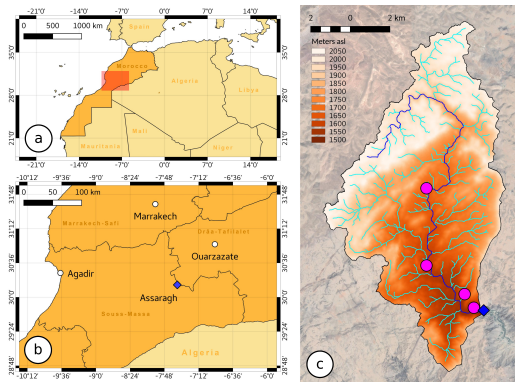
Sušnik, J., Vamvakiridou-Lyroudia, L.S., Savić, D.A., Kapelan, Z. **(2012)** Integrated System Dynamics Modelling for water scarcity assessment: Case study of the Kairouan region. *Sci. Total Environ.* 440, 290-306.

A case study - the reasons for the abandonment of the terraces in an oasis of the Anti Atlas (Morocco) ^{1/2}



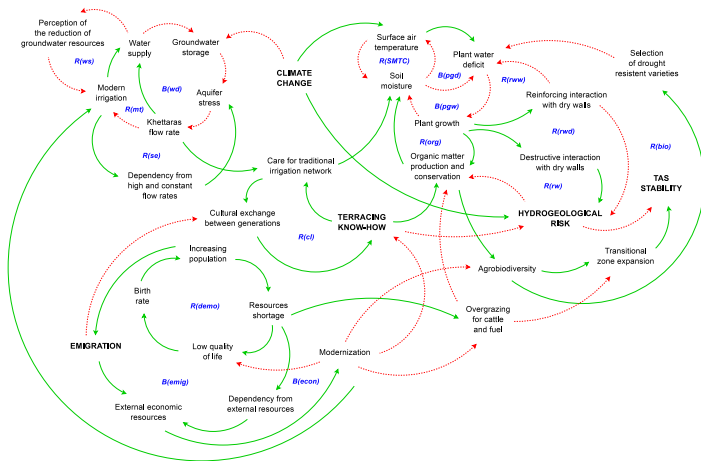
Boselli, V., Ouallali, A., Briak, H., Houssni, M., Kassout, J., El Ouahrani, A., and Michailidi, E. M. (2020) *System Dynamics Applied to Terraced Agroecosystems: The Case Study of Assaragh (Anti-Atlas Mountains, Morocco)*. *Water*, 12(6), 1693.

A case study - the reasons for the abandonment of the terraces in an oasis of the Anti Atlas (Morocco) $2/2$



Geographic framing of the case study.

A case study - the mapping of the dynamics _{2/2}



A case study - the results

The main drivers in the investigated case were social and cultural rather than climatic and water resources related, therefore the actions to be taken for a dynamic conservation of traditional agricultural and irrigation systems, analyzed in the case study, must be aimed at favoring the cultural exchange between generations into preserving terracing know-how, and at promoting adaptation strategies through the selection of drought-resistant plant varieties.

Conclusions

The use of system dynamics to model problems related to the management of water resources in complex situations is now consolidated in the scientific literature and is extremely effective in the study of traditional irrigation systems with a multidisciplinary approach as possible.

The main disadvantage of the method is that it must be adapted from case study to case study, however it has the advantage of being particularly versatile even in situations of scarce data.

Thanks for your attention
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