



# MESSAGES FOR SUSTAINABLE GOVERNANCE OF THE WATER-ENERGY-FOOD NEXUS

## Insights from the DAFNE project

Sustainable planning and management of transboundary water resources is challenging. The DAFNE project developed an innovative approach for participatory planning and management of transboundary water resources that addresses the water-energy-food (WEF) nexus. This approach was applied to the Omo-Turkana Basin (OTB) in eastern Africa and the Zambezi River Basin (ZRB) in southern Africa. The insights gained during the project inform different aspects of sustainable governance of the WEF nexus.

### Messages on the water-energy-food nexus:

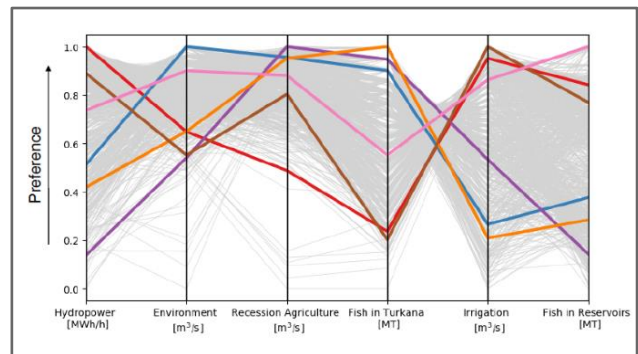
- ✓ **Addressing trade-offs in transboundary river basins is key to supporting sustainable development:** The DAFNE approach supports the identification of robust development pathways addressing trade-offs between water uses today and plausible but uncertain futures.
- ✓ **Visualizing the WEF nexus from different perspectives supports multi-stakeholder dialogue:** Gaining insights by using the DAFNE knowledge visualization tools in simulated multi-stakeholder negotiations facilitates mutual understanding and compromise.
- ✓ **Cooperation as the optimal strategy for sustainable water allocation:** An economic analysis shows that in the Omo-Turkana Basin, transboundary cooperation in water sharing is the optimal strategy in terms of both economic welfare and sustainability.
- ✓ **Using earth observation techniques to complement traditional data sources and convey messages:** Modern technologies can be used to provide data for research as well as to generate visuals that serve as powerful communication tools.
- ✓ **Common threads in legal and policy frameworks in the Omo-Turkana and Zambezi River Basins:** There is space for improvement in the coverage of environmental issues in laws and policies, harmonisation of frameworks within basins, and transboundary cooperation. The Omo-Turkana, in particular, may benefit from the establishment of a transboundary policy framework oriented toward conserving ecosystems.

# ADDRESSING TRADE-OFFS IN TRANSBOUNDARY RIVER BASINS IS KEY TO SUPPORTING SUSTAINABLE BASIN DEVELOPMENT.

## Key takeaways

- **DAFNE developed a Decision Analytic Framework (DAF) for advancing water management strategies.** It supports planning and management activities within a river basin through a quantitative assessment of trade-offs between alternative development pathways.
- **The DAF facilitates identification of widely accepted solutions.** The multitude of alternatives that it generates provides scope for negotiated agreements among sectors and stakeholders involved.
- **Coordinated and efficient operation of water infrastructure is more beneficial for adapting to global change than optimal sequencing of dam expansion.** The river basin strategic model developed in DAFNE enables comparative assessment of a multitude of alternative development pathways in the ZRB coupling infrastructure design, timing and operation.
- **Multi sectoral assessment of development pathways reduces sources of conflict across the WEF nexus.** The river basin strategic model developed in DAFNE enables comparative assessment of hydropower development and agricultural expansion in the OTB and their impact on riverine ecosystem services.

Trade-offs between water uses in a river basin pose a challenge for a sustainable and widely accepted design of infrastructure and their operations. The DAFNE Decision Analytic Framework facilitates this process by supporting the generation of development pathways that can be evaluated and compared on the basis of their expected impacts on the key sectors affected (see Figure 1).



*Figure 1: The lines show sectoral impacts of alternatives generated by the DAFNE Decision Analytic Framework. The pink line is a possible compromise pathway generating largely positive effects on all sectors involved.*

## DAFNE unveils compromise solutions and key multisector dynamics

The DAFNE case studies have shown that the DAF framework facilitates identification of river basin planning and management solutions that address existing and projected trade-offs and thus can meet evolving demands and expectations of a wide range of stakeholders.

In the Omo-Turkana Basins, DAFNE has explored alternative combinations of hydropower expansion and agricultural development in the basin. Results show that potential trade-offs exist that balance economic development and preservation of the main ecosystems services, including both recession agriculture along the river and ecosystems in the river delta and Lake Turkana.

In the Zambezi River Basin, DAFNE has explored a myriad of development pathways composed of alternative dam expansion and operations. The analysis show that the impacts on the WEF nexus generated by changing the trade-off adopted in the operation of the system are larger than those registered by changing the sequencing of dam construction.



# VIZUALIZING THE NEXUS FROM DIFFERENT PERSPECTIVES TO SUPPORT MULTI-STAKEHOLDER DIALOGUE

## Key takeaways

- **Knowledge visualization tools can effectively support dialogue and sustainable policy making.** They address common challenges in multi-stakeholder negotiation processes.
- **It is essential to engage users in the design of the tools.** Regular exchange with users ensures proper understanding of their needs.
- **Complementary tools can address diverse needs.** Differences in stakeholders' expertise and expectations call for an integrated set of complimentary tools.
- **Capacity building is needed for effective adoption of tools.** Evaluations showed that project stakeholders have limited experience with similar applications.

Conflicting interests, diverse expectations and various levels of expertise can hamper multi-stakeholder negotiation processes. A suite of complimentary knowledge visualization tools developed in DAFNE (**Fehler! Verweisquelle konnte nicht gefunden werden.**) has shown how visual aids can effectively facilitate dialogue. Together, the Screening Tool, the Multi-Perspective Visualization Tool, and the Geoportal provide both an easy-to-grasp overview of quantitative results and sectoral trade-offs and detailed information on possible alternatives and their expected impacts, which are suitable for both technical and non-technical users.

## Participatory design process is essential

The process of developing the tools has shown that a participatory design approach which involves frequent exchange with prospective users is crucial.

Initial consultations with stakeholders allowed the identification of their needs and promoted understanding of the local context. Intermediate feedback rounds confirmed whether the prototypes fulfilled their expectations and identified areas for improvement. This has helped to achieve a high level of usability of the tools which is vital for stakeholder acceptance.



### Screening tool

- Shows main trade-offs between multiple options
- Supports reducing the number of alternatives

### Multi-perspective visualization tool

- Shows various trade-offs between the main options
- Facilitates comparison of sectoral perspectives

### Geoportal

- Provides access to detailed results with high space-time resolution

**Figure 2:** The three visualization tools in DAFNE are tailored to satisfy the needs of different user groups.

Consultations also helped to better understand prospective users and validate the approach of developing a suite of complimentary tools. These consultations confirmed that stakeholders have different types and levels of expertise and expectations regarding the level of detail of the results. Therefore, a suite of closely linked tools tailored for different purposes and user groups fits the intended purpose well.

## Evaluations highlight the usefulness of the tools and the need for training

The interactions with stakeholders have shown that they find the tools useful for the negotiation process and are enthusiastic about the possibility of applying them in a real-life setting. They commented positively on:

- the possibility to easily **explore trade-offs**
- the basis for **evidence-based decision making**
- the possibility to consider the **perspectives of various sectors**
- the potential for **conflict-prevention**.

However, evaluations showed a limited confidence in using such applications, which highlights the need for capacity building.

# COOPERATION AS THE FOUNDATION FOR SUSTAINABLE WATER ALLOCATION

## Key takeaways

- **The game-theoretical model developed in DAFNE analyses the economic aspects of transboundary water allocation.** It considers the dynamics between countries located in the upstream and downstream regions.
- **Cooperation is the optimal mechanism for water allocation in the Omo-Turkana Basin.** Linking water management strategies to trade would benefit Ethiopia and Kenya in both economic and environmental terms.
- **Transboundary water sharing agreements can help the OTB countries to realize these benefits.** They can play an important role in facilitating the cooperation and trade.
- **Accounting for externalities is crucial.** Failing to consider the external effects of water consumption in the OTB have an impact on the hydrological scheme of Lake Turkana.

Unequal access to water resources has strong implications for economic development. A country located upstream on a river typically has more control over the resource and the benefits that come with it than a country located downstream. DAFNE used a game-theoretical framework to explore optimal water sharing strategies in transboundary river basins with this dynamic.

## Cooperation in water sharing in the Omo-Turkana Basins brings about economic and environmental benefits

The analysis of the Omo-Turkana Basins (OTB) highlights economic and environmental benefits of transboundary cooperation in water resources allocation facilitated by international trade. The model compares two scenarios:

1. **No cooperation:** There is no agreement between the countries on water sharing or trade.
2. **Cooperation:** Countries adopt a water sharing strategy facilitated by trade in food and hydropower.

The model indicates that in the OTB, cooperation on water allocation would be beneficial to both Ethiopia and Kenya, also in the light of possible extreme effects of climate change.

Cooperation through trade would lead to a higher economic benefit for each country than the non-cooperative scenario and would be more sustainable with respect to future water availability in Lake Turkana. This result highlights the opportunity for trade: it would allow the two countries to benefit from their comparative advantages, make better use of water resources and limit the destruction of ecosystems, in effect avoiding negative economic and social impacts. An international water sharing agreement could help to realize these benefits by facilitating the opening up of the economies and enhancing collaboration between them.

## Considering externalities is crucial for environmental sustainability

The modelling exercise also highlighted how important it is that the OTB countries consider the external effects of their water use. In the non-cooperative case, the model compares two strategies that each country can adopt:

1. **Myopic:** The country uses water resources extensively, without considering the impacts on water balance and its individual benefit.
2. **Non-myopic:** The country conserves water thus considering the benefits of doing so.

The choice of strategy by the OTB countries has strong environmental implications. In the long run, Kenya would benefit in economic terms from adopting the forward-looking, non-myopic strategy. While for Ethiopia a moderate use of water would translate into slightly lower economic benefits, it would reduce the negative externalities in form of decreasing water levels in Lake Turkana.



## USING EARTH OBSERVATION TECHNIQUES TO COMPLEMENT TRADITIONAL DATA SOURCES AND CONVEY MESSAGES

### Key takeaways

- **Earth observation (EO) techniques can be used to complement ground-based data.** Remote sensing through satellites or Unmanned Aerial Vehicles (UAVs) generate data at a variety of scales and resolutions.
- **EO products help to convey messages.** High quality EO-images can effectively illustrate the complex connections and conflicts in the landscape and engage a broad public.
- **EO technologies are not free of challenges.** Their use can be restricted by technical issues or formal obstacles.

Sufficiently accurate data is central for reliable modelling and informed decision making. The DAFNE project has demonstrated how cutting-edge monitoring techniques can be deployed to complement existing data and gain a better understanding of riverine ecosystems.

### Earth observation can generate data at various scales and resolutions

Satellite-based remote sensing generates visual data with resolutions that can range from meters to kilometres. They can be used to create highly accurate maps and decade-long monitoring of geophysical processes and land uses. The technology was used extensively in the DAFNE project. For example, it facilitated the estimation and validation of models of the hydrological regime of Lake Turkana in Kenya.

Conversely, Unmanned Aerial Vehicles (UAVs - or drones) can be used to provide more targeted, local data at very high resolutions. Among other things, they allow the monitoring of ecosystems or agricultural productivity. For example, DAFNE used drone images to determine water needs in sugar cane plantations and to monitor water hyacinths in the Zambezi River Basin in order to analyse the role of environmental flows in controlling the expansion of invasive species (**Figure 3**).



*Figure 3: Drone images can be used to monitor the spread of invasive species that clog rivers (image by ATEC-3D).*

### Earth imagery can serve as a strong communication tool

Visual EO products, such as high-quality photos and videos can illustrate spatial information and complex interactions in ecosystems, also for purposes beyond research. DAFNE suggests that spatial visuals can help develop a joint vision for the landscape in participatory processes, inform decision makers located further away from the places that their policies affect, or trigger reflections about human-nature interactions among a broader public.



*Figure 4: Kafue gorge dam in Zambia with floating vegetation trapped at the spillway (picture by ATEC-3D).*



## Technical and legal obstacles in using EO need to be addressed

Addressing technical and legal challenges could facilitate broader adoption of EO for research. Incorporating earth observation data into modelling procedures can be extremely convenient. However, it is important to remember that EO data products are the outputs of models themselves. Therefore, traditional data remains crucial for calibration, validation and explaining potential disparities.

The strong limitations for the use of UAV's come with the limited spatial reach depending on the battery, the large amounts of data that need to be processed and the vulnerability to bad weather conditions, including rain, wind and strong sun.

In addition, legal obstacles can limit the applicability of some technologies. Laws governing operation of UAVs differ between countries, often involve extensive paperwork, and sometimes prohibit it altogether. Streamlining procedures could facilitate a broader use of UAVs for research.



**Figure 5:** Satellite image of the Kafue gorge with floating vegetation (PlanetScope Scene, 3-m resolution, [www.planet.com](http://www.planet.com))



**Figure 6:** Part of the Kafue flats wetland in Zambia. The bright green fringe along the shore is composed of two exotic floating plant species, water hyacinth and Amazon frogbit (picture by ATEC-3D).

# COMMON THREADS IN LEGAL AND POLICY FRAMEWORKS IN THE OMO-TURKANA AND ZAMBEZI RIVER BASINS

## Key takeaways

- **Suitable institutional frameworks are vital for sustainable transboundary governance of natural resources.** DAFNE assessed current frameworks that apply to the key environmental issues in the Omo-Turkana (OTB) and Zambezi River Basins (ZRB).
- **While existing institutional foundations in the two basins are encouraging, there is scope for improvement.** The coverage of environmental issues in legal and policy frameworks, harmonisation of frameworks across countries within the basins and transboundary cooperation need strengthening.

Strong institutional frameworks governing natural resources are instrumental for avoiding the *tragedy of the commons* that leads to environmental degradation. This regards several dimensions: adequate coverage of environmental issues in laws and policies, also those related to non-environmental sectors, alignment of policies of different countries within a basin, and transboundary cooperation. DAFNE assessed these aspects in the Omo-Turkana (OTB) and Zambezi River (ZRB) basins.

## Better coverage of environmental issues in institutional frameworks is needed

In both OTB and ZRB, the extent to which environmental issues are addressed in policies and legislation varies across countries. While generally good foundations are in place, improvement in terms of depth and specificity is possible. Within the OTB, for example, no country has a legal or policy framework in place that addresses biodiversity. In the ZRB, although environmental issues are largely addressed at least to some extent, coverage of biodiversity and wetlands remains fragmented.

Legal documents specific to the water, energy, and food sectors in OTB and ZRB address environmental concerns to some extent, but they could

internalize the environmental impacts of the sectors better. In OTB, more holistic incorporation of environmental issues in water and energy policies is needed. In ZRB, while environmental provisions in sectoral documents are present, they tend to be quite general.

## Greater harmonization of legal frameworks within river basins can be achieved

In the river basins analysed, policy and legal frameworks are harmonized among countries to some extent. However, in both OTB and ZRB, some misalignments among countries persist. In both river basins, these are found in the following areas:

- Types of fishing gear allowed
- Categorisations of forests
- Degree of protection of wetlands
- Level of policy coverage on biodiversity
- Protected species

## Basin-wide cooperation mechanisms should be established or strengthened

In both OTB and ZRB, basin-wide cooperation structures possess scope for further improvement and empowerment. In the OTB, basin-wide frameworks – which have the potential to address environmental challenges – remain undeveloped. In the ZRB, on the other hand, the tradition of basin-wide cooperation is more established and formalized, for example through the 2004 ZAMCOM agreement. However, specific binding regulations concerning the environment to empower such river basins organisations with regulatory authority are lacking.

## The legacy of DAFNE

WEF Nexus projects have proliferated in number since DAFNE has been implemented, and it is expected that the new crops of related projects – both in and beyond the two basins of focus – will absorb and are likely to build on approaches conceptualized in DAFNE.





## ABOUT THE DAFNE PROJECT

The DAFNE project advocates an integrated and adaptive water resources planning and management approach that explicitly addresses the water-energy-food (WEF) nexus from a novel participatory and multidisciplinary perspective that includes social, economic, and ecologic dimensions. In two cross-boundary case studies, the Zambezi River Basin and the Omo-Turkana Basins, the WEF nexus has been quantified and analysed as the trade-offs between conflicting objectives such as hydropower production versus irrigation or land exploitation versus conservation. DAFNE generates and explores alternative planning and management solutions based on the cooperation of public and private stakeholders, which fosters the profitable but equitable use of resources without transgressing environmental limits or creating societal conflicts.

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For more information on DAFNE visit [www.dafne-project.eu](http://www.dafne-project.eu)



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