

## AGROECOLOGICAL REENGINEERING OF IRRIGATED SCHEMES: FROM THEORY TO CASE STUDIES

### REORGANISATION AGROÉCOLOGIQUE DES PÉRIMÈTRES IRRIGUÉS : DE LA THÉORIE AUX ÉTUDES DE CAS

N. Urruty<sup>1</sup>, E. Dressayre<sup>2</sup>, C. Hello<sup>2</sup>, J. Lecollinet<sup>1</sup>, S. Sauviat<sup>1</sup>, B. Vennat<sup>2</sup>

#### ABSTRACT

Irrigated agriculture remains a cornerstone of global food security (20% of cultivated land that produce 40% of total food). However, large-scale collective irrigation schemes are most often characterized by intensive agricultural practices and their associated drawbacks, such as biodiversity reduction, soil degradation, water pollution and greenhouse gas emissions. Among the alternative ways to reconcile environmental, sustainability and production goals, agroecology is now receiving increasing attention by emphasizing the application of ecological concepts and principles to the design and management of agricultural systems. However, recent work by COSTEA<sup>3</sup> has shown that few agroecological innovations are present in large-scale irrigation schemes, which could be partly explained by the inflexibility of the associated hydro-agricultural infrastructures and their management. To explore this avenue, a study conducted by BRLi & SCP and commissioned by COSTEA aimed to examine various reengineering options to promote the adoption of agroecological principles in large-scale irrigated areas. A framework (multi-input analysis grid) was established to analyze these irrigated areas according to various agroecological criteria. The adopted agroecological principles are based on an integrated approach which considers the interactions between water, energy and food. This grid was applied to various collective irrigation projects in Senegal and Cambodia to assess the level of commitment to agroecology. Results of this study revealed that: i) agroecology principles are often cited in design and rehabilitation studies but they rarely cover all the dimensions mentioned above, ii) the shift from gravity-fed to modern irrigation infrastructures are highly limited by various factors (e.g. availability of water resources, budget constraints, technical skills of users and maintenance services...), which leave little room for technical innovation, and iii) the proposed changes are multifaceted and therefore require long time for concertation and adaptation.

**Keywords:** Irrigated agriculture; agroecological principles; water resources; budget constraints; technical innovation.

#### RESUME

L'agriculture irriguée reste la première pierre de la sécurité alimentaire mondiale (20% des terres cultivées produisent 40% de l'alimentation totale). Cependant, les périmètres irrigués collectifs à grande échelle sont le plus souvent caractérisés par des pratiques agricoles intensives et leurs inconvénients associés, tels que la réduction de la biodiversité, la dégradation des sols, la pollution de l'eau et les émissions de gaz à effet de serre. Parmi les moyens alternatifs pour concilier les objectifs environnementaux, de durabilité et de production, l'agroécologie reçoit aujourd'hui une attention croissante en mettant l'accent sur l'application des concepts et principes écologiques à la conception et à la gestion des systèmes agricoles. Cependant, des travaux récents menés par le COSTEA ont montré que peu d'innovations agroécologiques existent dans les grands périmètres irrigués, ce qui pourrait

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<sup>1</sup> Société du Canal de Provence, LE THOLONET, France

<sup>2</sup> BRL Ingénierie, NÎMES, France

<sup>3</sup> Comité Scientifique et Technique de l'Eau Agricole

s'expliquer en partie par la rigidité des infrastructures hydro-agricoles associées et de leur gestion. Pour explorer cette voie, une étude menée par BRLi & SCP et commandée par COSTEA, a visé à examiner diverses options de réorganisation afin de promouvoir l'adoption des principes agroécologiques dans les zones irriguées à grande échelle. Un cadre d'analyse (grille d'analyse d'intrants multiples) a été mis en place pour analyser ces surfaces irriguées selon différents critères agroécologiques. Les principes agroécologiques retenus sont basés sur une approche intégrée qui prend en compte les interactions entre l'eau, l'énergie et l'alimentation. Cette grille a été appliquée à divers projets d'irrigation collective au Sénégal et au Cambodge pour évaluer le niveau d'engagement en faveur de l'agroécologie. Les résultats obtenus de cette étude ont révélé que : i) les principes de l'agroécologie sont souvent cités dans les études de conception et de réhabilitation, mais ils couvrent rarement toutes les dimensions susmentionnées, ii) le passage des infrastructures d'irrigation gravitaires aux infrastructures modernes est fortement limité par divers facteurs (par exemple, disponibilité des ressources en eau, contraintes budgétaires, habiletés techniques des usagers et des services de maintenance...), qui laissent peu d'espace à l'innovation technique, et iii) les changements proposés sont multidimensionnels et nécessitent donc beaucoup de temps pour la concertation et l'adaptation.

**Mots-clés :** Agriculture irriguée; Principes agroécologiques; Ressources en eau; Contraintes budgétaires; Innovation technique.

## INTRODUCTION

During the 20th century, agricultural modernization was largely driven by processes of homogenization and standardization of production systems. This paradigm relied on the widespread use of improved crop varieties and animal breeds, combined with uniform management practices, mechanization, and the intensive use of external inputs such as fertilizers and pesticides. By maximizing the genetic potential of a limited range of plant and animal species under controlled and optimized conditions, this model enabled substantial increases in agricultural productivity and contributed significantly to global food security (Gollin *et al.*, 2021).

Following a similar trajectory, large-scale irrigation schemes have been developed worldwide through the construction and expansion of hydraulic infrastructures and increasingly sophisticated water management systems. These schemes rely mainly on collective organization, enabling the coordinated allocation and distribution of water resources across extensive agricultural areas. By ensuring more reliable water supply, reducing dependence on rainfall variability, and supporting the intensification of agricultural practices, such systems have significantly enhanced crop productivity and stability of yields. In many regions, they have facilitated the adoption of high-yielding varieties and input-intensive farming systems, thereby amplifying the overall gains of agricultural modernization. As a result, collective irrigation schemes have contributed substantially to increases in agricultural output and have played a critical role in meeting the food demands of a rapidly growing global population, which has nearly quadrupled over the past century (FAO, 2020).

However, these developments have also raised important challenges related to water resource sustainability, equity in access, and environmental impacts. Moreover, a recent work by COSTEA has shown that few agroecological innovations are present in large-scale irrigation systems, which could be partly explained by the inflexibility of the associated hydro-agricultural infrastructure and management (Roesch *et al.*, 2022).

This process of agricultural modernization and intensification is now approaching its limits within an increasingly unfavorable context, characterized by rising climatic, economic, and sociopolitical uncertainties, mounting constraints on critical inputs such as water, and stagnating system performance dynamics that call into question the continued acceptability of the significant environmental externalities it produces (Leauthaud *et al.*, 2025).

Accordingly, this situation calls for the emergence of a new paradigm commonly framed as the agroecological transition (Gliessman, 2018) structured around several core principles:

- a shift from yield maximization towards multi-functional and water efficient use of irrigation water (e.g. irrigation of cover crops, agroforestry, soil and water conservation);
- a decentralization of governance with strengthened roles for farmers and stakeholder coordination;
- and the pursuit of flexible and modular water access systems to support more autonomous and adaptive farming practices.

In this paper, we propose an analytical framework aimed at facilitating both the diagnosis and the design of irrigated schemes within an agroecological perspective. This framework aims to illustrate the links between the various components of irrigated schemes and their agroecological performance.

After outlining the core principles of this conceptual framework, we demonstrate its applicability through two irrigated case-studies in Senegal and Cambodia.

## PRESENTATION OF THE CONCEPTUAL FRAMEWORK

The conceptual framework is based on the intersection between, on the one hand, the core components of irrigated schemes and, on the other, the various agroecological objectives pursued.

### The seven dimensions of irrigated schemes

While the implementation of irrigated systems may solve the challenges related to insufficient available water resources for rainfed cultivation, it also radically increases the diversity of skills and expertise required of farmers, governance systems and policy makers. We have identified seven dimensions that reflect the complexity of collective irrigated systems and their integration into different spatial, economic, and political levels. (**Figure 1**).

**Dimension 1: Governance.** The governance of irrigated systems encompasses the institutional frameworks, policies, and decision-making processes that shape how water resources are allocated, managed, and monitored within irrigation schemes. It involves multiple stakeholders, including public authorities, water user associations, farmers, and private actors, whose interactions determine the performance and sustainability of the system.

**Dimension 2: Infrastructure design.** It refers to the physical and technical components that enable water storage, conveyance, distribution, and application within irrigation schemes. It includes both large-scale hydraulic structures (e.g., dams, reservoirs, diversion weirs) and distribution networks (e.g., canals, pipelines, control gates), as well as on-farm irrigation technologies (e.g., drip, sprinkler, or surface irrigation systems).

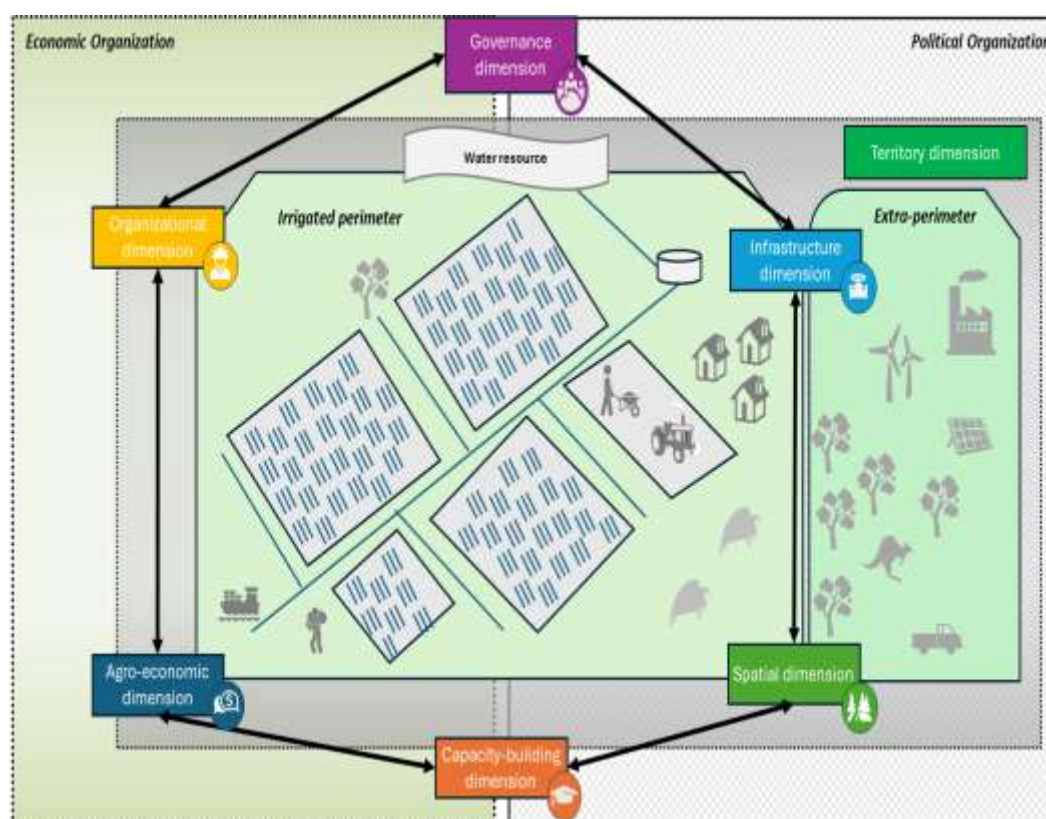
**Dimension 3: Spatial organization.** This aspect relates to the internal spatial configuration of plots and the different areas within the perimeter. It also emphasizes the interactions between irrigation systems and the broader landscape, including land use patterns, agricultural and livestock practices, rural development dynamics, and ecosystem functions.

**Dimension 4: Support and capacity building.** It refers to the set of institutional, technical, and human processes that aim to strengthen stakeholders' capacities to effectively manage, operate, and adapt irrigation systems. It encompasses advisory services, technical experimentations, knowledge transfer, training, technical assistance, and facilitation mechanisms provided to farmers, farmers organisations, water user associations, and other actors.

**Dimension 5: Agro-economic strategy.** This dimension examines the interactions between agricultural production, economic performance, and institutional-economic arrangements that shape farmers' decisions. It extends beyond farm-level production to include the influence of agricultural value chains (e.g., processors, cooperatives, distributors), public policies (e.g. subsidies, pricing), and market structures that structure demand and influence production choices.

**Dimension 6: Organization and maintenance.** It refers to the structures, arrangements, and coordination mechanisms through which actors involved in irrigation collectively organize the operation, management, and use of water resources and infrastructure. It focuses on how responsibilities, roles, and interactions are structured among stakeholders at different levels.

**Dimension 7: Territorial integration.** This dimension refers to the relationship between the irrigated scheme and the territory in which it is embedded. It encompasses the relationships between irrigation and other water uses (e.g., domestic, industrial, environmental flows), as well as the integration of irrigation into regional development strategies.



**Figure 1.** Schematic representation of the seven dimensions of irrigated schemes

### Key challenges associated with agroecological redesign of irrigated schemes

The major challenges and objectives associated with the agroecological transition of irrigated schemes encompass water, agri-food, socio-economic, energy, and environmental dimensions. This type of categorization is inspired by the Water–Energy–Food (WEF) Nexus approach, to which economic and environmental considerations have been added. **Table 1** below illustrates the diversity of these challenges, while highlighting the different spatial scales at which they occur.

**Table 1:** Examples of agroecological issues and success drivers at local, irrigated scheme and territory scales

| Agroecological issues           | Local scale --> (farm, field)                                                                                                                                                             | <-- Irrigated Scheme --> scale                                                                                                                                                                                                                                            | <-- Territory Scale (> irrigated scheme)                                                                                                                                                                                                                |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Water management</b>         | <ul style="list-style-type: none"> <li>Enhance water-use efficiency and water productivity at the field scale</li> <li>Promote flexible access to water resources</li> </ul>              | <ul style="list-style-type: none"> <li>Minimize water losses between abstraction and farm distribution</li> <li>Design infrastructure according to actual water demand</li> <li>Deploy a soil and plant sensor network for early warning of water stress risks</li> </ul> | <ul style="list-style-type: none"> <li>Reduce pressure on water resources under conditions of scarcity</li> <li>Mitigate conflicts over water use with other stakeholders in the territory</li> <li>Ensure adequate drainage of excess water</li> </ul> |
| <b>Food supply</b>              | <ul style="list-style-type: none"> <li>Increase crop and sustainability</li> </ul>                                                                                                        | <ul style="list-style-type: none"> <li>Promote food-oriented production and supply to local markets</li> <li>Support collective organization among farmers</li> </ul>                                                                                                     | <ul style="list-style-type: none"> <li>Support the organization of supply chains (e.g. storage, commercialization systems, transport infrastructure)</li> </ul>                                                                                         |
| <b>Rural Livelihoods</b>        | <ul style="list-style-type: none"> <li>Enhance income per crop and per household</li> <li>Improve access to land resources</li> <li>Promote the establishment of young farmers</li> </ul> | <ul style="list-style-type: none"> <li>Reduce poverty among farming households</li> <li>Improve the association of crop and livestock systems</li> <li>Promote gender equity and youth inclusion in collective organizations</li> </ul>                                   | <ul style="list-style-type: none"> <li>Promote the integration of neighbouring communities (e.g. livestock keepers)</li> <li>Encourage the interactions with agricultural extension and R&amp;D services</li> </ul>                                     |
| <b>Energy supply</b>            | <ul style="list-style-type: none"> <li>Reduce the use of fossil-based inputs (e.g. mineral fertilizers, diesel) by farmers</li> </ul>                                                     | <ul style="list-style-type: none"> <li>Enhance the integration and use of renewable energy for water pumping</li> <li>Reduce operational costs and dependency on external energy inputs</li> </ul>                                                                        | <ul style="list-style-type: none"> <li>Promote the transfer of renewable energy solutions into irrigated schemes</li> </ul>                                                                                                                             |
| <b>Environmental protection</b> | <ul style="list-style-type: none"> <li>Encourage the adoption of agroecological farming practices (e.g. agroforestry, soil and water conservation, biological pest control...)</li> </ul> | <ul style="list-style-type: none"> <li>Preserve ecological continuity in the design of the irrigated scheme (e.g. trees, wetlands, etc.)</li> <li>Implement sustainable canal maintenance practices (e.g. mechanical weed removal)</li> </ul>                             | <ul style="list-style-type: none"> <li>Reduce the risk of downstream pollution from irrigated scheme</li> </ul>                                                                                                                                         |

## Presentation of the analytical framework

The analytical framework ultimately consists of a cross-analysis between the seven dimensions of irrigated schemes and the main agroecological transition challenges. **Table 2** below provides an illustration of this framework, highlighting some agroecological redesign options.

## USE OF THE ANALYTICAL FRAMEWORK IN TWO CASE STUDIES

### Overview of the case studies

#### *DELTA project in Senegal*

The DELTA programme operates across 13 municipalities in the Senegal River Valley —eight in the Saint-Louis region (Dagana and Saint-Louis) and five in the Louga region (Louga and Linguère)—with planned expansion toward Podor and Matam. Aligned with Senegal's national agricultural development strategy and the 2021–2025 mandate of SAED, the programme supports territorial planning and rural development through an integrated approach combining land-use management, irrigation development, and value chain strengthening.

**Table 2.** Analytical framework and examples of agroecological redesign options in collective irrigated schemes

|                          | Governance                                                    | Infrastructure design                                                                  | Spatial organization                                                    | Support and capacity-building                                               | Agro-economic paradigm                                                              | Organization and maintenance                             | Territorial integration                       |
|--------------------------|---------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------|-----------------------------------------------|
| Water management         |                                                               | Modernization with pressurized systems to allow the use of drip irrigation systems     |                                                                         |                                                                             |                                                                                     |                                                          | Establishment of a resource monitoring center |
| Food supply              |                                                               |                                                                                        | Areas dedicated to crop and livestock associations (e.g. rice and fish) |                                                                             | Subsidies to encourage the purchase of materials suited to agroecological practices |                                                          |                                               |
| Rural Livelihoods        |                                                               |                                                                                        |                                                                         | Training programmes to support farmers in adopting agroecological practices |                                                                                     |                                                          |                                               |
| Energy supply            |                                                               | Use of renewable energies to offset increased carbon emissions and energy requirements |                                                                         |                                                                             |                                                                                     |                                                          |                                               |
| Environmental protection | Integration of environmental stakeholders into the governance |                                                                                        |                                                                         |                                                                             |                                                                                     | Sustainable maintenance with mechanically weeding canals |                                               |

DELTA aims to address key structural challenges, including land saturation, limitations in territorial planning, and the need for professionalization of agricultural value chains, while also integrating cross-cutting issues such as climate change, environmental impacts, social inclusion, nutrition, and gender equality. It builds on a long-standing partnership with SAED to enhance institutional resilience and capitalize on previous interventions.

Based on preliminary design studies (APS), the programme focuses on two main investment pillars: the rehabilitation of approximately 2,700 ha of irrigated rice schemes and three village irrigation schemes (PIVs) in Dagana, and the development of around 2,200 ha of new irrigated areas in the Lake Guiers zone, with the objective of sustainably improving agricultural productivity and resource management. However, the targeted irrigated schemes face significant structural and organizational constraints. Ageing hydraulic infrastructure (levees, drainage networks), largely dating from the 1960s–1980s, requires substantial rehabilitation to restore functionality and ensure long-term sustainability. In addition, collective governance arrangements, primarily involving SAED and farmer organizations (GIEs), combined with flat-rate water pricing, limit the flexibility and efficiency of irrigation practices relative to farmers' needs. Finally, the system is characterized by weak integration between crop and livestock systems and a high dependence on diesel for pumping, increasing vulnerability to energy price volatility and environmental pressures.

#### *Svay Chek project in Cambodia*

The Svay Chek River Basin, located at the transboundary interface between Thailand and Cambodia, is subject to significant environmental and hydro-climatic pressures, including deforestation, soil erosion, biodiversity loss, and increasing variability in water availability, characterized by recurrent flooding during the wet season and droughts in the dry season. These constraints are further exacerbated by degraded hydraulic infrastructure and limited integration of governance frameworks across sectors and national boundaries.

In this context, Sway Chek project adopts an integrated water resources management (IWRM) approach, combined with the deployment of nature-based solutions (NbS), to improve rural livelihoods while enhancing the sustainability and resilience of agro-ecosystems.

Main objectives include the rehabilitation of water storage systems, restoration of river ecological connectivity (e.g. fish passages and reforestation), and the implementation of integrated flood risk management strategies. The project also promotes the transition toward sustainable agricultural

systems through capacity building of farmer water user communities, the dissemination of agroecological practices, and investments in resilient infrastructure such as solar-powered irrigation systems, storage facilities, and rural access roads.

In parallel, efforts are made to strengthen water governance through the establishment of basin-level coordination mechanisms, the development of integrated management plans, and the use of modelling tools to assess water resources and ecosystem services, complemented by early warning systems. Particular attention is given to climate vulnerability, recognizing the high sensitivity of agricultural systems to hydro-climatic hazards and the need to enhance adaptive capacity through diversification, improved water management, and institutional strengthening.

By combining infrastructure investments, governance reforms, and ecosystem-based approaches, the project seeks to foster a more resilient, inclusive, and ecologically sustainable socio-agricultural system at the basin scale.

### *Overview of the reviewed documents*

The adopted methodology relies on the analysis of available documentation from the two case studies (**Table 3**) and the identification of agroecological elements aligned with the analytical framework previously detailed.

In the case of Senegal, the availability of multiple project phases enabled the analysis of how agroecological challenges were addressed and evolved over time.

**Table 3.** List of the reviewed documents for each project

| Project                      | List of the reviewed documents                                                                                                                                                                                                                                                                                                |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DELTA project (Senegal)      | <ul style="list-style-type: none"> <li>• Project formulation report</li> <li>• Pre-feasibility and feasibility studies (APS)</li> <li>• Environmental and Social Impact Assessment (ESIA)</li> <li>• Terms of Reference (ToR) and Detailed Design Reports (APD)</li> <li>• Climate change vulnerability assessment</li> </ul> |
| Svay Chek project (Cambodia) | <ul style="list-style-type: none"> <li>• Baseline study</li> <li>• Full feasibility study report</li> <li>• Gender action plan</li> <li>• Stakeholder engagement plan</li> <li>• Vulnerability to climate change</li> </ul>                                                                                                   |

## **3.3. Key findings from the document analysis**

### *3.3.1. Agroecological assessment of DELTA project*

The analysis of the DELTA project documents through the analytical framework revealed the strengths and weaknesses of the project design in agroecological terms. **Table 4** presents the results of this analysis at different spatial scales, highlighting the proposed actions for each dimension of the irrigated schemes.

**Table 4.** Inventory of proposed actions in DELTA project documents and cross-checking with the analytical framework criteria

| Agroecological issues    | Local scale --> (farm, parcel)                                                                                                                          | <-- Irrigated Scheme --> scale                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <-- Territory Scale (> irrigated scheme)                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Water management</b>  |  Field-scale irrigation mode adapted to local pedo-climatic conditions |  Improvements to drainage and earthworks on the plots<br> Lining of canal<br> Weeding the non-lining canal and ridges<br> Availability of a weather station for appropriate climate monitoring                                                                                                                                                                                                                                                                                    |  Establishment of a resource monitoring center                                                                                                                                                                                                                                                                                                                                                   |
| <b>Food supply</b>       |  Capacity building of farmers                                         |  Promoting interaction between the irrigation system and livestock farming<br> Certified seed producer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |  Development of local initiatives such as DYTAEL (Dynamique pour la Transition Agroécologique Locale)<br> Improvement of roads and tracks<br> Existence of advisory bodies and research center in agroecology (ISRA)    |
| <b>Rural Livelihoods</b> |                                                                                                                                                         |  Renovation (or design) that considers non-agricultural uses of infrastructure<br> Promoting of areas designated for women and young people<br> Gender representation in the governing bodies of the group<br> Rules/allowances for livestock farmers and other users/Existence of a dispute resolution body<br> Availability of a demonstration plot, educational farm, or pilot farm |  Encourage women and young people to participate in training programs<br> Promotion of activities aimed at women and young people<br> Development of downstream production sectors to promote value-added processing |
| <b>Energy supply</b>     |                                                                                                                                                         |  Promotion and used Solar-powered water pumping systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Agroecological issues    | Local scale --> (farm, parcel) | <-- Irrigated Scheme --> scale                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <-- Territory Scale (> irrigated scheme)                                                                                                                |
|--------------------------|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Environmental protection |                                | <br>Support to produce compost from Tiffa and use of biofertilisers<br><br>Promotion of organic production system<br><br>Encouraging the planting of non-productive elements (hedges)<br><br>Rehabilitation of the drainage area | <br>Managing the impact of irrigated areas on adjacent natural areas |

**Legend:**
 Governance
  Infrastructure
  Spatial organization
  Capacity building  
 Agroecological paradigm
  Organization and maintenance

The cross-analysis of DELTA project documents against the agroecological assessment framework shows that agroecological considerations are incorporated to varying degrees across different scales, with a strong emphasis on water management, infrastructure development, and capacity building:

- Strong focus on water management, with actions including improved irrigation and drainage systems, canal rehabilitation, weather stations, and resource monitoring tools to enhance water-use efficiency and climate resilience.
- Support for sustainable agricultural production, through farmer training, seed production initiatives, crop–livestock integration, and local agroecological initiatives such as DYTAEL.
- Attention to rural livelihoods and inclusion, with measures promoting the participation of women and youth, conflict-resolution mechanisms, demonstration farms, and the development of value-added agricultural value chains.
- Environmental and energy considerations are addressed through solar-powered irrigation, compost production from *Typha*, biofertilisers, organic farming promotion, hedge planting, and the management of impacts on surrounding ecosystems.

Overall, the DELTA project incorporates several agroecological principles, particularly regarding natural resource management, capacity building, and governance. However, it remains primarily focused on irrigation infrastructure and productivity improvements, while more transformative agroecological dimensions such as biodiversity enhancement and farming system diversification are less explicitly addressed.

### ***Agroecological assessment of Svay Chek project***

The same analysis was performed for Svay Chek project documents. **Table 5** presents the results of this analysis at different spatial scales, highlighting the proposed actions for each dimension of the irrigated schemes.

**Table 5.** Inventory of proposed actions in Svay Chek project documents and cross-checking with the analytical framework criteria

| Agroecological issues           | Local scale --> (farm, parcel)                                                                                          | <-- Irrigated Scheme --> scale                                                                                                                                                                                                                                                                                                                                                                                                                                    | <-- Territory Scale (> irrigated scheme)                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Water management</b>         |                                                                                                                         |  Upgrading of network infrastructure, canal regulation and drainage<br> Capacity strengthening of Water User Associations (WUAs)<br> Strengthening the operation and maintenance (O&M) of hydraulic structures |  Strengthening of the Watershed Management Committee and development of a risk prevention plan<br> Enhanced coordination with Thailand                                                                                                                               |
| <b>Food supply</b>              |  Capacity building of farmers          |  Lotus cultivation in reservoirs<br> Promotion of vegetable cultivation in raised areas<br> Improvement of roads and tracks                                                                                   |  Establishment of modern cooperatives<br> Strengthening agricultural strategies across 15 municipalities<br> Promotion of off-soil activities (beekeeping, mushroom cultivation) |
| <b>Rural Livelihoods</b>        |  Promotion of crop insurance         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |  Promotion of gender equity and youth inclusion in agriculture                                                                                                                                                                                                                                                                                        |
| <b>Energy supply</b>            |                                                                                                                         |  Carbon footprint analysis of the project<br> Solar-powered water pumping systems for high-elevation areas<br> Promotion of subsidies for solar-powered pumps                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Environmental protection</b> |  Support for on-farm waste recycling |  Bank stabilization and revegetation<br> Implementation of an agricultural input management plan<br> Training of 15 municipal staff in agroecology                                                       |  Establishment of flow allocation rules<br> Protection of buffer zones<br> Removal of in-stream obstacles                                                                   |

**Legend:**  Governance  Infrastructure  Spatial organization  Capacity building  
 Agroeconomic paradigm  Organization and maintenance

The analysis of this cross-referenced information highlights the following key aspects:

- The irrigation scheme and territorial scales are particularly well addressed in the analyzed documents, whereas the local scale of the plot or farm is treated more superficially;
- The most prominently addressed dimensions are governance (6 actions), stakeholder support (6 actions), infrastructure (4 actions) and spatial organization (4 actions), whereas the agro-economic (2 actions) and organizational (1 action) dimensions are comparatively less represented.
- The most prioritized agroecological issues identified through the analysis include water management (5 actions), food systems (7 actions), and environmental protection (7 actions), whereas energy-related issues (3 actions) and livelihood improvement (2 actions) appear to be of lower priority in this development project.

## DISCUSSION AND CONCLUSION

### Strengths and limitations of the analytical framework

The application of this analytical framework to two case studies highlighted its usefulness in identifying gaps or, conversely, the prominence of certain agroecological issues. This analytical framework can cover at least four main uses for the design or rehabilitation of irrigated schemes:

- Scoping and formulation: it can facilitate the project design by identifying the key elements to be considered from the initial stages;
- Diagnosis: it can be used to assess the initial state of an irrigated scheme and the main agroecological challenges
- Techno-economic sizing: it allows the project to be aligned with technical and financial realities, and helps define intervention priorities.
- Monitoring and evaluation: it supports the project over time by measuring progress and assessing results before and after implementation.

In summary, the framework is a cross-cutting tool that can be used to design, assess, size, and monitor irrigation and agroecological projects.

However, some limitations were identified during the use of the analytical framework:

- The high number of dimensions and agroecological issues, that may not always fit with the nature and context of the project.
- The ambiguity of certain indicators (e.g., canal lining, which enhances efficiency but negatively affects environmental outcomes and groundwater recharge).
- In the case of an ongoing project, assessing the level of completion of the framework is challenging: whether it should be evaluated based on the initial objectives (project design phase) or on tangible results.

This analytical approach can be viewed as complementary to the multicriteria evaluations already used in project and scenario assessments. It should also be noted that project owners and consulting firms are themselves constrained by several factors: i) agroecology principles are often cited in design and rehabilitation studies but they rarely cover all the dimensions mentioned above, ii) infrastructure choices towards a greater flexibility are highly limited by various factors (e.g. availability of water resources,

budget constraints...), which leave little room for technical innovation, and iii) the proposed changes are multifaceted and therefore require more time for concertation and adaptation.

## Perspectives

This analytical framework was developed as part of the COSTEA 3 initiative on the agroecological re-engineering of irrigated schemes. Beyond its ex-post application to already completed studies, COSTEA members intend to use this approach in new pilot schemes to define agroecological transformation and adaptation options for hydraulic infrastructure, productive areas and collective management arrangements.

In this regard, a study is currently underway, led by BRLi and SCP with the support of CIRAD, to define the most appropriate agroecological re-engineering options in several irrigation schemes in Senegal and Cambodia. A side event will be organized on this topic at the ICID conference.

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