COSTEA STRUCTURING ACTION 'AGROECOLOGICAL TRANSITIONS IN IRRIGATED SCHEMES'

FINAL SYNTHESIS AND RECOMMENDATIONS

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COSTEA Ensemble pour relever les défis de l'agriculture irriguée

COSTEA STRUCTURING ACTION AGROECOLOGICAL TRANSITIONS IN IRRIGATED SCHEMES

LIST OF ACRONYMS

ALiSEA	Agroecology Learning Alliance in South-East Asia
APEB	Association de Protection de l'Environnement de Beni Isguen (Environmental Protection Association of Beni Isguen)
AVSF	Agronomes et vétérinaires sans frontières (Agronomists and Vets without Borders)
CARI	Centre d'Actions et de Réalisations Internationales (International Action and Realisation Centre)
CIRAD	Centre de Recherche en Economie Appliquée pour le Développement (Centre for Applied Economic Research for Development)
FWUC	Farmer Water User Communities
EIG	Economic Interest Grouping
ENDA Pronat	Environnement Developpement Action pour la Protection Naturelle des Terroirs (Environmental Development Action for the Natural Protection of Lands)
ISRA	Institut Sénégalais de Recherche Agricole (Senegalese Institute for Agricultural Research)
ONBT	Office National des Barrages et des Transferts (National Dam and Transfer Office)
ONID	Office National de l'Irrigation et du Drainage (National Irrigation and Drainage Office)
SAED	Société d'Aménagement et d'Exploitation des terres du Delta du fleuve Sénégal (Agency for the Development and Use of the Land of the Senegal River Delta)
TORBA	Association specialised in support for agroecological projects
WAIDMA	West African Irrigation Development and Management Agency

INTRODUCTION

In an agricultural, social and climatic context where it is becoming necessary to rethink the intensification of production in irrigated systems no longer through external chemical inputs, but by intensifying the use of the natural functions of ecosystems, resources available on farms and farmers' knowledge, the promotion of agroecological practices is an important avenue to explore. For this purpose, COSTEA commissioned a group of French organisations coordinated by AVSF (GRET, CARI, CIRAD) and their partners (ENDA Pronat, ISRA, the University of Battambang, APEB, TORBA and CREAD) to carry out studies on six irrigated systems in three countries (Senegal, Cambodia and Algeria).

The objective is to promote the development of agroecological practices in irrigated schemes, by:

- identifying innovative agroecological practices by capitalising on feedback from farmers in irrigated systems;
- producing knowledge on the socioeconomic and agri-environmental impacts and performances of these practices;
- identifying and analysing obstacles and levers, i.e. constraints and conditions for the development of agroecological transitions in irrigated systems;
- developing networks among national and regional stakeholders and between COSTEA members, to strengthen multi-stakeholder dialogue and initiate agroecological transition in irrigated systems and its scaling up.

The study areas that were chosen are the following:

Irrigated systems in Cambodia

Photo credit: A. Lucas

KANGHOT: a large irrigated rice scheme with partial to total water control depending on the topography and the position of the plots in relation to the canal. The portion of the scheme selected for this evaluation has relatively good water control compared to the rest of the scheme. This is because additional investments have been made in it as it is the only part of the scheme that can irrigate land by gravity flow. The water control is nevertheless not total. On the one hand, if there is flooding, drainage is difficult as there is little difference in level between the irrigation and the drainage canals, and on the other, in case of drought, the system cannot supply the canals if water is not available upstream. In particular, there is competition for the use of the dam water between agriculture, businesses and the city

Figure 1: Geographical location of the six studies and of the organisation in charge of carrying them out

of Battambang. The plots are irrigated either by individual pumping directly on the canals or, when they are far from a canal, gravitationally from plot to plot by opening bunds. They are therefore subject to coordination with the upstream plot owner(s). Farmer water user communities (FWUCs) are in charge of optimising the use of the water resource and organising its collective management, but they have only recently begun to implement irrigation service plans. Decisions are therefore based more on local consultations between the communal authorities and villages of the different irrigation blocks.

The main issues of this system are the availability of and access to water, uncovered soils, soil compaction, contamination of the environment by chemical inputs, the intensification of production with the cultivation of double-cycle rice with little possibility of diversification (due to the structure of the value chains and markets mainly oriented towards this crop, a lack of technical know-how and of access to inputs for other crops and techniques such as agroecology, and of commercial policies in favour of other production systems), and the significant migration of farmers from the area.

Photo credit: F. Mias

VEAL KRORPEU: **An irrigated rice scheme with partial water control**, whose access to water is based on three different sources: a secondary irrigation canal coming from the Sek Sor reservoir (Kanghot dam), a canal connected to the Damnac Dancao dam, and canals coming from the Kamping Puoy reservoir, which allow two to three rice cycles per year. However, a large portion of the Veal Krorpeu territory is also rainfed, allowing only one rice cycle per year.

The main issues of this system are the availability of and access to water, uncovered soils, risks of flooding or drought at the beginning of the rice cycle, contamination of the environment by chemical inputs, and the significant migration of farmers from the area. The diversification of the land in this area, especially of the 'high' land, as well as the single rice cycle practiced in the part of the plain that does not have access to the irrigation canals, makes it possible to have more diversified farms and production systems than in the previous irrigated system. However, there is once again the problem of access to technical advisory services for crops other than rice, the absence of structured value chains and of markets for them, and the lack of commercial policies in their favour.

Irrigated systems in Senegal

Photo credit : R. Belmin et S.Vercruysse

MBORO: small market gardening schemes in peri-urban areas from 1 to 5 ha, where diversified crops are grown in rotation (onion, cabbage, aubergine, tomato), with significant demand from urban centres which pushes for the intensification of production. The water resource comes solely from the water table, which makes the farms more or less vulnerable to water availability (which is impacted by rainfall and overexploitation of the water table). Water is managed individually and most of the farms extract it from wells, pits or mini-boreholes of varying depths (depending on the location of the plots in or outside valley bottoms). Water extraction can be manual but most often the wells are equipped with motor pumps and pipes, mainly for distribution by lance (little sprinkling and more rarely drip irrigation). Energy consumption for water extraction is high because it is linked to the hours of irrigation, the type of motor and inefficient agricultural practices. The establishment of Industries Chimiques du Sénégal (a chemical industry company) in the area poses a threat to the water resource, overexploitation of the water table and pollution by chemical waste and mineralised fertilisers from the various agricultural and industrial production activities.

Photo credit: R. Belmin et KJestin

GUEDE: **large irrigated schemes in the area of intervention of SAED** supplied by significant surface water (Senegal River and tributaries). The area studied includes the large schemes of Guédé Chantier (595 ha) and Mbantou (200 ha), consisting of a plunge basin and pumping station, village irrigated schemes fed by motor pump units and private irrigated schemes located in the former levees.

In the large schemes, the plots are developed with bunds and a drainage system. Pumping is done with motor pumps or submersible pumps and electric pumps at river or groundwater level. Irrigation is generally gravity fed, with some initiatives to use sprinkler or Californian systems. It is done by water turn with pricing systems per are and per season. The management of the infrastructures, water turns and agricultural production is organised by unions and economic interest groupings (EIGs), and by section (choice of crops, purchase of inputs, cultivation operations). The dominant crops are rice and tomato, and sometimes onion, in rotation and as single-crop farming. Diversification market gardening can be found on the edges of plots, but also in strips within the plots of private schemes.

The main issues of this system are collective organisation, the costs of maintaining the infrastructures, the limited access to organic matter, the use of phytosanitary products, the intensification of production to make the infrastructures profitable and marketing via contracting (tomato production).

Irrigated systems in Algeria

Photo credit: H. Irekti

MITIDJA: **The large irrigated scheme** of West Mitidja is mainly based on two water sources, the water table (45 to 150 m deep) and the Boukerdane dam which supplies farms with irrigation water from spring to autumn. The dam is managed by ONBT (National Office for Dams and Transfers), assisted for water distribution by ONID (National Office for Irrigation and Drainage). The latter is in charge of the upkeep and maintenance of the water transfer equipment upstream of the farms, but also of the distribution of irrigation water according to its availability in the dam. It coexists with collective networks, whose use is hampered by a low level of maintenance, and individual irrigation from the water table. In a dry year such as 2020, water can be allocated solely to supply the population or restricted to the irrigation of strategic crops (potatoes in particular). In situations like this, the administration allows partial exploitation of groundwater by boreholes for the farms that have them.

The main challenges of this system are the irregular availability of water (summer period), strong competition with drinking water but also with other sectors (industries), the significant risk of pollution of the water table by inputs (particularly nitrogenous), the risk of soil erosion, and the intensification of production to meet the demand for low-cost market garden and fruit products from Algiers.

Photo credit: A. Moulai

MZAB: **an oasis zone**, in which water resources are mainly underground, with the main source being the deep intercalary continental water table (more than 600 m deep), which generates very high water extraction costs. As rainfall is very low (91 mm on average per year), surface water resources come mainly from the flooding of wadis, which are themselves dependent on rainfall.
The farms are very small with a terraced cultivation system (oasis effect) and mainly use the drip irrigation system encouraged by public policies. 100% of the utilised agricultural area is irrigated.
The main issues of this system are water scarcity and difficult access to water, overexploitation of the underground resource, the availability of arable land, the significant use of chemical inputs for phytosanitary protection by some farms, and the management of salinity and wastewater.

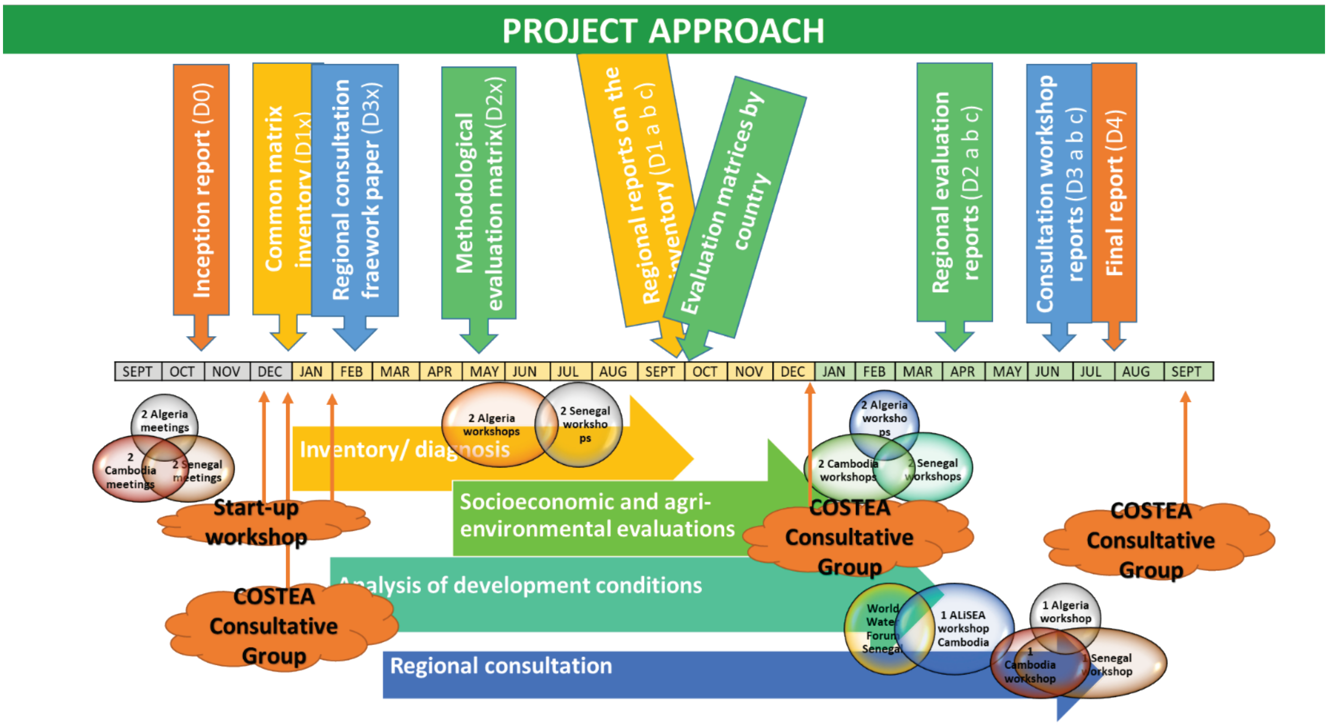
1. ACHIEVEMENTS

1.1 Project approach

In order to ensure the optimal implementation of this project, a steering committee was formed. It was made up of one CARI representative, one GRET representative, three CIRAD representatives and was coordinated by a representative of AVSF. The project started in September 2020 with significant work on developing the methodology with all the partners involved. This was done during meetings in the study countries and then with all the partners during the kick-off workshop. The kick-off workshop took place in two stages, remotely due to COVID, in December 2020 and then February 2021 (given the difficulty of mobilising people remotely for a whole week, we split the workshop into two periods of 3 days and then 2 days).

COSTEA's Consultative Group, which was in charge of accompanying this structuring action, met on two occasions in December 2021 and December 2022, to provide an expert view on the progress of the project. Another meeting was held in September 2022 to close the structuring action.

Figure 2: General project approach



The various deliverables expected by COSTEA were submitted according to schedule or with a slight delay announced before the deadline. These deliverables are presented in the following table:

Table 1: List of deliverables and submission dates

Deliverable no.	Name of the deliverable	Date of submission of the deliverable
D0	Inception report	October 2020
D1x	Common matrix for inventorying and characterising agroecological practices	December 2020
D3x	Regional consultation framework paper	February2021
D2x	Methodological evaluation matrix Evaluation matrices for each country, requested in addition	May 2021 September 2021
D1 a, b, c	Regional reports on the inventory and characterisation of agroecological practices	September 2021
D2 a, b, c	Regional evaluation reports	April 2022
D3 a, b, c	Consultation workshop reports	June and July 2022
D4	Synthesis report	July 2022

In addition, local consultation workshops were organised in each of the territories studied. These were to share and debate the results of the territorial diagnosis and of the inventory of agroecological practices in a first phase (Senegal and Algeria in May, June and July 2021, and Cambodia in February 2022), then the results of the socioeconomic evaluations and the initially identified conditions for the development of agroecology in irrigated schemes in a second workshop on each territory studied (Senegal, Algeria and Cambodia in February and March 2022). As the agri-environmental assessments were carried out belatedly, the results were presented at the national consultation workshops along with all the study results and recommendations:

- CAMBODIA: South East Asia regional workshop in March 2022 (remotely) then national workshop of all COSTEA structuring actions in Phnom Penh, Cambodia, in May 2022;
- SENEGAL: three interventions in different side events at the World Water Forum in Dakar in March 2022 and national workshop in Dakar in May 2022;
- ALGERIA: national workshop in Ghardaïa organised in June 2022.

The diagram (figure 2) presents the approach adopted.

1.2 Methodology implemented

The methodological approach implemented to carry out the six field studies is based on the integration and adaptation of various tools that already existed or were created for the project:

- the **Handbook for the Evaluation of Agroecology**, based on the global approach of the diagnostic study of agrarian systems in order to answer questions relating to agroecology. It proposes a series of indicators to measure the socioeconomic and agri-environmental effects of these practices and systems, and identifies obstacles and levers for their development.
- the **nexus analysis matrix**, a multi-scale and multi-dimensional framework used to understand irrigated systems in all their complexity and to highlight their main issues. It was filled in during the first stages of the diagnosis of the study areas.

The issues identified made it possible to formulate evaluation questions that facilitated the selection of socioeconomic and agri-environmental evaluation indicators;

- the **matrix for inventorying and characterising agroecological practices**, which helps guide the choice of priority agroecological practices and systems to be studied in the following phase of evaluating and measuring the performance of agroecological systems;
- the **agroecology matrix**, which consists of estimating the extent to which a farm meets agroecological principles. To carry out this evaluation, the method calculates an 'agro-eco-score' based on these different principles. This matrix was used in the phase to characterise and compare the farms in the typology.

The following diagram (figure 3) presents the different stages of the study, the periods during which it was carried out and the associated tools.

2. THE MAIN RESULTS

2.1 Results of the inventory and characterisation of agroecological practices

As indicated in Table 2, in each zone studied, the most 'popular'/ frequently encountered agroecological practices correspond to crop association, agriculture-livestock integration and water and soil conservation. For example, the systems studied include:

- the incorporation of manure and burial of crop residues in the soil for organic fertilisation;
- crop association and plot rotations.

Although these are the most frequently encountered practices, in some contexts they remain quite scarce or marginal, with crop diversification/rotation being, for example, only very rarely observed in the Kanghot scheme. Seed saving and multiplication and some agroforestry practices were also found in the majority of the systems.

The vast majority of practices were observed at the plot and farm scale, more rarely at the scheme scale (only in the large irrigated scheme of Guédé in Senegal, where grassing of canals and trees in the drainage network were observed) and never at the territorial scale.

The innovations in the irrigated schemes are often fairly recent, and mainly introduced by development or research-action projects, with the exception of Mzab, where 'the new development schemes seem to be innovation incubators'. For example, there are new trials in terms of palm tree/arboriculture spacing and alignments, and instead of spreading compost at the foot of palm trees, burying it in pits between lines of palm trees to ensure a longer diffusion of nutrients and avoid leaching. Manure use practices are ancient and can be found in all the schemes studied, although they are sometimes evolving: for example, in Mzab, farmers are experimenting with composting techniques to improve the quality of the product, such as fermentation or association with green barley, or even layering.

Figure 3: Stages of the methodology and tools used

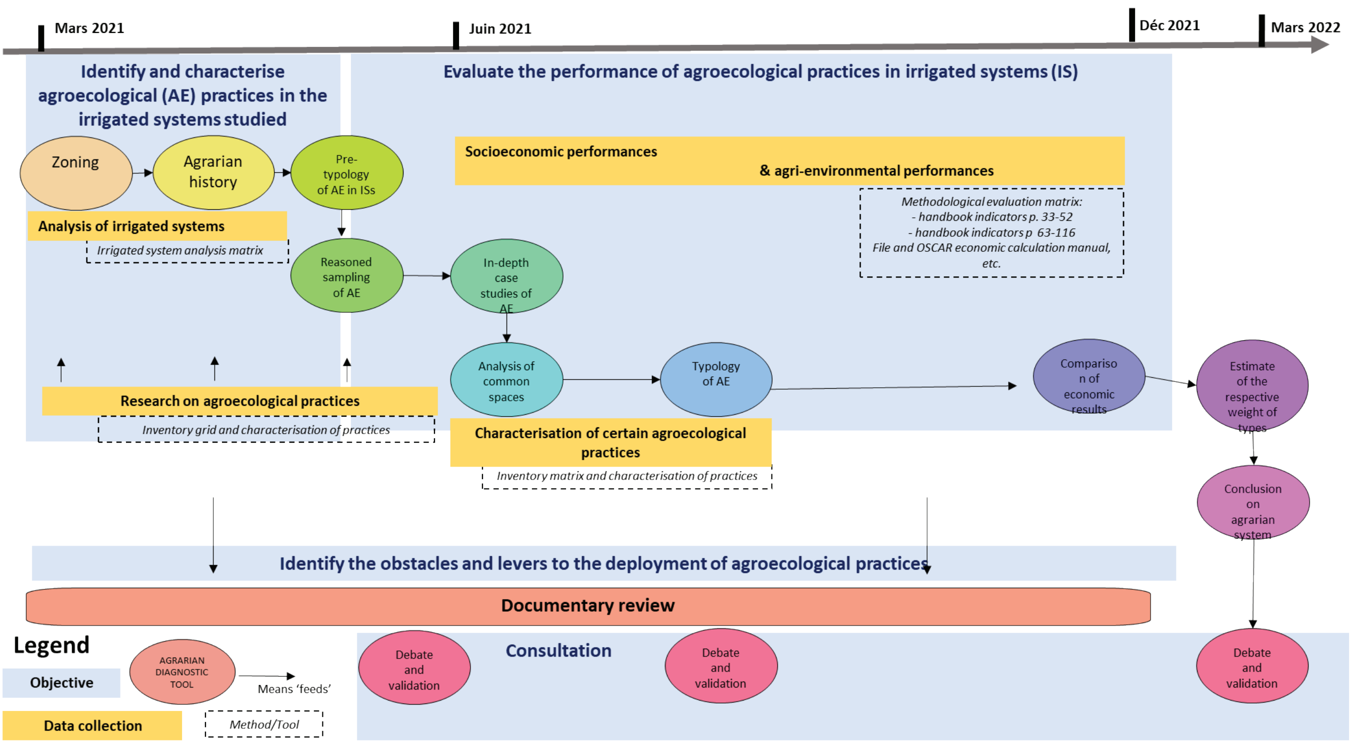


Table 2: Summary of the different practices identified according to their classification and the irrigated systems studied

Country synthesis	Area	Classification of agroecological practices								Scales
		Crop diversification and rotation crops	Agroforestery	Agriculture-livestock integration	Soil and water management and conservation	Organic and mechanical prevention, other alternatives to pesticides	Farmers'seeds	Others	**Total**	**Plot (P) Farm (F) Irrigated system (IS) Territory/landscape (T)**
Cambodia	Veal Kropeau (large-scale hydraulics)	4	1	2	2	0	1		10	P : 7 F : 3 IS : 0 T : 0
	Kanghot (large-scale hydraulics)	2	0	2	6	1	0	0	11	P : 9 F : 2 IS : 0 T : 0
Senegal	Guédé (large-scale hydraulics)	3	3	4	3	1	1	2	17	P : 5 F : 2 IS : 9 T : 1
	MBoro (small-scale valley bottom hydraulics)	1	4	2	6	2	4	2	21	P : 12 F : 9 IS : 0 T : 0
Algeria	Mzab (medium-scale underground hydraulics)	1	1	4	4	5	1	2	18	P : 9 F : 9 IS : 0 T : 0
	Mitidja (large-scale hydraulics)	2	0	0	4	1	0	0	7	P : 5 F : 2 IS : 0 T : 0
Total		13	9	14	25	10	7	6		P : 47 F : 27 IS : 9 T : 0

Moreover, the practices are implemented in isolation; the studies identified few or no agroecological systems (which could lead to a transition of systems), but rather the combination of an agroecological practice with other conventional practices in technical itineraries or on the farm scale. The only irrigated system where agroecological systems were found was the area studied in Mzab in Algeria. This is strongly inspired by the oasis system, where there is rational management of water resources through the oasis effect and organic fertilisation, and plant and animal diversity (livestock).

There is also a notable difference in the range of diversity and association of agroecological practices identified in systems with individual irrigation (examples of the Mboro area in Senegal and the Mzab Valley in Algeria) **compared to large collective hydraulic** systems (examples of West Mitidja in Algeria, the Kanghot area in Cambodia and the Guédé area in Senegal). This can notably be explained by a greater leeway for farmers with individual irrigation in terms of access to water (wells, individual boreholes, sometimes collective boreholes), its use and possibilities for diversifying production. However, other limits exist which can justify the lack of diversification in the schemes studied.

Indeed, farmers who cultivate in large and medium collective irrigation systems are often constrained by:

- access to water coordinated by the group (EIG in Senegal, FWUC in Cambodia) or directed by the irrigation system manager (such as the strategic citrus, cereal and potato value chains prioritised for irrigation by ONID in west Mitidja in Algeria).
- the specialisation and intensification of these schemes, through the homogenisation of cropping schedules and technical itineraries between water users in the plots in order to: make costly developments profitable (e.g. rice and tomato production in the Guédé plots managed by SAED); or to respond to a political orientation, market or cultural attachment to a crop (e.g. in Cambodia, the obligation to grow rice on a low-lying plot when it is irrigated, as a farmer who wanted to grow another crop would risk losing access to this plot); or to manage the collective organisation of tillage in the plots. This problem of the infrastructural and socio-political locking of irrigated schemes is addressed in more detail in part *'Political, institutional and value chain constraints'* (page 11).
- problems of soil hydromorphism in some of these large schemes and relatively high upper water table rises, which in themselves limit the possibilities of diversifying production.
- difficulties in supplying organic matter due to the specialisation of large irrigated areas, which creates a gap between plant and animal production. This does not facilitate the reintegration of livestock farming, which is fundamental to gradually move

away from these irrigated farms' dependence on chemical inputs. Experiments with the introduction of ducks and fish into rice fields in Cambodia, for example, have proven beneficial from an economic and environmental point of view.

2.2 The results of the agrarian diagnoses and of the assessments of the conditions for the development of agroecological transition

These initial observations concerning the obstacles encountered by farmers in all the irrigated areas studied must also be linked to other factors, both internal and external to the farms, which were highlighted during the agrarian diagnoses and the evaluations of the conditions for the development of agroecological transition. It is important to note that these constraints, although identified in the irrigated farming territories of the present study, are for the most part not specific to this type of farming, as they have also been highlighted in other studies on the conditions for development in rainfed farming. Nevertheless, they are reinforced by the structuring of the space and the infrastructures that are specific to irrigated systems.

Constraints at farm level

- The farmers lack **technical know-how**, support, awareness and knowledge transfer on seed production, phytosanitary crop protection techniques (preparations from natural products such as lime, soap and ash, neem, coarse salt and fodder cabbage, to control aphids and cryptogamic diseases), etc.
- Farmers also lack the **capital to invest in** or develop agroecological practices. The cost of the installation, depreciation and renewal of equipment to accompany agroecological transition is significant (purchase of seeds for cover crops, carts for transporting manure, sometimes de-stoning, construction of storage basins, etc.).
- **There are major land constraints** (sharecropping/rental of land in Senegal and Cambodia, for example, overly small areas under cultivation, plots of land rented by farmers that change every year, etc.) for the deployment of medium- and long-term practices and to cover risk-taking and yield reduction during the first years of production.
- The absence or poor integration of livestock in the areas leads to a **low availability of organic matter** for organic fertilisation practices, but also the cost of buying/transporting/using manure compared to chemical inputs when they are subsidised.
- **The labour time** required for certain practices, for example to prepare and apply biofertilisers or biopesticides, also linked to the problems of insufficient labour and increasing migration in the areas studied.

Political, institutional and value chain constraints

- **An absence of public policies** conducive to the development of agroecology, or policies that are contrary to agroecological transition, sometimes with subsidies that encourage the use of chemical fertilisers and the intensification of certain types of production (e.g. the political choice of rice growing in Cambodia).
- **The absence of local or national markets** that value products from agroecological practices, which are still being sold at the price of conventional products;
- There is **little organisation/structuring of producers** to collectively support changes in practices towards agroecology, with few farmers' organisations and limited extension services that have no training to support this transition. Indeed, in the three countries studied, it is common for technical support to be provided by commercial agents, agronomists who can provide technical expertise in response to a pest/disease/deficiency, and who recommend a chemical treatment from the company represented without measuring the environmental and economic impact of this treatment.
- The **results of research** on the performance of agroecology in irrigated systems are still insufficient and not disseminated enough to support the advocacy for which they could be used.
- Hydraulic infrastructures are designed to meet needs defined according to a socioeconomic vision at a given time. In the various studies carried out, the infrastructural constraints related to conventional models of hydro-agricultural facilities have been guided by productivist and trade policies linked to the green revolution in a food security perspective for the countries. In Senegal, for example, the schemes are designed for rice and industrial tomato cultivation. Moreover, their plan does not allow the quantities of water consumed at plot level to be measured (no meter) to evaluate efficiency. In Cambodia, it is a voluntarist policy focused on rice production that responded to the country's need due to a food deficit in rice at a given time. It currently responds to a demand to improve the quality of rice production for an international market, but without regard for environmental externalities. Thus, the socio-political restrictions associated with the infrastructures are at least as important as the technical constraints.

Environmental constraints

- The reduction in water availability due to the overexploitation of groundwater, the poor sizing of collective boreholes in relation to needs, or the decrease in rainfall to recharge surface and groundwater, pushes farms to optimise environmental conditions, to seek greater resilience in the face of climate change and to increase the means of access to water (wells, individual and collective boreholes). A context of water scarcity can also be a factor favouring agroecological transition, as seen in the farms of the Mzab valley, which have diversified their crops and production workshops in order to boost their resilience to water scarcity.
- Market garden crops are sometimes grown on land with low water retention, as is the case with the dior soils on the Niayes hills in Senegal. This results in uneconomic water use, which remains the main environmental concern in Senegal.

- Soil depletion and the pollution of water tables and rivers by the use of chemical inputs (mainly pesticides and nitrates) linked to conventional practices and the intensification of single-crop farming (rice in the case of Cambodia and the Senegal River for example) are also major constraints.
- Concerning irrigated systems using surface water:
  - In flooded systems with long flooding periods crop diversification is limited, and there is still little varietal richness in these intensive rice systems, as is the case in Cambodia. In terms of possibilities, diversification should be practised in the off-season.
  - For systems with access to surface water from a river and its tributaries, this resource can also be non-perennial and fluctuate during the season in some places (risk of water stress if the water is temporarily interrupted); there is also a risk of flooding if the plots are too close to the river.
- The development plans promoted until now by agricultural policies do not favour the maintenance of natural biodiversity due to deforestation, terracing and the exposure of plots.

Organisational constraints

- Irrigated schemes with water turns allowing access to irrigation for farmers are not conducive to crop diversification. Indeed, having diversified crops (in association or in crop rotation) requires access to water in a way that is more spread out over time compared to other crops. Even if this could be an advantage for the management of irrigated schemes (by decreasing peaks in demand), in practice, when water turns are imposed, access to water and needs can be out of sync. In these situations, where access to water is 'constrained', there are few small-scale infrastructures at the farm/plot level to make access more flexible.
- In the large irrigated schemes studied in northern Senegal, decisions on starting crops and irrigating plots that are centralised at the level of the managers of the farmers' groups union, as well as the organisation of irrigation by sector or hydraulic district, deprive farmers of their autonomy and full control over the watering of their crops. Moreover, this system also limits them from adopting certain agroecological practices such as diversification, crop association, and the recovery of organic residues in a complete nutrient cycle process (inputs-soil-crop). This is a constraint for scaling-up agroecology in these irrigated systems.
- Another organisational obstacle is the weight of individual interests to the detriment of the collectivity and the difficulty of agreeing on a transition model at the scale of the hydro-agricultural area (need for social engineering). In addition, there are social obstacles (the weight of castes in Senegal, for example) that hinder initiatives to reorganise plots and/or allocate them permanently or long term, to encourage farmers to invest in the adoption of agroecological practices on the plots they have been allocated on large collective hydro-agricultural developments.

2.3 Results of the socioeconomic and agri-environmental performance evaluations

The analysis of the performance of agroecological cropping systems compared to conventional systems, at the farm level for socioeconomic performance and at the plot level for agri-environmental performance, showed encouraging results for agroecological transition.

Socioeconomic performance results

- Diversifying production, within or outside of irrigated plots, plays a key role in securing and increasing the agricultural income of the farming families in the areas studied. When they have the possibility, some farmers use fertile but non-irrigated areas, such as the flood recession areas in Senegal and the Veal Krorpeu highlands in Cambodia, to diversify the farm's production. In the Mzab valley, the farmers who have implemented diversification strategies by cultivating two or three production layers (oasis system) in addition to having livestock, obtain the best economic results with lower water consumption. The combination of agroecological practices can thus yield better returns by optimising the environmental conditions. In the West Mitidja plain, the diversification of production has made it possible to reduce the risk of losses due to climatic events such as drought.
- Chemical inputs account for a large share of intermediate consumption in the cropping systems studied (see Figure 2 below, in the case of rice cultivation in Kanghot, Cambodia, for example, where mineral fertilisers account for 30% of production costs). By gradually replacing chemical inputs with organic fertilisers from local resources (manure, crop residues, fruit and food scraps, etc.), farms would be less financially dependent for the renewal of the fertility of their soil, but would also gain in decision-making and technical autonomy.

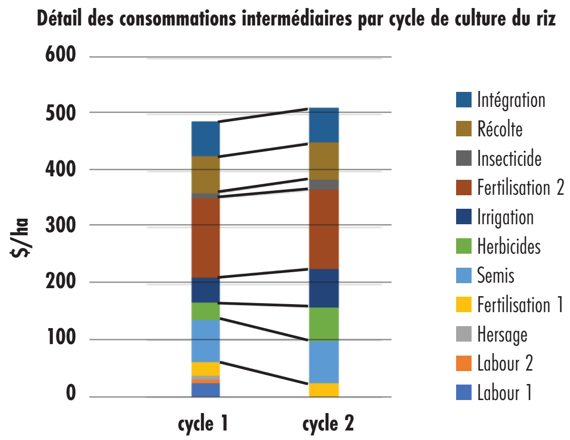


Figure 4: Details of intermediate consumption per rice cycle in Kanghot (A. Lucas, IRC, 2021)

In the different areas studied where farmers use motor pumps, it is also important to note the large share of fuel used to operate these devices (between 35% and 60% of intermediate consumption in the case of the Mboro area in Senegal, for example).

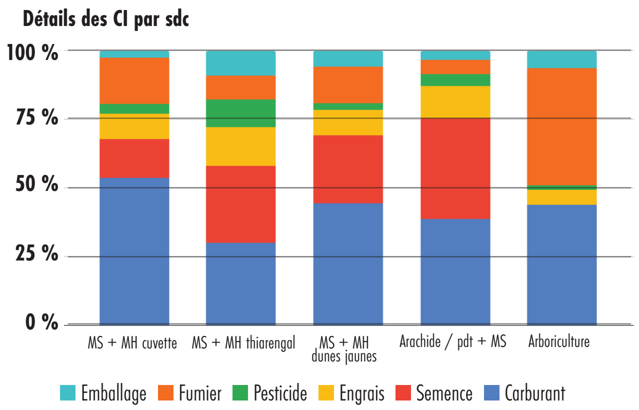
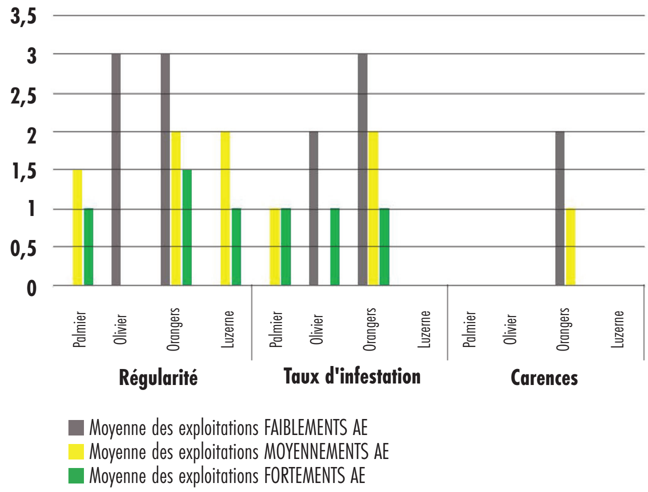


Figure 5: Details of intermediate consumption by cropping system in Mboro, Senegal (S.Vercruysse, IRC, 2021)

Agri-environmental performance results

- In the diversified systems in Senegal and Algeria, a lower variation in interannual yield for the plots where agroecological practices are implemented can be observed, as illustrated in the graph below, which was produced using the results obtained in the Mzab valley in Algeria.
- The samples to compare yields between agroecological plots and conventional plots for the same crop were not large enough to be scientifically representative. However, there is a trend towards better yields for agroecological plots (e.g. in Senegal, aubergine cultivation associated with tree crops obtains more than double the yield of aubergine cultivated alone; in Cambodia, the yield of rice cultivated in association with fish is higher than that of rice cultivated alone, 6t/ha compared to 4.5t/ha on average).
- In general, soil structure and the diversity of biological activity tend to respond quickly to agroecological practices: in the Kanghot area of Cambodia, a comparison between plots under green manure and ploughed plots showed a significant improvement in soil health in the plots under green manure. This is based on the formation of macro-aggregates (which is one of the most relevant indicators for assessing the efficiency of a system), with a higher water retention and infiltration capacity.



Legend of the graph:
In this graph, regularity, infestation rate, and deficiencies are scored from a qualitative point of view.

- For regularity, 1 = regular; 2 = moderately regular; 3 = irregular. Thus, for this criterion, the higher the score, the more irregular the yields, according to the farmers.
- For deficiencies: 1 = low; 2 = medium; 3 = high.
- Regarding the level of infestation by bio-pests: 1 = low = less than 10% of plants; 2 = medium = between 10 and 50% of plants; 3 = high = more than 50% of plants affected by infestation.

Figure 6: Regularity, infestation rate and deficiencies of four crops as a function of the extent to which the production system is agroecological, in Mzab (A. Moulai, APEB, 2021).

- A small difference could be observed on pest control (such as a slightly higher level of blast disease in the conventional system in Veal Krorpeau, Cambodia, for example).
- The table for estimating GHG emissions was tested in Cambodia. It shows that these emissions are significant in rice cultivation, particularly in the Kanghot area where a double rice cycle is practised (compared to Veal Krorpeu, where there is mainly a single cycle). Indeed, for Kanghot and based on current practices, the estimate reflects sustained greenhouse gas emissions. The calculation is presented in Table 3 below.

Table 3: Estimate of the level of water contamination in agricultural plots in the irrigated scheme of Kanghot studied (A. Lucas, IRC, 2021)

Criteria	Level 1	Level 2	Level 3
Irrigation	No water level: Score 1	Intermittent water level (50%): Score 3	Permanent water level: For two rice cycles Score 4
Soils	Soil poor and sandy: Score 1	Average texture and average soil organic matter: Score 2	Texture and rich in soil organic matter: 511 g/1 kg clay, 339 g/1 kg silt, 150 g/ 1 kg sand 1.53% SOM (0-10 cm) Score 3
Fertilisation	No or very little nitrogen fertiliser: Score 0	Average dose of nitrogen fertiliser: Score 1	High dose of nitrogen fertiliser: 2 cycles of rice, Sen Kra Ob and Sra Ngae Average > 45 N/ha/cycle, > 90 N/ha Score 2

3. MAIN RECOMMENDATIONS

The different results highlighted by the studies carried out in the six zones were then discussed during national workshops organised in each country with various stakeholders involved in the agricultural and hydraulic development of the zones (local and national authorities, scheme managers, farmers, producers' organisations, researchers, NGOs, advisory bodies, COSTEA representatives, etc.). The aim was to gather their opinions and formulate recommendations on levers to be used to favour agroecological transition in irrigated schemes.

The main recommendations that were formulated, shared and validated by the participants are the following:

- Develop the regulatory and policy framework, implement development programmes, incentives and public aid to support production and value chain actors in the agroecological transition of irrigated agriculture:
  > Create a compensation system for the possible decrease in yields linked to the agroecological transition phase.
  > Protect the internal market to develop new diversification and quality value chains (particularly market gardening in Cambodia).
  > Orient agricultural sector support policies towards more subsidies for organic fertilisers (in Senegal, the state currently transfers 10% of the subsidies initially allocated to synthetic fertilisers to organic fertilisers).
- Develop specific markets and organise value chains to enhance the value of agroecological production:
  > Advocate with local authorities to encourage the development of local markets for agroecological products.
  > Contribute to the development of short circuits to market agroecological products, such as Associations for the Preservation of Smallholdings (AMAPs). In the western plain of the Mitidja in Algeria, an AMAP has been set up which enables farmers to market their agroecological produce directly to a group of consumers. These are promising options for the sustainability of production systems in response to significant societal demands.
  > Organise value chains for the supply of specific inputs for agroecological production (seeds for the establishment of cover crops in Cambodia, for example).
- Rethink design (or co-design) and collective management in the creation or rehabilitation of large schemes, in order to limit the constraints linked to the infrastructural bottlenecks mentioned above, and facilitate the implementation of agroecological practices by producers:
  > In the engineering or rehabilitation of irrigated schemes, include the possibility of restoring biological diversity in intensive production, water saving and optimisation, the question of energy, livestock farming, etc.
  > Ensure the establishment of governance and collective water management methods that provide the necessary flexibility to encourage agroecological production initiatives.
- Support stakeholders in the sustainable management of small and medium-sized irrigated areas by maximising the ecosystem services of the irrigated system:
  > Increase ecosystem services to improve biodiversity and better regulate flows, which can contribute to a more agroecological territory.
- Design and implement research systems to produce scientific evidence on the socioeconomic and agri-environmental performance of agroecology, which is necessary for better extension and advocacy actions to encourage support for agroecological transition:
  > Capitalise on the scientific results of pilot projects for the development of agroecological systems in different irrigated schemes.
- Develop secondary training and agricultural advisory systems for better knowledge and dissemination of agroecological learning
  > Create field schools, educational farms and networks for exchange and consultation between professionals.
  > Develop training programmes to accompany farmers towards agroecological transition, in particular with adapted technical reference systems (the Tipaza Chamber of Agriculture in the Mitidja plain in Algeria, for example, is in the process of creating this type of programme).

4. DIFFICULTIES OF THE MISSION AND ANALYSIS OF THE METHODOLOGY USED

4.1 Difficulties encountered during the project

The main difficulties are listed below:

- **The health context in relation to Covid:**

- The work was mainly carried out remotely, on a subject and in fields that require detailed local knowledge and interactions between partners. This strongly hindered the group dynamics, as well as the possible inter-comparisons between the study areas.
- Most of the missions were cancelled in year 1 and at the beginning of year 2, which corresponded to the appropriate period of support for the implementation and follow-up phase of the studies.
- In Cambodia, the health situation prevented travel to the inner part of the country. This had an impact on the method itself, which had been designed to have close monitoring, frequent physical meetings with partners, workshops to discuss the results at the halfway point, and the organisation of measurements in the plots, which had to be modified at the last minute.

- Despite the efforts of the partners involved in the studies to invest additional working time, **budgetary constraints** did not allow for the number of person-days that would have been necessary for an optimal follow-up of the studies by the teams in France and in the field, or to carry out a number of expensive agri-environmental assessments (certain soil and GHG emission studies, for example).

- **Contingencies related to the period and duration of the study**: the drought in Algeria and Covid in Senegal had consequences on the recent strategies of the farms and on the crops that were being cultivated, hence an ad hoc evaluation that is not representative of the usual cultivation conditions. The agri-environmental assessment was impacted by these changes. An evaluation over a longer period of time would have made it possible to measure the evolution of the socioeconomic and agri-environmental results.

4.2 Methodological limitations and proposals

The methodology used to carry out the studies had some limitations, which are specified below:

- Despite the relevance of the methodology used, it was highly complex due to the multiple steps to be carried out in a short time: agrarian diagnosis + nexus matrix + inventory of practices + socioeconomic analysis + agri-environmental analysis + analysis of development conditions.
- The teams also encountered difficulties in identifying agroecological practices (there were few initiatives in the study areas), in detecting those that are silent and also practices at the upstream and downstream levels of the irrigated system. Furthermore, they did not have enough knowledge and hindsight to determine or estimate the degree of application/adoption of each identified practice at the scale of the zones. Due to the low degree of agroecology of the territories studied (no agroecological or organic value chains on the study sites, for example) and to the approach used, which is geared towards the adoption of agroecological practices, the comparison of economic performance and environmental impacts was at the scale of the cropping system and not at the scale of the irrigated system or territory.
- The definition of indicators and their measurement took time for the evaluations. The samples were ultimately not large enough, so it was not possible to set up a relevant comparison system (capacity, number of plots to be included in the sample for characterisation, balance between quantity of practices and quantity of plots to be compared). Thus, the representativeness and degree of precision are questionable and many averages have been made. Moreover, in agri-environmental evaluation, there are many indicators that are complex to set up. Finally, the time needed to carry out the evaluation of certain indicators was different from the time available for the project. For example, to make assessments on irrigation efficiency, an entire cropping season needs to be followed.

In view of these observations, some **methodological recommendations** can be made:

- As agroecology is a holistic and systemic science, this study tried to have a global approach by maintaining advanced agrarian diagnoses, which may have obscured some specificities of irrigated systems and in particular a more in-depth analysis of the modalities of water management and governance. One proposal would be to simplify part of the agrarian diagnosis (the initial stages of zoning and agrarian history) in order to free up time for the analysis of irrigated systems (nexus matrix), the identification of practices, and the characterisation of existing agricultural systems (agroecological matrix). It would then be a matter of orienting the comparison of water management between agroecological and non-agroecological systems in order to make analyses in relation to water needs and infrastructures. This comparison is possible if there are actually agroecological systems in the area studied.
- Since irrigation is expensive either in terms of investment (and rehabilitation) for large-scale hydraulics, or in terms of operation (pumping costs), economic profitability presupposes the practice of cash crops that are well integrated into profitable value chains, except if this irrigation is intended for local food security in very remote areas (for example, oases where the lack of access makes it difficult to transport food and therefore more expensive), or locally for the purpose of securing a labour force. A more detailed analysis of the value chains at play in the irrigated schemes studied, their functioning, the relations between actors and therefore the room for manoeuvre, would be interesting to complete the analysis of the conditions for development.
- The study should take place over a longer time span, more than three years, to analyse the evolution and the socioeconomic and agri-environmental impacts of agroecological transition.
- Particular attention should be paid to sampling for comparisons between agroecological and conventional practices.
- It would be interesting to test serious trials developed around the spatial arrangement and distribution of water between agroecological farms in a situation of water constraints, or of living labs. However, this should be done in an approach of support to agroecological transitions in order to find ways of unlocking irrigated systems.

5. CONCLUSION

Agroecological transition in irrigated systems remains a major challenge to ensure the sustainability of the production systems that will provide food for populations in the years to come. It is therefore essential to encourage the diversification of production, which is necessary to facilitate risk management in the face of market fluctuations and climatic shocks. However, the study has shown many obstacles to diversification in large irrigated schemes, linked to significant infrastructural and socio-political barriers, which must be taken into account in the design of future irrigated systems or in the redevelopment of current systems. It is therefore necessary to have real political will on the one hand, and on the other, work on governance and operation with an approach that is not only managerial but also socio-political, so that the reconstruction brings the desired progress.