DYTAEL Fatick

Synthetic 2024 report on codesign of innovation for Senegal

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Executive summary

The Initiative Agroecology (I-AE) project is an international initiative, supported by the CGIAR, for the holistic implementation of the 13 principles of agroecology. It is being implemented in several countries, including Senegal, with the aim of producing scientific evidence of the positive impact of agroecology, in order to encourage its large-scale development in local areas. The initiative is centered on local partnerships, with a focus on producing scientific data and demonstrating the feasibility of large-scale agroecology in order to foster the agroecological transition by adapting approaches to each local context. To this end, I-AE is supporting the "Dynamique pour la Transition agroécologique locale" (DYTAEL) in the department of Fatick, in line with the priorities identified by the collective.

This report highlights the co-design efforts undertaken within this Agroecology Living Landscape (ALL) since 2023. The objective is to foster agroecological transitions and sustainable agricultural practices. But some activities are part of the FAIR Sahel project developed in the same region since 2020, of which an agronomic assessment and farm-level modelling have been carried out as part of the project IAE.

The co-design approach integrates diverse stakeholders, and has been developed across multiple scales from plot-level trials to territorial planning, emphasizing participatory methodologies to ensure that solutions are inclusive, practical, and tailored to local contexts.

A variety of thematic (intensification agroecological technologies, saline soil restoration, farm-level scenario, agroforestry and organic matter, and ideotyping of cropping systems and territory), of methodologies (participatory workshops, field trials, computational modeling, and data-driven performance evaluations, foresight, ideotyping of territory…) were employed.

Key findings include the success of groundnut-cowpea associations and organic amendments in improving yields, the restoration of saline soils using locally adapted techniques, and the effectiveness of participatory modeling in balancing agroforestry and organic matter trade-offs.

The report underscores the importance in a co-design process, of combining technical, organizational, and socio-cultural dimensions in designing and scaling innovations to co-design a transition path. Lessons learned emphasize the need for holistic, inclusive approaches to address agricultural transformation while ensuring local ownership and sustainability.

Looking forward, the findings provide a foundation for scaling agroecological practices and co-designing future initiatives aimed at agroecological transition path.

Introduction

This report provides a comprehensive overview of the co-design process implemented in the Agroecology Living Lanscape (ALL) in Senegal, within the Fatick department, a critical area in the groundnut basin. Indeed, the department faces significant challenges, including land degradation, soil salinity, and limited access to agricultural inputs. These challenges necessitate innovative and sustainable approaches to farming that can enhance productivity while preserving natural resources. The co-design activities in Senegal's ALL were tailored to these challenges, building on ongoing local initiatives and leveraging partnerships to create a comprehensive framework for agroecological transformation.

The work has been developed in the framework of the CGIAR Agroecology Initiative. The objective is to foster agroecological transitions and sustainable agricultural practices. The initiative is centered on local partnerships, with a focus on producing scientific data and demonstrating the feasibility of large-scale agroecology in order to foster the agroecological transition by adapting approaches to each local context. To this end, I-AE is supporting the "Dynamique pour la Transition écologique locale" (DYTAEL) in Fatick, in line with the priorities identified by the collective.

The Agroecology initiative arrived in Senegal only in 2023, following the impossibility of running a Living Lab in northern Burkina Faso (security conditions). When the Agroecology Initiative was launched in Senegal, numerous agronomic trials were already underway, mobilizing a large number of local researchers and local partners in some villages in the department of Fatick. These activities are part of the FAIR Sahel project (Fostering an Agroecological Intensification to improve farmers' Resilience in Sahel) developed in the same region since 2020, of which an agronomic assessment and farm-level modelling have been carried out as part of the project IAE. The FAIR Sahel project is part of the "Development of Smart Innovation through Research in Agriculture" (DeSIRA) initiative funded by the European Union (EU), which aims to accelerate the development of agriculture in developing countries, mainly in Africa, based on research results. In the framework of this project, initial trials on groundnut-cowpea associations and organic amendments were conducted in Ndiob in 2021, and in 2022, there has been an expansion of trials to additional sites, introduction of compost treatments, and ideotyping workshops to design innovative cropping systems.

In general, the co-design process serves as the cornerstone of the AE initiative, bringing together diverse stakeholders, including local farmers, researchers, development partners, and policymakers, to collaboratively design, test, and refine agricultural innovations. Rooted in inclusivity and systemic thinking, the co-design approach has been pivotal in ensuring that solutions are practical, scalable, and contextually relevant. This process has unfolded across various scales, from the plot and farm levels to the territorial level, addressing technical, social, economic, and environmental dimensions, with different themes and using complementary methodologies:

- at plot and cropping system level through:1) codesigned agroecological technologies for intensification and agronomic evaluation, 2) restauration of saline land through demonstration tests; 3) cropping ideotyping ;

- at farm level by co-designing scenarios based on localized innovations;

- at regional level, through: 1) innovation box, 2) participatory modeling for agroforestry and organic matter, and finally, 3) conditions for appropriating and scaling innovations to construct the transition path.

Different methodologies were used. These various approaches are summarized in this report and presented at the figure 1 (numbers refer to the various chapters of the report), a final part of which draws lessons and opens perspectives, notably for the next CJAIR SP 2.

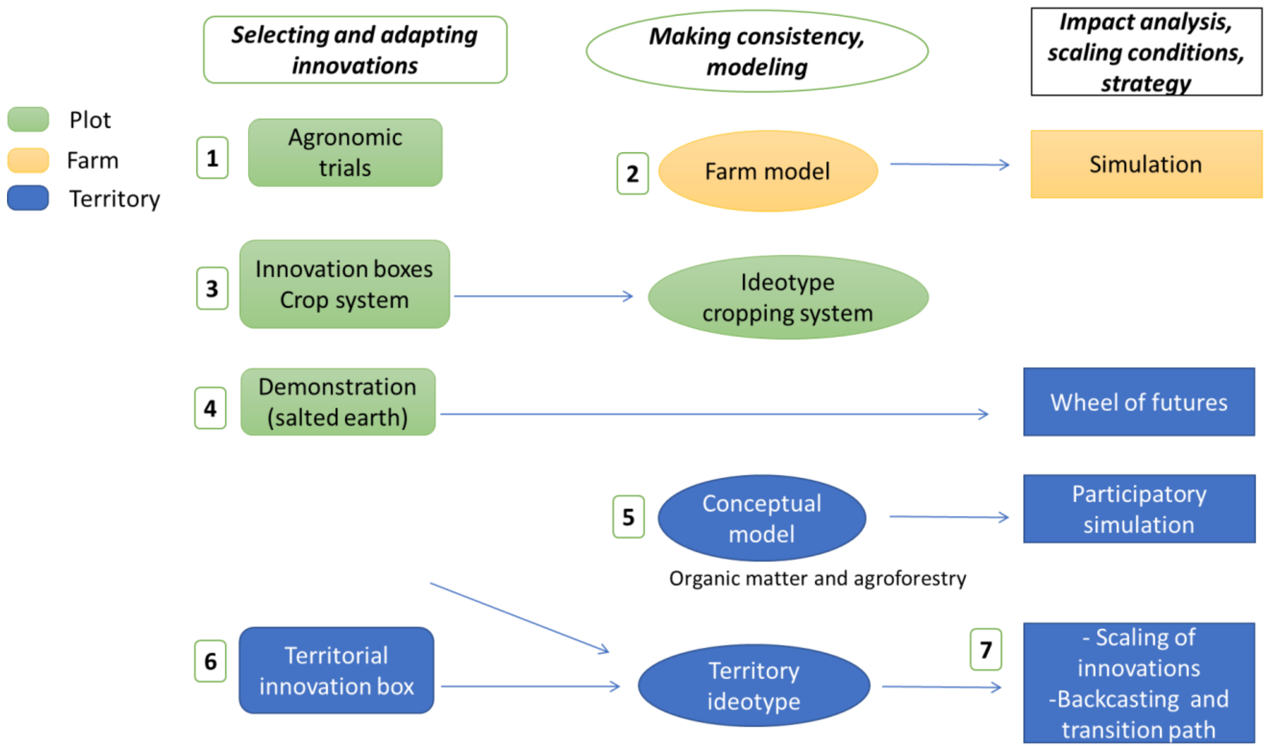

Figure 1. Synthesis of the co-design process developed within the framework of WP 1 in All de Fatick

The figure 1 shows the complementarity between the different works, all of which revolve around i) a process of selecting and adapting innovations, ii) a consistency at different levels and analyzing their impacts, and iii) the conditions for scaling them up to co-design a transition path. The document is structured to cover the following major themes:

1. Co-designed agroecological technologies and trials: This section explores the development and assessment of agroecological technologies, including trials on groundnut-cowpea associations, the use of organic amendments such as horse manure and compost, and agronomic performance evaluations (this one conducted in the framework of IAE). These trials aimed to enhance productivity, improve soil health, and support agroecological transitions at the farm level.
2. Farm-level scenario co-design: This part highlights the use of participatory modeling tools to design and evaluate farm-level scenarios integrating trials results. The objective is to facilitate discussions with farmers, enabling them to envision and test the impacts of agroecological innovations on their production systems.
3. Innovation toolbox and cropping system ideotyping**:** The report details the ideotyping process, where stakeholders collaboratively designed theoretical cropping systems tailored to local constraints and opportunities.

4. Saline soil restoration**:** Addressing soil salinity, a major challenge in the Fatick department, this section documents efforts to reclaim degraded lands through the use of organic amendments, adapted crop varieties, and participatory methods involving local communities.
5. Holistic understanding and participatory modeling: Activities at village and territorial scales are detailed, focusing on balancing trade-offs in agroforestry and organic matter systems, optimizing resource use, and integrating territorial metabolism concepts to achieve sustainable land management.
6. Territorial innovation box : constructed in the framework of the ideotyping of Fatick territory (Belmin *et al*, 2024), organizing a structured compilation of technical and organizational solutions adapted to local needs.
7. Conditions for scaling innovations and transition pathways: Insights into the sustainability and scalability of innovations are presented, emphasizing the importance of technical, organizational, institutional, and socio-cultural dimensions. Transition pathways are outlined to guide the agroecological transformation of the Fatick department.

This report is primarily a synthesis and offers a general reflection on the co-design process, while full details on each theme can be found in the specific reports (cited elsewhere).

1. Co-design of cropping system and farm-level scenarios

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Co-design of cropping systems

The aim of the cropping system co-design activity was to co-construct multidimensional agroecological intensification systems with producers, while ensuring a privileged/balanced role for women and young people. Specifically, this involved: (1) adapt options and systems to growers' contexts; (2) understand the evaluation criteria used by growers; (3) support growers in evaluating innovative options and systems; and (4) support growers in innovating themselves.

Crop system co-design activities were carried out in the Fatick department, specifically in villages in the communes of Ndiob and Diouroup, from 2021 to 2024 (Figure 2). The villages were selected on the basis of the following criteria:

- villages visited during the pre-diagnosis;
- existence of agroecological initiatives;
- be within a 30 km radius of the main town;
- have high agronomic potential.

Thus, 14 villages were selected in the commune of Ndiob and 6 in the commune of Diouroup (figure 2). It should be pointed out that the villages are sometimes small, similar to hamlets, hence their large number.

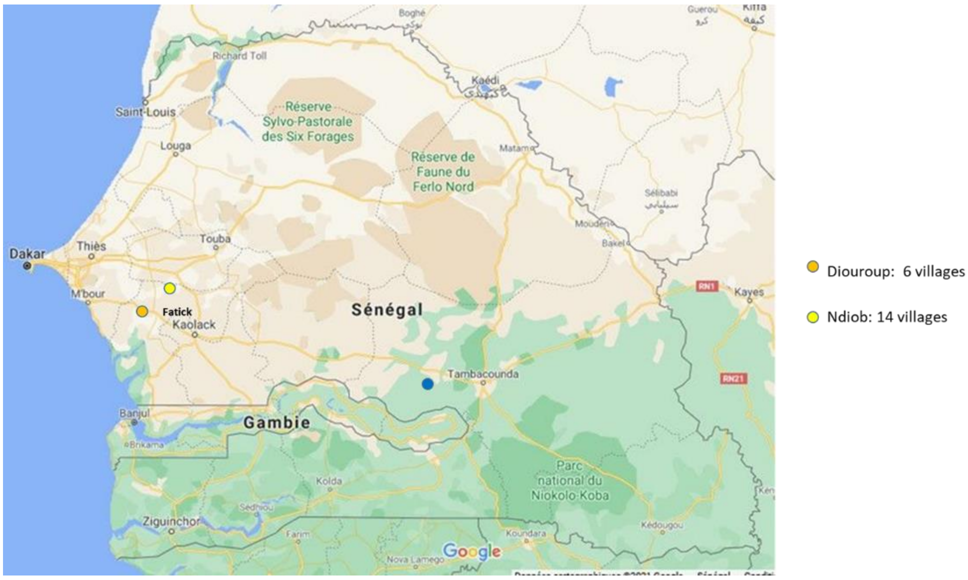


Figure2: Location map of Fatick department communes (Ndiob and Diouroup) where village workshops were held.

The various stages that made up the crop system co-design activities were diagnosis, participatory prototyping, experimentation and co-evaluation. These different stages have operated in a loop for the duration of the project. Various tools (workshops, experimental devices, etc.) were used during these different stages.

Diagnosis and prototyping methodology

An initial diagnosis was carried out to gain an overall understanding of agricultural constraints. A major survey was carried out to this end. However, the analysis of the survey data was delayed, so a rapid diagnosis was organized to move the process forward. In order not to fall behind schedule for the first campaign, the rapid diagnostic workshop provided an opportunity to initiate prototyping. The workshop was organized in three sessions: (A) brief presentation of the project idea, workshop objective and key concepts/principles of agroecology, (B) restitution and validation of the salient results of the pre-diagnosis and other constraints/assets of the current systems, and (C) identification, using a rapid diagnosis approach, of innovations or options for agroecological intensification systems to be tested locally.

Session A was devoted to a presentation of the team and its partners, followed by a presentation of the FAIR Sahel project, its objectives and components, and finally, the workshop objectives. Following these presentations, discussions focused on importance of agroecology for soil preservation and hence future generations, organic matter for sustainable agriculture, and the role of women in healthy, sustainable agriculture, given their role in food production.

In session B, the results of the pre-diagnosis carried out earlier were presented. Following this presentation, a number of constraints were highlighted by participants. To go further, this session identified and characterized current farming systems. The work was carried out following a transect across the commune, from north to south in each commune. On the transect, the different cropping systems are listed, along with their potential and constraints, soil types and different plant formations. Following this description, a zoning plan was drawn up showing the similarities and differences between the commune's cropping zones. Discussions were held on zoning factors (soil type, landscape, crop, cropping system (hut fields and bush fields), pest management, fertilization)

Session C consisted of group work. Three groups (young people, men and women) were formed to work on 4 main questions:

- What are the constraints observed in the cropping systems?
- Faced with these constraints, what alternatives have been developed?
- Which of the alternatives did not work or were ineffective?
- In their opinion, which options should be tested or experimented with to improve cropping systems?

A second workshop, this time for prototyping, was organized to confirm the various options with the growers and also to define the technical itineraries for conducting the tests. During this prototyping workshop, the players (research, technicians and growers) discussed and selected the different systems to be implemented and the technical itineraries to be tested in comparison with usual practices.

The workshops were held in April and May 2021 and saw the participation of producers (men, women and young people) from the various villages, researchers (ISRA, CIRAD), the development service (NGO ENDA Pronat) and technical services (agricultural council, water and forestry). It capitalized on producers' endogenous knowledge, technicians' field experience and research results.

Experimentation

Experimental methodology

Once the cropping system and technical itinerary to be tested had been defined, the next step was to identify the villages and fields where the experimental set-up would be set up. A visit was organized in some villages of the commune to producers who offered to make a plot of land available to the project for the trial. This co-designed experimental set-up was named the "central field" and managed by the research team, the development department and the growers. The experimental set-up and cultivation operations were carried out in a participatory manner with the growers. The aim of such a system, which includes repetitions, is to facilitate the process of co-designing agroecological intensification options and systems. The central fields were installed in 2021 and repeated each year of the project.

During the first campaign, growers regularly visited the central field. During the 2022 seizure, each grower was inspired by the central field systems of the year 2021 to voluntarily reproduce a system in the central field on his farm in common agreement with the research. The grower was free to adapt the system to his own needs. This system was called a satellite field. The plots were managed by volunteer farmers with the support of field technicians. In the satellite fields, the system based on complete scattered blocks, with the grower forming a repetition. Each satellite field is divided into two elementary plots: one for the usual practice (monoculture), the other for the system chosen by the prosecutor and inspired by the central field, adapted or not. In each elementary plot, three (3) plots or yield squares (4 m × 4 m) are installed for monitoring and data collection. The choice of plot position is made with the help of the grower, who is familiar with the heterogeneity of his field. They are positioned on a diagonal of the plot, if the field is homogeneous on a plateau; at the top of a slope, in the middle of a slope, or at the bottom of a slope if the field is homogeneous on sloping ground; on different parts of the plot, if the field is heterogeneous.

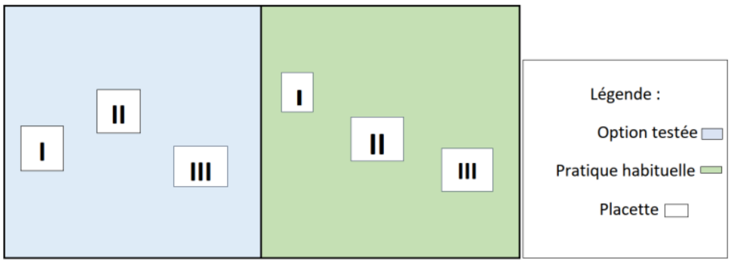


Figure 3: Satellite field system. This system is similar for all volunteer growers in all villages in the communes of Ndiob and Diouroup.

Summary of results

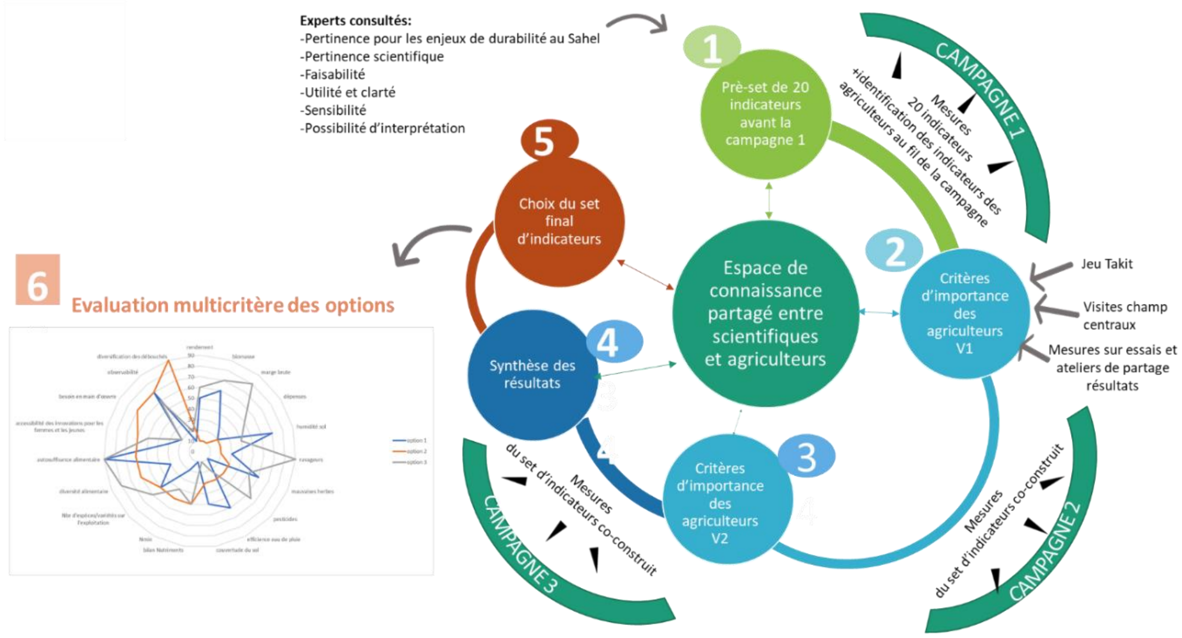
Compared with pure peanut cultivation, peanuts combined with cowpeas produced a surplus of peanut pods and fane in the central field at Ndiob. With the addition of organic inputs, these yields increased even further. Nodule analysis showed that when groundnuts were combined with cowpeas, there were twice as many nodules as when groundnuts were grown pure. Similar results were obtained in growers' satellite fields. In the various tests, the Land Equivalent Ratio (LER) obtained was greater than 1 for the association. This shows that there is a beneficial symbiosis between the two crops, and that the association is more beneficial in terms of land use than the pure millet crop.

Co-evaluations

Co-evaluation methodology

The central field and satellite field systems have been evaluated by all those involved in the process. Co-evaluations take place during vegetative development and at harvest, each year of the project. Two approaches have been used: (i) qualitative and (ii) quantitative. In 2021, the qualitative approach was mainly used. It consisted in recalling the process that led to the establishment of the central field and in a qualitative assessment, by the farmers, of crop performance, option by option according to the repetitions. Farmers gave an overall assessment of crop growth, through "better vegetative plant development" between options, and put forward explanations.

During the 2022 season, co-assessment was marked by the introduction of indicators enabling growers to assess parameters other than agronomic ones. The qualitative approach was combined with a quantitative one in which farmers, in groups, vote by classifying treatments as "Good", "Average" and "Bad" and note the reasons for their choice. The tools were developed as part of a thesis on multicriteria analysis. The proposed and reorganized methodological and organizational approach is summarized in the diagram below.



Summary of the results of co-assessments with growers on the central field at Ndiob

In 2021, these co-assessments revealed that the positive impact of manure on crop growth and development at 70 days after sowing was confirmed by growers' pod and haulm yield results. On the other hand, in these co-assessments, we note the lack of appreciation by growers between the groundnut monoculture (A) and the groundnut and cowpea association (A+N). However, the final results show that the difference is much more spectacular when groundnuts are combined with cowpeas than when FC is applied to groundnuts. Growers were also very attentive to the presence or absence of pests in the treatments. However, we (research) lack quantitative data to assess the infestation rate and severity of attacks, and their link with growth parameters, development and final crop production.

In 2022, as in 2021, two co-assessments were carried out, on August 27, in the middle of the campaign, and on October 1, as the harvest approached. In the first co-evaluation (photo 3), a total of 63 people from 16 villages took part, including 21% women and 40% young people. In the second co-evaluation (photo 4), 44 participants from 14 villages took part, including 25% women and 30% young people. The detailed results of these co-evaluations are presented in the co-evaluation reports.

Some of the farmers' observations were consistent with the final results. Indeed, in central field 2, groundnut plus manure application was considered "poor" in 2 out of 3 replications. The results for pod and haulm yields are indeed higher with groundnuts alone than with groundnuts plus manure application, which is in contradiction with the results for the 2021 central field 1. On the other hand, the application of compost to the two associated crops was considered positive, although its contribution (compost) was almost negligible compared with groundnut + cowpea without compost.

Co-design of farm-scale scenarios

The scenario co-design activity falls within the general framework of co-designing innovative agroecological intensification systems. The activity mobilizes a farm modelling tool based on data collected in satellite fields, and in other project systems. The farm modelling tool can be used to fuel discussions with producers in co-innovation approaches at the scale of their plots, as close as possible to their production context.

Scenarios are designed and evaluated in practice with volunteer producers, in conjunction with technicians from development organizations. The definition of the scenarios involves the participation of the producer (with his family assets if possible), the researcher or a research technician who is familiar with the approach. The entire interactive process and supporting tools are explained at length, to ensure that they remain comprehensible to both producers and technicians.

Thus, the objectives of the activity are to: (1) carry out an ex-ante assessment of the agronomic, economic and environmental impact of introducing an agroecological (cropping) system at farm level, (2) provide a simple tool (Excel, or even a mobile application) for use by PO and development technicians to discuss possible farm changes with producers, (3) enhance the data collected in all the systems in the 3 countries (satellite tests, central fields, station) in an agroecological system performance database.

Methodology

The scenario co-design activity used a simple farm modelling tool. The modelling tool was built in several stages, progressively during the second phase of the FAIR Sahel project. These included database construction, model development and real-life testing. The construction of the databases and the development were carried out simultaneously, due to the need for numerous round-trips to adapt the model to the structure of the databases. However, given the duration of the project and the time taken to build the model, it was not possible to test the scenarios resulting from the simulations on farmers' plots during this campaign.

Database construction

Two databases have been constructed. These are the Cropping Systems Performance Database (CSPD) and the Livestock Systems Performance Database (LSPD). They contain a list of systems as well as the performances linked to these systems and references for indicator calculations. At present, the database structures have been finalized, but the databases continue to be fed.

The creation of the databases followed a participative, multi-stage approach. The first step was to draw up specifications describing the tool, its purpose, its inputs and outputs, and the link with the operating model. The second stage consisted in presenting the idea of the operating model to producers, to obtain their opinions and suggestions on the tool and the performance indicators to be calculated. This second phase took place through workshops in the villages of Ndiob. The growers who took part in these meetings were those with satellite fields in the project. During these workshops, growers expressed their interest in this type of tool. They made a few suggestions for performance indicators (at household level). The growers then gave their opinions on the tool and their suggestions for improvement and/or reorientation, in particular on the criteria to be taken into account.

The workshops also provided an opportunity to review the crops and cultivation operations practiced in each locality, according to soil type. Producers also indicated the agroecological practices they would like to test using the tool.

Data sources

In the database, cropping systems are defined through a combination of the main cultivation practices (tillage, crops, spatial arrangement, fertilization and phytosanitary treatment), with the soil types predominant in each zone.

The database was created by combining several sources and types of data. It consists of data collected in the FAIR Sahel research projects. The databases were supplemented by secondary data from the literature (scientific articles, technical data sheets, etc.) and discussions with stakeholders (producers, researchers, experts, technical agents).

In 2024, 10 farms were monitored as part of the OneCGIAR Agroecology Initiative project, in order to complete the database and test the model with this restricted network. This monitoring was carried out with volunteer farmers selected according to production orientation (farmers or agropastoralists), farm size (household members and equipment) and crop diversity. The aim was to identify all crop plots and livestock workshops, and to fill in a certain number of variables. Data was collected at household level (members and management), then at plot and livestock workshop level. In each plot, soil types were recorded, as well as the various elements of the technical itinerary, cropping operations and inputs. In the case of livestock units, management methods, feed types and maintenance operations (vaccination and deworming) were recorded. Performance measurements were also taken.

Operations modeling tool

The modeling strategy adopted is to start with a very simple model. Thus, a model that had already been used by the WUR team (Ronner et al., 2018) was used. This is a simple modeling tool in the form of an Excel file with different tabs for input data, output indicators and scenarios. However, in the course of discussions with stakeholders (researchers, growers, development technicians), the modeling tool became a little more complex by taking into account elements of the farming system, and also by the number of indicators to be calculated. The operating model is contained in the same Excel file as the databases, with different sheets interconnected by formulas. It includes different tabs for calculations and storage of references used to calculate indicators.

Model input data

Input data for cropping systems and livestock operations are entered in the same tab. For the cropping system, this includes the geographical position of the plots (agroecological zone and halo), the biophysical environment (soil type), the crops (main crop, associated crop and preceding crop), the type of cropping system and, if applicable, the type of cropping association. Cropping operations, equipment and products used are also part of the input data. The types of fertilizers and pesticides applied to the plots, the equipment used and the methods of application are also noted.

For livestock production facilities, input variables include the geographical location of the facilities, management and feeding practices, animal maintenance (vaccines and dewormers) and equipment (barns, feed troughs, drinking troughs and haylofts).

Output variables

The model's output variables are made up of indicators covering the fields of sustainability: agronomic, social, environmental and economic indicators. The model's expected outputs are crop yields, the economic profitability of the cropping system and its contribution to household food security (for the crop under consideration), and environmental criteria.

Tool development and stakeholder involvement

During 2022, several preparatory meetings were held with researchers and development technicians prior to the agricultural season. The aim of these meetings was to define the objectives of the activity, to discuss the modalities of implementation and the data collection required for its implementation. Subsequently, during the database-building workshops, the modalities for developing the model were discussed with producers.

Activity status

The activity is currently being finalized. The model's proof of concept has been completed. Indicator calculations have been carried out on a fictitious farm, along with fictitious input data. We still need to finalize a first version of the databases and complete the monitoring of 10 farms (post-harvest operations in progress) in order to simulate scenarios in December 2024. We hope that these scenarios can be tested in real-life situations on the farms during the second phase of the Agroecology Initiative project, which starts in 2025.

2. Generic framework for the agronomic assessment of codesigned agroecological technologies and trials

Moussa N'Dienor, Isidore Birame Diouf, David Berre

Report : https://agritrop.cirad.fr/611413/

This work was conducted in the framework of the IAE throughout a workshop held only in Ndiob at the end of the year 2024. A 2-day workshop was held this commune to understand how the 2 technologies tested could improve or reduce performance on the 4 elements of the selected CAET (Diversity, Synergies, Efficiency and Recycling). The first day was devoted to presenting the objectives of the workshop, and the different concepts through powerpoint illustrations. Once the discussions were over? the workshop team prepared the blank evaluation sheets, where each dimension was rated from 0 to 4, and each technology represented by a color. The second day was devoted to the actual evaluation by the farmers. It's important to note that the first dimension (diversity) took up almost half the workshop time, as it was important to understand the evaluation process, and explained in particular the conventional practice scores that had been given in advance by the facilitation team.

Results

Treatment	Element	Index[1]				Element Score[2]	Score
		I	II	III	IV		
Groundnut sole cropping	**Diversity**	1	1	3	1	6	37.5
Groundnut-cowpea association		2,5	3	3	3	11.5	71.9
Horse manure		1	2	3,5	1	7.5	46.9
Groundnut sole cropping	**Synergies**	2	1	3	2	8	50
Groundnut-cowpea association		3	2	3	2	10	62.5
Horse manure		2,5	2,5	3	2	10	62.5
Groundnut sole cropping	**Efficiency**	2	2	3	1	8	50
Groundnut-cowpea association		2	2	2,5	2	8.5	53.1
Horse manure		3	3	3	2	11	68.7
Groundnut sole cropping	**Recycling**	0,5	0	3	3	6.5	40.6
Groundnut-cowpea association		1	0	3	3	7	43.7
Horse manure		1,5	0	3	3	7.5	46.9

Scoring from 0 to 4 for each index as described in the supplementary material (see S1- Page 22). 2 Sum of scores, ranging from 0 to 16. 3 (Item score/16) * 100.

Table 1 : Results of the participatory evaluation of conventional practice and 2 alternative technologies in Fatick for 4 dimensions of CAET (diversity, synergies, efficiency, recycling)

Figure 4 show that the 2 selected technologies improve performance on all 4 dimensions, with greater improvements for diversity, which can be explained by the addition of a new plant species in the groundnut-cowpea association. Looking in more detail at figure 5, we can also see that the diversity of activities is increased because the new crop associated with groundnuts (cowpea) can be sold and diversify sources of income. The use of horse manure also performs well on the "synergy" component, with better integration of agriculture and livestock farming. Regarding the "recycling" dimension, there is little difference between conventional and agroecological practices, except for the "recycling biomass" sub-category, where both practices optimize biomass production, and reuse it in the case of horse manure. On the "efficiency" component, there is little difference between conventional practices and agroecological alternatives. In fact, this was the only case where an agroecological practice was rated less favorably than the conventional one, as cowpea attracted pests to groundnuts in the case of association. This result shows the importance of studying the trade-offs between the different dimensions of agroecology.

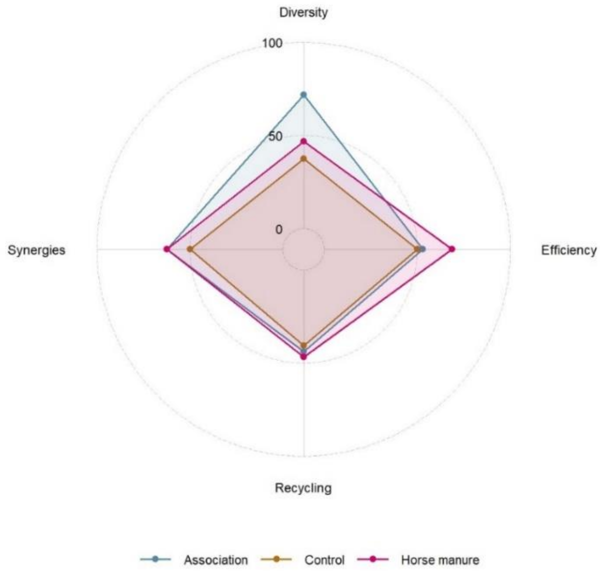


Figure 4: Radar plot of participatory assessment (CAET) of agroecological technologies in Fatick (horse manure and association cowpea-groundnut) for 4 dimensions (average value)

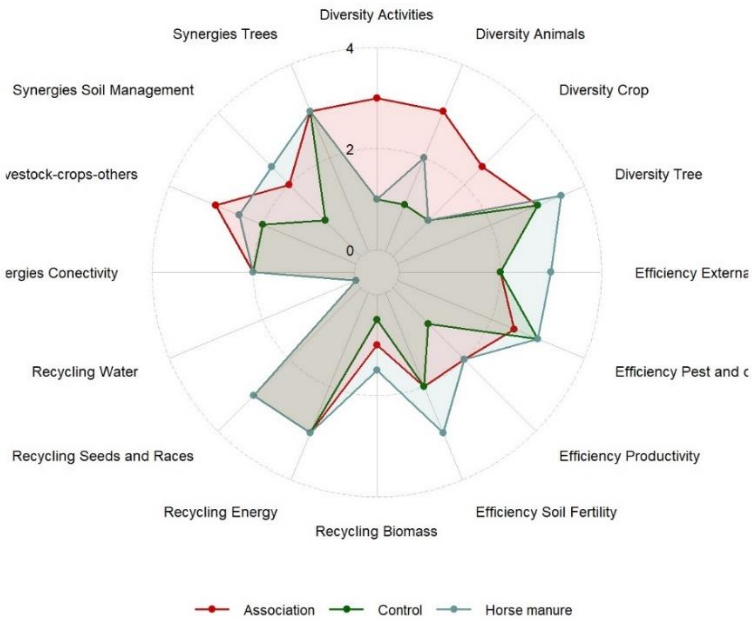


Figure 5: Radar plot of participatory assessment (CAET) of agroecological technologies in Fatick (horse manure and association cowpea-groundnut) for 4 dimensions and each subcategory .

Recommendations

The technologies tested in this first phase showed promising results and were positively evaluated by farmers. However, we can note avenues to explore to continue to evaluate their performance and thus assess their ability to be adopted on a larger scale:

- The **results in farming environments should include multi-criteria analyses including environmental and economic indicators, but also social ones (labor constraints, inequity, etc.).** This last point, economic profitability, should be at the heart of the new test phase (cost of transporting manure, economic contribution of cowpea in the association, etc.) in order to demonstrate the ability of these technologies to meet the constraints of producers.
- The legume-legume association is an original innovation tested in this living lab. It is quite innovative and relatively little explored in the literature. It is often found under the name of "double-up" legume rotations[1] . In the new phase of the initiative, it will be important to equip ourselves with ad hoc experimental trial to continue analyzing out these associations, in particular by determining the effects of competition or synergies between the physiology of the two plants (synergies and trade-off).
- We have seen in this first phase that the effects of horse manure or compost have fairly heterogeneous effects between years or between fields. It is therefore important during the second phase to deepen the analyses of the quality of these biomass sources (sand content, chemical analysis, biochemical content, near infrared spectrometry analysis) with diachronic measurements to study the evolution of quality over time according to different storage methods.

3. Innovation box and cropping system ideotype

Raphael Belmin, Banna Mbaye

The ideotyping approach presented above was carried out in 2022 in the Fatick department, as part of a project to co-design cropping systems. In 2022, Senegal applied an approach to co-design "ideotypes" of agroecological cropping systems mobilizing a number of local stakeholders and representatives from Fatick's ALL (the DyTAEL) for a 5-day mission. Here are a few highlights of the corresponding approach, based on the workshop report (Belmin et al 2022).

Box 1: A few useful definitions used in the codesign of ideotypes of agroecological cropping system (Belmin et al. 2022).

- Ideotype = Theoretical (i.e. 'ideal') cropping system that seems coherent from an agronomic and socio-technical point of view. An ideotype responds to a set of identified constraints, and is based on knowledge of the diversity of cropping systems and farms in a given area. The ideotype is therefore a result in itself, and has intrinsic value (i.e. it can be published) even if it has not yet been tested in the field.

[1] Smith et al., 2016. Doubled-up legume rotations improve soil fertility and maintain productivity under variable conditions in maize-based cropping systems in Malawi. Agricultural Systems, 145, 139-149.

- Ideotyping = Co-construction of one or more cropping system ideotypes in a multi-stakeholder workshop.

- Prototype = Real (and therefore sometimes incomplete) cropping system implemented by researchers (experimentation in semi-controlled conditions) or growers with the aim of testing an ideotype. There can be a variety of prototypes around an ideotype.

- Prototyping = In situ or ex situ testing of a range of cropping systems that are as close as possible to one or more ideotypes. To do this, we prefer to select growers' plots that already match certain characteristics of the target ideotypes. The prototypes cannot always 'match' the ideotypes, because growers cannot change their practices quickly and radically in just one year. On the other hand, ideotypes can be used as compasses to guide farmers through step-by-step changes to their production systems. Prototyping produces knowledge that can lead researchers to develop their ideotypes in an iterative approach.

Each step is described briefly below

Step 1 - Holding a preparatory meeting of the project team

The day before the start of the workshop, the project team met for a briefing session. Goal was to discuss how the workshop would be run, identify the role of each team member and agree on the agenda.

Step 2 - Analysis of constraints and levers for ecological intensification

The workshop began with group work with two objectives: (1) to identify the underlying causes of the agronomic constraints in the area (pre-identified via a rapid diagnosis in 2021) and (2) to propose technical or organizational levers that could potentially remove these constraints and sub-constraints. The participants were divided into 4 working groups. All the groups worked on all the pre-identified constraints.

Step 3 - Assembling levers into innovation pathways

The project team constructed summary figures bringing together, for each constraint, the underlying causes (orange) and the levers (light green) identified by the 4 groups. Innovation pathways (dark green column headings) have been constructed by grouping together several levers based on the same logic for transforming cropping systems. The innovation paths that directly concern farmers were selected (red circles) for the rest of the workshop. In all, 10 and 12 avenues of innovation were identified for market gardening systems and bush fields respectively.

Step 4 - "Expanding" innovation pathways

On the second day of the workshop, group work enabled a broader exploration of the avenues for innovation identified the previous day. The participants were divided into 4 working groups (3 bush fields + 1 market garden). For each avenue of innovation, they had to (i) put forward at least 4 concrete options, (ii) describe the options selected in detail and (iii) not limit themselves to what is currently being done in the area. The integration of 4 options for all innovation pathways (8 to 12 pathways depending on the group) resulted in the construction of an "innovation boxes" which served as resources the following day, for the ideotype construction stage (see below).

Step 5 - Construction of cropping system ideotypes

On the third day, group work enabled to construct ideotypes. Building ideotypes involves selecting, assembling and matching technical and organizational levers from innovation boxes. Participants were asked to explain the relationships between each of the levers making up the ideotype.

Step 6 & 7 - Selecting and visiting farmers-experimenter

At the end of the workshop, the project team asked participants to indicate their interest in trying out 1 of the 4 ideotypes that had been constructed. The following day, the project team visited several potential farmer-experimenters to assess the conditions and feasibility of such experiments.

The ideotypes thus created have intrinsic value because they are the result of a collective thought experiment. Thanks to an appropriate methodological framework, the participants were able to construct - at least in their minds - radically new forms of agriculture for their commune, based solely on their own knowledge. But if these ideotypes are to become resources for effective transformation, they need to be appropriated and put to good use by the development stakeholders. They can serve as a compass to guide technical support for agricultural projects or policies. The activity was also intended to provide input for the Fatick DyTAEL by defining the territorial changes needed to facilitate the adoption of the cropping system ideotypes. However, the ideotyping process took longer than expected, and it will be the task of a future workshop to tackle the regional scale.

4. Recovery of salty soil

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https://agritrop.cirad.fr/611638/

By adopting a participatory approach, ISRA/CNRF capitalized on several agroecological innovations on saline land restoration in the Fatick department, aiming to develop practical tools for scaling up. A saline land reclamation plot had in fact been set up in a one-hectare community demonstration plot installed in Fayil since 2017.

Background and approach

- **Issue**: Salinization, due to a rise in sea level, which leads to saltwater intrusion into the water tables and agricultural land near the Saloum delta, affects a large proportion of arable land, reducing agricultural productivity and impacting the resilience of local communities, particularly women rice growers.
- **Solutions tested**: Use of peanut shells and the phosphogyspe as soil improvers, combined with the planting of adapted halophyte species, with an emphasis on agroecological practices.
- **Co-design perspective**: Local communities, particularly women rice growers, have been at the heart of the process, co-developing and testing solutions adapted to their needs and resources.

Co-design approach

1. **Field visit**: Participants assessed the results obtained on a restored community plot, observing the impact of the methods applied.
2. **Focus group with local communities**: feedback on restoration successes and constraints. Concrete proposals included:
    - Alternatives for soil improvement (e.g. use of manure and compost).
    - Improved rice-growing techniques (short-cycle varieties, creation of bunds for water management).

   - Increased planting of more resistant halophytic species such as Melaleuca leucadendron.
3. **Wheel of the future method**: A participatory tool for visualizing the direct and indirect impacts of innovations, structured around five dimensions (social, technical, economic, environmental, political). This has enabled us to identify levers such as access to financing and improved water infrastructures.
4. **Collective development of a practical guide**: Integration of local experience and research findings to produce a restoration manual, taking into account :
   - Proven techniques.
   - Community feedback.
   - The specific needs of sustainable development.

Results and outlook

- **Identified impacts**: Improved farmland, higher yields and incomes, enhanced biodiversity, reduced rural exodus, job creation.
- **Lessons for co-design** :
  - Importance of constant dialogue between researchers and communities.
  - The need to adapt solutions to local economic and social realities.
  - The need for funding mechanisms to support the scaling-up of innovations.

The integrated and inclusive approach has enabled solutions to be co-constructed with local stakeholders, promoting greater ownership and greater effectiveness in the fight against land degradation.

5. Holistic Understanding and Participatory Modeling

JP Muller, E Delay, JD Cesaro et al.

https://agritrop.cirad.fr/611424/

https://agritrop.cirad.fr/611498/

https://agritrop.cirad.fr/611497/

The computational modeling of socio-ecosystems is an interdisciplinary analytical approach aimed at mathematically describing the complex interactions between human societies and their natural environment. Through a participatory process, the model and its results serve to enrich collective reflections on understanding the system holistically and may encourage stakeholders to transform their practices to achieve new objectives.

In the case of the Fatick Living Lab department, the approach is applied at two scales:

- A local approach at the village scale: Diohine (Niakhar municipality) : Etienne Delay & Jean-Daniel Cesaro
- A territorial approach at the departmental scale (with DYTAES) : Jean-Pierre Müller, Tingorou Sanogo *with support of Jean-Daniel Cesaro and Marc Piraux*

Village scale: balancing trade-off of agro-forestry in drylands

At the territorial scale, farmers seek to increase millet yields through agroecological practices. Millet represents 70% of the cultivated area in the department. Research shows that yields are positively correlated with the density of *Faidherbia albida* (Kad trees), but this depends partly on the demand for firewood. The modeling team at the IAE has built upon the momentum initiated by the DSCATT and PERP FairCarbon projects, in collaboration with Diohine's village environmental defense group, to continue work on the importance of agroforestry in the village's agroecological transition.

Simulations reveal that the territory cannot simultaneously meet both food and energy needs. Thus, it is necessary to design an energy transition that integrates the use of agricultural by-products at the village level. Developing biogas systems (to transform manure into composted exudates) or solar electricity could be of interest. A model is currently being developed under the PEPR FairCarbon project to assess the amount of energy required and transferable. At the same time, reintroducing Kad trees into agroforestry systems requires an assisted natural regeneration (ANR) program, with particular attention to identifying young Kad shoots. Many field workers fail to recognize natural Kad growth or disregard the plants marked by protection groups. Therefore, there is a need to improve territorial governance of agroforestry and ANR programs. These programs, already present in the area through DYTAES, lack influence among young people.

Territorial scale: understanding territorial metabolism of organic biomass

At the departmental level, DYTAES is questioning its ability to develop its "Fatick Nataange" (Well-Being) scenario (Piraux *et al*., 2023). This scenario embraces a multifactorial vision linked to the 13 principles of the agroecology coalition. To address the Nataange scenario from a multifunctional perspective, the team conducted a series of two missions to develop an initial model based on the Diohine experience (Nexus Agriculture/Trees/Energy), incorporating broader challenges (Nexus Land Use/Livestock/Water). This activity was supported by a doctoral student from PRAPS 2 working on the role of livestock in the multifunctionality of agro-sylvo-pastoral territories.

DYTAES stakeholders are exploring whether the department can meet its needs for organic fertilizers to achieve agroecological transition. Several sources of organic matter (OM) are available: animal manure, agricultural residues, aerial biomass, and urban waste. In developing a composting supply chain for producers, manure is particularly valued. The department has an estimated 175,000 tropical livestock units (TLUs) (Ba *et al*., 2023), producing approximately 1.6 million tons of fresh organic matter (excluding urine). With 150,000 hectares of cultivated land and a need for 30 units of nitrogen per hectare, the department theoretically has twice the manure required. However, the movement of these materials remains complex due to both livestock management within the territory and long-distance mobility (Scriban *et al.,* 2024).

Thanks to this initial conceptualization and problem framing, it is possible to engage stakeholders in a multifunctional vision (economic, social, environmental, and territorial development value) of the composting supply chain within the department. What are the best practices for OM management to support the agroecological transition, alongside practices such as crop rotation, fallowing, and intercropping, in the Fatick department?

Outlouk: combining up-scaling agroforestry and territorial metabolism in drylands

Combining the upscaling of agroforestry with territorial metabolism in drylands offers a comprehensive strategy to address environmental degradation, enhance livelihoods, and promote sustainable development

6. Innovation boxes and ideotyping at departmental level

Belmin R, Dione G, Mbaye B, Gueye Fall M, …, & Piraux M. 2024. Designing an agroecological territory for the department of Fatick, Senegal. Ideotyping workshop report. Dakar, Senegal, September 2-6, 2024, 60 p.

https://agritrop.cirad.fr/611597/

Within All, an ideotyping exercise was carried out at territorial level. The aim was to co-construct a vision of a resilient and sustainable agroecological territory. The causes and consequences of the territory's central problems were first analyzed using problem trees: degradation of land, water and biomass, low value-added of local products, and little consideration given to agroecology in public policies. The analysis of these problems then paved the way for the exploration of solutions, which were compiled (through solution trees), organized and completed in an "innovation box". This box takes the form of an organized repertoire of 258 solutions, levers or innovations (covering a wide range of levers (agronomic, organizational, etc.) intended to be used as building blocks for the ideotypes. These innovations were then grouped into innovation avenues. For example, the "stone barriers" and "shrubs in watersheds" solutions were grouped together under a single innovation avenue called "erosion control". In this way, 63 innovation avenues have been identified to restore land, regenerate forest resources and biomass, improve access to productive water, add value to products of local interest and integrate agroecology into local public policies.

The elements of the innovation box were analyzed in order to identify and prioritize the actions and responsibilities to be undertaken for an agroecological transition in the Fatick department. Finally, participants selected, assembled and organized elements from the innovation box to build an ideotype of an agroecological, resilient and innovative territory in the face of the existential threats facing the Fatick department.

7. Conditions for appropriating and scaling innovations and transition path

Marc Piraux, Raphael Belmin, Moussa Ndour, Modou Gueye Fall, Banna Mbaye, Finda Bayo, Marième Ba, Geneviève Dione, Cherif Mané, Ibrahima Diallo, Juliette Lairez, Arame Diouf, Patrice Kouakou, Coumba N. Ndour, Mame Birame Sene, Aby Barry, Pape Bilal Diakhaté.

https://agritrop.cirad.fr/611666/

Level and conditions of innovation scaling out and up

Following on from the ideotyping exercise, we looked at the extent to which innovations could be disseminated, and the conditions for sustaining them and scaling them up to the local level.

To do this, we drew on the hypotheses of the Dissem-in project (Bourgeois and Lesenfants, 2024), which we have supplemented. The aim is to mobilize a holistic approach encompassing the technical, organizational, institutional and socio-cultural dimensions, for innovations that guarantee sustainability and bring about change.

The 3 structuring hypotheses are as follows (Bourgeois and Lesenfants, 2024):
1. **The sustainability of** innovations depends on their multi-dimensional nature (technical, organizational, *institutional* and socio-cultural).
2. These dimensions correspond to the three **scaling** modes (horizontal, vertical and depth).
3. Any innovation process that combines these four dimensions carries within it the seeds of a change of scale.

In this context, innovation is seen as a process which, in order to modify individual *or collective* practices and behaviors, also acts on the organizations, institutions (rules) and values in place before the intervention. In this way, the change in practices is accompanied by the creation of new organizations, institutions and values, which in turn ratify this change in behavior, impacting on its sustainability.

It also makes it possible to analyze out scaling, up scaling and deep scaling, by studying how these changes in practices, rules, institutions and values spread to other individuals in other spaces.
- The **technical dimension** contributes to practical implementation*, an* attribute mainly motivated by the performance of an innovation according to three criteria (quality, availability and adaptability), which are essential to fostering appropriation, but also requiring repetition processes, enabled by the involvement of players over time.
- The **organizational *and institutional* dimension** enables us to set up multi-actor networks or exchange spaces, within which innovation emerges, and *institutions,* backed by a set of collectively-defined rules that are tending to become formalized.
- The **socio-cultural dimension** underpins the dissemination of new values and the learning that this requires. Often overlooked, it plays a crucial role in the acceptance and appropriation of innovation. It manifests itself, under the combined effect of the preceding attributes, in a change in the relationships maintained between players and in their ways of thinking.

In a workshop attended by some thirty DYTAEL players, discussions were held on the degree to which innovations should be scaled up, the conditions for their sustainability and then scaling up to the local level:

- Innovations have been classified according to their dimension (technical, organizational, institutional, socio-cultural), and may be complemented to address sustainability issues.
- Analysis of stakeholders' perceptions of the current degree of dissemination of innovations.
- Characterize what exists in the region (even a weak signal), what encourages or drives innovation in each major innovation theme.
- Write down what hinders or could hinder the scaling-up of innovations in the region.
- Devising synthetic solutions to consolidate innovations, support what drives them forward and/or limit what holds them back.

Transition path

As a follow-up to this exercise, local stakeholders co-designed an agro-ecological transition path for the Fatick department. To do this, the process has been as follow:

- Placing all innovations by major theme on a chronological line (short, medium and long term) results in a temporal sequencing of innovations, with the emphasis on the backcasting method (from the vision, the ideotype to the current situation).
- Innovations may be added to ensure a logical transition path.
- Cross-analysis of all themes to form the transition path.

For illustration purposes, the figure 6 shows the result without being discussed here, as the report explains these results in greater detail.

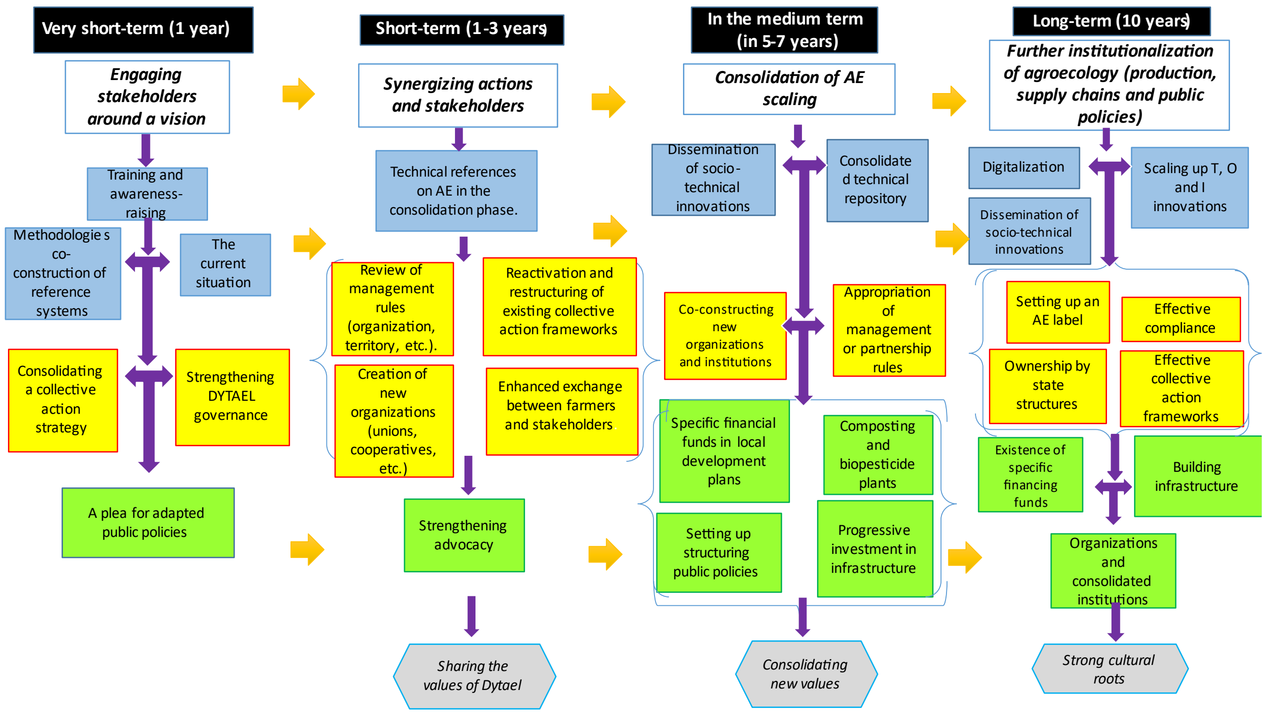

Figure 6. Transition pathway co-constructed with Fatick Dytael stakeholders.

. 8. Final considerations

M. Piraux

a) Overall reflections about the codesign process

WP 1 engaged a wide range of tools and methods related to the co-design of innovations. It includes an inclusive and systemic approach, necessary to address agricultural challenges in their entirety, while putting local communities at the center of the process.

It has developed at different scales, from the plot (cropping or land restoration system) to farm and territory. Whatever the thematic, the co-design of innovations is based on the following principles:

i) Inclusion and active participation, based on a diversity of stakeholders and anchored in the valorization of local knowledge ; ii) Systemic approach, involving multisectoral (includes social, economic and environmental dimensions, multicriteria evaluation), and multidimensional (exploring conditions of dissemination (horizontal, vertical, in-depth) of innovations; iii) Diversity of tools and methodologies (plot trials, ideotyping, innovation box, participatory modeling, co-design, foresight approach) iv) planification processes integrated in a transition path.

The report highlights a significant methodological transition: from traditional agroecological experiments, focused on specific indicators (yield, soil quality), to more holistic approaches. This doesn't mean that traditional trials are irrelevant, but it does mean that they need to be part of a wider process of reflection on the transition path, enabling researchers and actors to jointly rethink the themes of the trials and their place in a process of changing practices.

The modeling is central to our approach. The originality was to develop different kinds of modeling (excel spreadsheet, ideotyping, SMA...) at different levels (cropping system, farm, landscape (agroforestry, organic matter) and the department as a whole) to better support local realities. Each time, it has involved taking into account the perception of the future in order to better guide the present and specific tools were used for that (future wheels, scenario, visioning, backcasting…). Tools such as the “Wheel of the Future” or ideotyping approaches enable us to build strategic visions and anticipate the impact of innovations over time.

b) What worked especially well and why?

Considering critically the whole codesign process, the approach we used for codesigning innovations and resilience of the territory has been relevant by thematic, especially the logical process between selecting and adapting innovations, modelling, impact analysis, scaling conditions, strategy. The integration of multicriteria analyse of trials was well appreciated too. Using the future with new tools was very well appreciated by the participants.

The process established between problem identification, innovation box construction, ideotyping of the department, out and up scaling conditions of innovations, to co-design a transition path was very well accepted and useful. The level of participation from DYTAEL and local communities has been high each time, and the feedback from evaluations has been very positive.

c) What worked less well, why, and for whom?

The major difficulty has been the lack of coordination between the different themes which were launched in parallel, in different timeframes (e.g., agronomic trials launched in the FAIR project more than 2 years before the start of the AEI), and the lack of time to better coordinate them.

Indeed, a better articulation between plot trials, cropping and territorial ideotyping, computer modelling, included in the transition path is a big challenge to enhance the multi-scale and multi-sectorial processes.

Computer modelling also implies a learning process on the part of the stakeholders, as it's a particular mode of representation that's out of the ordinary.

d) How did the codesign of innovations (process, results) contribute to the agroecological transition and the vision of the ALL stakeholders about their future?

It was in fact the objective of the co-design process, declined at different level: farm, landscape and department. As we said before, it’s the articulation between this different process that we need to improve.

e) Do you have any specific suggestions and recommendations for how to go about codesign during the upcoming SP2 (Multi-functional landscapes)?

The work of WP 1 calls for a diversity of complementary approaches to be taken from the outset, guided by a vision and a transition path. The use of complementary methodologies and tools has enabled to co-construct a transition path based on innovation box, complemented by a holistic approach to sustainability and scaling factors of innovations, supported by a vision of the region's future. This path is not prescriptive; it is intended to guide action without constraining it, and participatory modeling also enables more detailed discussions and simulations on specific themes. This will be the big challenge for the future, particularly in terms of landscape (for us defined more at the level of villages).

For the SP 2, we believe that combining agronomic experimentation, modeling and scaling conditions of territorial innovations in drylands and holistic approach of innovations, underpinned by a vision and a path of transition, offers a comprehensive strategy to address environmental degradation, enhance livelihoods, and promote sustainable development.

Thought this way, these co-design approaches, offer an original framework for transforming agricultural systems and strengthening their sustainability, favoring a process-oriented rather than output-oriented approach.

Especially, the computational modeling of socio-ecosystems is an interdisciplinary analytical approach aimed at mathematically describing the complex interactions between human societies and their natural environment. At this level, in the Multifunctional Landscapes scientific program, it would be valuable in the example of agroforestry; to integrate data from HOLPA, innovation tracking, and GPS tracking of mobile herds to refine the results. In collaboration with ICARDA and ILRI teams, it is essential to share experiences across socio-ecosystemic landscapes to enhance the resilience of arid zones.

It will also be important to improve certain impact monitoring and evaluation methods in order to capture the mid-term effects of this approach on system resilience and sustainability.

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