MiCampo: A Multi-Level Digital Cooperative Infrastructure for Agroecological Planning, Participatory Certification and Territorial Market Coordination

Stéphane Dupas[1], Melchor Ruiz[2], Elyandre Buret[2], Lenny Vergerolle[2], Benjamin Lysaniuk[3]

[1]Université Paris-Saclay, CNRS, IRD, UMR Évolution, Génomes, Comportement et Écologie (EGCE), 6 Avenue de la Terrasse, 91198 Gif-sur-Yvette Cedex, France

[2]Université d'Orléans, Château de la Source, Avenue du Parc Floral, BP 6749, 45067 Orléans Cedex 2, France

[3]UMR 8586 PRODIG, Campus Condorcet, Bâtiment Recherche Sud, 5 Cours des Humanités, 93322 Aubervilliers, France

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Correspondence: Stéphane Dupas (`Stephane.Dupas@ird.fr`).
ORCID: `https://orcid.org/0000-0001-8332-6679`

Agroecological transitions require coordination across technical, certification, economic and research domains. We present MiCampo, a modular digital cooperative infrastructure organized into four functional levels: (1) agroecological technical planning, (2) digital participatory guarantee systems (PGS), (3) contractual territorial distribution planning and logistics, and (4) territorial research and monitoring. The platform integrates both a webmaster application for cooperative governance and a mobile application for producers and other territorial stakeholders. MiCampo is grounded in an action-research approach: by providing concrete services to producers and cooperatives (technical itineraries, participatory certification, contracting and logistics support), the platform simultaneously reduces transition costs and generates structured, longitudinal data on practices, certification processes and food-system coordination, which feed back into research on agroecological transitions. We describe the conceptual architecture, the implemented modules, and a roadmap for future integration, including AI-assisted biodiversity identification tools and territorial monitoring indicators.

1 Introduction

Agroecology is simultaneously a science, a practice and a social movement [**?** 1, 2]. As a science it applies ecological concepts to the design of food systems; as a practice it reorganises farm and landscape processes; as a movement it seeks fairer relations among producers, consumers and territories. These

three dimensions do not automatically communicate. Scientific indicators, farm-level routines and collective action often remain poorly coupled, which creates a persistent science–society gap in territorial implementation [3**?** , 4].

This gap helps explain a well-documented paradox. Agroecology is widely presented as a major lever for sustainable food systems [5], yet certified organic and explicitly agroecological production remain a small share of farmland and of domestic consumption in most countries [5, 6]. One observable barrier is economic access: products labelled organic or agroecological are typically sold at a substantial premium, which limits uptake among low- and middle-income households [7]. At the same time, this premium does not automatically reward small producers. In concentrated agrifood chains, a large share of value is captured downstream, while the share accruing to farmers is often modest and highly variable [8–10]. Agroecological food can thus be too expensive for poorer consumers and still insufficiently remunerative for smallholders.

Part of this paradox is organisational rather than agronomic. Long intermediated chains, costly third-party certification and high transaction costs of matching dispersed producers with local demand raise consumer prices without securing farm incomes or feeding back ecological knowledge into practice [6, 3]. Territorial implementation therefore requires coordination among producers, certification systems, markets and research actors—that is, an operational articulation of science, practice and collective action.

Digital agriculture platforms have expanded globally, yet most remain input-oriented and vertically integrated rather than cooperative and territorially embedded [11, 12]. In agricultural contexts the problem is acute: farmers face strong time and economic constraints, and participatory initiatives that mainly collect data for research struggle to sustain long-term engagement [13, 14]. Participatory approaches remain essential for agroecology, because they can integrate local knowledge, collective experimentation and social learning [15, 16]. Establishing them, however, usually requires heavy facilitation, lasting institutional support or direct incentives.

This raises a central question for agroecological research: how can participatory infrastructures generate research-relevant data while simultaneously providing tangible benefits for farmers and other local food-system stakeholders?

Digital platforms can address this tension when participatory data collection is embedded in services with immediate use—production planning, cooperative contracting or certification—so that research datasets arise as a by-product of practice rather than as the primary request made of farmers.

In this context, we present MiCampo, a cooperative digital platform designed to support agroecological production, participatory certification and territorial food-system coordination. The platform integrates technical planning tools, participatory guarantee systems, territorial contracting mechanisms and participatory research modules within a single digital infrastructure.

The platform emerged from exploratory work on digital tools for agroecological transitions and territorial food-system coordination. Early conceptual and software prototypes were developed in 2020–2021 within the project *Agroecología para la acción climática en América Latina* (CIAT–CGIAR, CIP, IRD, CIRAD), under the name *Agroecomakers* [17]. These experiments addressed agroecological resources in the area of production and provided initial frameworks for cooperative territorial digital services in Andean agriculture.

Building on that work, MiCampo was subsequently redesigned and substantially extended to support participatory certification, territorial logistics planning and participatory research. Later modules were supported by the joint CNRS–IRD initiative *Frugalité et sobriété* (MITI CNRS, 2023), in particular participatory surveys and socio-ecological indicators of agrochemical risk and agroecological transition in Andean potato systems of Cundinamarca, Colombia.

2 Platform concept

MiCampo is designed as a cooperative digital platform connecting producers, consumers, transporters, cooperatives and researchers.

The platform integrates four complementary layers:

(i) technical coordination of production activities, (ii) participatory guarantee systems, (iii) territorial distribution planning, (iv) participatory research modules.

2.1 System overview

MiCampo is structured around four functional levels combining governance (Webmaster) and operational (User) interfaces.

The four levels correspond to:

- Technical coordination of agroecological production
- Participatory guarantee systems (SPG)
- Territorial contracting and logistics coordination
- Participatory research and territorial monitoring

These levels interact to support both agroecological management and territorial food system coordination.

2.2 User roles

Four main actor roles interact within the platform:

- Producers
- Cooperatives / Academy
- Consumers
- Transporters

In addition, the system includes administrative roles (Webmaster IT, Webmaster SPG, Webmaster DistribPlan and Webmaster Investigate) responsible for configuring platform parameters and governance rules.

The implementation also distinguishes cooperative managers and platform administrators. A user account can be associated with different operational roles, allowing the same person to participate in production, consumption or transport while also interacting with a cooperative. Cooperative managers configure local rules and services, whereas platform administrators manage shared components and governance parameters. This separation allows global technical itineraries and certification frameworks to be made available to several cooperatives while allowing each cooperative to activate, adapt or create locally relevant variants.

2.3 Action-research approach

MiCampo is conceived not as a participatory-research tool *per se*, but as an action-research platform: The participatory data strategy implemented in MiCampo follows a different logic from many traditional participatory research frameworks. Instead of requesting farmers to provide data primarily for research purposes, the platform first delivers services addressing concrete needs of agroecological producers and territorial food systems. Data useful for research thus emerge as a by-product of the use of these services.

It should be emphasized that it is designed to actively support and transform cooperative practices and short-supply-chain governance, and as by product, to observe and document them.

Several components of the platform illustrate this service-oriented approach. First, anticipatory contracting mechanisms allow farmers and consumers to stabilize markets by agreeing on production volumes and prices at the time of sowing. This process simultaneously generates structured information on cropping calendars, sowing dates and expected production volumes.

Second, the platform provides activity agendas and technical itinerary tools designed to support low-cost agroecological farm management. Farmers use these tools to organize production activities and record observations related to crop management. These records progressively generate datasets that can support agronomic analysis and optimization of technical itineraries.

Third, MiCampo offers a participatory certification approach based not primarily on verifying declared practices—which can be difficult and costly—but on ecosystem indicators aligned with a One Health perspective. Farmers can record the presence of bioindicator species reflecting low levels of contamination affecting both farmers and consumers. These observations create ecosystem-level datasets that can later be analyzed in relation to farming practices and production systems.

At the current stage of development, the platform focuses on the co-construction of these services with local actors. In subsequent stages, the structured data generated through their use will support participatory research, agroecological monitoring and the modeling of territorial food systems.

This service-oriented data generation approach reduces the burden of participation while aligning the interests of farmers, consumers and researchers.

This article presents the design and implementation of MiCampo, a cooperative digital platform that integrates agroecological production planning, participatory certification and territorial market coordination. By embedding participatory data collection within services directly useful to farmers and territorial actors, the platform enables the generation of agroecological datasets as a by-product of operational activities rather than as a separate requirement of research processes.

3 System architecture

3.1 Platform architecture

The MiCampo architecture integrates four functional layers (Figure 1):

- technical coordination of production activities,
- digital participatory guarantee systems,
- territorial distribution planning,
- participatory research modules.

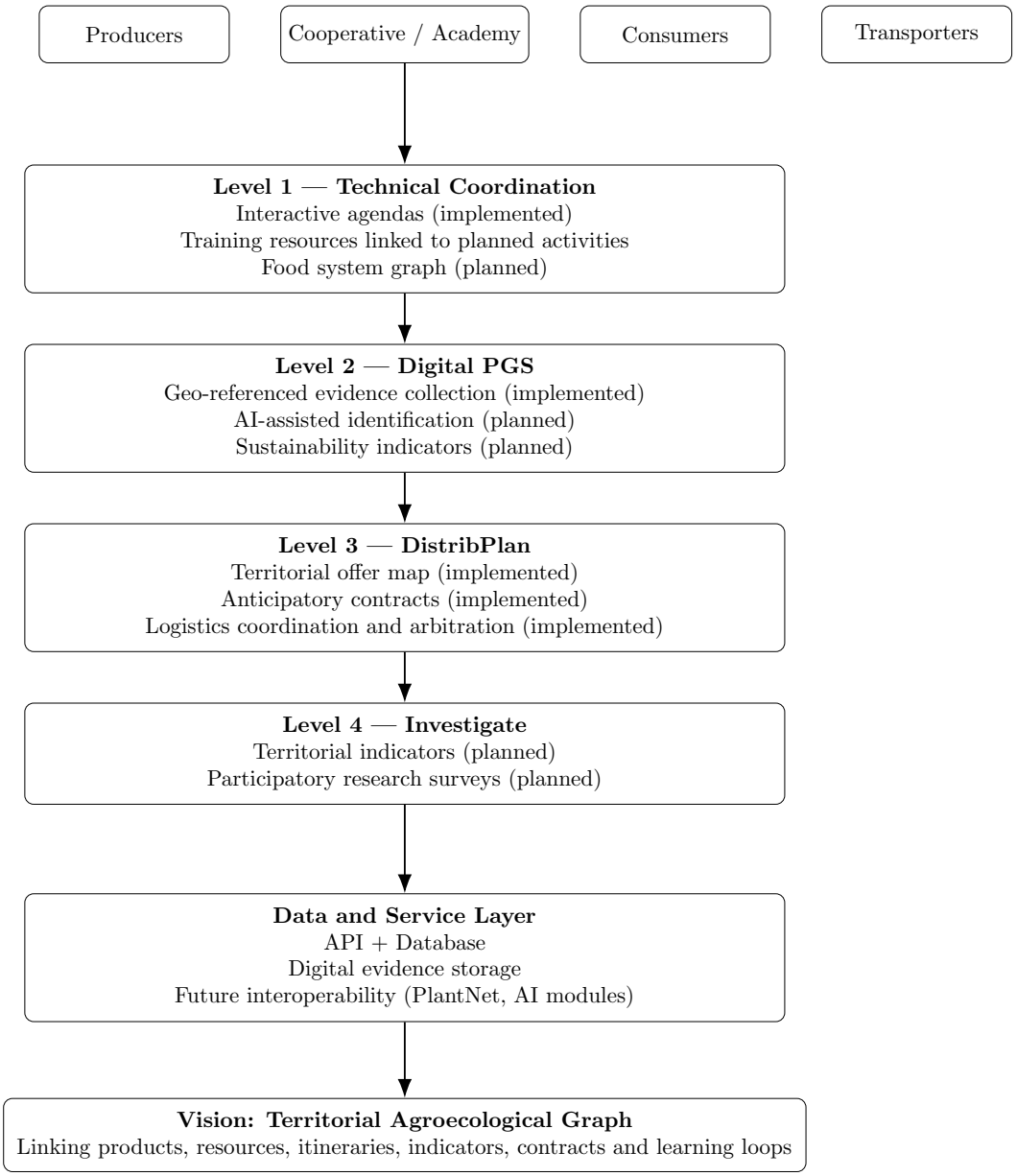

Figure 1: Conceptual architecture of the MiCampo platform.

Some functionalities remain under development, notably:

- full graph representation of the food system
- AI-assisted biodiversity identification integration
- territorial research analytics

3.2 Software stack

Software environment. The platform backend runs on Node.js (v20.20.0) with the Express framework, while frontend interfaces are implemented with Angular (v19–20) and Ionic (v8) for the mobile application.

Data persistence is handled through MongoDB using the Mongoose ODM.

Additional libraries support authentication (JSON Web Tokens and bcrypt), media processing (sharp), file uploads (multer), and API documentation through Swagger.

Component	Technology	Key Libraries
Mobile App	Ionic + Angular 20	Capacitor, ngx-translate, Swiper
Webmaster Interface	Angular 19 + Angular Material	ngx-file-drop, ngx-translate
Backend API	Node.js 20 + Express	Mongoose, JWT, bcrypt, Swagger
Database	MongoDB	Mongoose ODM
Media Handling	Node.js	sharp, multer
Authentication	JWT	bcryptjs

Table 1: Software stack of the MiCampo platform.

The platform backend runs on Node.js using the Express framework, while frontend interfaces are implemented with Angular and Ionic. Data persistence is handled through MongoDB.

Additional technical details on platform deployment and software repositories are provided in Appendix A and Appendix B.

Additional implementation details are provided in Appendix B and Appendix C.

Source code repositories are described in Appendix B, while installation and build procedures are documented in Appendix C.

4 Implemented functionalities

4.1 Technical itineraries (TI) and activity agendas

This module enables agroecological production planning through technical itineraries and interactive activity agendas.

Webmaster TI Configuration of technical itineraries and proposal programming. The implementation distinguishes shared itineraries managed by the platform from cooperative-specific itineraries. Cooperatives can activate relevant shared itineraries and create local variants, while producers can signal the need for a new or modified itinerary through the cooperative.

In the present version, a variant is a discrete itinerary derived from a base one (platform- or cooperative-level), not yet a parameterised generation from environmental conditions. Adaptation to local conditions is already possible *within* an itinerary: an activity may depend on an observation (for example, a gypsum amendment if aluminium-related soil constraints are observed). These dependencies remain qualitative (one observation, one action). Quantitative modulation of the same action—in particular dosing amendments and fertilisers from measured values—is not yet supported.

User TI Interactive agenda for producers including:

- selection and advice on TI choice
- planification of cycles linked to harvest prediction territorial market offers (Level 3)
- crop production activities
- processed products
- local inputs and recycling

4.2 Participatory certification (Digital PGS)

Inspired by participatory guarantee systems [18], MiCampo implements digital evidence-based certification grounded in collective indicator definition and participatory validation.

Certification workflow The certification process is designed as a sequential workflow that combines producer-generated evidence, lightweight automated checks, and a human consolidation step. At the time of writing, producers can already submit geo-referenced evidence and attach identification records from external biodiversity platforms; an automatic note is generated when a producer completes a submission. The consolidator role—a cooperative representative who reviews evidence and validates claims—is specified in the workflow and is considered indispensable for the legitimacy of a participatory guarantee system, but it is not yet implemented in the software. Until that module is deployed, certification cannot be closed within the platform alone.

The certification process operates through the following sequential steps:

1. **Criterion co-definition (participatory workshops):** Cooperatives and producers collectively define agroecological certification criteria during workshops. These criteria integrate ecosystem-level indicators, such as the presence of indicator species sensitive to pesticides (identified using PlantNet-based modules or photographs), agrobiodiversity observations, and habitat presence supporting beneficial organisms (auxiliary fauna).
2. **Webmaster SPG configuration:** Platform administrators program these criteria into the certification module, including validation rules and consolidation workflows.
3. **Evidence collection (User SPG):** Producers record geo-referenced evidence including soil condition photographs, biodiversity observations, indicator species identification, and production-consumption zone mapping.
4. **Participatory validation and consolidation:** A designated consolidator (cooperative representative) reviews submitted evidence and validates certification claims in collaboration with producers. This participatory review process ensures local legitimacy and collective ownership of certification decisions.
5. **Certification scoring and product association:** Once validated, producers receive a cooperative certification score, which is then associated with their products on the territorial offer map (Level 3 — DistribPlan). Certification scores contribute to product visibility and market value within the cooperative network.

Webmaster SPG Programming of agroecological indicators, certification criteria and validation workflows. Cooperatives can define criteria locally or adopt shared frameworks provided by MiCampo.

User SPG Mobile collection of geo-referenced evidence including:

- soil condition photographs
- biodiversity observations
- indicator species (with AI-assisted identification planned, e.g., PlantNet-based modules)
- production-consumption zones

4.3 Territorial contracting and logistics (DistribPlan)

DistribPlan implements anticipatory contractualization mechanisms connecting producers, consumers and transporters.

Webmaster DistribPlan Definition of cooperative rules and arbitration mechanisms.

DistribPlan

- territorial offer mapping (with SPG indicators)
- order and contract mapping
- transport coordination
- payment interface

The implementation supports anticipatory orders in which production offers are linked to technical itineraries and can be contracted before harvest. Contracts connect producers, clients and cooperatives, while transporters can define routes and validate collection and delivery. Electronic contract signature is supported through the implemented contract workflow. Delivery constraints and cooperative rules can be incorporated into the coordination process. The underlying data model is also being extended toward end-to-end traceability of products, inputs and territorial material flows.

Figure 2 illustrates the workflow implemented in MiCampo for coordinating production, contracting and delivery.

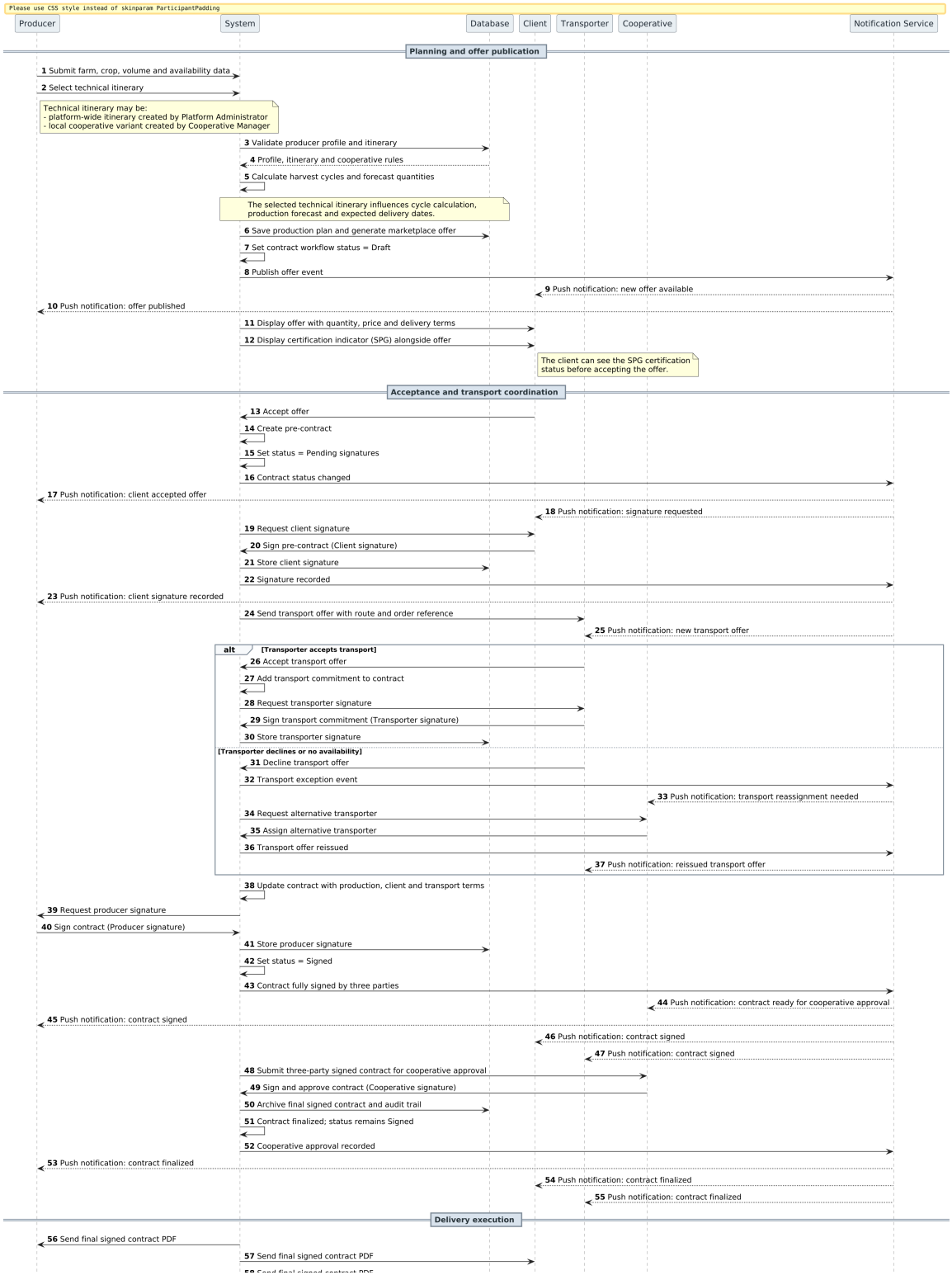

Figure 2: MiCampo usage diagram: the diagram shows the producer, cooperative, consumer and transporter interactions with the platform, including production and availability declarations, technical itinerary and activity-agenda management, participatory certification evidence, cooperative contracting, order and delivery coordination, notifications and research-survey participation.

4.4 Participatory research module (Investigate)

Investigate implements a service-oriented participatory research approach in which research questions are collaboratively defined with producers and territorial actors, and survey responses are valued through a points-based compensation system.

Research workflow The participatory research process follows this structure:

1. **Research question co-definition:** Research questions can be designed either by researchers or through participatory workshops with cooperatives and producer associations. This collaborative definition ensures research relevance to territorial priorities and agroecological transitions.
2. **Webmaster Investigate — survey design and publication:** Platform administrators program research surveys and publish them on the mobile application with participation instructions and context.
3. **User Investigate — participatory response:** Producers participate in surveys and receive points for each response. These points can be converted into purchase credit for products available on the territorial offer map.
4. **Points funding and budgetary balance:** Points allocated for research participation are funded by a cooperative levy (prélèvement) applied to platform transactions. The levy rate and allocation mechanisms are decided collectively during cooperative general assemblies (see Section 4.5).
5. **Data aggregation and research analysis:** Validated survey responses contribute to territorial datasets supporting participatory research, agroecological monitoring and territorial food-system modeling.

Webmaster Investigate Design and programming of research questions, survey instruments, and points allocation mechanisms. Managers can configure research priorities and compensation rates to align with cooperative capacities and territorial needs.

User Investigate Participation in research surveys with cooperative compensation mechanisms (points-based credits toward product purchases).

4.5 Cooperative governance and collective decision-making

Beyond operational service management, MiCampo includes tools for cooperative governance and collective decision-making through general assemblies (asambleas generales).

Webmaster governance tools for assemblies The Webmaster platform provides functionality to support cooperative general assemblies, including:

- Definition of decision-making questions to be voted on by cooperative members
- Polling and voting mechanisms for collective decisions
- Budget allocation decisions (e.g., levy rates on platform transactions)
- Reporting of assembly outcomes and decisions

Key decisions managed through the assembly include:

- **Platform levy rates:** Cooperatives collectively decide the percentage of transaction value to be retained as a platform fee. These revenues fund collective services including research participation compensation (points), platform maintenance and capacity building.

- **Service activation and priorities:** Assemblies decide which platform functionalities should be activated or emphasized locally (e.g., certification criteria, research focus areas, logistics coordination rules).
- **Membership and governance roles:** Cooperatives manage user roles, access permissions, and representative responsibilities through assembly decisions.

This governance layer embeds participatory decision-making within the digital infrastructure, ensuring that platform evolution and operational choices reflect collective interests rather than top-down administrative logic.

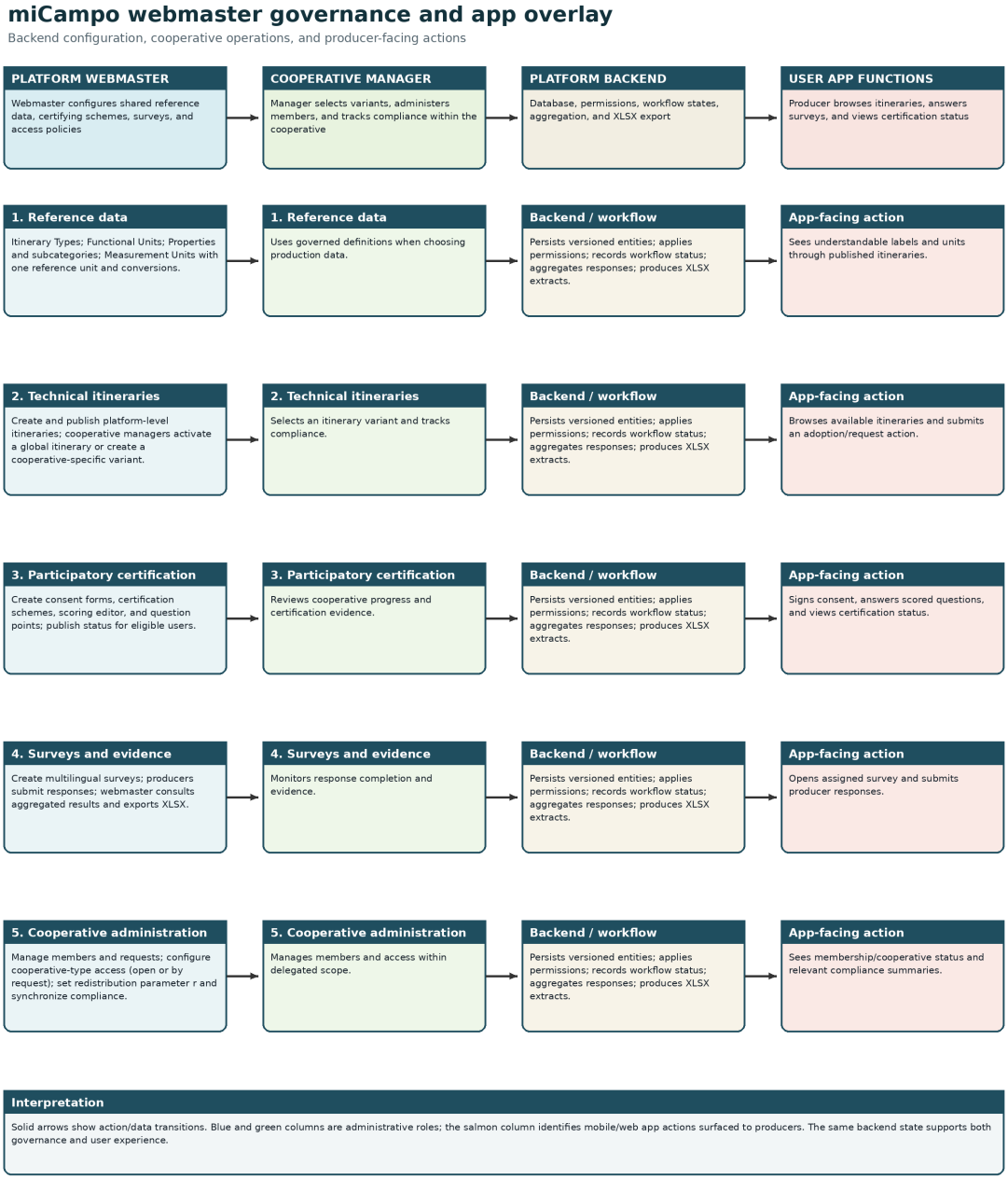

Figure 3: Webmaster workflow: sequence of platform-governance operations, from configuring shared or cooperative-specific kits and technical itineraries to managing certification criteria, cooperative services, producer interactions and the resulting operational data.

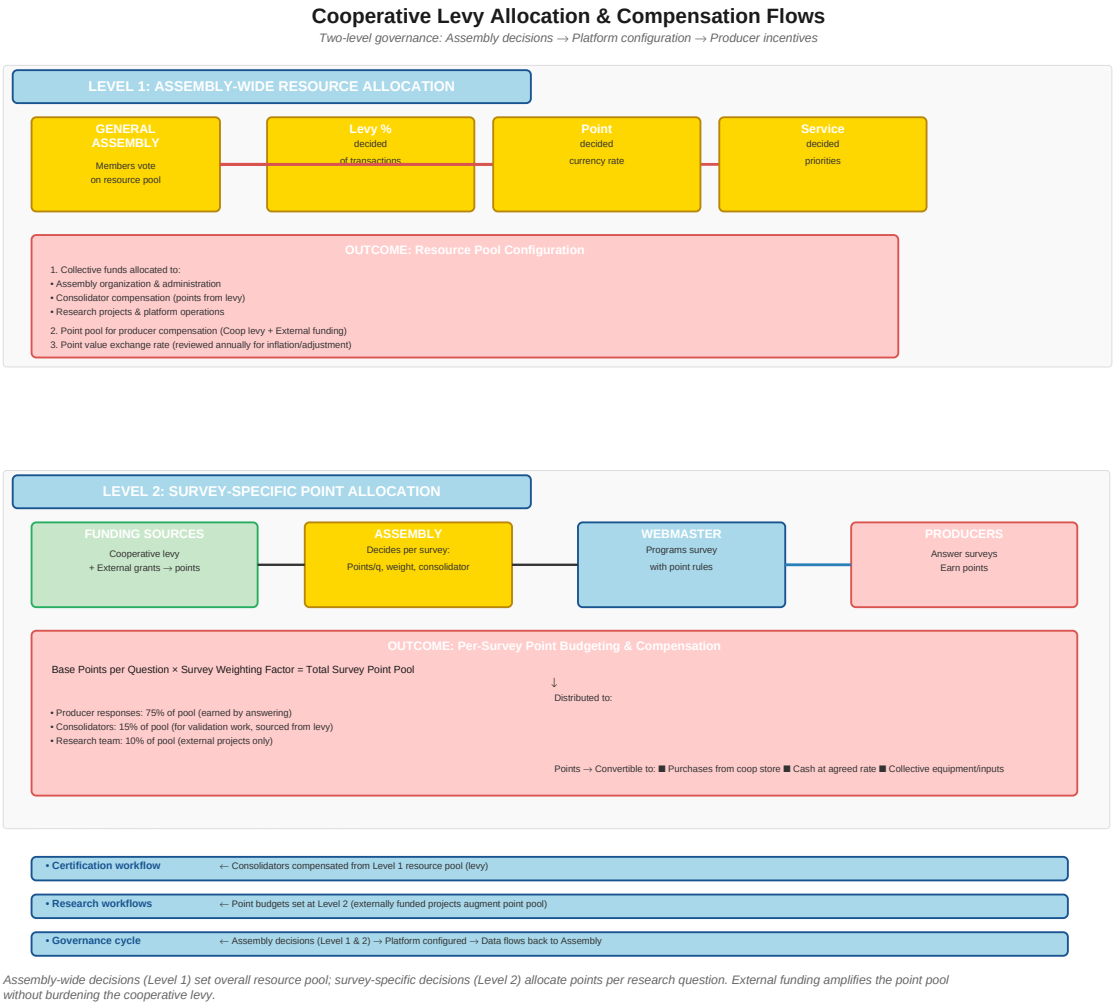

Figure 4: Cooperative levy allocation, survey-specific point budgeting, and compensatory flow to producers. Assembly decisions at two levels (resource allocation and survey budgeting) drive platform configuration and producer incentives.

4.6 Participatory research module (Investigate)

Investigate aims to generate territorial indicators and participatory research surveys.

Webmaster Investigate Design of indicators and survey instruments.

User Investigate Participation in surveys with cooperative compensation mechanisms.

5 Discussion

The MiCampo platform explores a service-oriented participatory data approach for agroecological systems. In contrast to many participatory research initiatives where data collection is organized as a dedicated research activity, MiCampo integrates data generation within operational services that support production planning, certification and territorial food system coordination.

This design reflects an alternative model of participatory research in which datasets emerge as a by-product of collective action and cooperative services rather than as an externally imposed research

requirement. Such an approach may help sustain participation over time while generating ecologically and socially grounded datasets relevant for agroecological research and territorial monitoring.

5.1 MiCampo as a socio-technical infrastructure

MiCampo proposes an integrated socio-technical infrastructure rather than a standalone agricultural application. By linking technical planning, participatory certification, market coordination and research monitoring, the platform connects multiple functions that are usually addressed by separate digital tools.

Such integration contributes to the emergence of digital commons-based agroecological governance, where producers, consumers, cooperatives and researchers interact within shared digital infrastructures that support collective decision-making and territorial coordination.

5.2 Continuity with previous participatory research tools

The present platform builds upon earlier work developing a participatory agroecological data collection web application that integrated participatory research and certification systems [19]. While this earlier tool demonstrated the feasibility of adaptive data models for agroecology, the current platform extends this approach by integrating territorial coordination, digital cooperative organization and agroecological market interactions within a single infrastructure.

This evolution reflects a shift from isolated participatory data collection tools toward integrated digital infrastructures capable of supporting both operational services and participatory research activities.

5.3 Towards graph-based representation of territorial food systems

Digital infrastructures enabling participatory data collection make it possible to operationalize structured representations of agroecological systems and analyze emergent properties such as circularity of flows, coordination efficiency and territorial resilience.

Future developments of MiCampo will include an explicit representation of the territorial food system as a socio-agro-ecological graph derived from the structured datasets generated by the platform. Such graph-based representations may provide novel analytical tools for studying resource flows, production interactions and cooperative dynamics within agroecological territories.

5.4 Towards participatory agroecological observatories

More broadly, the MiCampo platform illustrates how digital cooperative infrastructures may support both agroecological transition and the generation of participatory knowledge. By embedding data collection within operational services such as production planning, participatory certification and territorial contracting, the platform proposes a model in which agroecological datasets emerge from collective action rather than from externally organized research protocols.

Such service-oriented participatory data infrastructures could help bridge the gap between scientific research and the everyday practices of agroecological actors. As the platform is progressively deployed and used by territorial communities, future work will focus on analysing the crowdsourced datasets generated through these services and on exploring how they can contribute to the understanding of agroecological systems and territorial food dynamics.

6 Conclusion

MiCampo illustrates how a cooperative digital platform can integrate agroecological production planning, participatory certification, territorial market coordination and participatory research within a single socio-technical infrastructure. By embedding data generation within services directly useful to farmers

and territorial actors, the platform proposes a service-oriented participatory data approach in which agroecological datasets emerge as a by-product of operational activities.

Beyond the present implementation, future developments will focus on the explicit representation of territorial food systems as socio-agro-ecological graphs derived from the structured data generated by the platform. Such infrastructures may contribute both to the coordination of agroecological transitions and to the development of novel empirical approaches for studying territorial food systems.

Author Contributions

Stéphane Dupas: Conceptualization, project design, supervision, writing.

Melchor Ruiz: Backend architecture, technical itinerary system, certification and survey modules.

Elyandre Buret and Lenny Vergerolle: Territorial offer planning, contract system, logistics coordination and validation workflows.

Anthony Gardelle: Technical supervision and contributions to software development.

Benjamin Lysaniuk: Survey methodology design, field investigations, and ethical protocol preparation.

Ethics approval

The MiCampoApp research protocol was reviewed and approved by the Institutional Research Ethics Committee of Universidad EAFIT (Medellín, Colombia), project code CEI 20250827-1. The project involves participatory data collection with potato producers in the Sumapaz region and near the Bogotá river source.

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A Platform deployment

The MiCampo platform is implemented as a modular web and mobile application architecture. The system includes:

- a mobile application for producers built with Ionic and Angular,
- a web-based administrative interface (Webmaster),
- backend services implemented in Node.js,
- a MongoDB database storing operational and participatory data.

The platform is currently deployed in a development environment supporting cooperative experimentation and participatory research.

B Software repositories

The source code of the MiCampo platform is maintained in the Agroecomakers GitHub organization.

Main repositories include:

- Mobile application:
  https://github.com/agroecomakers/front_miCampoApp_2024
- Webmaster interface:
  https://github.com/agroecomakers/front_miCampoWebMaster_2024
- Backend services:
  https://github.com/agroecomakers/back_miCampoApp_2024

These repositories contain the source code, dependency configurations and build scripts required to deploy the platform components.

C Mobile application build

The mobile application is built using the Ionic framework and Angular.

Typical installation workflow:

```
git clone https://github.com/agroecomakers/front_miCampoApp_2024
cd front_miCampoApp_2024
npm install
ionic build
ionic capacitor build android
```

The generated APK can then be installed on Android devices for field deployment with producers.