The Economics of Agroecology

How to organize agricultural diversity, finance the long term and reward resilience

White Paper

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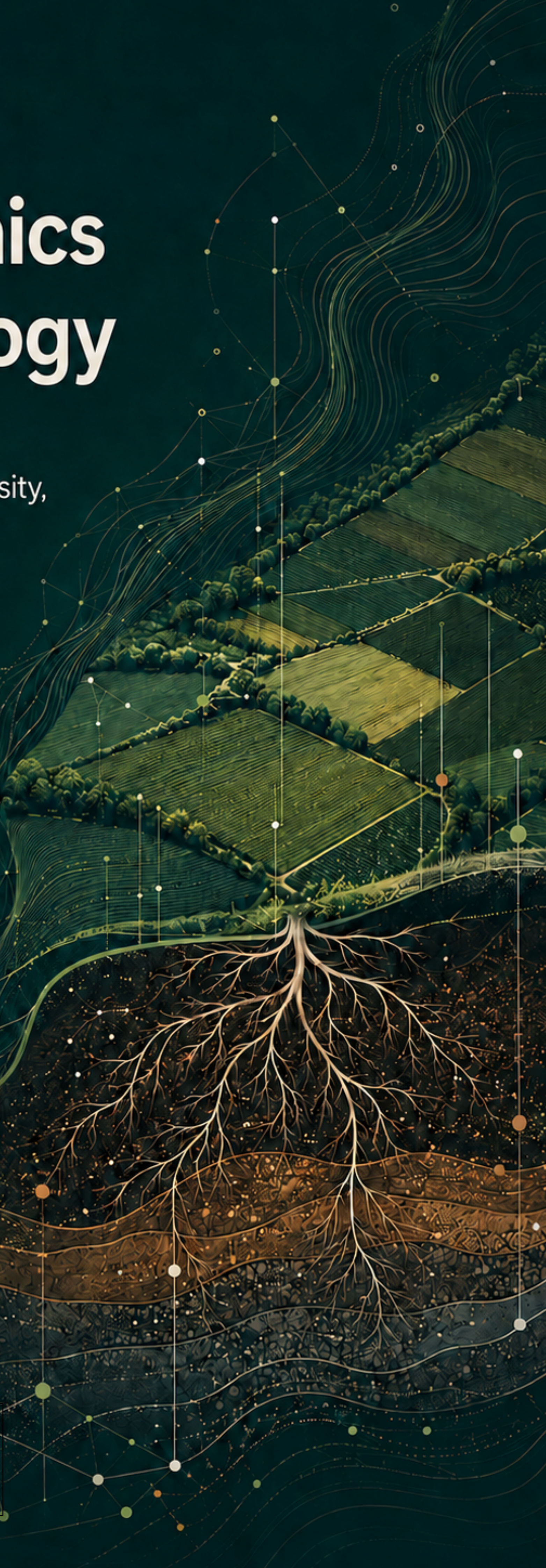
Towards a new value architecture for farms, value chains and funders.



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Executive summary

Agroecology is now recognized as a major response to the limitations of the intensive agricultural model: input dependency, soil degradation, climate vulnerability, water pressure, biodiversity loss, and the weakening of farm incomes. Yet, despite its agronomic relevance, it still struggles to become economically dominant.

This white paper champions a central conviction: scaling up agroecology does not solely depend on widespread adoption of new practices, but on transforming the economic architecture within which farms make their decisions. As long as markets, contracts, financial tools, public policies, and measurement frameworks continue to primarily reward volume, standardization, and short-term performance, agroecology will remain confined to niches—driven by individual convictions, sporadic public schemes, or differentiated markets that are still insufficiently structured.

To align economic viability with ecological transition, this report outlines several strategic pathways:

- Redefining agricultural performance through the "resilient margin": Volume-based yield can no longer be the sole indicator of success. A farm can produce a lot while remaining vulnerable, highly dependent on external inputs, and exposed to climate or geopolitical shocks. A farm's viability must be assessed through a multi-criteria lens, that of the resilient margin: a performance metric that integrates net margin, income stability, autonomy, diversification, soil health, and the capacity to absorb shocks.

- Adapting supply chains to absorb the diversification intrinsic to agroecology: Agroecology often relies on the diversification of crops, rotations, enterprises, and income streams. However, agricultural supply chains remain predominantly organized around homogeneous volumes, product standards, and specialized infrastructure. To make diversification viable, value chains must adapt: this involves structuring multi-species collection, investing in suitable sorting and storage tools, developing local processing, and widespread adoption of multi-year contracts.

- Hybridizing reward mechanisms: Rather than pitting practice-based logic against result-based logic, an approach must be adopted that distributes risk more equitably among farmers, buyers, funders, and public authorities. This can operate through a hybrid architecture: a base payment to secure commitment, a reward for progress to support the trajectory, and a result-based premium to remunerate verified ecological impacts.

- Deploying tools to finance the long term: Transition costs are often immediate, whereas agronomic, economic, and environmental benefits build up over several years. Financial tools must therefore evolve: transition loans, deferred repayments, guarantees, adapted insurance, supply chain contracts, and blended finance. Resilience must be recognized as an economic asset, rather than a mere positive externality.

- Aligning public policies and economic incentives with transition goals: The CAP, public procurement, taxation, guarantees, payments for environmental services, food education, and regulatory frameworks must be mobilized to reduce risk, organize demand, support collective infrastructure, and remunerate the services provided by farms. Public policies must therefore act as an alignment infrastructure. Their goal is not merely to subsidize isolated practices, but to make the transition rational for farms, credible for funders, and attractive for supply chains.

- Steering the transition through data and AI: In living, complex systems subject to climate disruption, perfect prediction is an illusion. The value of data and AI lies instead in their capacity to make uncertainty manageable: facilitating access to knowledge, establishing diagnoses, comparing scenarios, tracking trajectories, detecting weak signals, making hypotheses explicit, and adjusting decisions over time.

- Reinventing agricultural advisory services: Agroecology is a knowledge-intensive form of agriculture. It requires moving from a logic of standardized prescription to one of adaptive support, based on observation, experimentation, long-term monitoring, and collective learning. The advisor must become an architect of the transition, capable of co-designing with the farmer a trajectory that is technically coherent, economically sustainable, and compatible with the real-world constraints of the farm.

Agroecology will not scale if it continues to be thought of as a set of practices to be adopted individually. It must be recognized as a transformation of the agricultural economy itself. Making agroecology viable means organizing a new value architecture capable of rewarding resilience, financing the long term, valuing diversity, and sharing risk among all stakeholders in the agricultural system.

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Foreword

Agriculture today sits at the heart of a dual historical constraint. It must continue to feed growing populations, secure producers' incomes and contribute to the food sovereignty of territories, while facing the acceleration of climate change, soil degradation, biodiversity's erosion, pressure on water and the increasing volatility of agricultural markets and input prices.

In this context, agroecology is increasingly presented as a necessary response to the limits of the dominant agricultural model. By mobilizing the functionalities of living organisms (biological fertility of soils, diversification, complementarities between species, natural regulation of pests, circularity of nutrients, better water infiltration and retention), it offers a way to produce differently: with less dependence on external inputs, more autonomy, better resilience to hazards and an increased contribution to ecosystem restoration.

However, reducing agroecology to a set of technical practices would be a mistake. Its generalization does not depend only on the ability of farmers to introduce cover crops, lengthen their rotations, plant hedgerows, diversify their crops, reduce inputs or restore soil life. It depends on a more fundamental question: How can we make economically viable, at farm level, a model whose benefits are often deferred, diffuse, collective, and still insufficiently remunerated?

This question is all the more urgent as the hidden costs of current agri-food systems are now widely documented. FAO estimates that these negative impacts, linked in particular to health, the environment and social dimensions, represent at least 10,000 billion dollars per year, or nearly 10% of global GDP[1]. Agri-food systems also account for about a third of anthropogenic greenhouse gas emissions and significantly contribute to the degradation of productive resources. According to the Global Soil Partnership, about 33% of the world's soils are already degraded and 90% will be by 2050 if the system is not thoroughly transformed[2]. IPBES also estimates that land degradation has reduced productivity by about 23% of the world's land surface, while the loss of pollinators would put between $235 billion and $577 billion in annual agricultural production at risk[3].

These figures show that the current model cannot be evaluated solely based on its apparent returns or direct costs. A significant part of its impacts is externalized: loss of fertility, pollution, emissions, increased vulnerability to droughts, erosion of biodiversity, loss of sovereignty and weakening of agricultural incomes. Conversely, a significant part of the value created by agroecology remains insufficiently accounted for: improved soil health, reduced carbon footprint, reduced erosion, water regulation, functional biodiversity, yield stability and economic resilience.

The problem is therefore not just agronomic and environmental. It is also economic, financial, organizational and institutional. As long as farms are essentially remunerated on the basis of volume, homogeneity and short-term competitiveness, the systemic benefits of agroecology will remain difficult

[1] https://www.fao.org/newsroom/detail/hidden-costs-of-global-agrifood-systems-worth-at-least--10-trillion/
[2] https://www.fao.org/global-soil-partnership/about/why-the-partnership/
[3] https://files.ipbes.net/ipbes-web-prod-public-files/webform/impact_tracking_database/46408/2019%20IPBES%20Biodiversity%20and%20Ecosystem%20Services%20report%20Final.pdf

to value. As long as the value chains remain structured around standardized raw materials, they will not absorb the intrinsic diversification of agroecological systems. As long as financial tools remain calibrated on specialized production models and rapid returns, they will struggle to finance transition trajectories whose benefits are built over the long term.

This white paper defends a simple conviction: agroecology can only change scale if we transform the economic environment in which farms make their decisions. It is not enough to change practices on the farm; We also need to transform the value chains, remuneration mechanisms, financial tools, impact measurement, agricultural advice and public policies.

The challenge is not to oppose economic performance and ecological performance, but on the contrary to build the conditions in which they can reinforce each other. A farm that is less dependent on inputs, more diversified, better adapted to climatic hazards and better integrated into its territory becomes intrinsically more robust. However, this robustness must be measured, recognized, financed and paid for by the economic ecosystem.

This is precisely the purpose of the reflection developed in this white paper: to explore avenues for shaping a new economic architecture for agroecology, one capable of rewarding resilience, organising diversity, financing the long term, making impacts more visible, and sharing transition risks more equitably among farmers, value chains, financiers, buyers and public authorities.

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I. Anatomy of a systemic lock-in

I.1. Agroecology as a response to the structural vulnerabilities of intensive agriculture

The agricultural model that prevailed during the twentieth century allowed a considerable increase in the physical productivity of labour and land. Thanks to mechanisation, varietal selection, the use of mineral fertilisers, phytosanitary products, fossil fuels and the organisation of long supply chains, agriculture has been able to significantly increase the volumes produced and contribute to the food security of many territories.

But this model is now showing its limits. Its apparent performance is often based on an incomplete reading of costs and risks[4]. Yields and market prices do not reflect soil degradation, biodiversity erosion, water pollution, greenhouse gas emissions, dependence on imported inputs and vulnerability to climate shocks.

Beyond this critical environmental imbalance, there is also a major social impasse: the net margin captured by producers has become so low that many farmers, especially smallholders, can no longer make a living from their work[5]. The race for volume and standardisation has ultimately weakened the very viability of farms, disconnecting productivity from fair remuneration of human labour.

These observations in no way deny the historical success of modern agriculture in increasing volumes. On the other hand, they reveal that productive performance alone is no longer enough. Producing a lot is meaningless if it weakens farms, depletes natural resources, depends on highly volatile input markets or externalizes its costs to society and future generations.

Climate change is dramatically accelerating this vulnerability. Droughts, excess rainfall, heat stress and mounting pest and disease pressures are no longer exceptions, but part of a new reality that is destabilising yields. In this context of uncertainty, a model of hyper-specialisation based on a narrow range of crops, heavy input use and rigid schedules has become both structurally and economically risky.

It is precisely in this context that agroecology is emerging as a response for the future. Far from being a step backwards or a unique model, it is a real process of systemic transformation. The FAO[6] defines it as a holistic and integrated approach, simultaneously applying ecological, economic and social principles to the management of food systems. Its objective is to optimize the interactions between plants, animals, humans and their environment, while guaranteeing a fair, sustainable and resilient territorial anchoring.

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[4] https://www.fao.org/newsroom/detail/hidden-costs-of-global-agrifood-systems-worth-at-least--10-trillion/
[5] https://www.insee.fr/fr/statistiques/8376591?sommaire=8376600#
https://www.worldbank.org/en/news/feature/2014/11/12/for-up-to-800-million-rural-poor-a-strong-world-bank-commitment-to-agriculture
[6] https://www.fao.org/agroecology/home/en/

Agroecology responds to the shortcomings of the dominant model by drawing on a set of complementary levers, including crop diversification, longer rotations, permanent soil cover, agroforestry and reduced reliance on synthetic inputs.

These practices share a fundamental objective: replacing external dependencies with ecological functionalities that are internal to the production system. From then on, the balance shifts positively:

- Fertility no longer depends on massive mineral inputs, but on organic matter, soil biological life and nitrogen fixation by legumes.
- Crop protection is no longer based on all-chemicals, but on functional biodiversity, beneficial insects and the breaking of pest and disease cycles through rotations.
- Water management goes beyond the use of irrigation to integrate the structure of the soil, its water retention capacity and the limitation of evaporation by the plant cover.

Agroecology thus shifts the cursor of performance: from maximizing immediate yield to building robust, autonomous and resilient productivity. It ceases to be a simple alternative production method to become a global strategy for reducing the structural vulnerabilities of farms.

I.2. The economic model, a blind spot in the transition

However, validating the agronomic relevance of agroecology is not enough to guarantee its economic viability.

Its benefits (regenerated soil structure, strengthening of functional biodiversity, better water management, carbon storage, regained autonomy) are long-term. They are investments in natural capital that do not translate into an immediate income gain in the current market. These investments generate value that extends beyond the product sold. Yet this value is largely systemic, progressive and collective.

This is precisely where the economic difficulty lies. The transition costs are often immediate: learning time, investment in new equipment, planting of hedges or trees, crop diversification, changes in technical itineraries, increased need for advice, reorganization of work, sometimes temporary drop in yield or commercial uncertainty for new production. Profits, on the other hand, often appear over the long term and are not always captured directly by the farm.

This temporal and economic lag explains why the agroecological transition cannot be treated as a simple technical substitution. Replacing one practice with another is not enough when the underlying income, risk and valuation model remains unchanged.

This is where one of the main barriers to scaling agroecology lies: the economic environment in which farms make their decisions.

Farms do not choose their practices in the abstract. They operate within a framework shaped by their markets, contracts, costs, access to credit, equipment, debt levels, public support, exposure to risk, available skills, working time and the structure of the value chains to which they belong. Asking a farm to transform without transforming this environment therefore means placing most of the economic risk of the transition on the farmer.

The dominant agricultural model remains largely organised around a few core economic principles: producing homogeneous volumes, reducing unit costs, maximising marketable yields, securing industrial supplies, integrating farms into specialised value chains and meeting their standards.

This economic organization produces a major asymmetry: it effectively values what is measurable, standardizable and immediately marketable, but it makes the environmental and social costs generated by production systems, as well as the benefits created by more resilient models, much less visible.

As recalled in the preamble, institutional work on the hidden costs of agri-food systems confirms this asymmetry. FAO estimates that the global hidden costs of agri-food systems related to health, the environment and social dimensions account for at least $10 trillion per year, or nearly 10% of global GDP. This estimate shows that market prices do not perfectly reflect the real impacts of production systems. In other words, some models appear to be economically efficient because part of their costs is outsourced to society, ecosystems or future generations. Conversely, models that reduce these costs do not always capture the value they create.

The agronomic relevance of agroecology is therefore inseparable from an economic challenge: creating the conditions in which farms that regenerate their resources, reduce their dependencies and strengthen their resilience can also secure their income, access financing and capture a fairer share of the value they create.

The question is therefore not only which agroecological practices to recommend. It is to know under what conditions these practices become rational, financeable and remunerative for exploitation. A plant cover, a long rotation or a hedge can be agronomically relevant; They only become economically adoptable if the farmer has an outlet, support, a return on investment horizon, the ability to absorb the risk and, in some cases, a specific remuneration for the service provided.

Agroecology therefore forces us to revisit the question of value. What exactly is remunerated in agriculture: the volume produced? the raw material delivered? the compliance with specifications? the ability to preserve productive resources? reducing future risks? the resilience of a territory? the ecological quality of a production system?

As long as the value created by agroecology remains partially invisible, its dissemination will depend too strongly on individual convictions, ad hoc public mechanisms or commercial niches. To change scale, it must become economically understandable for all stakeholders: farmers, cooperatives, processors, distributors, banks, insurers, local authorities and public authorities.

This analysis leads to a central question: if agroecology creates real value that is still insufficiently recognised by current economic tools, how can we transform the value architecture that determines what is measured, remunerated, financed, insured, contracted and valued? This is the focus of the next section.

II. Building the economic architecture of the transition

II.1. Organising downstream markets to support agroecological diversification

The agroecological transition requires a departure from the dogma of hyper-specialisation. Restoring soil capital, disrupting pest cycles and mitigating climate risks all require farmers to diversify cropping systems, integrate legumes and lengthen rotations. Yet this agronomic imperative runs up against a downstream industrial system designed for another era: collection, storage and processing infrastructure calibrated for large volumes of homogeneous, standardised and low-cost commodities.

This phenomenon of "socio-technical lock-in", widely documented by INRAE[7] in its work on crop diversification, creates a real logistical bottleneck. It penalises the introduction of secondary or disruptive crops, which often struggle to find profitable outlets. Expecting farmers to bear the market risk of diversification alone is a dead end. The viability of the transition depends on shifting the effort downstream: the challenge is no longer simply to manage the compliance of an isolated product, but to organise value chains capable of absorbing the diversity produced by agroecosystems.

To remove this barrier, downstream operators must move away from simple volume purchasing to systemic supply contracts. In concrete terms, a cooperative or an industrial company no longer contracts only a delivery of wheat or rapeseed but commits to the entire portfolio of crops from the farm's rotation. By guaranteeing multi-year outlets and purchase prices for diversification crops, such as plant proteins, cereal-legume mixtures or agroforestry products, buyers can secure the farm's financial trajectory over the long term. These contracts can include risk-smoothing mechanisms, whereby the higher profitability of main rotation crops helps offset the lower commercial returns of intermediate or break crops, whose primary value is agronomic. This approach is consistent with the recommendations of the Economic, Social and Environmental Council (EESC) [8] which calls for the generalisation of multi-year, multi-party value chain contracts to improve the sharing of risks and value between upstream and downstream actors.

At the same time, this approach requires a qualitative leap in territorial logistics engineering. In the absence of sufficient volumes at the scale of a single farm, the massification of niche crops must be organised through pooling dynamics at the level of production areas. This requires targeted investments in flexible and versatile infrastructures capable of managing load breakage and batch splitting. In concrete terms, funding must be directed towards modular multi-species silos, state-of-the-art optical sorting stations adapted to seed mixtures, and local primary processing units such as seed breakers or legume drying units. In its "Transitions 2050" prospective scenarios[9], ADEME demonstrates precisely that the decentralisation of these primary processing tools (flour mills, local vegetable factories) is the sine qua non condition for adapting the industrial apparatus to the diversity of territories. Digital predictive planning tools make it possible to map the emerging and fragmented offer to effectively connect it to manufacturers' purchasing grids.

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[7] https://www.inrae.fr/actualites/diversification-cultures-transition-penser-lechelle-territoires

[8] https://www.lecese.fr/sites/default/files/pdf/Avis/2020/2020_27_alimentation%20_territoires.pdf

[9] https://www.ademe.fr/les-futurs-en-transition/les-scenarios/

Finally, the economic development of this diversity depends on value sharing and the activation of regulatory levers. Through these more resilient systems, processors and retailers benefit from more secure supplies in the face of climate shocks and from significantly reduced carbon footprints. This environmental value must be translated into explicit price signals, in the form of diversification bonuses or guaranteed floor price mechanisms, indexed to the real costs of production. The public authorities must act as a catalyst for these markets by mobilising public procurement, in particular via strict multi-year contracting criteria in collective catering, and by directing industrial subsidies towards the modernisation of regional collection tools. This vision is at the heart of the EU's Farm to Fork strategy, which reiterates that environmental targets for reducing inputs depend on shared responsibility throughout the value chain[10]. By shifting from subsidizing agricultural practices alone to financing the adaptation of logistics infrastructure, the agricultural economy can finally recognize diversity as the primary condition for its own resilience.

II.2. Redefining agricultural performance: From gross productivity to resilient margins

The evaluation of agricultural performance remains trapped in a quantitative lens inherited from the post-war period: gross productivity per hectare. While yield remains a useful flow indicator for monitoring a territory’s production capacity, using it as the sole management compass creates an economic contradiction. By focusing attention on the volumes marketed, this indicator masks the structural weaknesses of farms. A farm can post record yields while being on the verge of financial asphyxiation, under the effect of a deleterious scissors effect: loads of inputs (nitrogen fertilizers, phytos) and energy indexed on hyper-volatile world markets, heavy debt to maintain an oversized machine capital, and soil capital in the process of accelerated degradation.

Conversely, the transition to agroecology redefines the balance of the income statement. While it might lead initially to lower gross yields, it can profoundly optimise the farm’s cost structure. This is the principle of low-input agriculture, highlighted by the DEPHY experimental network[11] in France. The technical and economic analyses of this network show that a drastic reduction in the use of pesticides (sometimes more than 30% or 40%) combined with an increase in rotations does not lead to a collapse in the net margin. On the contrary, the drastic decrease in structural and operating expenses more than offset the slight variation in volumes. Performance no longer lies in maximising gross turnover, but in maximising the added value retained by the farmer.

Therefore, financial analysis must therefore adopt a new pivotal indicator: the resilient margin. Unlike the traditional gross margin calculated over a single season, the resilient margin assesses an agroecosystem’s ability to maintain its economic efficiency in the face of exogenous shocks. This approach is aligned with the principles of biophysical and multi-criteria accounting promoted by actors such as Cerfrance, among others[12]. In particular, it incorporates two critical variables :

1. The financial autonomy index: The ratio between the cost of imported inputs and the net worth created. The less synthetic nitrogen or external feed a farm buys, the less its margin is exposed to geopolitical crises.

[10] https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf
[11] https://ecophytopic.fr/dephy
[12] https://www.cerfrance.fr/

2. The valuation of soil capital: Taking into account the rate of organic matter and biological porosity as productive assets. Living soil enhances water infiltration, resistance to erosion, water stress and flooding, and the gradual availability of nutrients.

The work of the BASIC (Bureau d'Analyse Societale pour une Information Citoyenne) on value chains reminds us that hyper-specialised models tend to transfer the cost of climate risks to insurers, mutual funds and the State, notably through agricultural disaster relief schemes[13]. Steering the transition through the resilient margin means internalizing risk management at the heart of the farm by diversifying sources of income and strengthening natural regulations. Producing is no longer conceived as a race to extract immediate volumes, but as the management of a balance in which today's profitability preserves tomorrow's productive potential.

II.3. Value Architecture: rewarding practices, progress, or results?

The large-scale deployment of agroecology also raises a major strategic trade-off: what exactly should financial remuneration be based on? Should it reward the practices implemented, recognise continuous improvement trajectories, or pay for ecosystem services delivered on the basis of measured outcomes? This choice determines how transition risk is allocated between upstream agricultural actors and downstream industrial or financial players.

Remunerating practices, an essential but insufficient starting point

Historically, public policies, such as the "green payment" or the CAP's Agri-Environmental and Climate Measures (AECM), have favoured the remuneration of practices. Agri-environmental and climate measures, eco-schemes or certain value chain specifications are often based on a logic of commitment: the farmer is paid because he or she establishes plant cover, lengthens his rotations, reduces certain inputs, maintains meadows, plants hedges or respects a defined technical itinerary. This approach has a decisive advantage: it is clear, contractable and relatively easy to monitor. It secures cash flow from the beginning of the transition and recognises that changing practices involves immediate costs: diagnosis, advice, seeds, equipment, learning time, reorganisation of work and sometimes risk-taking on yield before the first biological effects materialize.

However, critical reports by the European Court of Auditors' on the greening of the CAP have shown that this model breaks down when reduced to a one-size-fits-all administrative framework[14]. For the remuneration of practices to work, it must imperatively comply with two conditions :

- A higher level of ambition than the baseline: Premiums should not finance the status quo or marginal adjustments, the well-known windfall effect of the CAP, but should instead target clear, territorially grounded significant shifts in practice.

- Local agronomic flexibility: Administration should stop imposing rigid technical calendars, such as fixed dates for cover crop destruction, and allow farmers to adapt their practices to the realities of their soils and weather conditions.

[13] https://lebasic.com/v2/content/uploads/2024/11/BASIC_Couts-societaux-systeme-alimentaire_Rapport-de-recherche_novembre-2024-2.pdf
[14] https://www.eca.europa.eu/en/publications?did=44179

Even when these two conditions are met, this first level remains structurally insufficient on its own for two fundamental reasons:

- The absence of a guarantee of impact (biological decoupling): In agronomy, the relationship between a practice and its effects is never linear. A highly beneficial cover crop in one region may become a harmful competitor for water in another if drought sets in. Financing practices alone means stopping at procedural compliance without measuring whether the system is actually regenerating, or whether the money invested produces a real ecological benefit for the wider community. This is precisely what several CAP evaluation studies have pointed out: linking support to standardised practices does not always guarantee measurable environmental improvement.

- The economic glass ceiling (The absence of value creation): Practice-based remuneration follows a logic of compensation for costs incurred or income foregone. It keeps farmers dependent on subsidies or support premiums. It does not requalify production in the market, nor does it generate intrinsic economic value that would allow farms to move beyond long-term aid.

Conversely, the exclusive remuneration of results seems more robust in theory. It consists of paying for observable impacts: tonnes of CO_2 equivalent avoided or sequestered, improvement of soil organic carbon, reduction of nitrates, restoration of habitats, improvement of biodiversity indicators or improvement of water resilience. This logic is attractive because it remunerates the value actually created and not the compliance with a list of practices. It also responds to a growing demand for credibility from funders, public authorities and industrial companies committed to their environmental footprint.

However, the results-based approach comes up against the very nature of living things. Agroecological effects are often deferred, contextual and subject to uncontrollable hazards. Carbon storage in soils is built over long periods of time and remains reversible. Biodiversity depends as much on the practices of the farm as on the surrounding landscape. Water quality is influenced by all the uses of a watershed. Biophysical measures have margins of uncertainty, and their cost can become disproportionate for small and medium-sized farms. Making most of a farmer's annual remuneration dependent on long, uncertain and partially exogenous results would amount to transferring to him a systemic risk that he cannot bear alone.

A hybrid and dynamic approach to compensation

To move beyond the binary opposition between the obligation of means and the obligation of results, we defend a hybrid approach to remuneration, articulated around three complementary levels:

- The first level, commitment-based remuneration, must act as a safety net. It helps absorb opportunity costs and upfront investments. It should not be seen as an administrative bonus, but as a financing of agronomic risk-taking. This foundation is essential to prevent the transition from relying solely on the individual financial capacity of farms.

- The second level, progress-based remuneration, is the heart of the system. It makes it possible to remunerate not a fixed state, but a trajectory. The farm is evaluated on its ability to evolve in the right direction: diversifying rotations, increasing soil cover, structurally reducing dependence on chemical inputs, improving of fodder or fertilizer autonomy, developing agroecological infrastructures, reducing margin volatility. This intermediate level is particularly important because it makes transformations visible even before all final biophysical impacts are fully measurable.

- The third level, result-based remuneration, must be designed as an impact bonus and not as the sole basis of remuneration. It comes into play when the results reach a sufficient level of methodological robustness: reduction of emissions, carbon storage, improvement of water quality, restoration of habitats, reduction of erosion or improvement of biodiversity indicators. This bonus can be financed by actors who benefit directly or indirectly from these results: companies committed to reducing the impacts of their value chain, local authorities, water agencies, climate funds, insurers or buyers seeking to secure their supplies.

This hybrid architecture has three benefits. Tier 1 protects farmers during the initial transition phase; Tier 2 recognises their transformation effort; and Tier 3 crystallises the environmental value created, making it legible for downstream financing, from Scope 3 decarbonisation for manufacturers to lower claims for insurers and reduced drinking-water treatment costs for local authorities.

It also helps overcome two dead ends. The first is funding standardised practices without considering their local relevance. The second is making all remuneration conditional on final outcomes whose timing and determinants farmers cannot fully control. Between these two extremes, trajectory-based remuneration offers a fairer and more operational compromise, one that is better aligned with biological cycles.

II.4. Financing the long-term agroecological transition

The agroecological transition suffers from a cash flow paradox: its costs and investments are immediate, while its economic and ecosystem benefits are built over the long term. The farmer must incur operational expenses, change his technical itineraries and assume an initial yield risk, even though the expected gains only materialise gradually.

This time lag creates a short-term financial scissor effect that traditional credit tools are unable to solve. The traditional banking model is structurally configured to finance an identifiable tangible asset (a tractor, a building) or a standardized production campaign. It assesses solvency in terms of historical ratios and material guarantees. However, agroecology shifts performance towards intangible and biophysical assets that are still invisible on balance sheets.

To overcome this hurdle, financial engineering must make its own transition around three complementary pillars.

Pillar 1: Flow engineering

First, financing tools must be aligned with the biological cycles of transition. Banks should deploy sustainability-linked loans, while moving beyond the individual farm-level approach that has so far limited their development. To overcome the prohibitive cost of certification audits and avoid concentrating the risk of agronomic setbacks on a single farm, financial engineering should shift towards downstream-aggregated SLL mechanisms.

In concrete terms, the impact loan should no longer be taken out by the individual farmer, but by the cooperative or industrial buyer, which raises mutualised credit lines, for example through sustainability-linked notes, at the scale of a production basin or value chain.

The financial institution would adjust the interest rate of the overall facility according to a collective transition trajectory, such as reaching 60% of the cultivated area under long rotations at territorial level, validated through existing proxies such as satellite remote sensing or nitrogen balances. The cooperative or industrial buyer would then pass this financial benefit on to its members or suppliers in the form of transition premiums.

To absorb the cash-flow gap inherent in the first years of technical disruption, these facilities should structurally include full repayment deferrals over the first three years.

Pillar 2: Risk sharing

At the same time, the de-risking of private capital requires the implementation of blended finance architectures. Commercial banks will not take the risk of accompanying agronomic breakthroughs without an effective protection mechanism. The State, the European Investment Fund (EIF) or philanthropic capital must intervene as guarantors of the first loss.

By agreeing to absorb the first levels of financial claims in the event of a transition accident or extreme climatic hazard, these public funds de facto lower the overall risk profile of the loan portfolio. This macroeconomic leverage reassures first-tier banks, which then agree to release larger volumes of private capital on concessional terms and over long maturities, which are inaccessible in the standard credit market.

Pillar 3: Risk measurement

Beyond commercial incentives (SLL) or public insurance mechanisms (mixed finance), the real systemic shift requires a change in the intrinsic measurement of agricultural risk. Banks and insurers share the same prudential interest here: a resilient farm reduces both the probability of default on a loan and the loss rate of an insurance contract.

For the banking sector: The internal rating models dictated by the Basel III agreements must integrate agronomic resilience factors (organic matter rate, diversity of crop rotations, input autonomy) as indicators of future solvency. By demonstrating that an agroecological system is less exposed to energy market volatility and climate shocks, the farmer justifies a mathematical reduction in his risk profile, which should automatically lower his commercial risk premium and therefore the base rate of his credit.

For the insurance sector: Insurance companies must carry out a similar actuarial revolution by integrating these same biophysical criteria into the calculation of their additional premiums. Farms engaged in soil regeneration trajectories must benefit from significant premium discounts, proportional to the capacity to retain water, resist climatic hazards and regulate pests and diseases in their agroecosystem.

Financing agroecology should not be seen only as a matter of subsidies or non-repayable support; it is a strategic investment in the future viability of productive capital. By transforming systemic resilience into an auditable and valuable financial asset, finance can move from a retrospective reading of risk to forward-looking management of long-term agricultural performance.

II.5. Public policies, regulation and market shaping: aligning economic incentives

The agroecological transition cannot rest solely on individual farmers' decisions or on the goodwill of value chains. It requires a broader alignment of the rules of the economic game: public support, taxation, market regulation, public procurement, reporting standards, guarantee schemes, water policies, territorial food strategies and frameworks for payments for environmental services.

The role of public policy is precisely to correct the discrepancies that markets do not resolve spontaneously. Today, many of the costs of the dominant agricultural model remain externalised: soil degradation, water pollution, emissions, biodiversity loss, climate vulnerability and reduced strategic autonomy. Conversely, many of the benefits of agroecology remain insufficiently remunerated: carbon storage, improved water infiltration, reduced erosion, landscape resilience, productive autonomy and functional biodiversity. As long as these costs and benefits are poorly reflected in prices, contracts and financing arrangements, the transition will remain economically fragile.

Public policy must therefore act as an infrastructure for alignment. Its role is not only to subsidise isolated practices, but to make the transition rational for farms, credible for funders and attractive for value chains. This means moving from a logic of one-off compensation to a logic of trajectory: financing entry into transition, securing the long term, remunerating progress, supporting collective infrastructure and organising demand.

The Common Agricultural Policy 2023-2027 already illustrates this tension[15]. Its objectives combine sustainable farm income, competitiveness, farmers' position in the value chain, climate action, environmental protection, biodiversity, generational renewal, vitality of rural areas, food quality and innovation. This formulation shows that agricultural performance can no longer be considered solely from the perspective of produced volumes. It must articulate economic viability, ecological resilience and contribution to common goods.

But as long as the main flows of CAP funding continue to prioritise area-based payments, and as long as this ambition is not translated into coherent, additional and clear incentives for farms, the agroecological transition will remain structurally underfunded.

The challenge, therefore, is to gradually reorient the CAP's budgetary architecture towards risk reduction, diversification, soil health, productive autonomy and ecosystem services. In other words, the CAP must evolve from a compensation mechanism into an investment tool for agricultural resilience.

A first lever is to better target public aid. Support must encourage ambitious agroecological trajectories and not simply remunerate practices that are already widely established or only slightly additional. This involves a combination of pay-as-you-go, progress indicators, and performance bonuses, as proposed in the hybrid compensation architecture. Aid must also take into account the starting points: a very specialised farm, very dependent on inputs or located in a vulnerable area will not have the same support needs as an already diversified farm.

[15] https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-glance/key-policy-objectives-cap-2023-27_en

A second lever concerns risk sharing. Governments can reduce the cost of the transition by mobilizing guarantees, interest rate subsidies, transition funds, repayable advances, insurance schemes or co-financing mechanisms. When the expected benefits go beyond individual farming (water quality, climate, biodiversity, food security, territorial resilience), it is legitimate that the initial risk is not borne solely by the farmer.

A third lever concerns the evolution of demand, starting with public procurement. Collective catering, public food procurement, territorial food policies and relocation programmes can create stable demand for products from more diversified and sustainable farming systems. This demand is essential to secure outlets for rotational crops, legumes, local production, agroforestry products and emerging value chains. Public procurement can thus become a market-shaping tool, rather than merely a purchasing mechanism. Public policy can also play an important role through food education, consumer information, awareness campaigns and environmental labelling. By making the links between food, health, soil, climate, biodiversity and agricultural income more visible, it can help shift demand towards products that genuinely support farms' transition.

A fourth lever concerns the regulation of trade relations. Farmers often remain in a weak position relative to highly concentrated buyers. The European Union recognises this asymmetry through its rules on unfair trading practices, which aim to protect farmers and small suppliers from certain abuses in the food chain[16]. or agroecology, this issue is critical: a transition that increases production requirements without fairer value sharing risks increasing pressure on the agricultural sector.

A fifth lever is investment in community infrastructure. Agroecological diversification requires tools for sorting, storage, processing, logistics, advice, data, territorial coordination and marketing. These infrastructures are rarely profitable on the scale of a single farm, but they become strategic on the scale of a territory or a value chain. Public policies must therefore support cooperatives, territorial platforms, shared workshops, data collection and support mechanisms that allow agricultural diversity to become economically viable.

A sixth lever concerns taxation and economic signals. Fiscal policies can encourage transitional investments, reduce the cost of resilience-building equipment, support low-input practices, or direct financial flows towards impactful agricultural projects. Conversely, they can gradually reduce the incentives that sustain input dependence, excessive specialization or degradation of productive resources. The goal is not to heavily penalize farms, but to align economic incentives with long-term objective

Finally, public policies must support proportionate and useful impact measurement. Environmental reporting must not become an additional administrative burden. Instead, it should help guide sustainable transitions, secure financing, validate payments, and highlight the value created. This requires common repositories, interoperable data, transparent methods, controlled verification costs and clear governance of agricultural data. The European "Farm to Fork" strategy recognises this need for a systemic approach: it aims for a transition of the entire food system, capable of reducing environmental impact, preserving food accessibility and generating fairer economic returns for actors, in particular primary producers.

[16] https://agriculture.ec.europa.eu/common-agricultural-policy/agri-food-supply-chain/unfair-trading-practices_en

The idea is therefore not to add one more public policy to an already complex landscape, but to align existing policies around the same logic: remunerating what regenerates, financing what reduces risk, organising markets that value diversity, and protecting farmers against excessive transfer of transition costs.

Making agroecology economically viable thus requires a strategic public authority. Not a public authority that prescribes each practice, but a public authority that creates the conditions for investment, trust and fair risk and value sharing. Farmers can transform their systems; the value chains can adapt their contracts; Funders can integrate resilience into their risk models. But this transformation will only change scale if public policies make these choices possible, coherent and economically sustainable.

III. Implement and manage the scale-up

III.1. Data, AI and impact measurement: managing and reducing uncertainty

The agroecological transition takes place within complex, open, and non-linear biophysical systems. Its effects depend on a matrix of constantly interacting variables—including soil science, microclimates, fluid dynamics, microbiological cycles, landscape mosaics, and farmer trade-offs. These impacts accumulate over the long term, influence one another, and remain subject to ecosystem feedbacks that are often impossible to model.

In this context, the promise that artificial intelligence can provide definitive, immediate, and exhaustive predictions of agroecological impacts is a technological mirage.

First, agroecosystems are not merely isolated aggregations of data; they are networks of symbiotic relationships driven by complex biological, physical, and climatic mechanisms that are often non-linear and highly context-dependent.

Second, climate change, marked by extreme events and thermal instability that are fast becoming the norm, causes structural breaks in stationarity (meaning past climate data no longer predicts future patterns). This deprives artificial intelligence of its foundational statistical benchmarks.

In this context, AI can help compare trajectories under specific assumptions (ceteris paribus), but it cannot provide ex-ante guarantees regarding the future impact of an agroecological practice within a living, open system that is increasingly vulnerable to frequent, severe hazards.

Furthermore, modeling dynamic, living systems requires massive datasets of near-infinite granularity. Today, however, agricultural field data remains fragmented, expensive to collect, and highly heterogeneous from one plot to another. For instance, the effect of a cover crop on the structure of a clay-silt soil after three consecutive years of drought will depend on a myriad of factors: soil texture, baseline conditions, organic matter, biological activity, species selection, rooting depth, planting and termination dates, and unpredictable future rainfall.

Consequently, data and artificial intelligence should not be framed as instruments of absolute certainty capable of mechanically guaranteeing the outcome of a trajectory or rigidly locking in a technical roadmap.

Rather, their true value lies in their ability to structure information, simulate and compare scenarios, track weak signals, measure progress objectively and dynamically adjust decisions over time, in other words, to mitigate and navigate uncertainty.

The first function of data combined with AI is to produce a comprehensive diagnosis of the farm. Soil analyses, field observations, climate data, yield histories, crop management practices, crop rotations, livestock stocking rates, satellite data, plot photos, biodiversity measurements, and economic information provide a better understanding of the starting point. Without an initial diagnosis, it is difficult to distinguish real progress from cyclical variation, or to attribute an observed change to a given practice.

The second function is to track transition trajectories rather than merely looking for definitive final proof. In an agroecological transition, certain impacts only become measurable after several years. Consequently, intermediate indicators are vital to show that a farm is moving in the right direction. These include increased soil cover, diversified rotations, reduced reliance on inputs, improved margin stability, the development of agroecological infrastructure, reduced tillage, and greater self-sufficiency in fertilizers and fodder. While these signals do not replace final outcomes, they enable the transition to be actively managed before all long-term effects fully manifest.

The third function is to make strategic trade-offs more explicit. Agroecology is not about applying a universal recipe; a practice that is highly relevant in one context may be less appropriate in another. For instance, a cover crop can improve soil structure but create fierce competition for water. Similarly, reducing inputs can lower costs but temporarily increase pest and disease pressures, while diversification can build resilience but complicate logistics and marketing. Digital tools and AI can help compare these options, identify conditions for success, anticipate risks, and formally document these trade-offs.

Artificial intelligence can contribute to this framework in several ways. Generative AI can democratize agronomic knowledge, help formulate diagnoses, explain complex recommendations, synthesize scientific literature, structure field feedback, and support advisors and farmers in their decision-making. Meanwhile, specialized models can estimate biophysical variables, detect changes in vegetation cover, analyze imagery, map localized risks, model water or carbon balances, and monitor biodiversity and soil health indicators.

However, distinguishing between these use cases is vital. Generative AI is highly effective for questioning, explaining, contextualizing, and guiding; it should never be used in isolation to quantify impact. True impact estimates must rely on agronomic models, field data, strict measurement protocols, satellite observations, explicit assumptions, and verification rules. A robust technical architecture therefore combines multiple modular components: in-situ data, remote sensing, specialized models, agronomic expertise, field feedback, and a seamless decision-support interface.

This approach makes it possible to build a dynamic management. Monitoring, reporting and verification should not be reduced to a one-off administrative check. They can become a continuous process: measuring, interpreting, adjusting, verifying, learning. The objective is not to produce an absolute truth about each plot, but to gradually reduce uncertainty and improve the quality of decisions.

Dynamic management must also be proportionate. A measurement system that is too costly, too complex or too time-consuming risks discouraging average farmers, effectively limiting green premiums to elite, hyper-equipped operations. Conversely, an overly relaxed, self-declaratory system lacks the integrity required by corporate buyers, carbon financiers, or regulators.

The solution lies in a graduated proof architecture. Baseline practices can be verified cheaply via digital records and geotagged field photos. Transition progress can then be monitored through scalable agronomic and satellite indicators. Finally, rigorous, expensive quantification protocols are reserved for high-stakes scenarios where major funding or bold environmental claims demand them. Ultimately, the standard of proof must always scale with the weight of the claim.

Data and AI can also facilitate risk sharing. By making transition trajectories transparent, they enable banks, insurers, buyers, and public authorities to better assess a farm's long-term viability. For instance, a farm that actively reduces its dependency on inputs, diversifies production, improves soil cover, and stabilizes its profit margins can be recognized as being on a de-risking pathway, even if its exact environmental impacts are not yet fully measurable. This visibility can unlock access to preferential financing, transition bridge premiums, multi-year off-take contracts, or more tailored insurance terms.

To maintain legitimacy, however, these digital tools must meet several strict conditions. Models must feature explainable assumptions, remain transparent about their limitations, and be carefully calibrated to local contexts. Data governance must be explicitly defined: who collects the data, who accesses it, for what purposes, and what data rights do farmers retain? Furthermore, algorithmic recommendations must remain open to debate and review. Digital tools should never replace human agronomic judgment; their role is to inform and enrich it.

Crucially, impact measurement must not morph into a new administrative burden for farmers. Instead, it must deliver an immediate, tangible service: helping them better understand their land, track operational progress, monetize their ecological efforts, access financing, secure market outlets, and ultimately strengthen their decision-making autonomy. If data collection only serves the corporate reporting needs of funders or buyers, it will inevitably be rejected as an unfair constraint. If, instead, it empowers farmers to optimize their operations and capture the value they create, it becomes a powerful catalyst for widespread adoption.

Ultimately, making uncertainty manageable means accepting that the agroecological transition cannot be reduced to a simplistic equation. It requires building tools capable of navigating uncertainty rather than denying its existence. It means shifting from a philosophy of perfect prediction to a framework of continuous learning.

From this perspective, data and AI are not standalone silver bullets; they are a decision-making infrastructure. They bridge the gap between practices and trajectories, trajectories and impacts, impacts to financial rewards, and rewards to transition finance. Properly deployed, they render agroecology more transparent, more investable, and more credible, all without claiming to erase the beautiful complexity of living systems.

III.2. Reinventing agricultural advice: from standardised prescription to systemic support

The agroecological transition relies on far more than the mere adoption of new practices; it demands a fundamental shift in how agricultural systems are observed, evaluated, managed, and adapted. Consequently, agricultural advisory services constitute a foundational pillar of this transition. Without tailored, context-specific guidance, agroecological practices risk being poorly implemented, inadequately contextualized, or economically untenable for farmers.

For decades, the dominant model of agricultural extension was structured around a relatively linear logic: diagnosing a problem, recommending a solution, applying a product, and correcting an imbalance. While this symptom-response approach successfully supported the expansion of highly specialized, input-dependent farming systems, its utility is changing. It remains valuable for addressing acute crop health or technical emergencies, but it falls short when the goal shifts from treating isolated symptoms to comprehensively transforming the functioning of an entire agroecosystem.

Indeed, agroecology fundamentally shifts the very nature of agricultural advice. It is no longer a matter of recommending a standardized treatment, dosage, or technical roadmap. Instead, it is about helping the farmer understand the complex interactions among soil, climate, water, biodiversity, crop rotations, management practices, workload, market outlets, and economic margins. Moving from a logic of chemical substitution to one of biological regulation demands a higher level of agronomic expertise; the farmer is no longer following repeatable recipes, but rather steering a living, localized, evolving, and interconnected system.

This shift profoundly changes the role of the advisor. An agronomic decision can no longer be evaluated solely at the scale of the season; it must be included in a multi-year trajectory. The advisor can therefore no longer be just a prescriber of standardised solutions. He becomes a trajectory coach, capable of helping the farm to diagnose its starting point, identify its room for manoeuvre, prioritise the levers, explain the risks, monitor the effects over time and adjust decisions as the observation progresses.

Agricultural advice must therefore evolve from a logic of prescription to a logic of adaptive support. Its role is no longer just to transfer a top-down recommendation, but to build with the farmer a trajectory that is technically coherent, economically sustainable and compatible with the real constraints of the farm. In this regard, the advisor becomes an architect of transition.

However, this transformation faces an often-underestimated hurdle: the shift toward agroecology demands a parallel evolution in the skills of agricultural advisors. Many technicians have been trained in an agronomic paradigm based on rapid diagnostics, standardized itineraries and relatively linear technical responses. However, supporting living soil, a long rotation, a diversified system or complex biological balances requires other skills: observation, systemic reasoning, uncertainty management, economic analysis, experimentation and monitoring over time.

Without massive investment in continuing education, decision-support tools, learning networks, and the synthesis of field feedback, the agroecological transition will remain bottlenecked by the advisory system's actual capacity to deliver it. Training farmers is not enough; we must also upskill the advisors who support them, enabling them to shift from a prescription-based model to one grounded in diagnosis, continuous learning, and dynamic adjustment.

It is precisely at the intersection of this cognitive overload and the need for highly contextualized guidance that artificial intelligence delivers its true added value. Used as an amplifier of human expertise, AI can help advisors structure baseline diagnoses, rapidly synthesize scientific literature, simulate scenarios, analyze soil or satellite data, track weak signals, document practices, and monitor progress indicators. Furthermore, it can democratize access to agronomic knowledge, particularly in regions where human advisory services are scarce, expensive, or difficult to access.

Reinventing agricultural advisory services also means shifting from periodic, one-off interventions to continuous, long-term monitoring. The agroecological transition does not occur over a single growing season; it requires several years of experimentation, iterative refinement, and stabilization. Advisory services must therefore be reframed as a continuous lifecycle: diagnosis, action planning, experimentation, monitoring, feedback loops, adjustment, and impact measurement. This continuity is essential to ensure that farmers do not bear the burden of uncertainty alone during the critical gap between implementing new practices and realizing tangible benefits.

This transformation also demands new collaborative models of extension. Peer-learning groups, networks of pilot farms, cooperatives, chambers of agriculture, producer organizations, technical associations, and territorial platforms play a vital role in disseminating knowledge. Agroecology thrives on cross-comparison, mutual observation, and local adaptation; consequently, experiential field feedback is just as valuable as traditional experimental trials.

Finally, this evolution requires a closer integration of three distinct forms of knowledge: scientific research, advisory expertise, and the farmer's firsthand experience. Science provides the foundational principles, biophysical models, and validation of proxies. The advisor contributes the capacity to interpret, benchmark, and operationally translate those concepts. Meanwhile, the farmer brings granular knowledge of their specific plots, operational constraints, machinery, labor availability, economic trade-offs, and risk appetite. The ultimate quality of agricultural advice hinges on the ability to foster a continuous dialogue among these three pillars.

IV. Conclusion: Making agroecology an economically sustainable model

Agroecology will not scale up if it continues to be viewed as merely an individual effort by farmers to adapt. It can only become the dominant model if the macroeconomic environment in which agricultural decisions are made evolves alongside it.

This white paper is based on a simple observation: agroecology creates tangible value, but it is still imperfectly recognized by markets, contracts, financing mechanisms, and measurement frameworks. It strengthens soil fertility, operational autonomy, functional biodiversity, water management, economic stability, and the adaptive capacity of farms. However, a large part of this value remains diffuse, deferred, or captured entirely outside the farm gates.

The core question is therefore no longer just how to produce differently, but rather: how do we organize an agricultural economy capable of recognizing, financing, and rewarding what agroecology makes possible?

This transformation implies shifting our perspective. Agricultural performance can no longer be assessed solely on the basis of yield or volume marketed. It must integrate profit margins, financial stability, self-reliance, risk mitigation, and the preservation of productive natural assets. A resilient farm is not just an ecologically virtuous one; it is a business operation that protects its future capacity to produce in an unstable world.

This change in outlook also forces us to rethink risk sharing. Today, transition costs are often immediate and borne entirely by the farmer, while the benefits accumulate over time and spill over beyond the farm. Making agroecology viable therefore requires building mechanisms capable of securing these transition trajectories: multi-year off-take contracts, progress-based remuneration, tailored financing, guarantees, advisory services, robust impact measurement, and structured market outlets.

It is not a matter of adding an environmental layer to an unchanged economic model. It is a matter of modifying what the market considers profitable, bankable, insurable, contractualizable, and monetizable. As long as resilience, soil health, self-sufficiency, biodiversity, or reduced input dependence remain viewed as peripheral benefits, agroecology will remain economically fragile. The moment they become recognized assets, they will guide the decisions of farmers, supply chain sectors, financiers, and public authorities alike.

The agroecological transition is therefore less about a substitution of practices and more about a reorganization of value. It calls for a new economic architecture—one capable of organizing and valuing diversity, financing long-term horizons, making uncertainty manageable, and sharing risks and benefits more equitably.

Only under this condition can agroecology move from an agronomic promise to a credible, mainstream economic model, not as an additional constraint imposed on farms, but as a way to restore their capacity for autonomy, resilience, and value creation in a world where instability is becoming the new normal.

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