THE OFFICE SUMMARIES

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Agriculture and the challenges of climate change and biodiversity loss: the role of science

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Agriculture, as it currently stands, plays a key role in climate change. In 2023, greenhouse gas emissions from French agriculture accounted for 76.3 million tonnes of CO_2 equivalent, or 20.4% of France's overall emissions. The sector also has major impacts on biodiversity, particularly due to the conversion of natural habitats into farmland or to the use of inputs that contaminate water and soil. Yet, at the same time, the farming sector is one of the primary victims of climate change and biodiversity loss.

In order to shed scientific light on these developments, the Office organised a public hearing to take stock of scientific progress that could promote agriculture that is better adapted to climate change and respectful of biodiversity, and examine the changes that need to be made to the production system to ensure the effectiveness of this scientific progress.

Pierre Henriet,
Member of the National Assembly

Daniel Salmon,
Senator

Science offers promising avenues that could ensure the sustainability of agriculture, but there are numerous obstacles to their application and it is not possible to address all of the challenges facing agriculture at once

Dominant agricultural practices pose a threat to the sustainability of agriculture

➢ The current model is on the path to exceeding some of the planet's limits

Life on Earth is conditioned by interactions between biological, physical and chemical processes. In 2009, researchers from Stockholm Resilience Center (SRC) defined **thresholds, beyond which the planet's natural balances could be undermined and living conditions would become challenging for humanity**. These thresholds are presented as **nine limits for the planet**.

Agriculture is one of the human activities that contributes to exceeding some of these limits, such as global warming and loss of biodiversity. Pesticides are a threat for many insects. According to a German study, 75% of insect biomass has been lost in protected zones, and close to 95% in agricultural land in Germany.

Agriculture is also largely responsible for disturbing the nitrogen and phosphorus cycles. The current estimated excess of nitrogen per hectare per year on farming land stands at 48 kg worldwide, whereas the sustainable limit is approximately 15 kg.

➢ Agriculture is the primary victim of imbalances caused by human activity

While agriculture plays a role in exceeding the planet's limits, **it is also one of the primary victims of nature's resulting imbalances**. The sustainability of the current agricultural model is being called into question. In Brazil, the limitations of this model are reflected with the development of pesticide resistance in certain insects such as the *Spodoptera Frugiperda* moth, declining soybean yields and rising levels of phytotoxicity from crop treatments. **In Brazil, an insecticide becomes ineffective just two to four years after its introduction**, despite taking around ten years to develop and costing €130 million.

Scientific research offers promising alternatives to develop agriculture that is adapted to climate change and respectful of biodiversity

➢ Innovative biological control techniques, such as the manipulation of olfactory landscapes and the use of plant microbiota

- *Manipulation of olfactory landscapes*

Living organisms evolve in olfactory landscapes, shaped by a diverse array of organic compounds released into the atmosphere as part of natural ecological processes. **These scents play a crucial role for insects, guiding them to food sources, potential mates, host plants and suitable egg-laying sites.** This is why insects have developed an extremely efficient odour detection system, which makes them very sensitive to changes in odours and semiochemicals.

Studies have been conducted on how the scents of plants impact insect behaviour. For each species, there are attractive scents known as kairomones, and repellent ones known as allomones. Thanks to improvements in the performance of odour detection machines and reductions in their production costs, **it is now possible to create natural fragrances that repel insect pests and protect crops.**

The manipulation of olfactory landscapes is used to protect beet crops from aphids in order to reduce cases of yellowing disease, without using neonicotinoids. INRAE and the company Agriodor have identified odours that have a repellent effect on aphids, thereby reducing their ability to feed and reproduce.

This solution offers several advantages. Firstly, **it is harmless to pollinators**, as it targets the chemoreceptors that allow specific insects to detect certain odours. Secondly, **it is a preventive rather than curative approach** in that insects are not killed, but deterred from colonising crops during their peak activity periods. Moreover, **it does not contribute to resistance**, as it does not foster evolutionary selection in insect populations. Finally, **the development cost and time required for the molecules are significantly lower than those for pesticides**.

The manipulation of olfactory landscapes could be effective for 70% of insect pests, specifically those that are sensitive to odours and whose behaviour can be influenced.

- *The role of plant microbiota*

Plants coexist with a wide range of microorganisms that form their microbiota. These microorganisms are found around the roots, on the roots, inside and on the surface of the leaves, on the seeds and in the stems.

They offer key benefits to plants: by blocking pathogens, they help maintain their health; they increase their tolerance to abiotic stresses such as drought, temperature and salinity, and they improve overall plant nutrition. They also offer protection against certain insect pests, thereby contributing to more sustainable farming practices that are less dependent on pesticides and more resilient to climate change, all while maintaining productivity.

➢ Genomics for greater resistance to climate change and disease

Significant progress has been made in genomic selection, making it possible to select any trait. **Genetics could therefore play a vital role in helping cattle adapt to future challenges and ensuring sustainable production**.

If we are to adapt to climate change, animals need to be more heat-tolerant, especially as hot periods grow longer and more intense. Genetics can help address these challenges by promoting crossbreeding strategies to develop more resilient animals.

Genetics also plays a role in reducing methane emissions. Technological innovations now allow for the prediction of methane emissions in dairy cows by analysing the mid-infrared spectra of their milk. Methane is produced during fermentation in the rumen, and various milk components contain traces of this fermentation process.

Another technique is being developed to quantify methane emissions in suckler cows, through the analysis of their dung using near-infrared spectroscopy.

Characterising the gut microbiota is also a promising avenue for assessing methane production levels and tailoring genetic selection accordingly.

Methane emissions can also be reduced indirectly by avoiding unnecessary emissions. This involves earlier calving, at the age of two instead of three, which could cut methane emissions by 10%; improving cattle longevity, in order to reduce the need to rear young animals for renewal; reducing cattle size; and improving overall animal health, as sick animals are less productive yet still emit methane.

In this regard, genetics has already made considerable progress in reducing the risk of mastitis, leg diseases, paratuberculosis and calf infections. In addition, research into functional longevity and analysis of the innate immune response of animals could provide more comprehensive protection.

The increasing prevalence of diseases is a major concern, whether they are existing diseases or new diseases emerging from southern countries. Global warming is accelerating the spread of diseases such as EHD (Epizootic Haemorrhagic Disease) and BT (Bluetongue disease). As these diseases are expected to become endemic, genetic tools will need to be developed to boost animals' resistance to them.

➢ Digital technology in agroecology

Digital technology has the potential not only to optimise practices but also to drive profound transformation in agriculture. The 'Agroecology and Digital Technology' Priority Research Programme and Equipment (PEPR), launched as part of France 2030 and co-led by INRAE and INRIA, has three main areas of focus aimed at developing innovative technologies for agriculture:

- the first is concerned with characterising genetic resources to assess their potential for agroecology;

- the second aims to design new generations of agricultural equipment;

- the third is dedicated to developing digital tools and methods for data processing and modelling in agriculture.

The GeoPl@ntNet application is a prime example of how digital technology can transform agriculture, through the creation of highly detailed biodiversity maps, while artificial intelligence enables farmers to access accurate information very quickly.

There are however many obstacles to rolling out this scientific progress, and it can only be effective if there is also a profound change in production systems

➢ Scientific and technical obstacles

While research offers promising avenues for more resilient and sustainable agriculture, there are still many scientific and technical obstacles to overcome.

Microbial biosolutions have been developed in order to restore and strengthen the microbiota that protect plants. **However, the effectiveness of single-strain biosolutions in protecting plants against disease and boosting their growth and drought tolerance is limited**, leading to a loss of confidence in these solutions among farmers. **It is crucial not only to improve existing biosolutions**, by modifying their application methods for instance, but also to **develop multi-strain biosolutions** that are more effective and resilient to environmental changes than single-strain products.

At the same time, **initiates to promote varietal improvement** should focus on selecting plant varieties that are capable of associating with beneficial microorganisms.

Finally, **the development of sensors and digital tools to monitor plant and soil microbiota is essential**. Current microbiota diagnostics only provide a snapshot of soil health and plant vulnerability to certain diseases. On another note, epidemiological surveillance networks using spore sensors assess the risks of disease on a daily basis. The technical challenge is now to merge these two approaches in order to monitor microbiota in real time and incorporate this data into epidemiological surveillance programmes, improving risk prediction.

➢ More structural obstacles

- *Regulatory obstacles*

Many of those present pointed out the regulatory hurdles encountered when seeking approval for certain innovations.

For example, **the incorrect classification of Agriodor's pellet-form fragrances as plant protection products unnecessarily complicates the approval process**. These substances undergo ecotoxicological studies that are unrelated to their intended use, as they are designed as fragrances that repel insects without harming them. As a result, precious time is lost as it takes between 10 and 12 years to obtain approval, and resources are wasted, with the estimated cost of preparing the necessary documentation estimated at €3 million.

The regulations governing the approval of biosolutions are also inadequate, creating significant barriers to the development of alternative solutions to pesticides.

- *Human obstacles*

An obstacle to widespread adoption of technological innovations is the insufficient training of those working in the agricultural sector.

Ongoing training for both young people starting their careers and experienced farmers must therefore be encouraged to help them keep up with emerging digital tools.

To train future farmers for the transitions, the Ministry of Agriculture launched two successive plans, called 'Teaching to Produce Differently', between 2014 and 2024.

The diploma reference standards have been updated to prioritise agronomic and economic knowledge, with the aim of developing resilient agricultural systems. Emphasis was put on systemic and skills-based approaches, efforts were made to encourage initiatives from institutions supporting transitions, and collaboration between technical education, higher education and research was promoted to ensure training for future farmers aligned with scientific innovations.

Nevertheless, a recent assessment of the second 'Teaching to produce differently' plan showed mixed results. Only one in six teachers received training in transitions, a total of just 3,000 individuals, and the practices of teacher trainers have not evolved sufficiently. This is attributed to varying levels of commitment among teachers and inadequate resources and teaching materials available to them.

The assessment also revealed significant obstacles to teaching transitions, including the sociological profiles of learners, the gap between the knowledge acquired at training centres and actual field conditions, and the agronomic and economic uncertainties faced by farmers. The report showed that barriers persist between technical education, higher education, research, professionals and agricultural advisors, resulting in inadequate support for teaching practices and educational institutions focused on transitions.

- *Financial obstacles*

The cost of digital tools is not a major obstacle to their widespread use in agriculture, as it is in fact very low compared to the cost of agricultural equipment.

However, the same cannot be said for other innovations. **Innovations in alternatives to pesticides for example, are too costly due to two factors**.

First, **they are in direct competition with pesticides, which have long served as the cost for crop protection**. Pesticides are more affordable because they have been widely used for decades and benefit from economies of scale that have drastically reduced their marginal production costs.

Second, unlike other sectors such as healthcare or cosmetics, **agriculture lacks sufficient resources to invest in innovation, as consumers are not willing to pay higher prices**. Organic products are an example of this issue: while their benefits are widely acknowledged, many consumers hesitate to pay the premium for them.

The use of genetic selection to reduce methane emissions in cattle also represents a cost for farmers. Without incentive policies, this innovation is likely to face limited adoption, as farmers will have no financial incentive to implement this technical solution.

The development of microbial biosolutions also involves financial costs that must be borne by farmers willing to adopt this technique.

➢ **The effectiveness of certain scientific developments will remain limited unless there is a more profound transformation in production systems**

To boost the impact of biosolutions, farming systems need to be restructured to incorporate more preventive measures. Plant biodiversity in fields and landscapes therefore plays a significant role in fostering the presence of beneficial microorganisms. This means that one key scientific challenge is to identify the plant species that serve as reservoirs of beneficial microorganisms for cultivated plants, and to determine how to integrate them into farming systems to boost the flow of microorganisms, by planting strips of grass, hedges and trees for example.

It would also be imprudent to believe that digital technology alone can make the agricultural system more sustainable. The first focus of the PEPR 'Agroecology and Digital Technology' highlights this by focusing on the need to shape a socio-ecosystem that supports sustainable research and innovation. Indeed, **technological innovations alone are not enough to guide farmers through a successful transition. They must be combined with organisational, economic, institutional and political innovations**.

Given the lock-in of current agricultural production systems, a fundamental transformation of the agri-food system would provide sustainable solutions for the agricultural sector

The lock-in of current agricultural production systems prevents the development of new, more sustainable initiatives

➢ **What drives the lock-in of agricultural production systems**?

The technical choices that shaped the current agricultural production model, such as specialisation in field crops such as cereals, beet and oilseed rape, **stem from the discovery of the Haber-Bosch process at the beginning of the last century, which led to the development of synthetic fertilisers and pesticides derived from fossil fuels. The use of these products marked a break with the dominant practices of the time**, that relied on biological and mechanical regulations within the farm. **Within a few decades, these products became so widespread that the agricultural production system became locked-in to these initial choices**.

The concept of **'increasing returns to adoption'** explains how a technology comes to dominate competing technologies once it is widely adopted by stakeholders. In fact, **as a technique becomes more widely adopted, its performance improves over time and it becomes more profitable due to economies of scale and scope, which significantly reduce marginal production costs**.

As a result, a technology is not necessarily chosen because it is the best, but it becomes the best after being initially chosen and then refined over time.

Other factors contribute to this dominance:

- **technological interdependencies with the agri-food system**, which impose technologies and production standards linked to the dominant technology;

- **network externalities associated with agricultural advisory services**, which encourage farmers to adopt the dominant technology in order to benefit from other compatible services.

These self-reinforcing mechanisms form a set of norms, standards and regulations that lock the market into the initial technical choices.

A locked-in production system results in producers, manufacturers and consumers all adopting similar patterns of thinking and acting. Consequently, our consumption habits become aligned with the agro-industrial supply (more than 75% of purchases made in supermarkets, high consumption of ultra-processed products), at the expense of a diet that could be more directly linked to agriculture. Social sciences refer to this gradual alignment as a **socio-technical regime**, which is a set of rules for collective action that have become a systemic force and hinder change.

➢ The challenges of scaling innovation niches

An innovation niche can be defined as a network of stakeholders who are aware of the challenges facing the current agricultural model and seek to make it more sustainable, by mobilising scientific knowledge and experimenting with new technical choices. These innovation niches are made up of a diverse range of organisations: private companies, self-employed entrepreneurs, cooperatives, associations, consumers and local authorities.

As these niches develop, they gradually merge with the components of the existing model so that new technical choices can be introduced, in the field of agroecology for example.

In reality, these innovations face significant challenges due to the lock-in of the current sociotechnical regime.

First of all, **they require a more or less lengthy learning phase**, which is inherent to the development of any new technique. It takes time for a new approach to deliver the desired outcomes at a lower cost, much like the performance and pricing challenges faced by early computers in other industries. **This learning phase can be further slowed down when innovations conflict with existing infrastructures and regulations**, as illustrated by the difficulties faced in the approval processes for techniques like the manipulation of olfactory landscapes and microbial biosolutions.

Narratives and beliefs can also hinder the adoption of innovations, as explicitly mentioned in the 'Teaching to Produce Differently' plan assessment report. The report highlights obstacles linked to the sociological profiles of learners, as well as the gap between the knowledge acquired at training centres and the realities of the field.

In this regard, caution is required when certain intuitions prove to be incorrect when tested against scientific evidence. For example, the common belief among some farmers that introducing legumes is unprofitable is not supported in the long term. A collaborative expert review conducted by INRAE in 2022 demonstrated the long-term profitability of this practice, due to improvements in soil structure and health. The core issue, therefore, is not to focus solely on the costs incurred over the current year, but to also consider the cumulative effects over several years.

Innovation often struggles to trigger a dynamic of increasing returns to adoption and generate profits. Market competition means that innovations cannot reach a sufficient scale to reduce marginal costs and become profitable.

Organic farming, which accounts for only 6% of food expenditures, is a prime example of these innovation niches, holding only a minor share within our production systems.

Building a new sociotechnical regime requires profound transformation of the agri-food system

➢ This calls for a systemic approach driven by coupled innovations

The concept of the agri-food system encompasses not only production, processing, and distribution chains, but also includes varietal selection, research, technical advisory services, public policies, and regulatory bodies. These various stakeholders are interdependent and all operate within the same system of production and consumption.

Yet, **innovation today remains primarily driven by individual stakeholders.** For example, a farmer might develop technical innovations on their own land but find themselves forced to conform to downstream regulations that seem inflexible. **Such initiatives often fail** due to the lock-in dynamics described earlier.

To overcome these structural barriers, it is essential to develop innovations that combine multiple components of the agri-food system in a coherent manner, and that involve the coordination of several stakeholders within this system to address complex problems together.

The initiative to supply nursery school canteens in Paris with 100% organic vegetables illustrates the value of coupled innovations, as it required close collaboration between producers (initially cereal growers), the Île-de-France organic cooperative, a collective catering operator, and the City of Paris.

This project initially focused on potatoes, which remain one of the most heavily treated crops, yet are also a staple food in meals for very young children. Cereal farmers in the Île-de-France region introduced potatoes into their crop rotations and adopted organic farming methods to supply the Parisian nurseries. They formed a cooperative to pool their harvest and set up a processing facility to transform raw potatoes into fifth-range products, i.e. pre-cooked, vacuum-packed potatoes delivered directly to the canteens. However, transporting the potatoes from the rural processing facility to the 300 kitchens serving Paris' nurseries posed a challenge. To address this issue, the collective catering operator set up a logistics platform.

The City of Paris played a central role in this innovative initiative by including a clause in its public procurement contract, requiring that 100% of the potatoes be organically produced.

The success of this innovation lay in the effective coordination among stakeholders and their ability to combine their innovations in a coherent way.

Nevertheless, several challenges arose during this process of unlocking a system that was initially deeply entrenched. It took ten years for the stakeholders involved to learn how to interact and coordinate with one another effectively.

As one participant remarked, ‘it took a century to stabilise our current technical choices; it will likely take another century to consolidate new ones’.

- **Integrating the challenges of sustainable and healthy agriculture into a broader reflection on our food systems**

The challenges of achieving sustainable and healthy agriculture must be incorporated into the broader context of our food systems.

Issues such as respecting the planet’s limits, addressing the rise in cardiovascular and metabolic diseases, and responding to the population’s increasing concern for animal welfare are driving significant changes in the agricultural model, not only in its production methods but also in the types of crops grown.

Agroecology is one of the key strategies for ensuring the long-term sustainability of agriculture. Thanks to its low use of inputs, it generates few greenhouse gas emissions and helps preserve biodiversity.

However, it requires a significant transformation of production methods, particularly by introducing more plant biodiversity in fields and landscapes, and adopting more diverse and extended crop rotations, which, in turn, would lead to increased legume production.

The recognition of livestock farming, particularly cattle, as a major contributor to agricultural greenhouse gas emissions, the accumulation of scientific evidence on the health risks associated with diets that are high in red meat, and increasing public concern for animal welfare are all expected to lead to a reduction in livestock numbers. As a result, the production of animal proteins and milk is likely to decline in France. However, it will be crucial to ensure that this decline does not result in a sharp increase in imports.

Nutritional guidelines also emphasise the importance of including fruit, vegetables, and legumes in our diet, and farmers could be given incentives to grow these products, provided they can access viable markets.

A policy that focuses solely on the supply side of agricultural products will not shift food preferences and consumption habits.

Coherent policies are needed across the entire food system, including strategies to influence consumer behaviour toward healthier diets. **As well as examining consumer behaviour, public authorities can influence preferences by targeting specific economic mechanisms**.

Agricultural issues should also be addressed in a broader scope that includes issues related to renewable energy and food loss and waste, which currently affects over 30% of edible food.

- **Setting clear objectives**

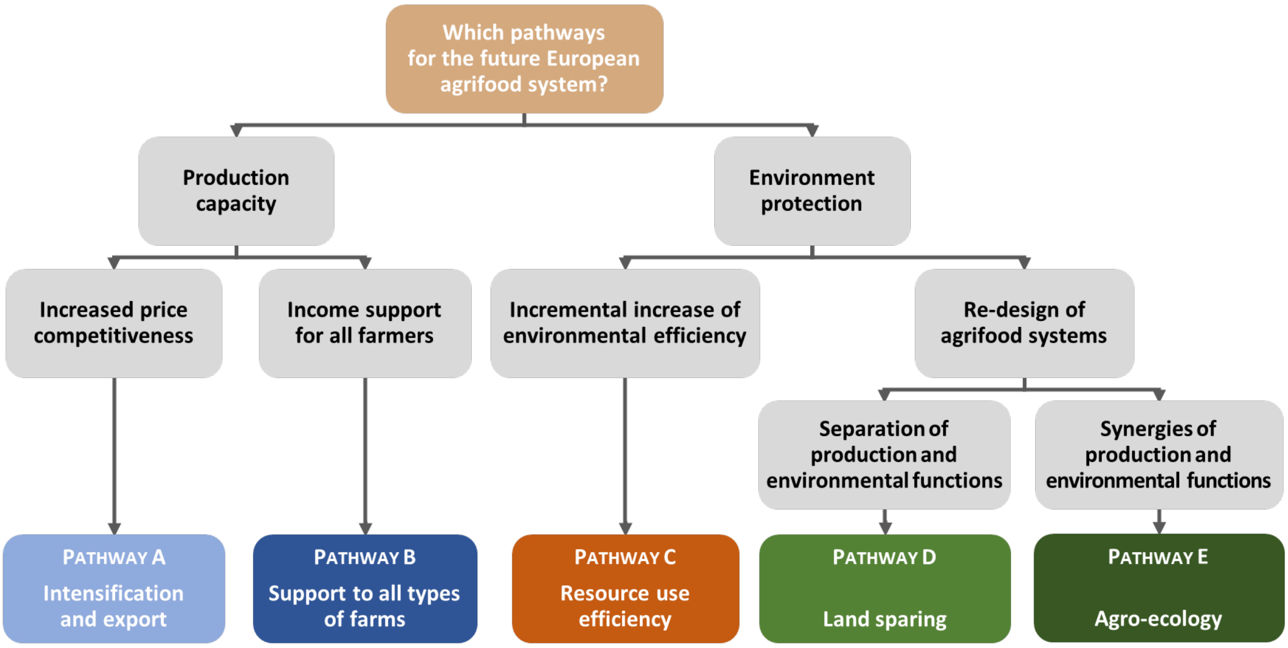
Building a new sociotechnical regime requires clear objectives and strategic choices, as illustrated by an INRAE study on the potential paths forward for the Common Agricultural Policy (CAP) post-2027. The study provides an analytical framework based on both societal and agricultural challenges associated with the CAP. Five alternative pathways are put forward depending on the chosen political priorities, emphasising the need for strategic choices.

One of the key choices is between scenarios focused on maintaining or increasing the European Union’s agricultural production capacity (scenarios A and B), **and those that prioritise environmental protection** (scenarios C, D, and E). At least in the short term, these two objectives are incompatible.

For the two production-focused scenarios (scenarios A and B), **there is a second strategic choice to make between scenario A, that gives priority to boosting agriculture and exports with a focus on price competitiveness, and scenario B, focused on providing support for all types of agricultural stakeholders**, with the aim of maintaining production capacity while ensuring financial aid across the sector.

Of the three scenarios devoted to the climate and the environment, scenario C, which advocates for resource efficiency by optimising current production systems, conflicts with scenarios D (preservation of land by separating production and environmental functions) and E (combining production and ecological functions through agroecology), which calls for radical societal changes, particularly in terms of diet.

The five possible scenarios for the future CAP



None of the five scenarios can simultaneously guarantee environmental protection, food self-sufficiency, fair incomes for farmers, low food prices, and widespread adoption of healthy diets. Policymakers will therefore need to make strategic choices.

According to the INRAE study, the number of farms is expected to continue declining, regardless of the chosen scenario. However, this decline is expected to be more limited in scenario B which supports all types of agricultural stakeholders, and in scenario E that is focused on agroecology.

➢ **The role of training for stakeholders**

A successful transition to a more sustainable model of agricultural production relies heavily on the support and training given to the stakeholders involved. Farmers need to be made aware of the issues surrounding more sustainable and resilient agriculture, and they must be given the resources to adopt technologies and innovations derived from scientific research.

Other stakeholders in the agri-food system should also be trained so that they fully understand the concept and procedures involved in the locking-in of sociotechnical regimes, and the importance of combined innovations in shaping the dominant sociotechnical regime.

The Office's Recommendations

➢ First focus: encourage the development of technological innovations for more sustainable and resilient agriculture

1. **Develop regulations to facilitate approval processes for technological innovations that are more environmentally friendly,** to reduce the cost and time to market innovative products.

2. **Adjust pricing related to different production models in an effort to discourage practices that lead to negative externalities** (such as the intensive use of pesticides and synthetic fertilisers) and encourage less profitable but more sustainable practices. The idea is to develop initiatives that provide incentives while compensating for any loss in income. A possible solution could be to introduce a tax on pesticides and reinvest any funds paid by farmers into environmental protection initiatives by decoupling taxes from reimbursements.

3. **Improve the effectiveness of genetic tools to select animals that are more resistant to disease, by cross-referencing genetic data with health data**.

➢ Second focus: adopt a proactive policy for a sustainable and healthy agri-food system

4. **Prioritise a systemic approach that links agricultural issues to food system issues**: agricultural issues must be considered within the context of a broader reflection on our food systems, which need to evolve to become more sustainable and healthier. Actions in agricultural production must therefore be coordinated with other public policies relating to the entire food chain in order to influence food preferences and supply.

5. **Balance CAP objectives without sacrificing environmental protection**: the CAP encompasses multiple objectives, including the development of sustainable agriculture, food self-sufficiency, guaranteeing decent income for all farmers, low food prices to safeguard consumer purchasing power and remaining competitive outside the EU. It is difficult to achieve these objectives all at once, especially within a fixed budget. Strategic choices must therefore be made that do not sacrifice environmental protection in favour of shorter-term priorities that may be counter-productive in the long-term.

6. **Develop new financial instruments as part of the next CAP, moving from a subsidy-based approach to one based on remuneration for explicit services**, in order to support farmers in transforming their production methods while guaranteeing their level of income.

➢ Third focus: support grassroots initiatives to unlock production systems

7. **Encourage combined innovations involving all stakeholders upstream and downstream of production** by increasing financial aid for research programmes dedicated to these initiatives.

8. **Decentralise transition initiatives** to reflect the specific ecological and socio-economic characteristics of different regions.

➢ Fourth focus: accelerate training for transitions

9. **Mobilise a broader network of stakeholders in the field** – teachers, trainers, industry professionals, technology workshops, professionals, higher education and research institutions – **and break down barriers between approaches to training for transitions**.

10. **Actively involve learners in the design, implementation and monitoring of actions** aimed at promoting transitions to new production models.

National Assembly Report no. 1253 (XVII legislature) – Senate Report no. 516 (2024-2025)

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