Crop diversification is often presented as a way to improve the sustainability of agricultural production systems. Well managed, it promotes a reduction in the use of inputs - pesticides, fertiliser, water – and the environmental damage resulting from their excessive use. Conversely, the simplification of cropping systems that has been under way for the past 40 years has been accompanied by the growing use of inputs. However, despite the benefits to production systems in terms of both ecological and economic sustainability (spreading of risks) and its incorporation within various incentive programmes and mechanisms, crop diversification is gaining little ground. The French Ministries for Agriculture and the Environment therefore tasked the INRA (French National Institute for Agricultural Research) with producing a report aimed at identifying the obstacles to crop diversification and the levers that could be employed by the public authorities, in particular, to promote it. The working hypothesis is that these obstacles are related to the way the dominant agro-industrial system operates overall and the development capacities of supply chains promoting diversification crops. The study examined a number of cases representative of the broad diversity of the agro-industrial supply chains and, in particular, their modes of organisation, which, in turn, determine the coordination and commitment of the stakeholders involved in the development of a diversification crop.

Study context and objectives

The post-war agricultural revolution led to a significant intensification of French agriculture as a result of the development of mechanisation and the large-scale use of inputs. This intensification was accompanied by the progressive specialisation of farms. Furthermore, the parallel structuring of agro-industrial sectors has promoted a high level of regional specialisation of agricultural systems, the aim being to more effectively control quality, volumes and supply logistics. This specialisation of farms and regions has been accompanied by a reduction in the number of crops, a shortening of crop rotations, with the growing efficiency of plant health (chemical) products reducing the detrimental effects of short rotations and monocropping.

This reduction in the diversity of crops and the increasing recognition of the negative external impacts associated with “intensive” systems (pollution of local environments, greenhouse gas emissions, loss of biodiversity, etc.) are driving public authorities to consider the challenges involved in promoting a more sustainable form of agriculture. Several recent studies and expert reports conducted by the INRA at the request of the public authorities, have highlighted crop diversification – meaning the diversification of the crop types grown within a farm or region – as a way to reduce the use of pesticides or pressure on irrigation water.

But, while French agriculture needs to become more sustainable, it also needs to remain competitive within the context of a global market economy. It is therefore essential to examine the economic benefits of greater crop diversification, and hence the market outlets that diversification crops can find, agro-industrial strategies, consumer demand and the technological innovations underpinning these. Consequently, the issue of greater diversification of arable land relates more broadly to the choices we make in terms of how agricultural and agro-industrial supply chains are structured, as well as our dietary habits and our product quality policy. The challenge is to combine diversification with the competitiveness of the agricultural and agro-industrial system.
The objective of this study is to identify: i) the main obstacles to crop diversification at agro-industrial supply chain and farm level; ii) the levers that can be employed by the public authorities, in particular, to encourage these stakeholders to integrate greater crop diversity within their production system. However, the study does not aim to define which diversification crops French agriculture should develop or to demonstrate the virtues of any particular crop. The case studies conducted are designed to reveal processes with a generic value.

An analysis and hypothesis framework...

To simultaneously conduct a study of diversification obstacles and levers at farm and supply chain level, an interdisciplinary analysis framework was used, integrating agronomy of practices and supply chain economics. This theoretical framework is centred around the "technological lock-in" theory, derived from the innovation economy, and socio-technical transition theory, which proposes potential "break-out" avenues.

The "technological lock-in" hypothesis

The term "technological lock-in" is used to describe a situation whereby the technology initially chosen remains the norm, despite the fact that a more efficient technology exists - the original technology has become so standard for society that it appears to be difficult to change it. This "lock-in" effect may concern a technical production, product, norm or paradigm choice. Lock-in of a production system leads to a sorting process between innovations: those that are totally compatible with the reference technology have a chance of developing, while those that call into question either it, or the relationships between the main stakeholders of the supply chains, have much less chance of developing. Lock-in does not result from a deliberate strategy on the part of one or other stakeholder, but from self-reinforcement mechanisms created around a technological solution: the initial training of the stakeholders involved, the accumulation of knowledge and complementary technologies, and the links that structure the various stakeholders in a supply chain are built up in line with the standard technology and increase the cost of adopting an alternative technology.

This study is therefore based on the hypothesis that a transition to agricultural production practices based on greater diversification comes up against the obstacle of a highly structured organisation of agricultural and agro-industrial production systems. Against this background, the identification of "break-out" mechanisms requires an analysis of the socio-technical system, i.e., the relationships between norms, procedures, networks of stakeholders, institutions and infrastructures governing technological choices.

Niches and potential "break-out" avenues

A socio-technical system - even one that is locked in - is not generally totally uniform: innovation niches may appear, creating a space partially isolated from the normal operation of the system and, in particular, from the processes that select markets and technological innovations. Operating with different norms and institutional rules, niches allow learning and the construction of economic networks capable of supporting innovations, such as production and/or marketing sectors (socio-technical transition theory).

To facilitate transition processes, these niches need to form a structure in order to overcome the self-reinforcement effects of the standard socio-technical system. The process underpinning the emergence of an innovation within a niche requires a minimum level of coordination between the different stakeholders involved in a supply chain. Consequently, strong connections between the various producer and end-user networks must be established. Transaction cost theory provides a framework for analysis of these different modes of coordination between the stakeholders involved in a supply chain.

... tested on case studies

The hypothesis adopted, based on the literature, is that crop diversification assumes break-out from the socio-technical system that dominates current agriculture. This hypothesis was tested on concrete crop diversification cases studies. Initially, twelve cases were analysed to establish a panorama of the obstacles and levers mentioned in the scientific and technical literature as well as by experts from the agricultural world. Of these twelve cases, three were then selected for in-depth analysis of the way the supply chains operate. The objective was to provide an updated assessment of the systemic nature of the lock-in, on the basis of interviews with the economic actors concerned, and with farmers having opted for this kind of crop diversification.

The twelve crops studied are: hemp, field beans, flax and linseed, lupins, alfalfa, condiment mustard, field peas, chick peas, soybean, sorghum and sunflowers (in northern regions only for the latter). These crops are all marginal in terms of surface area (compared to major annual crops), whereas outlets exist in France for their development (either in place of other crops or in place of imports). In addition, these crops offer a diversity of situations: they differ in terms of their current surface areas and trends (surface areas decreasing, relative expansion or highly fluctuating) and their potential outlets, on a variable number of markets (each variable in terms of size and dynamics). Some of these crops are concerned by large, highly competitive markets for "standard" agricultural raw materials (production of livestock feed, in particular), whereas others have niche markets in the human nutrition sector (condiment mustard, chick peas, soybean, etc.), eco-construction sector (hemp, flax) or animal feed sector (linseed oil).

In the in-depth analysis of three diversification cases, the objective was to examine the whole supply chain (from downstream to upstream) in order to understand the influence of its organisational structure on the development of the crop. The analysis focused on all the production processes (at agricultural and agro-industrial level), the coordination between the stakeholders involved (contracts, specifications, market structure) and their capacity to generate enough incentives to adopt the crop at the various links in the chain. The three cases selected - field peas for animal nutrition, linseed and hemp - were chosen from the 12 examples examined in the panorama of obstacles and levers.
Obstacles identified throughout the supply chains

The case studies - and the three in-depth cases, in particular, - confirmed the hypothesis of technological lock-in around the specialisation of cropping systems and introduced greater precision: all the stakeholders (from farmers to manufacturers, research institutes to agricultural extension and advisory structures, seed companies to cooperatives) have built their strategies on the basis of "major crops", for either organisational or logistics reasons, in order to address the supply or demand of their economic partners, to achieve economies of scale or to reduce transaction costs. Numerous self-reinforcement mechanisms, characteristic of technological lock-in, were described, with the interconnections between these being particularly highlighted by the in-depth studies in the three supply chains. The socio-technical system organised on the basis of dominant crops and the simplification of cropping plans is therefore an obstacle to the development of diversification crops as a result of various closely interlinked processes: (i) genetic progress that is less rapid than for "major crops"; (ii) a lack of crop protection solutions; (iii) a shortage of technical references concerning minor crops; (iv) competition with "major crops" on the raw material market and (v) the diversity of coordination methods between the different stakeholders in the supply chains.

Genetic progress that is less rapid than for major crops

One of the obstacles frequently cited is the limited range of crop varieties available, with varieties not always being suited to the soil and climate conditions, plant health risks and qualities demanded by the market. The markets for these crops are too small to guarantee a return on the substantial investments required for their genetic improvement. However, the creation of varieties does not appear to be uniform between crops: very low for some, it can also remain relatively active for crops in which the surface area is barely more extensive (field peas, etc.), or be boosted (lupin, mustard, etc.) when the economic actors invest in the development of a market outlet.

For a plant breeder, investing in an emerging supply chain is a major risk, particularly if the quality criteria sought have still not been clearly defined. The public authorities undoubtedly have a role to play by helping plant breeders (as was done for peas or lupins in the 1970s and 80s) to invest in a few strategic crops, within the framework of a coordinated European process. There is a strong demand on the part of the stakeholders in the supply chains for reinvestment in public research in the field of "minor" crop genetics and selection.

A lack of crop protection solutions

Paradoxically, pest control in diversification crops appears to be an obstacle to their development, even though it is one of the reasons for seeking to diversify cropping plans and rotations from an agronomic and environmental point of view. The approval of plant health products suitable for diversification crops is impeded by the low economic value represented by these crops for agrochemical companies and by the difficulty the supply chains concerned have funding their approval. The absence of a chemical solution to address parasite or weed problems is perceived as an additional risk by farmers and therefore constitutes an obstacle to the development of diversification crops. Other biological or agronomic solutions often exist (although not always), but these are very little used, partly, undoubtedly, because they are still little known, but also because they are based on temporal (agronomic principles in terms of the rotation) and spatial (collective management on a regional scale) approaches that are more complex to implement.

A shortage of technical references

The lack of technical references available to farmers to help them make their decisions represents an obstacle to the development of most minor crops. In particular, these deficiencies concern management of the crops in various soil and climate conditions, their "carry-over" effects and the causes of poor yields (that need to be known to be corrected).

These shortcomings affect the competitiveness of production. In addition, when a new crop gathers momentum, competition between growing areas can also delay the development and dissemination of these references.

Today, farmers and agricultural advisers are fully conversant with management techniques for major crops (wheat, grain maize, barley, oilseed rape). In contrast, certain diversification crops are less well mastered from a technical point of view or confronted with as yet unresolved problems. This is the case for pest control, as well as for planting and harvesting. The regional adaptation of references requires the performance of agronomic trials and the long-term implementation of networked observation mechanisms, something that is often too expensive for "small supply chains".

Dissemination of information aimed at farmers that is highly heterogeneous depending on the diversification crop: Number of references disseminated on the internet by technical institutes and in the farming press over the period 2009-2012 concerning each of the diversification crops studied
A lack of knowledge of the real requirements of the crops or deficient technical expertise in a particular operation can lead to disappointing results, prompting farmers to abandon production. Crops wrongly reputed to be undemanding are thus sown in low-potential fields, leading to harvests falling well short of the yields expected. For the majority of diversification crops, given the inadequate knowledge of the ecophysiology of these crops, farmers and their advisers do not have the diagnostic capacity to explain a low yield or quality defects of a harvest. The inability to identify the reasons for a failure can further reinforce rejection of the crop, sometimes for several years.

While several of the experts consulted identified the low availability of references concerning the “carry-over” and cumulative effects of diversification crops as an obstacle to their development, a bibliometric analysis of the technical publications (2009-2012) demonstrates the existence of knowledge that is sometimes extensive, but often incomplete and of highly variable quality depending on the crops. For some crops, such as peas, alfalfa or linseed, the “carry-over” effects are well known and comparisons of margins on results obtained over several years are widely disseminated, highlighting the economic benefits of introducing the diversification crop. For other crops, knowledge of the “carry-over” effects and margins on rotation remains very sparse, however, and inadequately supported by quantitative data. The accounting and management bodies that calculate for their customers average profit margins per crop in their region do not have the data required to qualify these margins on the basis of the previous crop or, better still, to perform calculations over a period of several years. While price fluctuations encourage the adoption of a short-term approach to cropping plans, farmers tend to lose sight of the benefits of a rotation-based approach, which would be favourable to diversification.

Problems related to the availability (and cost) of equipment and suitable technical references for diversification crops are encountered at farm level, but also at subsequent stages: the need to dry sorghum or the difficult-to-balance storage conditions for linseed can constitute obstacles to the adoption of these crops.

**Competition with "major crops" on the commodities market**

Numerous diversification crops have outlets (real or potential) in the animal nutrition sector. However, the production of compound feeds, based on the constant optimization of the nutritional composition and costs of feeds, leads to competition between numerous raw materials (grains as well as by-products of human nutrition or agrifuel sectors) and is mainly supplied by “spot” markets (where prices are set “day to day” or in the very short term). These economic approaches select raw materials on the basis of their nature as “commodities”, i.e. the fact that they constitute standardised products with perfectly defined and known characteristics and hence are easily substitutable. The criterion for choosing between commodities is therefore primarily based on their price per tonne, but also their accessibility (availability, logistics costs). Despite the high level of substitutability of raw materials, the result of these approaches is a tendency to simplify, favouring the wheat – soybean meal pairing.

![Diagram of animal feed formulation practices](image_url)

Disadvantaged due to their limited production in terms of volume, variable depending on the year and geographically dispersed, diversification crops are only able to compete with commodities if they present specific nutritional properties, known and valued by the market. This is the case for linseed, the seeds of which have a fatty acid composition (high omega 3 content) bringing that of animal products (milk and meat) more into line with current nutritional recommendations. Other crops have beneficial properties (high protein content of lupin seeds, etc.) but still remain little known.

Diversification crops are faced with similar competition in other industrial sectors, particularly the building insulation segment, in which hemp (and flax) fibres compete with glass wool, which is less expensive.

Organisations that collect and store harvested crops, be they brokers or cooperatives, favour the most profitable markets and specialise in a small number of crops in order to reduce their logistics costs. Once again, diversification crops have to compete with dominant crops for transport and silo space, again difficult to make profitable with low volumes.

**The diversity of coordination within the supply chains**

The literature concerning organisation economics reveals three main types of supply chain organisation, for which the characteristics are summed up in the table below. This coordination diversity reflects the diversity of stakeholders and the complexity of the relationships between companies and between the information subsystem and the operational subsystem of a supply chain.
• **Spot-type organisation**

The majority of animal feed supply chains in which diversification crops are used (except for linseed) are characterised by this type of organisation. Hence the obstacles to the development of peas, field beans, lupins and sorghum originate from this type of market organisation, which pits them against dominant raw materials (soybean meal, wheat, maize, rapeseed cake, etc.). These supply chains are characterised by strong competition between the raw materials, which are easily substitutable in formulation processes aimed at ensuring standardisation of market outlets. Consequently, it is difficult to effectively encourage farmers to incorporate these crops in cropping plans and the same is true when it comes to encouraging downstream stakeholders to use them. These supply chains are therefore characterised by weak coordination links between the upstream and the downstream, either in terms of transaction methods (few contracts) or information exchange (knowledge, technical references, etc.).

• **Vertical integration-type organisation**

These supply chains are characterised by strong vertical coordination, through the introduction of production contracts and specifications to guarantee traceable production, but also reflecting the need to ensure the specific quality of the raw material. To secure a regular supply, manufacturers sign contracts with collecting agencies, which in turn sign contracts with farmers. The latter are therefore encouraged to produce these crops by downstream stakeholders (manufacturers and cooperatives), via production contracts with prices index-linked on the basis of the dominant crops in the cropping plan, as well as via a support and training mechanism. The risk is shared between the farmer and the other stakeholders in the supply chains. This method of organisation is found in the case of linseed oil for animal feed and several human nutrition supply chains (condiment mustard, field beans for the Egyptian market, lupins, chick peas). These supply chains are also structured by networks of stakeholders bringing together the various links in the chain, facilitating the exchange of information between the various operators, as well as between operators and Research & Development structures.

• **"Hybrid" organisation**

Upstream, these supply chains are generally highly vertically integrated (production contracts between storage centres and farmers), but the downstream products are subject to competition on a less differentiated market, confronted with other products with similar properties (for example, hemp panels compete against glass wool, linen clothing against cotton clothing, alfalfa pellets against soybean meal, etc.). Manufacturers, which are often structurally linked to cooperatives seeking to diversify their markets, specifically want to secure supplies of a raw material and hence want to encourage farmers to incorporate these crops in their cropping plans. But the competitive difficulties encountered by the downstream market do not allow them to obtain sufficient added value to be able to fund these incentives and thereby extend their supply pool. This competitive difficulty may be due to a perception of inadequate product differentiation by consumers.

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The diversity of coordination methods between the stakeholders in the supply chains: case of three supply chains having been the subject of an in-depth study

<table>
<thead>
<tr>
<th>Specimen supply chain</th>
<th>Peas</th>
<th>Flax</th>
<th>Hemp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method of organisation of the supply chain</strong></td>
<td>Spot</td>
<td>Contract-based (+)</td>
<td>Hybrid</td>
</tr>
<tr>
<td><strong>Method of organisation of upstream relationships</strong></td>
<td>Spot</td>
<td>Contract-based (++)</td>
<td>Spot Integrated (++)</td>
</tr>
<tr>
<td><strong>Incentive for upstream production</strong></td>
<td>Low incentives (market price not very encouraging, occasional aids)</td>
<td>Incentives that vary in strength and credibility (index-linked guaranteed prices) depending on production areas</td>
<td>Incentives relatively strong for the various production areas</td>
</tr>
<tr>
<td>Transaction costs (related to logistics)</td>
<td>High (supply is too dispersed)</td>
<td>Low (existence of intermediaries aggregating a dispersed offer)</td>
<td>Moderate (competition between production areas)</td>
</tr>
<tr>
<td>Technical support</td>
<td>Low at local level, loss of technical expertise for the crop</td>
<td>High: provided by storage centre but variable depending on production areas</td>
<td>Localised references, inadequately shared between production areas</td>
</tr>
<tr>
<td><strong>Method of organisation of upstream-downstream relationships</strong></td>
<td>Low coordination. &quot;a-regionalised&quot; supply chain</td>
<td>Strong: organisation into colleges of each link in the chain</td>
<td>Contract-based at industry level</td>
</tr>
<tr>
<td><strong>Method of organisation of downstream relationships</strong></td>
<td>Spot</td>
<td>Integrated</td>
<td>Spot (competition of outlets)</td>
</tr>
<tr>
<td><strong>Organisation of the information system</strong></td>
<td>Weak upstream-downstream information transmission</td>
<td>Strong upstream-downstream information transmission (numerous intermediaries)</td>
<td>Strong transmission, within production areas Weak transmission between production areas</td>
</tr>
</tbody>
</table>
Levers for the development of diversification supply chains

The hypothesis adopted at the start of the study is that crop diversification assumes break-out from the socio-technical regime that dominates current agriculture. However, the network of stakeholders, the innovations and reference and key skill acquisitions that have accompanied the construction of major crop supply chains mean that they are better equipped to strengthen their competitive position on markets. If we wish to encourage the development of diversification crops, it is essential that they can offer sufficiently compelling competitive advantages. To achieve this, it would appear to be essential to act simultaneously and in a coordinated manner on three levers: market outlets, coordination of stakeholders and improvement of production techniques and varieties.

Promoting crop diversification requires the prior promotion of new market outlets

Against a background of agricultural policy deregulation, governments are demonstrating a desire to rely on more regulation by markets. Although it needs to be supported by the public authorities to be triggered, diversification will only be sustained in the long term if the actions of public authorities are supported by market mechanisms. Hence the choice, in this study, to begin with market outlets and to examine agricultural production approaches on the basis of market principles.

To create new outlets, a constant factor revealed in the case studies is the importance of basing the differentiation of products derived from diversification crops on qualities that are recognised by the market: nutritional quality (promoted by the Bleu-Blanc-Cœur label in the case of linseed); technological quality, often associated with a new patented process (thermo-extrusion of oil and protein seeds by the industrial firm Valorex, production of lupin protein powder by the cooperative Terrena, extraction of pea starch by the firm Roquette, etc.); environmental quality in the use of the product (hemp in the eco-construction sector); quality related to the source (official labels already present or to be created). Promotion of these qualities by the market brings extra added value liable to encourage and support the production of these diversification crops. However, this differentiation can lead to transaction costs (collection, storage, traceability, etc.) that might reduce the economic value, particularly in the presence of a fragmented diversification crop offer across the territory. The coordination of stakeholders in the supply chain is essential to reduce these transaction costs.

The coordination of stakeholders and structuring of supply chains play a major role

Given that only a strategy based on differentiation via quality could generate enough added value to promote the development of diversification crops, the supply chains related to these crops must manage the various transaction costs that could affect them at various stages: upstream production (choice of management techniques, choice of varieties, etc.), processing (choice of technological processes, choice of additives and ingredients, etc.), marketing (choice of distribution channel, etc.). For a farmer, adopting a new crop requires specific investments (in terms of equipment, as well as training and new knowledge in order to master management techniques). Opting to diversify is a risky strategy and these investments can therefore be considerable. To encourage farmers to make these choices, it is essential to guarantee an adequate and stable return on their investments. To achieve this, it is important that the supply chain providing access to the diversification crop market be coordinated on the basis of contracts, guaranteeing farmers technical support and an outlet for their product, and securing supplies for processors in the long term. Generally speaking, contracts signed for a period of several years help to encourage the long-term commitment of the various links in the supply chain to the specific production process set up. This approach thus provides greater transparency in terms of production choices, from the upstream to the downstream, ensuring that added value and knowledge are more effectively shared between the various stakeholders. However, the efficiency of a contract-based approach requires the contracting parties to be sufficiently balanced to ensure that the contract cannot be weighted too far in favour of one or the other. To this end, public policy regulating these long-term contracts may be useful.

This coordination between the stakeholders involved is crucial. The case of flax perfectly illustrates the risk of a market outlet opening up and then being filled by imports, due to a lack of adequate coordination between production and processing stakeholders. This coordination requires specifications guaranteeing the quality of the agricultural product and its traceability. It must also include the development and dissemination of references, as is demonstrated by the case of peas: it has been shown that it is possible to encourage farmers to produce a crop with a low annual profit margin by making them aware of the benefits of evaluating their cropping system over a period of several years. Inadequate structuring of supply chains and poor coordination between the various upstream and downstream stakeholders appear to represent a major cause of failure for the building of new chains.

In most of the cases analysed, the impetus for diversification was initiated on a local level, with the production area appearing to represent an ideal scale for the emergence of a new supply chain and the coordination of the stakeholders involved in it. Sometimes the supply chain remains limited to this scale (chick peas, mustard) and sometimes it is extended to other regions (flax, hemp). Cooperatives play a major role in the construction of these local supply chains, by mobilising farmers and negotiating agreements with downstream stakeholders, opening up market outlets. But the in-depth analysis of the three cases demonstrates the importance of simultaneously mobilising other stakeholders: agricultural R&D, plant breeders, management centres. It is necessary to promote the emergence and consolidation of local drives of this type in order to develop innovation niches. What can be done to ensure that the various stakeholders involved in the supply chains (cooperatives, processors, distributors) and in agricultural R&D (research bodies, technical institutes, chambers of agriculture, cooperatives, Civam (French centres that promote agriculture and the rural environment), etc.) and the farmers coordinate their
strategies with respect to a diversification crop? Would it be possible to create original partnerships inspired by the industrial clusters developed in other fields (such as aviation or computing, for instance)? The latter, which are supported by long-term public policies (10 years, with assessment midway through the period, for example), could promote the application of technological, agronomic and organisational innovations and capitalisation on the experience (technical and economic) required for the construction and long-term future of new agro-industrial supply chains. To this end, European Innovation Partnerships (EIPs) in the area of “agriculture”, as envisaged by the European Commission, could offer the ideal framework. These EIPs aim to develop “local innovation groups”, uniting the various stakeholders in an area around local issues, while encouraging capitalisation on knowledge and experience.

Getting R&D, advisory and plant breeding actors involved on a national and regional level

Although the impetus for coordination between the various stakeholders often originates at local level, an investment on the part of national research and development bodies, working in a coordinated manner with their European counterparts, is essential, both to create knowledge relative to diversification crops (genetics, ecophysiology, agro-ecology, processing technology, economics of supply chains, etc.) and to provide methodological support to the stakeholders involved in the emerging supply chains (selection methods, support for the construction of cropping systems or industrial processes, for example). Investment in some diversification crops is already significant, as demonstrated by the bibliometric analysis conducted in this study. However, several crops do not appear to be the subject of any real Research & Development (R&D) investment at present, for French conditions: lupins, condiment mustard, chick peas, as well as lentils, buckwheat, etc.; others are relatively well known on an agronomic level, but very few basic genetic studies have been conducted: hemp, flax, oats, etc. Setting a national objective of curbing the specialisation process implies questioning the balance of R&D investments between major crops (wheat, maize, oilseed rape, etc.) and minor ones. Reinvestment focusing on the latter needs to be carefully thought out and coordinated on a regional, national and European level.

On a regional level, it would appear to be essential to consolidate and adapt the references relative to productivity, profit margins and the “carry-over” effects of diversification crops. Although, nationally, the scientific literature often highlights the beneficial effects of diversification crops on subsequent crops (and sometimes quantifies these benefits), the references rarely have a regional focus. A sustained effort (on the part of R&D, advisory and accounting/management bodies) to disseminate quantified information, concerning the comparative profit margins of rotations diversified to varying degrees, was shown to be essential. This has to be done along with the organisation of support offered to farmers to help them learn about new crops, via the reinforcement of trial and advisory networks as well as innovative experience-sharing between farmers’ groups. The production contracts offered to farmers could schedule the incorporation of simple mechanisms to collect indicators suitable for explaining performance variabilities (between fields, between years) and guiding practices. Thus, as stakeholders in the collective innovation process related to the development of the diversification process, farmers would be more inclined to invest in the new supply chain for the long term.

However, tensions were revealed between competing regional trajectories, which could be detrimental to the setting of consensual selection objectives and the sharing of references. While the development of diversification crops remains the domain of local stakeholders, uncoordinated on a regional level, it will rapidly reach a ceiling. From the moment that several production areas are formed with different stakeholders, it would appear to be essential to construct a solid structure linking these stakeholders in order, firstly, to initiate dialogue with plant breeders regarding the selection objectives to be favoured and, secondly, to organise exchange and the adaptation of references between areas.

What levers for public action?

One of the major conclusions to emerge from the study, supported both by the scientific literature (lock-in and transition theories) and the results of the field survey, is that any process towards diversification is necessarily dependent on the simultaneous and organised mobilisation of numerous stakeholders. To drive or facilitate this mobilisation, public action must adopt a systematic approach and combine a variety of complementary measures designed to link together and coordinate the strategies of the different stakeholders involved. In the complex situation described in the study and given the numerous interdependences and sources of lock-in that it highlights, there is no longer any place for superficially attractive over-simplifications, such as “one problem, one solution” or “one public policy objective, one instrument”.

The theory of socio-technical transitions leads us to propose the simultaneous and coordinated mobilisation of two major categories of levers: (i) develop innovation niches, places for the implementation of learning processes and the construction of new economic networks; the purpose of these niches will be to play host to the construction and consolidation of diversification supply chains; (ii) encourage the standard socio-technical system to evolve, to open up new windows of opportunity, through which certain diversification supply chains will be able to grow and expand beyond the niche status, or even to form a hybrid with the standard system, thereby contributing to its evolution, i.e. its transition.

1- Support the development of innovation niches, for the construction and consolidation of diversification supply chains. The supply chains to be supported could be chosen on the basis of their potential market outlets and the dynamism of the stakeholders concerned, as well as their impact on the environmental performances of cropping systems. The possible actions will have the following objectives:

- To promote the implementation of and support relatively long-term (for example 10-year) partnership mechanisms between supply chain, R&D, advisory and public research actors, plant breeders and local
authorities, aimed at constructing diversification supply chains on a local or regional level. In particular, these mechanisms should help build and secure the long-term future of networks of stakeholders and contribute to the incubation and validation of the technological, agronomic and organisational innovations required to ensure the competitiveness of the market. They would aim to rally the support of all the stakeholders of the supply chain around projects favourable both to regional development and the environment. It is possible that mechanisms of this type could be supported as part of the second pillar of the CAP and, in particular, within the European innovation partnerships currently being constructed.

- To reinforce the label system (primarily official quality labels) making it easier to signal characteristics of the products derived from diversification to consumers by highlighting a specific quality, such as an environmental and/or nutritional quality. To this end HVE (Haute Valeur Environnementale - High Environmental Value) certification could contribute to the development of diversification crops. The introduction of an "agriculture-health" quality label for products with a high nutritional quality (such as animal products with a high omega 3 content, dried vegetables) could also promote some diversification crops.

- To sustain technological and genetic innovation relative to diversification supply chains. Generally, this point is related to the programming of public research choices, the funding of clusters in the agrifoods sector and, doubtless, the priorities of the future investment bank. As regards varietal innovation more specifically, several routes (non exclusive) can be taken: encourage public research reinvestment in orphan species, organise partnerships between public and private stakeholders for the selection of minor crops, support private plant breeders investing in diversification crops, in a coordinated manner with production and processing stakeholders. Innovation support should also concern the provision of plant health solutions for minor uses, in particular "diversification crop / pest" pairings for which there are no efficient alternative solutions.

- To promote investment on the part of the entire French agricultural R&D system in the field of ecophysiology and the management of diversification crops (to understand and reduce yield instability), diversified cropping systems and the ecological role of crop diversification at landscape level. The objectives would be to develop, for all diversification crops: (i) regionally adapted references concerning their performance, from a quantitative, qualitative and environmental point of view; (ii) references concerning their "carry-over" effects and the profit margins over a period of several years; (iii) diagnostic tools to help farmers analyse and resolve failures while they are learning to grow new crops. The creation of references concerning diversification crops and diversified rotations could be a compulsory theme in the objectives contracts of bodies financed by Ministry of Agriculture funds dedicated to agricultural and rural development. Farm management bodies could be encouraged to offer their clients analyses over a period of several years including "carry-over" effects or rotational margins. Finally, although the study did not examine this point in detail, it would be a good idea to step up research in the area of mixed arable and livestock farming systems, the historic decline of which has contributed to the simplification of cropping plans.

- To promote an observatory to monitor minor crops in regions and their role in cropping plans and rotations, in order to track the diversification process at work and be able to assess the agronomic, ecological and economic implications. To do this, it would be necessary to differentiate between the various minor crops in statistics, since at present they are often grouped together into a single category, making monitoring difficult.

2- Encourage the standard socio-technical system to evolve, in order to more effectively integrate diversification crops. The following proposals aim to modify the "landscape" of the standard socio-technical system in order to encourage stakeholders to change their behaviour with respect to diversification crops and markets. These levers are not derived from the three in-depth cases but were mentioned by the experts questioned for the first part of this study:

- Encourage crop diversification via CAP regulations: the diversification measure in the CAP 2013 greening component represents a first signal, even though studies conducted under the auspices of the General Commission for Sustainable Development, for example, suggest that it will have only limited effects as it currently stands. The long-term maintenance and stepping up of specific support for leguminous crops could have a beneficial effect, as long as the supply chains related to these crops are consolidated.

- Promote diversification supply chains via public contracts (mass catering for public institutions, insulation using local agricultural resources in public buildings, etc.), which almost certainly requires changes to contract awarding criteria.

- Encourage the reduction of inputs: given the historic link - highlighted in the introduction - between the simplification of cropping plans and rotations and the increase in input consumptions (water, pesticides, fertilisers), any public action aimed at reducing the use of inputs will be liable to facilitate a trend towards crop diversification.

Since they are aimed at processes with a high level of inertia, all these proposals can only be effective if the corresponding measures are implemented over the long term (10 years rather than 5 years) and highlighted, from the time they are implemented, as measures that need to be sustained. This condition is essential to encourage - both for selection and for the processing supply chains - the specific and long-term investments required to trigger innovation and to consolidate credible, long-term actions by all the stakeholders involved in the transition process.

To find out more:

This synoptic document and the study report (200 p) can be consulted on the INRA website (www.inra.fr).