Towards healthy and sustainable food ?

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TOWARDS HEALTHY AND SUSTAINABLE FOOD ?

The world's population is growing and with it the need for agricultural and food resources, as well as the impact on the environment. To meet these challenges, research is taking action and developing concrete solutions with its partners, in particular to facilitate the adoption of diets that are both healthy and sustainable.


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SUSTAINABLE & HEALTHY EATING, THE BASICS

Healthy for humans and sustainable for the planet: the equation for our diets is a hard one to solve. However, the foundations for building this new paradigm are beginning to emerge.
An analysis of western customs and practices.

If we only ate fatty and sweet products whose production is low in greenhouse gas (GHG) emissions, our diet would have a low impact on the environment, but a deleterious one on our health. If we were to cut out soft drinks, cured meat products and crisps and eat mainly fruit, vegetables, dairy products and fish, our diet would be healthy, but socially difficult to accept by a large part of the population. And if there were a diet that was at once healthy, more environmentally friendly and acceptable, it would still have to be economically accessible to all.

Sustainability, beyond environmental issues

According to the Food and Agriculture Organisation of the United Nations (FAO), the sustainability of a diet is based on several criteria: it must have a low impact on the environment; it must contribute to the food and nutritional security of the population; it must be culturally acceptable, economically equitable and accessible.
However, the cultural, economic, social and agricultural situations are so diverse around the world that it is impossible to define "the" diet that could be adopted by the whole world population. There is thus a variety of conceivable and desirable developments in our diets. As far as France is concerned, the State relies on the nutritional recommendations issued by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) in order to establish the National Nutrition and Health Programme (PNNS), which supports public policies aimed at improving the nutritional and health situation of the population. The main points of this plan are: to reduce our consumption of sugary products and drinks, cold cuts and meats (except poultry); to control the consumption of highly processed foods; to consume fish from sustainable stocks; to emphasise local and seasonal foods; to increase our consumption of plant products of good nutritional quality such as whole grains, legumes, fruit and vegetables...

These recommendations allow us to move towards a healthier diet, but do they allow us to have a lesser impact on the environment? To answer this question, INRAE researchers have studied the diets of the French.

The environmental impact of diets

Studies (INCA 3 2014-2015, ANSES collective expertise 2017 and CREDOC 2013) on the French population show that the 20% of people with the best diet from a nutritional point of view consume less meat, cured meat products, sweetened and alcoholic drinks, and more plant products than the average. By doing so, their diet emits 18% less GHGs and is therefore more environmentally friendly.

To go further, the researchers used modelling to design a diet that meets the nutritional recommendations and further reduces GHG emissions. With a greater reduction in animal products, an increase in plant products and a decrease in the consumption of hot beverages (like coffee and tea), the researchers found a diet that emits 30% less GHGs than the current average diet. These two diets, the observed and the modelled, cost less than the current diet (€6.20 and €6.40 per day per person, instead of €6.70) but are still unaffordable for part of the population – bearing in mind that the average French budget stands at between €5 and €6 per day per person, and around €3.50 for the lowest income households. Moreover, the question of their social and cultural acceptance remains, particularly for the reduction in meat consumption.

What place for meat?

Meat consumption is very uneven around the world (an African consumes 6 to 10 times less meat than a Westerner, and an Asian 2 times less), but it is projected to increase by 60% by 2050, due to the combined increase in the world's population and the purchasing power of fast-growing countries. While animal products provide all the amino acids we need and are the main source of vitamin B12, iron and zinc essential during pregnancy and growth, excessive consumption of meat, particularly red meat, can have adverse health consequences. Its saturated and monounsaturated fatty acids can lead to cardiovascular disease. Recent studies conducted at the TOXALIM Research Centre in Food Toxicology have shown the link between excessive consumption of red meat or cured meat products and colon cancer. Moreover, livestock farming, particularly ruminant farming, is responsible for a portion of GHG emissions. Indeed, at the global level, direct and indirect GHG emissions from livestock farming are estimated at 14.5% [1] of total emissions linked to human activities, the equivalent of 7.1 gigatons of CO_2 each year. In addition, animal welfare, a growing concern in society, calls into question certain production practices in industrial livestock farms. But while it is undeniable that a reduction in meat consumption is in the interest of the environment, livestock farming also has its virtues.

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250 kcal
Desired reduction in daily calorie intake

30%
Potential for GHG emission reductions with the adoption of less meaty and more plant-based diets

+60%
Estimated increase in global meat consumption by 2050

500 g
Recommended meat consumption (excluding poultry) per week per person

1. Direct and indirect emissions related to food production, energy consumption, enteric fermentation, etc. Source FAO: www.fao.org/3/i6345e/i6345e.pdf

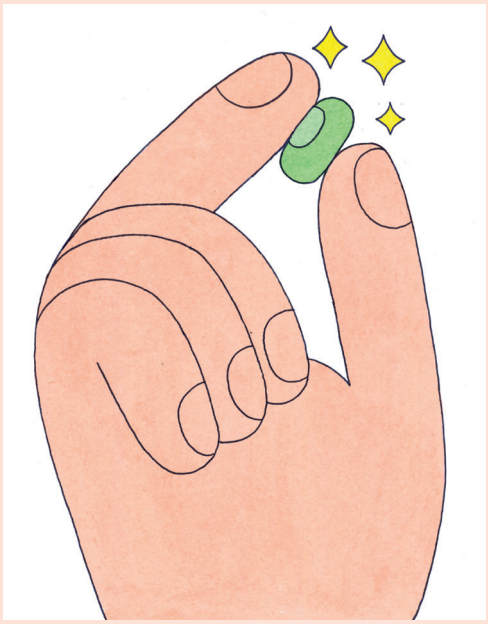
Preserving livestock farming

Livestock farming allows the use of uncultivable agricultural land as temporary or permanent grasslands (more than 5 years without cultivation) which play a major role in storing carbon in the soil. Animals also enable the valorisation of co- and by-products of the plant sector that cannot be consumed directly by humans, or provide organic fertilisation of the land. Furthermore, if everyone adopted a diet based solely on plant products, the increase in demand for these products would proportionally increase the need for cultivated land and probably the quantity of pesticides used. The recommendations of the World Health Organisation (WHO) therefore call for a rebalancing of intakes between animal and plant products. In France, this would mean changing our ratio of animal and plant protein consumption from 65/35 to 50/50 on average.

Sustainable eating means thinking food systems

Consumption should not be thought of separately from agricultural production. A sustainable diet starts with environmentally friendly production. →

Rebalancing animal and plant proteins intakes in western diets is key.



SOLUTION

Promising legumes

At present, legumes are good candidates for solving the complex equation of a healthy and sustainable diet: lentils, broad beans and dry beans for human consumption; peas, horse beans, clover and alfalfa for animal feed. Both good for our health and the environment, they are an essential link in the transition to sustainable diets.

As a source of protein (20 to 40% depending on the species, compared with 10 to 13% in wheat, for example), legumes allow us to cut down on our consumption of meat and reduce the need to import soya for animal feed. In addition, legumes have agronomic and even climatic advantages. Integrated into crop rotations, they can act as a nitrate trap and fix nitrogen for the following crop. They help to break the cycle of diseases, pests and weeds, and thus to use less pesticides on a crop rotation scale.

Despite these many advantages, legumes account for only 4% of the utilised agricultural area in France and the consumption of dried pulses (such as lentils, beans, broad beans and chickpeas) has dropped to a quarter over the past 20 years to reach very low levels in France (2 kg per person per year in 2020 according to Agreste). How can this disenchantment be explained? As far as consumption is concerned, one can blame the time they can take to cook, the digestive disorders they may cause or an exacerbated taste of the "green note" type. They are also victims of prejudice: studies show that dried pulses are associated with a vegetarian diet and are not perceived as a source of protein but rather as an accompaniment to meat. On the production side, their high sensitivity to climatic stresses, such as frost or drought, and their low resistance to biological pests lead to uncertain yields. Neglected for years, the value-added chains are today relatively unstructured. Logistics are complex and costly for small volumes. These productions are thus seen as economically unattractive in the absence of public aid.

Weaknesses that researchers are trying to overcome, from production to processing and consumption. They are, for example, developing new pea and horse bean varieties that are more resistant to drought, frost and disease, as well as new legume-based products *(see article on page 25)*. This objective is directly supported by the French government with the "plant protein plan" launched in 2020, which aims to double the agricultural area used for crops rich in plant proteins (like soya, peas, dried pulses, alfalfa and feed legumes) over a 10-year period, to reach 8% of the utilised agricultural area at national level.

20-40%
Proportion of protein in legumes

8%
Target of French agricultural area devoted to legumes in 2030, compared to 4% in 2020

2 kg
Consumption of dried pulses per person per year in France in 2020

100%
of the amino acid intake provided by a legume/cereal combination

"It's a virtuous circle, producing better allows us to eat better, and eating better allows us to stimulate demand for better production", says Sophie Nicklaus, an INRAE specialist in eating behaviour at the Centre for Taste and Feeding Behavior (CSGA) in Dijon. Today, our food systems (including agricultural practices, manufacturing processes in the agrifood industry, transport methods and distance travelled by products) have an impact on our environment, such as water and soil pollution, GHG emissions, deforestation and loss of biodiversity, as well as on our health, since a polluted environment and unsustainable environmental practices will increase our exposure to various contaminants.

... and adopting more agroecological practices

On the fields, it is a matter of developing more environmentally friendly models. Agroecology is a good example. The principle: agricultural practices (like biocontrol, winter cover crops, intercropping and permanent grasslands) that rely on the functionalities offered by ecosystems with the aim of reducing GHG emissions, limiting the use of synthetic inputs and preserving natural resources. Organic farming, characterised by the absence of synthetic inputs and antibiotics, is also a good way of greening agricultural practices with the added bonus of beneficial impacts on health. Recent research based on the Bio NutriNet study, which followed 69,000 people over 7 years, showed a 25% reduction in the risk of cancer (all types) in regular consumers of organically produced food, compared to those who consumed it less frequently. Research is ongoing in order to explain these results. For Emmanuelle Kesse-Guyot, an INRAE epidemiologist with the Nutritional Epidemiology Research Unit (UMR EREN), several leads need to be explored: *"potentially higher levels of certain micronutrients (antioxidants, carotenoids, polyphenols, vitamin C or more beneficial fatty acid profiles) in organic food, or the presence of synthetic pesticide residues, more frequently and in higher doses, in conventionally farmed food compared with organic food."*

At this stage, these are only hypotheses, as researchers are still assessing the potential relationship between the consumption of organic products and health, as well as the links between pesticides and metabolic diseases (such as diabetes, obesity and hypertension) or cancer. What is certain, however, is that at the individual level, those who consume large amounts of organic products have adopted a diet that emits far less GHGs as they tend to have a more plant-based diet than other consumers. However, converting all agricultural land to organic agriculture would also have its limits: with lower yields, feeding the planet with organic agriculture raises the question of the availability of more arable land.

Adapting western diets: eat less, locally and seasonally?

While studies show that reducing the consumption of animal products has the greatest potential to reduce GHGs, complementary actions can also contribute. Eat less? The studies cited above indicate that Western diets should be reduced by 250 kcal to 3,000 kcal per day per person, including waste (i.e. 1,850 to 2,000 kcal actually consumed). Halving consumer food waste would reduce GHG emissions by about 5% on a global scale.

As for the very popular "eat local", it is not necessarily synonymous with sustainability. Indeed, although transport by air does increase the carbon impact of a food item, it represents only 1% of the fruit and vegetable import tonnage, and has therefore a limited overall impact. *"If we have to point the finger at a problem with food transport, we should look at the distance between the place of purchase and the home, which can account for up to 40% of a food's carbon impact"*, says Nicole Darmon, an epidemiologist at the Montpellier Interdisciplinary Center on Sustainable Agri-food Systems (social and nutritional sciences) (MoISA). Thus, going to →

Food systems are responsible for almost one third of global greenhouse gas emissions.

Cutting consumer food waste in half would reduce global GHG emissions by 5%.

pick up strawberries from a "local" producer by car is not necessarily more sustainable than eating an imported product. Eat seasonally? Again, it all depends on what you are looking at. For Emmanuelle Kesse-Guyot, the most important thing is to produce in season in order to limit the use of heated greenhouses, but there is nothing to stop you from eating in winter a tomato coulis produced in summer!

Food accessible to all

Does eating healthy and sustainable food have a cost for the French consumer? For Nicole Darmon, the impact would appear to be small. On the one hand, reducing meat purchases tends to bring down costs, especially as it represents the largest item in the food budget of the French. On the other hand, eating more fruit and vegetables can increase costs, even with the less expensive legumes. But Nicole Darmon warns: *"it is very difficult to have a healthy and sustainable diet below €3.50 to €4 per day per person"*.

Furthermore, when people are constrained by their budget, they tend to choose foods that provide cheap calories, such as refined cereal products and fatty and sweet products. These products –typically crisps and biscuits– are poor in essential nutrients and are often loaded with sugars or salt, which, when consumed in excess, make them harmful to our health. On the other hand, they are convenient, comforting and have the advantage of being wasted less...

Eating more sustainably undoubtedly implies that our diets should become more plant-based. But beware, reducing the share of animal products will only serve the sustainability and quality of our diets if it is to the benefit of a wide variety of plant-based products of good nutritional quality while at the same time bringing about conceivable changes for the consumer in terms of habits and budget. Even though eating more sustainably seems to be within the reach of Western countries such as France, it requires a strong political will to make transitions at all levels: production, processing and consumption. ●

40%

Share the carbon impact of a purchase/home journey for food can reach

3.50 to 4 €

Minimum budget per day and per person for a healthy and sustainable diet

ARE FRENCH CONSUMERS READY?

There is a consensus on the need to move towards more sustainable agricultural and food systems. But this transition can only be achieved if the consumer, at the end of the chain, changes his behaviour and habits. How can this be achieved? **Decoding the case of France.**

Social representations, accessibility, psychological factors and collective dynamics: the act of eating is more than the ingestion of food. Our eating behaviour is both linked to our sociocultural environment and subjected to psychological and physiological mechanisms.

Taste and conviviality at the heart of our behaviour

While food serves a vital need, it is also a source of gustatory and social pleasure when meals are shared at the table. This notion of pleasure is essential and plays a driving force in our choices: *"pleasure is linked to the food itself, to the social context and to the representations associated with the food"*, explains Sophie Nicklaus, an INRAE specialist in the study of eating behaviour at the Centre for Taste and Feeding Behavior (CSGA) in Dijon. A pleasure that can be taught from a very young age. INRAE is thus working with Santé publique France (the government agency for public health) on the dietary practices of parents to promote appropriate eating habits in children. This early food education is particularly important because the foundations of eating behaviour are laid during the first years of life, and the prevention of chronic diseases linked to food, such as obesity, is all the more effective the earlier it is implemented. Recent studies have shown that eating habits can be established as early as... during pregnancy! A study carried out on minipigs (an animal model close to humans in terms of physiology) has shown that a maternal diet during pregnancy and lactation, respecting a normal caloric intake but too rich in fat and sugar, has negative impacts on the lipid balance, the metabolic activity of the intestinal microbiota and leads to the production of neurons in an area involved in learning and memory in piglets. Thus, piglets fed this diet in utero were more motivated by fatty and sweet food rewards.

Learning to enjoy

Making our eating behaviour evolve also requires repeated exposure to a food. A new, unknown food is a priori rejected. By repeating the exposure to this food and doing so in a familiar and friendly context, the chances of being accepted will increase: *"This is for example the case of coffee, which is very bitter, but to which we are exposed* →

NUTRINET-SANTÉ

The transition monitored on a daily basis

Impact of prices on consumption, organic or conventional products, environmental impacts, economic trade-offs linked to purchases... Since 2009, the NutriNet-Santé project has been studying the relationship between health and food, and in particular the sustainability of food according to individual lifestyles. This cohort is based on the monitoring of volunteers, who are regularly questioned via online questionnaires about their lifestyle, consumption, health and environment. *"With more than 100,000 participants, the cohort allows us to obtain detailed behavioural analyses"*, explains Emmanuelle Kesse-Guyot, research director at INRAE. And indeed, all types of profiles are represented: the employed and unemployed, students, retirees, vegetarians, flexitarians, vegans and so forth. Emmanuelle Kesse-Guyot concludes: *"The people we are following have agreed to it, they are volunteers with a particular profile and they are more inclined to follow a balanced, sustainable and healthy diet... But we must see this cohort as a living lab! If these people are capable of approaching a healthy and sustainable diet, it means that the dietary transition is possible."*

OBSERVATION

Less cooking for more leisure time

Social progress and the resulting lifestyles have greatly changed our eating habits since the second half of the 20th century. Fabrice Etilé, an INRAE economist at the Paris School of Economics (PSE) has studied the evolution of time spent cooking, together with Marie Plessz, an INRAE sociologist at the Centre Maurice Halbwachs (CMH). *"We observe on average a decrease in cooking time between 1985 and 2010, going from 68 down to 55 minutes per day. 60% of the observed reduction is linked to the integration of women into the labour market."* Marie Plessz notes that the "meal norm", consisting of three meals a day, at fixed times, and allowing the household to gather around the same table, has been maintained in France, unlike the United States. *"The culinary culture of these two countries is known throughout the world. Even though it is very different, it is based on the idea that women are responsible for the food the family eats. We are still far from gender equality in this field: the decrease in the amount of time spent cooking by women has not been offset by an increase in the amount of time spent by men... It is a significant workload, unpaid and still largely invisible"*, says the sociologist. The decrease in the amount of time spent cooking, combined with the increase in income and education levels and the expansion of the agri-food industry, has favoured the development of ready-to-eat products at the expense of cooking from scratch. These ready-to-eat products *"meet one of society's demands: to have more free time"*, says Fabrice Etilé.

TIME SPENT COOKING PER DAY

68 MIN
in 1985

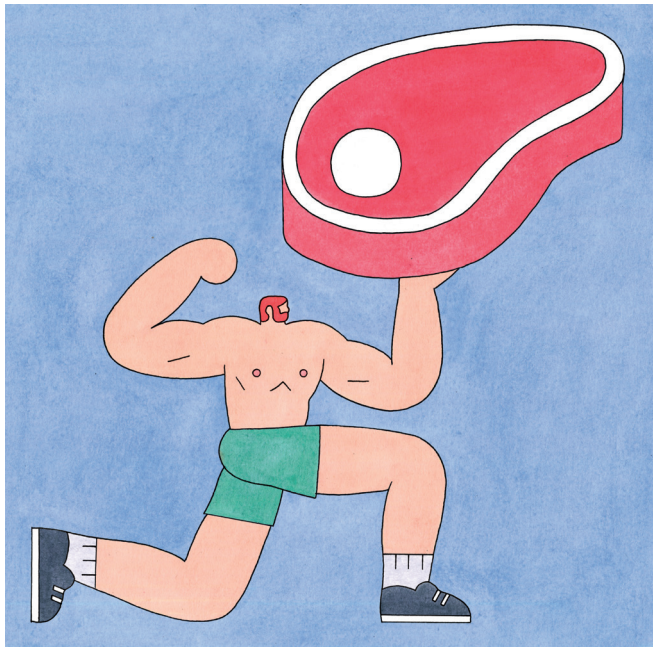
55 MIN
in 2010

regularly, at work during the coffee break, in the family circle. We are exposed to it in a positive context, which leads us to try this food again despite a taste that is not always appreciated at first", explains Sandrine Monnery-Patris, a researcher in cognitive psychology at the CSGA. Thus, offering plant-based protein dishes in the canteen could help children appreciate these products, but only if it is in a positive environment. A major challenge is to raise awareness and train canteen staff regarding the context and environment of the meals, especially with regard to novel foods.

Overcoming social representations

The strength of social representations and our cultures guide our diets. As a result, the adoption of nutritional recommendations comes up against numerous psychological biases. For example, replacing meat, still very much present on Western menus, seems difficult for the consumer. Sandrine Monnery-Patris' work explains this, showing that animal protein is associated with strength and virility, whereas plant protein is associated with lightness and femininity. In addition, meat is seen as the main element when we have to prepare a dish, whereas plant proteins (cereals, dried pulses) are seen as sides. In her opinion, these results explain why it is difficult for the consumer to replace a food that is synonymous with strength and at the centre of the dish with a food that is more associated with lightness and considered peripheral. Among the beliefs that have a life of their own, we can mention the issue of the practicality of dried pulses. For the people interviewed

Plant-based protein dishes in the canteen could help children appreciate these products, but only in a positive environment.



as part of the researcher's work, one obstacle to the consumption of these foods is their supposedly long preparation time, whereas in reality, there are now a good number of dishes based on legumes or cereals that do not require any additional preparation time. Another image to be challenged is that dried pulses are food for vegetarians or vegans...

To overcome these prejudices, the researcher points out that information and communication are effective means. It is a question of communicating on taste and proposing attractive and easy-to-make recipes.

Commitment as a driver for change?

Some consumers are committed to changing their diet, such as vegetarians or vegans. Benjamin Allès, an epidemiologist at the EREN research unit, explains that *"among the motivations of people turning to a diet that limits or eliminates animal products, the most frequently reported are animal welfare, the environment and sometimes health"*. The observations of the NutriNet-Santé study also indicate that nowadays the majority of people who exclude all or part of animal products from their diet belong to high socio-professional categories. →

This shows that the level of education and the ability to learn and integrate new benchmarks are important factors for change. However, the probability of adopting a vegan diet is rising among participants with a lower socio-economic level, suggesting a broadening of these categories of people. Furthermore, Stéphan Marette, an INRAE economist in the Paris-Saclay Applied Economics unit, points out that *"even though consumers may be aware that for their health and that of the environment it is better to change their diet, and may be interested in the approach, this does not mean that they will respect these recommendations. In particular, they face limitations in terms of budgetary capacity, attentiveness when shopping and/or memorising complex information which often prevent them from turning to more virtuous foods."*

Cost, a barrier to change?

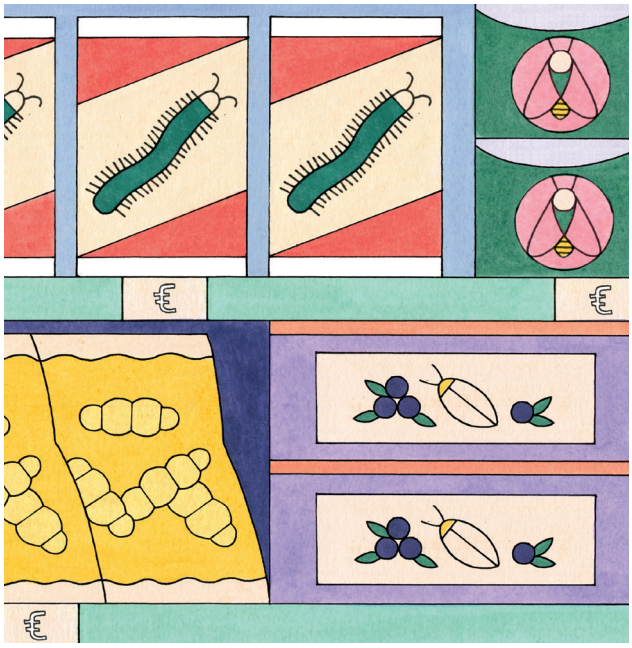
Obviously, especially for those with small budgets. The average food budget observed among disadvantaged households is around €3.50 to €4 per day per person. According to Nicole Darmon, below this budget, *"it is very difficult, if not impossible, to have a diet that meets all the nutritional recommendations"*. These results were obtained by observing the purchases made by these households, but also through modelling. When a nutritionally good diet is modelled for the lowest possible price, the minimum is €3.85 per person per day for an adult. As for the average French food budget, it is €5 to €6 per day (excluding alcoholic beverages). In contrast, in Western countries, the shift to a more sustainable diet will result in a small decrease in the cost as a result of reduced meat consumption.

Because of all these obstacles, the researchers at INRAE insist on the importance of small steps to achieve the objectives set. As Stéphan Marette points out, it is gradual changes that will facilitate the change of habits such as *"original recipes, more pleasant meals in the canteen... In short, tricks that make it possible to incorporate modest but realistic changes"*. And that, on a large scale, will bring about transitions. ●

FORESIGHT

Insects on the plate, is it possible?

Meat, eggs, fish, dairy products, dried pulses and cereals are the main sources of protein consumed in Western countries.
To successfully feed the world's growing population, other sources of protein are being explored, such as insects. Currently, about 2 billion people, mainly in Africa, Latin America and Asia, consume about 2,000 different species of insects worldwide.
However, in Western countries, insects are not yet part of our menus because their consumption raises questions: health issues, as the European Food Safety Authority (EFSA) only issued a positive opinion in January 2021; and cultural issues, as the consumption of insects still comes up against social representations. In France, a few start-ups have embarked on insect production, but for Benjamin Allès, an epidemiologist at the EREN unit, *"the most likely scenario is that insects will be consumed in the form of meal, or indirectly via the feed of farm animals, mainly for fish and chicken."*



In order to facilitate the transition to healthy and sustainable diets, researchers are experimenting with new, more attractive plant-based foods. To this end, legumes are making their way into the development of new product recipes. **An update on tomorrow's foods.**

LEGUMES, STARS OF THE LABS

Mitigating climate change, reducing the need for synthetic fertilisers, maintaining water and soil quality... In addition to contributing to healthy food systems, legumes seem to be able to meet society's new requirements, particularly in the face of environmental challenges. In the context of research on human nutrition, scientists are particularly interested in pulses, including soya, peas and lentils... After being shunned for a long time because they suffered from a poor image – difficult to digest, long to cook,...– these legumes are now back in the limelight. They are a source of protein, vitamins, fibre and minerals, have a low glycaemic index, limit the risk of cardiovascular disease and promote a feeling of satiety. Eaten with cereals, they provide all the amino acids we need and are a source of protein that can reduce our consumption of meat and our dependence on imported soya...

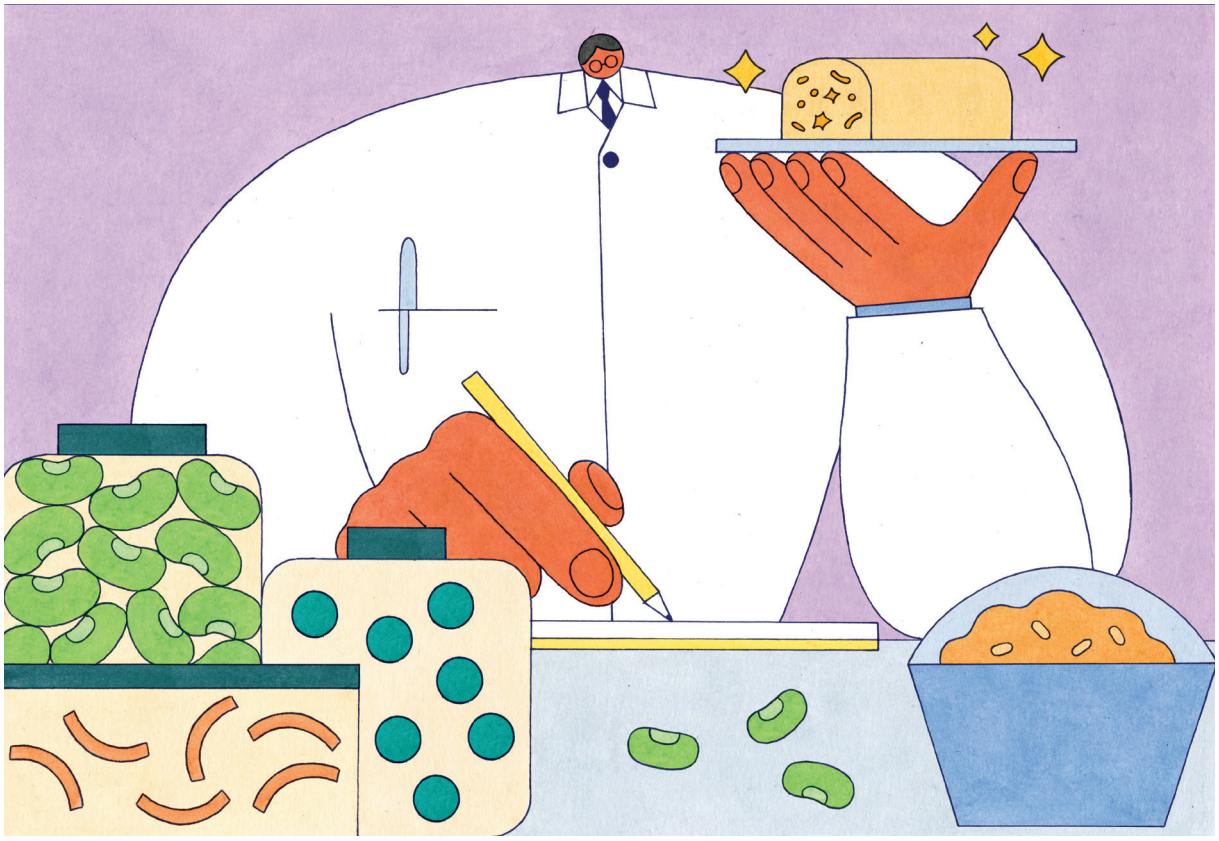
However, there is a downside: since the 1990s, French legume production and acreage have collapsed. The lack of outlets coupled with the problems of production and processing of legumes means that the sector is finding it difficult to structure itself. In the absence of public aid, these crops have been considered economically unattractive until now. At the end of 2020 and in an effort to help the sector, the government set up a new €100 million "plant protein plan", whose objectives include increasing the area under legume production by 40% in three years and supporting research and development in this sector. INRAE scientists are actively involved in this field and are working to facilitate the return of legumes to the consumer's plate, in particular by including them in recipes for products commonly consumed by the population.

€100 million
Budget of the "plant protein plan"

+40%
Target increase of area under legume production by 2024

For dairy products

INRAE is developing new manufacturing processes for foods such as dairy products. Stéphan Marette, an INRAE economist in the Paris-Saclay Applied Economics unit, is working on ways to combine and balance the plant and animal based parts of our diet: *"Even if we can note an increase in vegetarian or vegan diets, for the time being, 95% of consumers prefer animal derived products... Mixing cow's milk and plant proteins provides a way of initiating the dietary transition while limiting changes in eating habits, and preserving the hedonic aspect linked* →



to the consumption of milk", he explains. This is how a *"vegetarian milk product"* saw the light of day on the researchers' bench and is the subject of several patents with different compositions of up to 50% milk and 50% pea flour, the maximum level to still contain enough lactic ferments and to ensure that the taste is not too modified for the consumer. *"In our studies, the most popular products are for now those containing 25% peas and 75% milk."* Stéphan Marette emphasises that the industry has yet to be created, along with increased production in the field.

> **"Mixing milk and plant proteins provides a way of initiating the dietary transition."**
>
> Stéphan Marette, INRAE economist

For the softness of cakes

For its part, the SayFood joint research unit is working on obtaining a soft cake made from legume and cereal flours as this combination leads to a protein profile that is more balanced in terms of essential amino acids compared to cakes made exclusively with wheat flour. The FlexiProcess project has led to the development of a soft cake containing pea flour.

Camille Michon, former head of the unit (now director of Human Resources at INRAE), explains that this product was chosen because *"it is a product of mass consumption, which can impact the whole sector if the integration of the legume in the recipe is accepted by consumers"*. How do you find the right mix of wheat and pea flours to ensure the softness of the cakes and the honeycomb structure of the crumb? A multi-criteria and multi-constraint model was designed, taking into account, among other things, the proportion of pea flour in the cake, the particle size of the wheat and pea flours, the speed and duration of the mixing of the fat phase as well as the baking temperature. The idea behind it? Demonstrate that it is possible to equip oneself with tools to help steer the process and better

A genuine breeding ground for innovation, legumes meet nutritional and environmental needs.

control the quality of the finished products by correcting the effects of a raw material that is not fully standardised.

For the diet of the elderly

Here again, legumes are a solution to prevent potential problems of undernutrition in the elderly. In order to diversify the food offer adapted to the over-65s, it is necessary to understand the impact of changes in oral status. One of the objectives of the AlimaSSenS project is to understand the mechanisms of food breakdown and food bolus formation in the elderly. Most of the time, their oral physiology is altered and their protein needs are increased.

To meet these needs, INRAE researchers took examples of cereal-based foods with a honeycomb structure: brioche and sponge cake, and enriched them with legume proteins. Following studies using imaging and rheology (the study of the deformation and flow of matter under the effect of a stress), it was found that the latter only have a slight impact on breakdown and the enjoyment of eating. These results will enable the design of cereal foods enriched with proteins from legumes.

For a new pasta recipe

Owing to its taste, ease of preparation and reasonable price, pasta is one of the foods that is widely appreciated by all categories of consumers. Traditionally made from durum wheat semolina in France, pasta has a specific structure consisting of a protein network surrounding starch granules, which is responsible for its low glycaemic index and organoleptic qualities. However, it is low in certain amino acids essential to our health, such as lysine, and its consumption can lead to metabolic disorders in people who are intolerant to gluten... In order to supplement the gluten-free offer, INRAE is developing pasta made from a mixture of wheat semolina and legumes, thus providing essential amino acids, and which will soon be available on the shelves of supermarkets and specialist shops. The culinary, sensory and nutritional qualities are comparable to those of pasta made from 100% wheat or gluten-free cereal-based pasta. And what is more, the process retains the classic pasta-making steps, requiring no additional equipment!

A genuine breeding ground for innovation, legumes meet nutritional and environmental needs: research is thus actively pursuing the creation of a new food offer and the promotion of these plant proteins. But supply is not enough: public action will have to support it and help structure the sector to facilitate its adoption by consumers. ●

ACCELERATING THE TRANSITIONS

Combining nutritional quality and sustainability in our diets seems possible and accessible. So what can be done to accelerate everyone's transition to a healthy and sustainable diet? Taxation, awareness-raising, education... the levers for public policy action are numerous. **An overview.**

Acting on prices. This leverage seems to be essential for public policies in the face of consumers for whom price is a major criterion.

Taxes and their effects

The first strategy is to tax products that are less healthy because, according to economists, a taxation policy can bring about a change in consumer choices at little cost. This is the principle behind the "soda tax" introduced in France in 2012, then revised in 2018, whose objective is to encourage a reduction in the consumption of sugary drinks. Adopted in some 40 countries, this tax seems to be playing its role, particularly in the countries that are most fond of soda, such as the United States and the United Kingdom, where consumption of these drinks has fallen.

Economists at INRAE have shown that these taxes could have a significant impact on purchases, but this varies depending on the type and level of tax. For example, the UK tax, which is proportional to the sugar content of the product, led to a significant decrease in the purchase of these drinks, whereas the French tax, which was introduced in 2012 and was independent of the sugar content, led to little change in consumption. France therefore adopted the same taxation system as the UK in 2018. In addition to questioning purchasing decisions, these taxes reinforce the messages about the health consequences of excessive consumption of soft drinks. The introduction of this type of tax may also have the effect of encouraging manufacturers to reduce the sugar content of their products.

This leads to more ideas. What if products that have a negative impact on the environment were also taxed? Cécile Bonnet, an INRAE economist at the Toulouse School of Economics (TSE), has studied the effect that the introduction of a carbon tax on meat could have: the research shows that a tax indexed to the CO_2 emissions from meat production would lead to an increase in prices and therefore a decrease in the consumption of products with a greater impact in terms of GHG emissions. However, taxing products means passing on the costs to consumers, with greater economic consequences for the poorest households. A complementary strategy could therefore be to subsidise healthy products. A study shows that

in France, subsidising fruit and vegetables by 20% would increase their consumption by 8 to 10%.

Healthy food for all

Access to healthy and sustainable food for all seems to be the crux of the problem, especially as the poorest households are the biggest consumers of products of lower nutritional quality. Nicole Darmon, an epidemiologist at the MoISA unit in Montpellier, demonstrates as part of the Opticourse project that healthy and sustainable eating is possible, even on a small budget. A field trial, in partnership with two supermarkets, showed that affixing an "Eating great" logo can guide customers towards inexpensive and nutritious food choices and influence purchases. At the same time, researchers and facilitators organised fun group workshops focusing on taste, nutrition and price, offering tips on how to improve the nutritional quality of purchases without breaking the bank, while still indulging in taste. In the same vein, the Dijon metropolitan area *(see article on page 33)* is considering experimenting with food vouchers to help the most disadvantaged people buy fruit, vegetables and legumes.

Informing and raising awareness for better guidance

Informing and raising awareness are the key words in public policies to guide consumers towards a more sustainable diet. To this end, the French state relies on the National Nutrition and Health Programme (PNNS). Launched in 2001, this is a public health plan aimed at improving eating habits and thus the health of the population. It is deployed through various actions, including the introduction in 2017 of a display system called Nutri-Score, in order to enable consumers to make informed choices between products in the same category. Developed by researchers from various organisations including INRAE, this score is determined by a calculation that classifies the nutritional data of foods per 100g of product into five categories, from A to E (green to red). Researchers have shown that the Nutri-Score can improve the nutritional quality of purchases by 4% and that the easier the label is to understand, the more effective it is! However, to be even more effective, all brands should adopt it, which is still far from being the case. As European regulations currently prohibit the imposition of this labelling on brands, only a fraction of them have committed to implementing it. A study by the Food Quality Observatory (Oqali, located at the INRAE centre in Ivry-sur-Seine) shows that the market share of products with Nutri-Score varies from 10 to 50% depending on the food sector.

As the Nutri-Score makes it possible to guide purchases towards products that are good for health, one might wonder about a possible display of the environmental impact of products. This is a desire of the public authorities who, in the context of the law on the fight against food waste and the circular economy, have launched an 18-month experiment to define an environmental display for food products by the end of 2021. There are many systems in various formats (score, label and so on) that take into account a wide range of indicators, often including the carbon footprint. In this context, INRAE scientists are studying which system would be the most effective in guiding consumers. The results of the Lab2Green project show that environmental labelling, regardless of its format, has a significant effect on the environmental quality of consumers' purchases. Moreover, the traffic light approach is more effective than a quantitative model (such as displaying the amount of CO_2 emitted). It remains to be seen what the impact would be of placing an environmental label alongside the Nutri-Score label, and what choices consumers would make in the case of antagonistic displays. In parallel with these studies, ADEME and INRAE have developed the Agribalyse database, which provides information →

5 LINES OF ACTION

Tax unhealthy products

Subsidise healthy foods

Inform

Raise awareness

Develop the supply of healthy products

Taxes and subsidies must take into account issues of social and economic inequality.

PUBLIC POLICIES

Territorial food projects

Territorial food projects (PATs) were created as part of the National Food Programme (PNA) in 2016. The aim? To put the territories into action around food. Local authorities, farmers, associations, consumers and, more generally, all those concerned with food, are working together to relocalise our food.
Brigitte Nougarèdes, a sociologist at the Innovation joint research unit at INRAE in Montpellier, is taking a close look at the Pays Cœur d'Hérault project, winner of the PNA call for projects in 2019, and subsequently the TETRAA project (AgroParisTech, Fondation de France) which brings together 77 municipalities.
She highlights the areas of improvement needed to succeed in this "reconnection":
→ facilitate access to agricultural land and buildings to diversify agricultural production;
→ support agricultural models that can contribute to the agro-ecological and food transition;
→ and improve or build coordination between production, processing and marketing, in order to structure sustainable local food chains.
At the same time, new forms of food aid must be devised to ensure access to quality food for all.

VALUE CHAIN

When animals are fed well, humans feel better

The Bleu-Blanc-Cœur association was created in 2000 with the support of INRAE and the idea that if animals are better fed and do better, humans could also benefit from it in terms of their own health. The ambition? To develop a value chain "from field to fork" with the founding principle of better feeding animals to improve the nutritional quality of the products they yield. The aim is to diversify and balance animal feed by including more plants, legumes and forgotten seeds that are rich in nutritional value (flax, lupine, peas, grass) and to respect animal welfare.
Today, 7,000 farmers are involved in this sector, which has millions of consumers.

EXPERTISE

A 360° policy in Overseas France

Overseas departments and regions are among the most exposed to diet-related chronic diseases. The prevalence of obesity, diabetes and hypertension is high, which can be explained by both particularly high social inequalities and eating habits marked by a high consumption of sugary drinks and a low consumption of fruit, vegetables and dairy products.
In 2020, a collective scientific expertise led by the French National Research Institute for Sustainable Development (IRD), for which Caroline Méjean (research director at INRAE) chaired the panel of experts, formulated 24 recommendations for action in order to implement the National Nutrition and Health Programme in the French overseas departments. These include encouraging the installation of equipment and the development of urban facilities to enable physical activity, the reformulation of products (such as the reduction of added sugar, sodium and saturated fatty acids), the introduction of vouchers and workshops to raise awareness on nutrition, the promotion of allotments to improve access to quality products, and the strengthening of local health care services.

on the environmental impact of a product, from agricultural production to its purchase or preparation by the consumer. This database could be used as a basis for the display system that will be adopted.

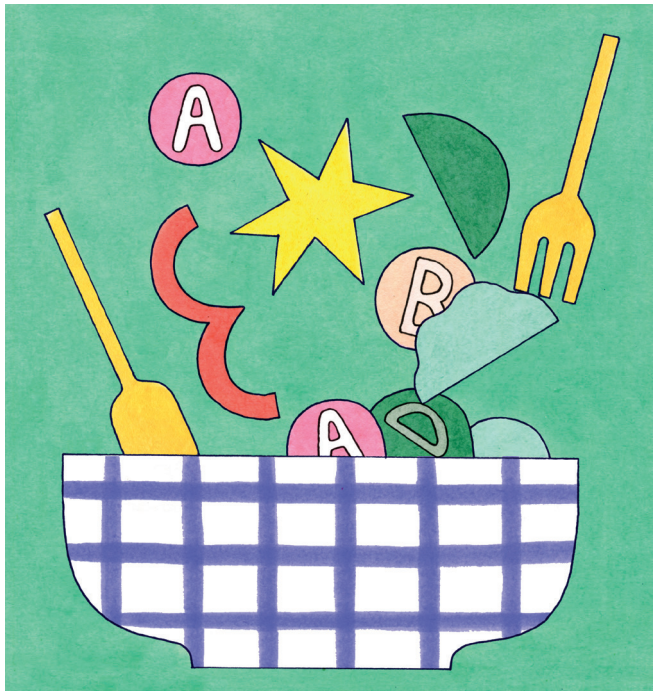
The issue of awareness-raising messages

It is also within the framework of the PNNS that awareness-raising messages are developed: "Eat at least 5 fruits and vegetables a day", "For your health, avoid eating too much fat, too much sugar, too much salt"... We have all heard these messages, but do they actually contribute to changing our eating habits? According to Vincent Requillart, an INRAE economist at TSE, these information campaigns generally have a positive effect on consumption, but their impact remains relatively modest.

Campaigns such as "5 fruits and vegetables a day" can temporarily increase the average consumption of fruits and vegetables by 5%. In the long term, they can thus contribute to changing social norms regarding food. However, it should not be overlooked that these norms may appear contradictory to the dietary practices of certain populations. As Faustine Régnier, an INRAE food sociologist from the Social Sciences and Food unit (ALISS, Ivry-sur-Seine), points out, *"for people from low-income backgrounds, food is an area of freedom, sometimes the only one, where they feel they can make a choice, express their tastes, and thus compensate somewhat for other daily constraints, which therefore limits the impact of awareness campaigns".*

For step-by-step changes

For Nicole Darmon, this implies working on a complementary approach in order to make step-by-step changes possible. For example, gradually introducing dried pulses into one's diet or preferring whole grains, and thus moving towards a more sustainable diet without upsetting one's habits. It is also a question of supporting transitions through actions that are close to the population: cooking workshops, community gardens, collective workshops to guide purchases. What about food-related mobile applications to support people in these steps? An estimated 30% of the population has already downloaded one. Once



again, however, it is the people on the lowest incomes who use them the least: technical barriers linked to poorly performing equipment are compounded by financial and time constraints, little knowledge of digital technologies and, in migration situations, a poor command of spoken and even more so written French.

Educate first

The adults of tomorrow are the children of today. Raising children's awareness of sustainable food from the youngest age is a real challenge. One lever for action to reach a maximum number of children, whatever their social background: schools and school catering. In France, there is no shortage of initiatives: the "Fruit for recess" operation, the creation of school vegetable gardens, educational workshops and the like. But above all, the meals served in the canteen are governed by regulations and recommendations pertaining to their nutritional quality. And since 2019, following the EGalim law, canteens must offer a vegetarian menu at least once a week. This sends out a strong signal, even though it is still →

Since 2019, French canteens must offer a vegetarian menu at least once a week.

too early to measure the effects of this public policy scientifically. The school and school catering sector are also a major lever abroad. In Kenya, the schools and colleges permaculture programme –SCOPE Kenya– educates and prepares young schoolchildren and non-schoolchildren in twelve counties to understand nutritional value and food consumption for improved health, and to participate in agricultural production through school permaculture gardens. In Brazil, interventions in public primary schools teach children about healthy diets, a topic included in the curriculum. At the same time, school canteen cooks are also trained on the subject.

Acting on products

The last card to be played in order to accelerate dietary transitions: act on the supply side. While research is working on the development of new products *(see page 25)*, it is also taking an interest in the development of new, healthier formulations, with less salt, sugar or fat in particular. This is the case, for example, with cold cuts. Although one option may be to simply reduce their salt and saturated fat content, the loss of sensory quality quickly puts a limit on it. A more promising option would seem to be the substitution of sodium chloride (salt) with potassium chloride, and of animal fats with vegetable oils containing unsaturated fatty acids, which are healthier. The results: researchers developed a dry sausage with a 30% reduction in salt and 60% reduction in saturated fatty acids without degrading the sensory quality. Public policies draw on a whole range of regulations or taxes that aim to encourage or require companies to change their products towards healthier formulations. In order to monitor changes in the nutritional composition of foods, INRAE and ANSES created the Food Quality Observatory (Oqali) in 2018, which allows reporting on the efforts made by the industry.

NUTRI-SCORE

In France, 500 companies have adopted the Nutri-Score display, representing 50% of the food market share.

Of all the products rated, 31.7% are classified A, 9.6% are classified E. For some fatty products such as vegetable oils (like olive and hazelnut), the best possible score is C. 94% of the French are in favour of the Nutri-Score. 1 French out of 2 declares having changed at least one purchasing habit thanks to Nutri-Score.

Source : www.oqali.fr

Steering production

And since our diets begin in the fields, public authorities are also endeavouring to steer production towards a rebalancing of animal/plant proteins. The French Ministry of Agriculture and Food thus initiated a 10-year national "plant protein" strategy in 2020. It aims to double the cultivated area of protein-rich plant species such as soya, peas, dried pulses, alfalfa and fodder legumes by 2030, in order to both rebalance diets and increase the protein autonomy of livestock animals. At the same time, this plan promotes the structuring of a local product offer for dried pulses.

There are therefore many levers to guide and accompany consumers towards healthier and more sustainable diets. If none of them seems strictly speaking more effective than another, the solution is probably to combine them and to rely on the complementarity between national and territorial policies, voluntary commitment of companies and changes in the behaviour of consumer-citizens. ●

Research put to the test

Sophie Nicklaus, an INRAE specialist in the study of eating behaviour at the Centre for Taste and Feeding Behavior (CSGA) in Dijon, is the scientific director of the "Dijon, Sustainable Food 2030" project led by the Dijon metropolitan area.
Interview.

The Territories of Innovation (TI), a new model for research, development and innovation encouraged by the government via the French Investments for the Future programme in 2019, aim to accelerate transitions through greater cooperation between players as close as possible to the territories and their expectations. Deeply committed to social and food issues, the metropolis of Dijon has brought on board more than 30 partners, including INRAE, in its "Dijon, Sustainable Food 2030" project. Sophie Nicklaus explains to us how this new type of project works and the perspectives it opens up.

What are the objectives of the "Dijon, Sustainable Food 2030" project?
This project targets both ends of the food chain: producing better and eating better. We see this as a virtuous circle, not as a straight line with a beginning and an end. Eating better stimulates more virtuous production practices, and producing better allows us to eat better! We analyse the quality of the soil and ascertain that it is possible to produce in an agroecological way, in particular by growing legume crops which, in addition to having nutritional qualities, enrich the soil with nitrogen and make it possible to limit the use of fertilisers and phytosanitary products. We are developing new processes with the industry in an effort to develop high quality value chains with local roots. We are also coordinating communities of citizens to identify their needs and expectations in terms of sustainable food.

Can you give us some examples of actions carried out within the framework of the TI?
Dijon Métropole wants to develop a local legume industry. At present, it is difficult for farmers to find a viable economic model on certain plots while meeting environmental constraints on water quality or reducing the use of nitrogen fertilisers and pesticides. We therefore study the quality of soils to identify those most suitable for the agroecological production of legumes and we support farmers in adopting more environmentally friendly practices. We also share with them our knowledge on these plants, as the Agroecology Joint Research Unit in Dijon holds Europe's largest collection of genetic resources on pulses. Another action consists of establishing a territorial label –for the moment called "Dijon Agroecology"– to certify the quality of the products. These are slightly more expensive, but they allow better social recognition and better remuneration for producers. It is then a question of ensuring outlets for these products at a fair price. The city has therefore committed itself to a purchasing policy through the collective catering it provides. For more than two years, even before the implementation of the EGalim law, children have been offered a weekly menu at the canteen in which the proteins are exclusively plant-based and, where possible, local. With 8,000 meals served every day in the canteen, the city's purchasing power is one of the most effective levers of transition. Moreover, through the adoption of less carbon-impacting eating habits in out-of-home catering, the city also aims to influence the consumption →

habits of citizens for their evening or weekend meals, by changing their habits and their perception of the products. In addition, in order to ensure access "for all", the city is financially committed through the social pricing of school meals: families pay for the canteen according to their income and, for a meal costing €12.90, those on low incomes only pay €0.50. This is decisive, especially as for some children this will be the only good, proper meal they have in the day.

How does research work on this expected change?

At the CSGA, we study the determinants of eating behaviour over the life course, using an approach that combines nutrition, sensory evaluation and psychology. We draw on observations or interventional experiments, both in the laboratory and in the population. For example, we are working on children's eating behaviour: how is it rooted in the educational and family environment? How is it modified? We know that certain cognitive elements (information, for example) play an important role in changing children's behaviour, but not only that: pleasure is an essential lever for getting them to adopt healthy behaviour. Obviously, the more healthy foods are enjoyed, the more they are consumed. The TI project allows us to study in real life the factors that would favour the acceptability of vegetarian menus by children and, in particular, the appreciation of legumes and vegetables. With more stringent requirements than set out in the EGalim law, particularly concerning the environmental impact of products and the nutritional quality of meals, we are observing children's behaviour and their responses to the various levers of action used, such as information, experimentation, repetition and sensory education. This allows us to develop decision-making tools for Dijon Métropole. We also offer training modules for professionals. Indeed, "cooking with plants" currently accounts for only 20% of the training hours for collective catering cooks, compared to 80% for "cooking with animal products". It is important to reverse these proportions in order to help cooks adopt more plant-based cooking practices. We are studying the practices and needs of the professions in order to understand the best ways to make them evolve. We are relying on local partners for this aspect with the Trades and Qualification Campus "Food, taste, tourism" and the engineering school AgroSup Dijon. Other INRAE studies are part of these reflections. In Dijon, Clermont-Ferrand and Versailles, for example, teams are developing new processing methods that integrate legumes into the preparation of everyday products to promote their consumption *(see p. 25)*.

Is the local scale relevant to meet the food issues?

The territorial dynamic is decisive because exchanges and meetings between stakeholders are facilitated. Long-term relationships can develop on a basis of great trust, strengthening the project. Moreover, the emotional dimension, which connects citizens and decision-makers to their territory, encourages their involvement and the development of local food supply chains. The local scale makes it possible to tackle the subject and find possible solutions, but it is obviously not enough to meet the needs of the population in terms of quantity and diversity of agricultural production. Moving towards the borders of the department, or even the region, is a natural step. The aim is not to be self-sufficient in food, but to encourage a dynamic towards greater sustainability.

How does research fit into this project, what are the mutual contributions?

The project's piloting structure meets every two weeks with the socio-economic and academic partners in order to examine the different initiatives, such as the implementation of the "Dijon Agroecology" label for quality products, in which we have been very involved. Meetings in the field complete this arrangement. For my part, I am in direct and regular contact with the city's director of catering. On the one hand, research provides scientific results and expertise in agroecology, decision support, in the fields of food, nutrition, eating habits, economics and sociology. We have the capacity to develop innovations that are technical, methodological, scientific as well as organisational, with a wide variety of methods,

"With 8,000 meals served every day, the canteen is one of the most effective levers of transition."

including participatory science approaches that are crucial if citizens are to become involved in their food. On the other hand, the strong partnership with Dijon Métropole offers us a unique testing ground where we can observe in "real life" the new systems devised in the laboratory. It is these experiments carried out on the scale of the territory which, when capitalised on in terms of knowledge, can be transposed to a larger scale in order to achieve the expected transitions. This is truly fascinating work because the city has a logic of action and multiplies the levers. I very much like the idea of leaving the laboratories and seeing what our skills can do for the city! Our work will have tangible benefits for everyone, which is very rewarding. ●

ENGAGEMENT

Dijon makes food a nutritional, health, agricultural and social issue

Food security is one of Dijon Métropole's key public policy issues. With the guiding notion that what we eat transforms the territory in which we live, Dijon has the ambition to achieve a profound transformation of its agri-food system, both on the production and consumption side, in order to build sustainability.

With little industry, the city has long been committed to projects in the fields of agriculture and the environment, with, for example, the implementation of an urban plan that preserves agricultural land. Based on the principle recalled by Philippe Lemanceau, former INRAE research director and vice-president of the Metropolis in charge of the food transition, that *"the agro-ecological transition can only be achieved if market and demand coincide"*, the food transition has become a priority issue for Dijon with the "Dijon, Sustainable Food 2030" project.

Economic players (like Dijon Céréales, Seb, Orange and Vitagora), social players (such as solidarity grocery stores and food banks) and academic players, including INRAE, quickly rallied around the initiative. Designated in the first wave of French Investments for the Future 3 as Territories of Innovation in 2019, the project has a budget of €46 million, including more than €26 million from private funds, to experiment together and develop prototypes that can be transposed to other territories.

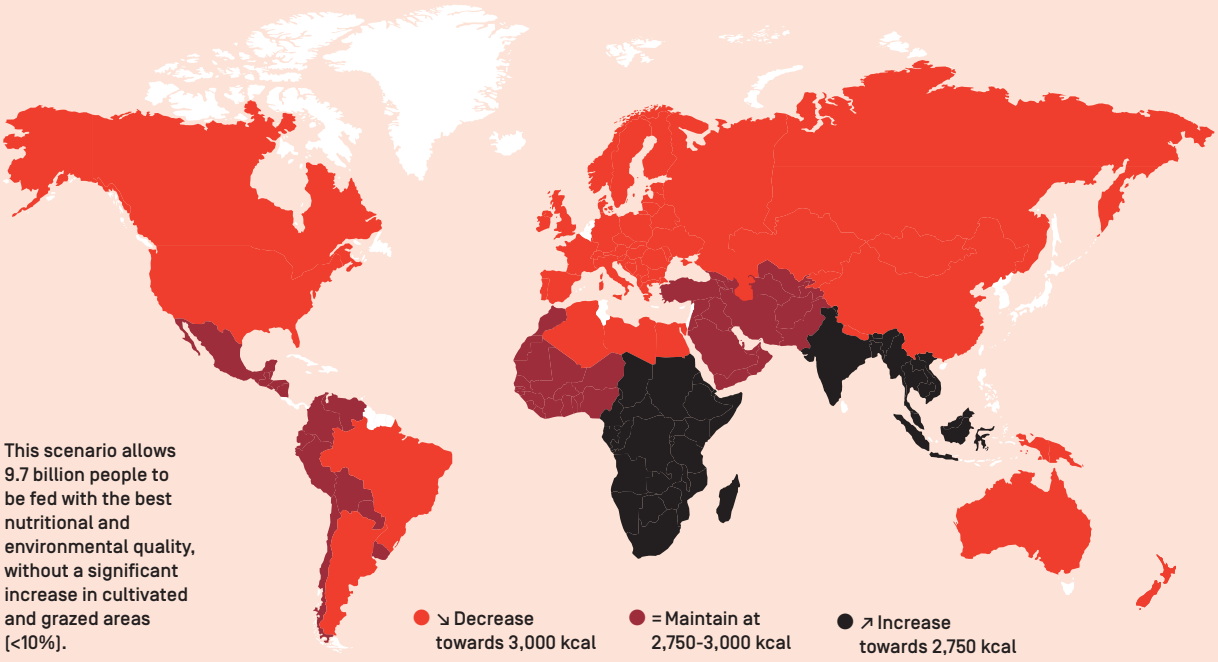
As Philippe Lemanceau points out, *"the aim is to show that the food transition involving the agroecological transition is possible, and that it is beneficial not only for the environment, but also for the local economy and social cohesion, particularly between farmers and citizens, between urban and rural areas. This social component is very important: healthy and sustainable diets must be accessible to all."*

It's a virtuous circle: produce better to eat better, and eat better to produce better.

"HEALTHY DIETS"
A SCENARIO TO FEED THE WORLD IN 2050

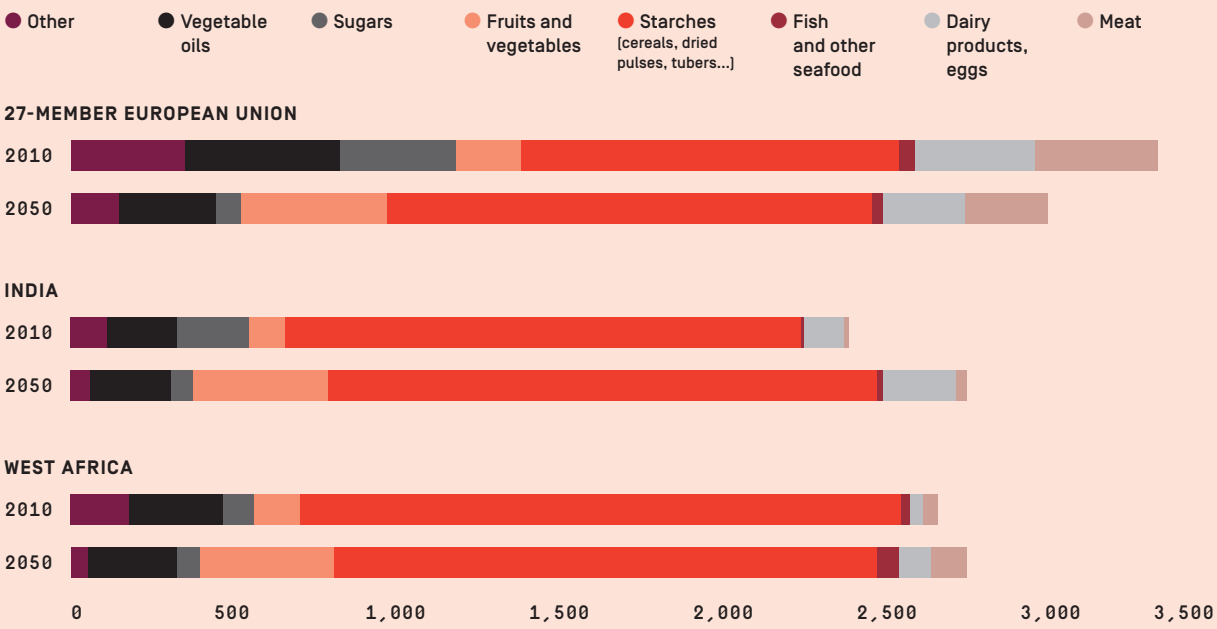
based on the *Agrimonde-Terra* study

REBALANCING ALL DIETS TO 2,750-3,000 KCAL PER DAY/PERSON (including waste)



This scenario allows 9.7 billion people to be fed with the best nutritional and environmental quality, without a significant increase in cultivated and grazed areas (<10%).

EVOLUTION OF THE DIET IN 3 REGIONS OF THE WORLD (in kcal/day/pers.)



HOW TO FEED THE PLANET IN 2050?

Under-nutrition, over-nutrition, ecological issues... How can we meet the challenge of feeding 9.7 billion people in 2050? A collective challenge with regional solutions, with a consensus on the need to think in an integrated manner.

The issues.

On 13 July 2020, the UN warned in its annual SOFI[1] report that "since 2014, the number of hungry people worldwide has been slowly rising", thus seeing the achievement of the second Sustainable Development Goal (SDG), "Zero Hunger", move further away. In 2021, the same report highlighted the worsening of the trend by the COVID-19[2] pandemic, which increased the number of people suffering from hunger in the world (moderate or severe energy insufficiency) from 650 million in 2019 to 768 million in 2020. In addition to these populations facing problems of undernutrition, there are now also 2 billion people with an unbalanced diet, characterised by an excessive consumption of calories and certain nutrients (like salt, sugar and fats). This consumption encourages overweight and obesity, and increases the risk of various metabolic diseases (such as hypertension, diabetes and certain cancers).

Even though these figures may be frightening, given that demographic forecasts predict a population of 9.7 billion on the planet in 2050, research has been actively engaged for many years in order to gain knowledge in the face of a challenge that goes far beyond the mere question of the quantities to be produced, and to examine, alongside geopolitical strategies, agricultural and food systems as a whole. A challenge for which solutions must be developed over time and by mobilising numerous levers for action.

The three pillars

In order to identify the paths to be explored, researchers are conducting foresight studies based on current data and trends. After considering the issue of food security exclusively from a production perspective in the early 2000s, advocating an increase in productivity without taking into account its impact on the environment or the quality and diversity of food, the studies quickly integrated the issues of losses and waste, as well as of the necessary changes to be implemented in food consumption. Gradually, the combination of agroecology, the reduction of losses and waste and the adoption of more balanced diets, combining more products of plant origin and fewer meat products (at least in developed countries), has emerged as a way of solving the food equation without leading to a damaging increase in the amount of land used. →

Agrimonde-Terra: an integrated and systemic approach for 2050

The intertwining of issues highlights the need to think about the transition of food systems in an integrated manner, encompassing the role of land use and including environmental and health issues. With this in mind, CIRAD and INRAE presented in 2016 the results of a joint study on "land use and food security in 2050". The aim of the Agrimonde-Terra[3] foresight study was to identify the levers likely to improve food security and nutrition on a global scale by 2050. It is part of the research priority on global food security explored by the INRAE-CIRAD interdisciplinary research programme "GloFoodS" *(see page 42)*. Using both a quantitative and qualitative approach, based on current data and trends and combining possible evolutions of a wide range of factors (such as climate change, diets, urban-rural relations, agricultural structures, crop and animal production systems and public policies), the results have identified five possible scenarios.

In order to develop them, the Agrimonde-Terra foresight first analysed the long-term dynamics of food security, focusing on land use: access and agronomic potential, intensity and distribution between the different uses and services provided by the land. Secondly, quantitative hypotheses were formulated, taking into account the evolution of the global context in its technical, economic and social dimensions. These dimensions include climate change and its mitigation, demographic transitions and urbanisation, international trade, the evolution of diets, and technical progress in agriculture and livestock farming. To examine these hypotheses, simulations were carried out by integrating elements of the global context, in particular the climate projections of the Intergovernmental Panel on Climate Change (IPCC).

A scenario based on "healthy diets" could reduce over- and under nutrition and associated chronic diseases.

1. SOFI report produced annually by the UN and its agencies (FAO, WHO, WFP, Unicef, IFAD) – The State of Food Security and Nutrition in the World – 2020. url.inrae.fr/3yfS0PT

2. The SOFI report estimated that between 80 and 130 million more people would suffer from hunger in 2020 as a result of the COVID-19 crisis.

3. Agrimonde-Terra. http://bit.ly/3GxzzNv

The different scenarios

Five scenarios were thus proposed: three based on current competing trends observed in most regions of the world ("Metropolisation", "Regionalisation" and "Households") and two corresponding to disruptive shifts in the relationship between land use and food security ("Healthy diets" and "Communities"). The Agrimonde-Terra foresight study concludes that most scenarios will not be able to ensure global food security in a sustainable way in 2050, due to an increase in deforestation for agricultural purposes, with some scenarios having ambivalent outcomes.

"Metropolisation" would contribute most to the increase in the prevalence of overweight and obesity. The "Communities" scenario, based on the development of small communities and the management of common agricultural goods, would imply a reduction in food availability at global and regional level.

In contrast, the "Regionalisation" scenario, with the networking of medium-sized cities and rural areas and the emergence of regional food systems based on family farming and traditional diets, would lead to ambiguous outcomes in terms of global food security.

The "Household" scenario, in which family farms and cooperatives would be major actors in land use, would lead to a decrease in undernutrition but with ambivalent effects on overnutrition.

The positive prospects of the "Healthy diets" scenario

The "Healthy diets" scenario would best reduce the prevalence of over- and under-nutrition and associated chronic diseases. It proposes diets that combine a variety of products: fish, meat, milk, cereals, fruits, vegetables and legumes, with their micronutrients and fibre preserved. →

THE PROJECTIONS FOR 2050
Agricultural land

Conducted by INRAE[1], the study "European Agriculture in 2050"[2] proposes projections for 2050 of the various components of the world's agricultural and food system, dividing it into 21 regions, 8 of which are in Europe.

The need for cultivated land
If current diets are maintained in developed regions and the nutritional transition continues in emerging or developing regions, the need for cultivated land in the world would vary from +223 to –11 million hectares, in addition to the 1.5 billion hectare cultivated in 2010. It would be considerable in Sub-Saharan Africa and India. A hypothesis of disruption towards "healthy" diets (as defined by the WHO) would ease the pressure somewhat, but not as much as might be expected: the need would change on a global scale from +194 to –51 million hectares compared to 2010.

In Europe, as in other developed regions, such a change would lead to a reduction in total caloric intake and consumption of animal products, allowing for a decrease in cultivated areas ranging from –14 to –30 million hectares.

Potential surpluses in Europe
The "surplus land" that could appear in several regions of Europe, particularly in Central and Eastern Europe, would be too small for its agricultural use to contribute to food security in other regions of the world.
It could, however, be an opportunity to reduce our dependence on soybean imports by developing oilseed crops, or to move towards less input-intensive cropping systems that require more land. Depending on the yield and diet hypotheses selected, between 4 and 44 million tons of soybean meal could thus be produced on this "surplus land", making it possible, in the best-case scenario, to avoid imports altogether, while still leaving 9 million hectares "available" for other uses or for yield reductions.

The results of this study, carried out for the Pluriagri[3] association, and in particular the uncertainties that it integrates or points out, are available to stakeholders in order to help them develop the (re)orientation of their policies, including in the context of the European Green Deal, which aims at a transition towards a more sustainable agriculture.

1. Directorate for Expertise, Foresight and Advanced Studies (DEPE).

2. The role of European agriculture in the world in 2050: between climate issues and food security challenges (2020). Synthesis report: https://url.inrae.fr/2HQjy6h

3. Pluriagri is an association that brings together various field crop stakeholders: Avril, Confédération générale des planteurs de betterave, Unigrains and Crédit Agricole SA.

METHODOLOGY

The study takes into account the combination of the effects of climate change (according to the IPCC's RCP-6.0 scenario) and technical developments (based in particular on the FAO's 2012 and 2018 projections) on agricultural yields. It also incorporates possible changes in the diets of a rapidly growing world population by 2050.
The proposed simulations are based on a set of contrasting hypotheses aimed at integrating the uncertainties that weigh on the evolution of these variables and determine, on this basis, the areas under cultivation by 2050 in each region of the world, the levels of production and the use of or contribution to international trade of each region.

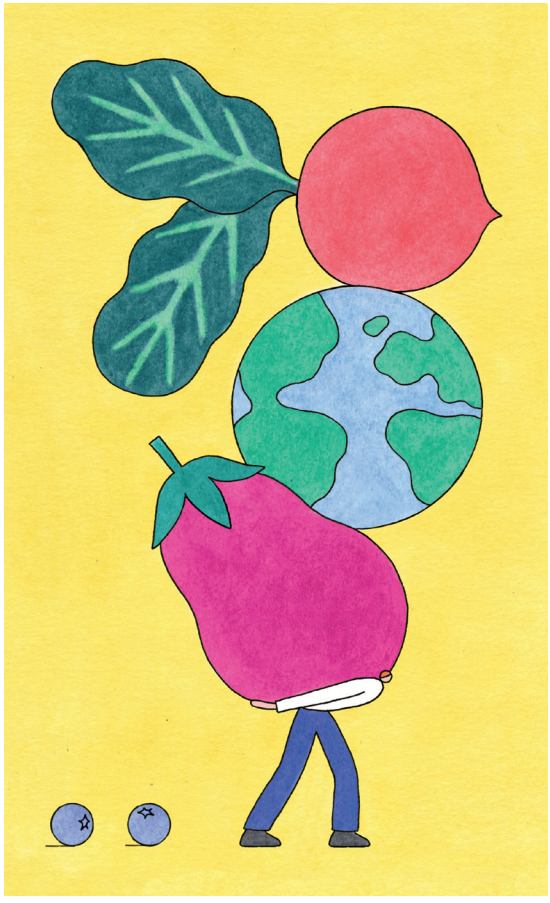
KEY FIGURES

1.5 billion ha
cultivated in the world in 2010

–11 to +223 Mha
Evolution of the need for cultivated areas according to different scenarios for 2050

–51 to +194 Mha
Evolution of the need for cultivated areas in the world with healthy diets; from -30 to -14 million ha for Europe

It implies a reconfiguration of agricultural and food systems through new alliances between stakeholders. The food chain becomes more efficient and reduces losses and waste. In this scenario, some regions would still be in a difficult situation, such as India and Sub-Saharan Africa, due to their high population growth and low agricultural yields, with persistent risks of deforestation. However, with favourable global governance, this path would make it possible to have food that is compatible with the health of populations as well as with environmentally friendly agricultural practices and land use. The challenge will then be to prevent food crises, land grabbing, deforestation and mitigate the effects of climate change through concerted international action on food security and land use.



2 billion
people in the world live on an unbalanced diet

1/3
of global GHG emissions are due to food

20%
of food is lost or wasted in Europe

The transition of food systems represents a powerful lever to promote human health and support environmental, economic and social sustainability.

A systemic approach to ensure sustainability

In all cases, international trade will play a key role in ensuring global food security in 2050, and some regions, in particular North Africa and the Near and Middle East, are likely to remain highly dependent on food imports. Increasing the volume of food produced and its diversity in order to move towards a healthier diet in 2050 while limiting deforestation, will require a significant diversification of cropping and livestock systems. The Agrimonde-Terra foresight confirms the importance of a systemic vision of the transitions necessary to ensure food and nutritional security for populations, using the levers of agricultural availability, diets and the optimisation of agricultural and food systems to reduce losses and waste.

As well as ensuring the food security of populations, the transition of food systems represents a powerful lever to promote human health and support environmental, economic and social sustainability. In order to succeed in this transition, transformations must take place in a profound manner over the next few years, through immediate actions and the implementation of progressive solutions and adaptive trajectories.

A challenge for all

Although there are now three main areas of research in the scientific communities on food security – changing production patterns based on

the agroecological transition, reducing losses and waste, and changing food consumption patterns – the challenge is complex, with many issues that overlap and cut across sectors, territories and actors. The preceding pages give an idea of the actions that can be taken to change Western food behaviour.

Other work focusing more on the levers of agricultural production methods and the reduction of loss and waste is being developed in France and around the world *(see double page below)*. Public policies can play a central role by encouraging consumers to adopt diets that reduce the consumption of animal products when excessive, in favour of cereals, legumes, fruit and vegetables. This can be achieved by acting on access to and the cost of food, and by launching education and awareness-raising policies. They must encourage the diversification of farming systems and the development of agroecological practices that are useful for limiting the environmental impact of agriculture and livestock farming. They must also regulate access to agricultural land at the national level and the functioning of international trade in order to guarantee stable access to healthy food for all. The industry is called upon to develop economic models based on an offer that includes new, healthier and more accessible products. Everyone must commit to reducing losses and waste in food systems.

There is no single path mapped out, but rather a systemic transformation to be achieved with actions in each country and region consistent with each other and accountable in the face of global challenges. To study and design these transformations and contribute to the acceleration of transitions, INRAE develops its research with an integrative and interdisciplinary vision, and collaborates with public and private actors to facilitate the transfer of knowledge for innovations and public policies likely to build sustainable food systems, specific to each region, beneficial to both humankind and the Earth.

Policies need to encourage the diversification of farming systems and the development of agroecology to limit environmental impacts.

The transformation of our food systems requires close coordination between stakeholders' strategies and between countries. Research is there to accompany them and foster this coordination. ●

A WHOLE SYSTEM

PROMOTING A GLOBAL DYNAMIC OF AGRICULTURAL AND FOOD SYSTEMS: EXAMPLES

Developing efficient and environmentally friendly agricultural practices

And to do so, assess the potential of the land that is available, and for what use.

In 2020, INRAE and CIRAD presented the results of the GloFoodS programme "Transitions for Global Food Security", which financed 45 research projects, mobilising more than 200 researchers over 8 years in France and abroad, particularly in French-speaking Africa and South-East Asia. The work contributed to a better understanding of variations in crop and animal production yields, to assessing on a global scale the potential of land available for food, energy and bio-industrial purposes, to identifying processes and organisations that limit losses and waste, as well as to providing information on the links between household access to food and social inequalities. Among the objectives: to propose more efficient and environmentally friendly production systems and practices and to limit losses and waste. These two aspects of transition rely on innovations in the organisation of food value chains, for better access to healthy and sufficient food, by means of agri-food processes that are more economical with agricultural resources. For example, the GloFoodS "Legend" project studied the adaptation of agriculture to urbanisation in a case study in Madagascar. The results showed that urban and peri-urban agriculture plays a key role in food security: it supplies the capital with fresh produce and covers almost all the needs of its population for eggs and poultry, as well as a large part of its vegetable needs. Agriculture does not inevitably succumb in the face of urban sprawl; it is maintained and developed, thanks to farmers who adapt their production systems by introducing new crops and using agroecological approaches. Another example of mobilising the lever of system change: the GloFoodS "Serena" project aimed to explore the potential benefits of agroforestry parks on food security and livelihoods of rural households in the groundnut basin of Senegal, through the diversity of agricultural landscapes. Using remote sensing data, modelling and statistical methods, the study showed the benefits of trees for crop productivity, but only up to a certain point: namely, when the tree starts competing with the crop. It thus appeared that trees cannot directly strengthen the coping strategies of food-insecure households, but contribute to the improvement of the production system.

Main goals of research programmes: more efficient production systems and practices, and limitation of losses and waste.

2

Creating resilient and solidarity-based food systems

by building solutions at all levels, international, national and local.

Because there is no one-size-fits-all solution, INRAE has partnered with the FAO to study numerous initiatives around the world that aim to produce, share, sell and consume more sustainable food. The study, led by sociologist Allison Marie Loconto, Deputy Director of INRAE's Interdisciplinary Laboratory for Science, Innovation and Society (LISIS), shows that the resilience of food systems depends in particular on innovations for the relocation and diversification of food systems. Incentives can help prioritise access to beneficial foods for vulnerable communities, promote sustainable agriculture, including the protection of biodiversity, and encourage healthy and nutritious diets. Examples include the creation of social networks in Finland to facilitate communication between producers and consumers, the development in France of "field schools" for producers or "incubator farms" so that producers can test new practices without economic risk, as well as the implementation of a plan in Brazil to collect organic waste at 900 weekly markets for compost.

Bringing producers and consumers closer together

The fundamental outcome of these initiatives is to increase the interactions between producers and consumers, and to change the way they influence and interact within their food environment.
This study was the subject of a book[1] designed as a manual for actors who wish to innovate in the food systems they are involved in. These types of local food systems have demonstrated their resilience during the COVID-19 crisis in Africa, India or Brazil. They all use sustainable farming practices based on the 10 elements of agroecology producing food for local and regional markets, thus ensuring food security and access to healthy and affordable food for the disadvantaged population and the middle class.

1. FAO and INRAE. 2020. Systèmes alimentaires durables – Un manuel pour s'y retrouver. Rome. https://doi.org/10.4060/ca9917fr

One of the keys: increasing producer-consumer interactions.

3

Stopping food waste along the chain

as 1 in 5 foods are lost or wasted in Europe, or 173 kg per person each year.

Generally speaking, in developed countries 2/3 of food waste occurs at the consumer end, with the rest being lost along the production chain. *"In developing countries, poverty effectively causes consumers not to waste. Instead, losses occur at the harvest, transport and storage stages. Difficult weather conditions, plant diseases, inadequate equipment and poor roads are all factors. In Africa and South-East Asia, post-harvest losses in cereals account for up to 20% of production",* explains Barbara Redlingshöfer, an INRAE engineer at the SADAPT (Science for Action and Development Activities, Products, Territories) joint research unit. Her work proposes combining different solutions to reduce food losses. On the one hand, genetically improving varieties to make them resistant to disease, optimising harvesting equipment and better organising the supply chain. On the other hand, lowering consumer expectations regarding the appearance of products, particularly fruit and vegetables.