AGRICULTURAL TRANSFORMATION PATHWAYS INITIATIVE

2016 Report

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This report is dedicated to Mario Mondelli, whose vision and energy inspired the project and who understood very well the need to bring together research and policy.

INTRODUCTION

Purpose of the Initiative

With the expiration of the MDGs at the end of 2015, the international community has agreed on an ambitious and transformational 2030 development agenda. While the new set of Sustainable Development Goals (SDGs) and the concrete Targets and Indicators for achieving these goals are crucial frameworks to guide the global understanding of complex sustainable development challenges, to encourage action and foster accountability, each country still needs to choose its own sustainable development path, with specific, achievable actions and outcomes at the national and sub-national levels. Planning for success requires an implementation scheme that provides a roadmap to realize strategic goals.

While the high-level SDGs for the post-2015 era are a crucial lever to galvanize the global community to work towards shared development goals, it is at the national and local levels that effective action and implementation will actually have to take place – donors, for instance, can only efficiently intervene if a national strategy is in place that can help bring about the convergence of the expectations of all actors. If the 2030 targets are to be successfully translated into political decisions and concrete action, then it is critical that national and local policy debates take long term visions of economic and social transformations into account, and if possible help towards the definition of a sequence of action and of national and local plans.

Directly and indirectly agriculture plays a central role for achieving numerous SDGs linked to poverty, food and nutritional security, health, gender equality, and a range of environmental issues. In total, agriculture will contribute to at least 8 out of 17 sustainable development goals (FAO, 2015). Therefore, it is fundamental that today, national and local governments take the lead in developing and implementing their own sustainable development strategies and action plans for the transformation of their agriculture and food systems.

While the new set of Sustainable Development Goals is a crucial framework to guide the global understanding of sustainable development challenges, each country still needs to choose its own transformation pathway, with specific and achievable actions and outcomes.

While many niche innovations exist that try to build alternative pathways for food systems at a local scale, many drivers of change - and conversely many lock-in factors - are situated at a national or supra-national scale (Freibauer *et al.*, 2011). It is therefore necessary to understand how national stakeholders can discuss possible transformation pathways and identify levers of action. Continuing agricultural growth in a business as usual (BAU) mode would not enable many targets to be met simultaneously (Paillard *et al.*, 2011). Deep changes are needed if we are to see concurrent improvements in poverty, food and nutrition security, health, rural development and the environment. To enter a sustainable development path under the right conditions, national stakeholders will need clear and converging socio-economic, policy and technology roadmaps to achieve the targets that they consider to be a high priority. However, as of today, few countries have developed a clear understanding of how to make transformative changes in complex and diverse food systems that would enable them to meet key cross-sectoral targets.

The Agricultural Transformation Pathways Initiative focuses on developing, adapting and applying practical toolkits for countries to build, adopt and implement long-term policy roadmaps to achieve transformative changes in agriculture and food systems.

The Agricultural Transformation Pathways Initiative (ATPi) focuses on developing, adapting and applying practical toolkits for countries to build, adopt and implement long-term policy roadmaps based on sound science to achieve transformative changes in the consumption and production of food and agricultural products by 2030, that could help them meet high priority targets for the future transformation and development of their agriculture and food sector. In this sense, this initiative aims to go beyond a traditional modelling exercise and intends to make a firm contribution to national policy debates through participatory processes and the identification of the critical building blocks for a transformation pathway.

The initiative also aims to contribute to an international learning process where countries help one another to achieve the transformation of their agricultural sectors and food systems. It therefore intends to share the national roadmaps and the methodology used on a wide scale. In an internationally coordinated effort, teams from different countries analyse what objectives their own country must achieve and how, share methodological tools and approaches, and exchange knowledge on the implementation of agricultural transformation strategies. Apart from demonstrating that goodwill exists, international exchanges also allow to identify the needs in terms of international cooperation which are, in many contexts, prerequisites for change that are beyond the reach of national levers of action.

Designing definite pathways to implement national sustainability targets for agriculture and food systems within an international platform provides firm experience on the development of trajectories and on the modalities of SDG implementation at national and international scales. It gives useful information on a variety of organizational, institutional, economic and technological roadblocks impeding transformation, but also levers that might help overcome them. The purpose of this report is to illustrate how the initiative can contribute to policy and planning at the national scale by showcasing three pilot case studies conducted in Uruguay, China and the United Kingdom, before proposing transversal lessons based on these pilot studies.

Methodology

The methodological approach promoted by the initiative is inspired by and builds on the extensive work conducted in the world's sixteen largest economies as part of the Deep Decarbonization Pathways Project (Deep Decarbonization Pathway Project, 2015), coordinated by SDSN and IDDRI. The approach is based on two main pillars: **(i)** a participatory approach involving key stakeholders; and **(ii)** a step-by-step methodology based on "backcasting".

Pillar 1: Participatory approach – Building a shared vision and encouraging buy-in

The first main pillar of the initiative is its special emphasis on the participatory building of pathways. Over the past decade, researchers and practitioners have repeatedly emphasized the importance of participatory approaches, especially to design transitions towards sustainability (Bohunovsky *et al.*, 2011; Weaver & Rotmans, 2006). In the framework of the initiative, the analysis and discussion of pathways are implemented in each country by national stakeholders and experts already involved in the national policy debate. National expert teams develop a participatory approach involving key stakeholders from academic institutions, industry asso-

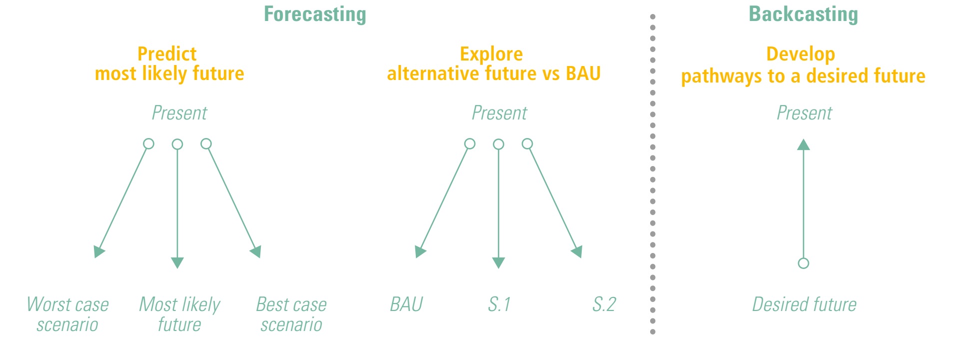
ciations, farmer organizations, civil society and government to achieve three goals:
(i) bring knowledge to the project by consulting experts and practitioners from within the country of interest; (ii) foster policy debates on the important issues facing the country; and (iii) generate buy-in among stakeholders, which is fundamental to overcome a number of sociological and political roadblocks to transition.

Pillar 2: Backcasting - Building a vision of the future we want

The term "backcasting" denotes a process in which a target is fixed for a future date, and then a pathway towards achieving that target is identified by moving backward in time (Robinson, 1990). Backcasting differs from forecasting scenario analysis in that the latter develops multiple futures from a single present, while the former develops pathway(s) for a single desired future. The approach is strongly problem-solving oriented and enables the setting of priorities and goals, the ranking of solutions in terms of priority and the identification of steps that need to be taken, and also when particular steps must be carried out to enable the desired outcome to be obtained.

Backcasting has been applied for more than three decades as an operational approach in the pursuit of sustainable development, and has been used extensively to develop strategic paths towards greater sustainability at different scales, from industrial parks or office areas (Robert, 2003) to cities (Carlsson-Kanyama *et al.*, 2007) and regions (Giurco *et al.*, 2011). While the majority of studies involving backcasting have focused on the energy sector or greenhouse gas emissions (Robinson, 1982; Mulder & Biesiot, 1998; Anderson, 2001; Giurco *et al.*, 2011; Deep Decarbonization Pathway Project, 2015…), a number of more recent analyses have used backcasting as a way to build futures for agricultural and food sectors (such as Vervoort *et al.*, 2014) and deserve further consideration and study. This initiative aims to make a contribution to this area of research.
One of the specific challenges that backcasting approaches have to face when building pathways for the agricultural and food sector is that sustainable agricultural transformation cannot focus on a single global target (such as the 2°C target or the greenhouse gas (GHG) emissions reduction target adopted for climate change), but instead must take into account and prioritize a raft of targets. Win-win solutions may not exist for some agriculture-related targets, and trade-offs are therefore to be expected, for instance between provisioning services (agricultural production in the near future) and regulating services (such as water purification, soil conservation or carbon sequestration) (Power, 2010). In this regard, a sustainable development pathway for an agricultural and food system can only result from a political choice concerning these trade-offs and priorities, and therefore needs to be de-

Figure 1. Illustration of different approaches for scenario planning and future studies



bated and decided at the national or local scale, taking into account the specific conditions of countries and regions.

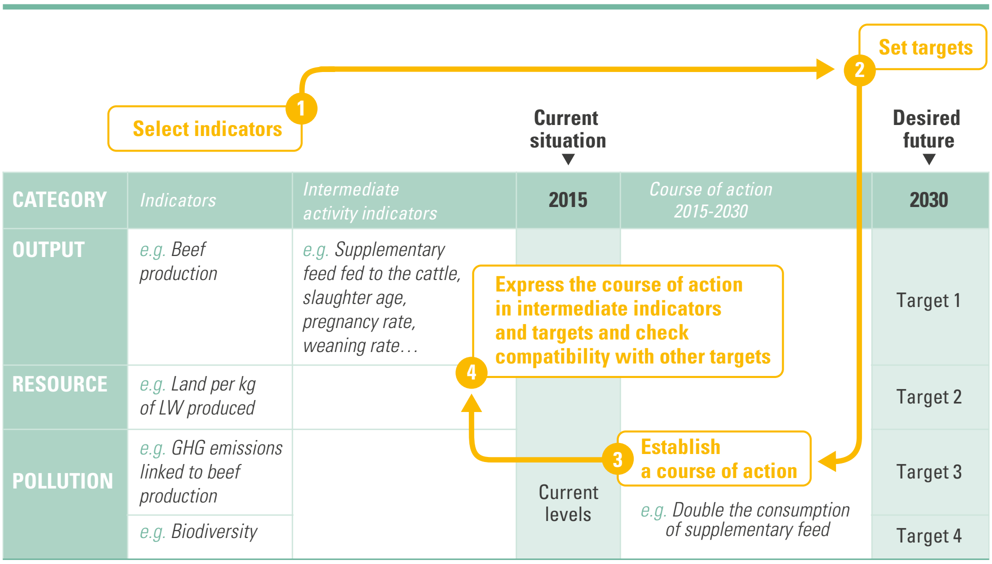
The first step in building a national transformation pathway is therefore to analyse the current situation of a country. Only by doing this can one identify the most critical challenges faced by a particular country, decide on the appropriate scale and scope of analysis and select indicators that enable the evaluation and monitoring of the transformation progress under particular conditions.

To reflect the critical challenges facing agricultural transformation under specific national situations, the selection of relevant indicators should come from all three dimensions of sustainability (economic, social and environmental) and across all 17 SDGs. The selected indicators should reflect the tensions between these different categories that the agricultural and food system in the country considered will have to overcome to reach sustainable development. To further refine the "sustainable agriculture" indicator proposed in the SDG framework (proportion of agricultural area under "productive and sustainable agriculture" (UN, 2016), indicators can be selected among three broad categories: production and productivity, resources/efficiency and pollution indicators (**Table 1**).

Table 1. Illustration of possible sustainability indicators for agriculture and food systems and corresponding SGDs

CATEGORY	Possible indicators	Dimension	SDG
OUTPUT	Total population, total food consumption, food consumption per capita, total food production, percentage of population below minimum level of dietary energy consumption, percentage of overweight and obese…	Food security and nutrition	SDG1, SDG2, SDG3, SDG12
	Agriculture and food chain GDP, farmers' income, proportion of farmers living poverty line, number of people active in agriculture and food chains…	Economic development, Poverty alleviation/ Resilience	SDG1, SDG8, SDG9, SDG10
WASTE	Food waste and losses as percentage of production	Efficiency	SDG2, SDG12
RESOURCES	Total agricultural area, agricultural land productivity, water use efficiency, nitrogen use efficiency, energy use efficiency…	Environment	SDG6, SDG7, SDG12, SDG13, SDG14, SDG15
WASTE	N and P losses from leaching and runoff	Environment	SDG2, SDG6, SDG12, SDG14, SDG15
POLLUTION	Net GHG emissions from the agricultural sector, degraded agricultural land, biodiversity loss, not collected solid farm waste (plastic etc.)	Environment	SDG2, SDG3, SDG6, SDG12, SDG13, SDG15

Figure 2. Illustration of the backcasting approach as used in the initiative



Determining the current levels and establishing 2030 target values for these indicators is another step towards the building of a *future we want*, towards which a pathway with a firm course of action remains to be discussed and refined.
To build such a pathway, the ATPi methodology produces two specific inputs that are essential but often not available for policy debate:

- The translation of 2030 targets (e.g. 30% reduction in GHG emissions) into tangible technical indicators of activity (e.g. number of animals; yields…) that enable decision makers to be better informed and also to provide more concrete elements to the national debate. Dashboards can help in making consistency checks that lead to feasible courses of action (**Figure 2**);
- The identification of particular bottlenecks and levers of action to address lock-in factors (see case studies below).

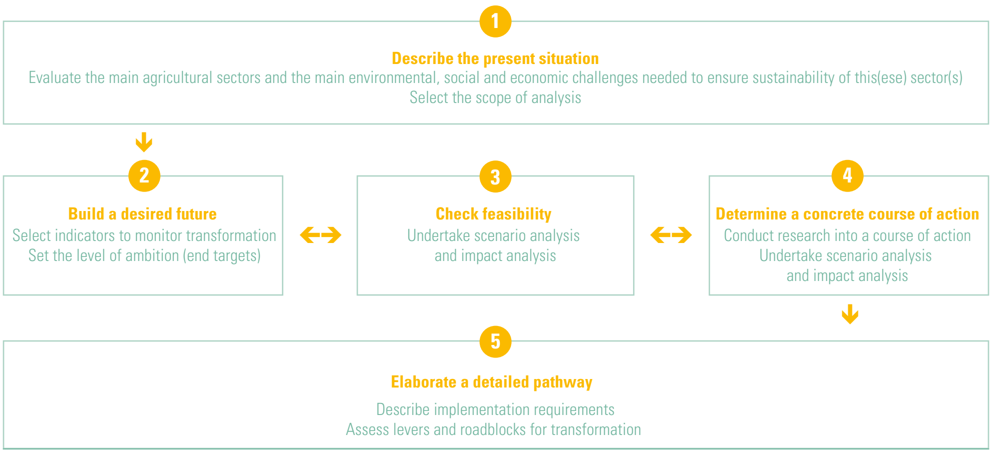
The collective development of roadmaps through backcasting and participatory methods does not only inform the conditions of transformation and enable the different types of stakeholders to make convergent decisions from the beginning, it also works towards the building of a compelling and shared vision for transformation.

Through its backcasting and participatory approach, this initiative provides particularly relevant input to the policy debate, as it enables:

1. the discussion of assumptions about technological progress in the agriculture and food sector, that economic modelling exercises generally represent as endogenously linked to changes in prices;
2. the identification and qualification of the main bottlenecks and roadblocks to transformation, across a variety of dimensions, including:
   a. technical and financial factors, such as the lifespan of infrastructure which, once an investment has been made in that infrastructure, cannot then be replaced by other investments, even if a different infrastructure type may be more relevant for sustainable food systems;
   b. economic factors such as the level of the relative prices of inputs and/or outputs, which drive or restrict investment in new technologies;
   c. organizational or logistical factors such as the existence of collective infrastructure or co-operatives which operate such infrastructure;
   d. sociological factors such as the existence or absence of networks sharing information and technical resources among groups of farmers;

Figure 3. A step-by-step methodology

The ATPi general methodological framework is designed to be adaptable to the particular situation of each country, and to help national expert teams develop scenario analyses and transformation processes that fit their own circumstances, while ensuring comparability among countries.



e. institutional factors such as path dependencies stemming from the business models in place (e.g. the input supply industry, which typically aims to sell more products); and political factors such as power relationships between local stakeholders that can prevent central policymaker reforms from reaching smallholder farmers (see for instance Schwoob, 2015).

Once the most critical of these roadblocks have been identified, further quantification exercises might also be relevant to further feed the policy debate. In this regard, the initiative also functions as a tool to prioritize needs for studies and analyses.

This 2016 report of the ATPi focuses on an initial analysis of the feasibility of agricultural transformation pathways in three pilot countries with contrasting types of agriculture and food systems: Uruguay, China and the United Kingdom. In the framework of the initiative, these countries have already started developing ambitious and realistic pathways supporting national policy debates and informing the conditions of implementation of the SDGs in the agricultural sector. From October 2014 to January 2016, the pilot country teams worked on the refinement of methods and tools, relying on an innovative blend of social and biophysical sciences. This report presents this latest research along with the initial results.

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URUGUAY

The Uruguayan case study was led by the main agricultural research institute (Instituto Nacional de Investigación Agropecuaria – INIA), the policy and planning office of the Ministry of Agriculture (Oficina de Programación y Política Agropecuaria – OPYPA), and the Uruguayan office of Columbia University's International Research Institute for Climate and Society (IRI).

Country profile and main challenges

Uruguay is a small country with a population of 3.4 million people. It is an open economy, strongly export-oriented, with large countries as neighbours such as Argentina and Brazil. Although it suffered a major downturn at the end of the 1990s and beginning of the 2000s, mostly stemming from the economic and financial crisis in Argentina and Brazil, Uruguay has now become an upper-middle-income country and the best performing continental economy of Latin America in terms of GDP per capita.

The agricultural sector plays a crucial role in the Uruguayan economy. The agricultural value added accounts for more than 8% of the national GDP and employment in agriculture accounts for 9% of the total employment. Moreover, more than 80% of the land is dedicated to agriculture (FAO database, 2013). Rice is the most important crop, followed by soybean (which has been developing tremendously over the past decade, partly driven by increased demand for silage, hay and grain in the beef and dairy sectors and influx of Argentinian capital) and wheat and barley (driven by the development of soybean, as complementary products for crop rotation). Livestock is another fundamental agricultural sub-sector, with permanent meadows and pastures accounting for 83% of the agricultural land (FAO database, 2013).

A national pathway towards more sustainability

Approach: a sectoral approach focusing on the beef sector

As a first step, in order to simplify the exercise and turn pathways into rapid, concrete and focused actions, it was decided to focus on the beef sector as a priority, for several reasons. The beef sector is a critical economic component of Uruguay's agricultural sector, responsible for approximately half of Uruguay's agricultural GDP.

Moreover, the sector supplies 5% of the volume of globally traded beef, making up 20% of the total value of Uruguay's exports (Bervejillo, 2015). Uruguay's beef sector is also the dominant source of employment in the agricultural sector, with about 44,000 production units, most being family owned and run (Bervejillo, 2015).

In addition to its economic importance, Uruguay's beef sector also has a significant environmental footprint – largely because of its impacts on land use and on the climate. Despite the recent increase in crop production that have infringed upon some of Uruguay's most productive soils, the land devoted to beef production still covers over two thirds of Uruguay's surface area, posing threats to this land in terms of nitrate leaching and erosion. In addition, beef production is responsible for approximately three quarters of Uruguay's greenhouse gas emissions, with 55% of these emissions from methane, and 45% from nitrous oxide (Piaggio *et al.*, 2012).

For all of these reasons, making the agricultural sector in Uruguay more sustainable necessarily requires significant investment in the transformation of the beef sector. The implicit business as usual scenario would consist of the continuation of the following interrelated trends:

- reduction in the pastureland area used for livestock production, that would intensify in feedlots as a result, with new environmental impacts (risk of excess in manure compared to what soils can actually absorb, for instance);
- conversion of pastureland into cropland, partially to feed the animals with soybean, increasing the risks of environmental degradation (water pollution increase, biodiversity losses, greenhouse gases emissions, soil erosion…);
- risk of a loss in the differentiation of Uruguayan beef on international markets, as a result of the reduction in environmental quality and lower emphasis on extensive production systems and preservation of the natural environment;
- potential changes in the structure of farms and the nature of jobs (for instance, a reduction in the number of family farmers and an increase in the number of agricultural workers in feedlots).

Despite its significant environmental footprint, the Uruguayan beef sector is strongly committed to stringent environmental and health quality standards. The international reputation of the Uruguayan beef, massively exported (over the past ten years, almost 70% of fresh beef has been exported annually on average), is based on a "Uruguay Natural" brand, with high added-value. Therefore, the Uruguay beef is largely grass-fed, committed to sanitary and food safety standards including zero use of antibiotics and hormones, and has a mandatory traceability system. The willingness to maintain these attributes and the place of the country in the niche in the global market provides a strong rationale to select targets and build a transformation pathway for the sector that would significantly differ from the above-depicted business as usual and intensification scenarios.

Identification of productivity targets and a course of action

The sustainable intensification of the Uruguayan beef sector is a multi-objective optimization issue: the challenge is to maximize productivity, while minimizing a range of environmental impacts such as impacts on land and climate mentioned above. Compared to the business as usual scenario, the aim of sustainable intensification in the extensive beef sector is to increase productivity while staying within the limits of an extensive production system. This challenge makes it a useful example for other similar situations around the world.

Productivity was seen as a fundamental objective of the beef sector's development roadmap and was therefore handled first by the national expert team. In order to set a productivity target and design a course of action to reach this target, an analysis of the best practices of farmers within FUCREA (Federación Uruguaya de los Grupos Crea, an organization that includes some of the most productive farmers in Uruguay) was conducted.

These practices were used as inputs for a beef productivity model developed by Soares de Lima (2009). This dynamic model simulates beef cattle production at the farm level, across all stages of development (from cow-calf to slaughter), following the performance of individual animals across time. The model includes a simulation of nutritional requirements (feed demand being determined by the requirements of the entire herd, which is the sum of the individual requirements of each animal in the system), herd dynamics, and different farm management strategies. Feed supply is one of the components of the model, determined by the quality and quantity of pasture produced by the farm in addition to any supplementary feed (silage, hay, grains, minerals, vitamins, etc.). For the purpose of this project, the model was adapted to represent Uruguay's national beef production as a single unit of production.

Feed supply comes from the area of pasture devoted to beef cattle in the country. This area comprises two types of land: natural grasslands, and improved pastures. Improved pastures are areas where selected grass and legumes are either sown with no tillage or minimum tillage operation, or broadcasted directly with fertilizers on the natural grassland surface. Legumes are a common choice to improve pasture, as they provide more nutrition, thereby accelerating animal growth rates.

Assuming that the total land carrying animals does not change (which is a key component of halting biodiversity loss – see below), the strategy to increase production focuses on the improvement of feed, through the following course of action:

- increase improved pastures from 15.4% to 30% of the total grazing area devoted to beef production by 2030;
- doubling the amount of feed supplements fed to young cattle by 2030 by integrating a variety of vitamins, amino acids, fatty acids and minerals into cattle diet that are not present in a regular grass-fed diet. Much of this can be provided by supplemental feed from grains, hay and silage.

Improved pastures and feed supplements accelerate animal growth rates, thus reducing the age of first pregnancy as well as slaughter age. The following intermediate targets of activity were set, as a way to check the technical consistency of actions and their effect on the total productivity:

- increasing the number of 2 year old heifers at first pregnancy to three quarters (compared to the current situation, where half of the heifers are two years old and the other half are three years old at first pregnancy);
- increasing the number of weaned calves from 67 weaned calves for every 100 breeding cows to 77 weaned calves for every 100 breeding cows.

These intermediate targets of activity were put as inputs to the Soares de Lima's beef productivity model to estimate the national average beef productivity by 2030. Reducing the average slaughter age from 38 months to 25 months by 2030, and increasing the total number of animals slaughtered from 2.4 million to 3 million per year, lead to a national productivity forecast in 2030 of approximately 128 kg (live weight) of beef per hectare and per year in the model, up from the current value of 102 kg, representing a 25% increase.

Table 2. Baseline values (current production levels) and results by 2030 simulated by the Beef Productivity Model

Parameters	Description	Baseline		2030	Baseline to 2030
End target	Production (kg LW/ha/year)	102	↗	128	
Related Outcome	Total slaughter (million heads)	2.4	↗	3.0	
	Breeding cows (million heads)	4.1	↗	4.5	
	Total herd (million heads)	11.7	↗	11.9	
Intermediate targets	Average slaughter age (months)	38	↘	25	
	First pregnancy at 2-year old (%)	50	↗	75	
	Average age at first pregnancy (months)	32	↘	25	
	Pregnancy rate (%)	72	↗	73	
	Weaning rate (%)	67	↗	77	
Course of action	Proportion of improved pastures (%)	15.4	↗	30.0	
	Feed supplements (kg/ha)	19	↗	37	
Imposed restriction	Total grazing area (million ha)	11.1	→	11.1	

Identification of environmental targets and a course of action

In terms of environmental targets, the approach was to combine literature review and expert consultation in order to get a sense of what could be the most ambitious environmental targets given the productivity goals Uruguay also wishes to achieve.

Targets were developed for three environmental issues: carbon footprint (kg CO_2/kg LW), biodiversity (maintaining pastureland for beef production area, million ha) and nitrogen losses (kg N/kg LW). For carbon footprint and nitrogen losses in particular, compiling the impacts of applying different practices and technologies enabled the defining of targets for 2030 as follows: 25% decrease in carbon footprint and 27% reduction in nitrogen losses (**Table 3**).

The biodiversity target was considered in terms of maintaining the pastureland for beef production area, meaning zero expansion (at the expense of natural land) and zero reduction (conversion into cropland) in the amount of land devoted to beef production by 2030. The zero expansion of pastureland is directly inspired by one of the proposed Sustainable Development Goals, which calls for a complete halt of forest conversion to crop or livestock agriculture by 2030. The effects on biodiversity of increasing, within different types of pastureland, the proportion of improved pastures (with respect to natural pastureland) still have to be assessed with precision.

Increasing the proportion of improved pasture has significant environmental co-benefits for carbon sequestration, methane reduction and nitrate leaching and run-off. Because legumes increase nitrate content in soils, which in turn drives grass growth, improved pasture allows more carbon sequestration in soils compared to natural grasses. Data from the CENTURY model suggests that, on average, improved leguminous pastures sequester 100 kg more carbon per hectare per year than natural grasslands. Increasing the proportion of improved pasture from 16.8% today to 30% in 2030, thus avoiding the emission of 1.1 million tons of CO_2e per year.

Improved pastures also have effects on methane reduction. Consumption of legumes has been shown in certain cases to increase diet digestibility in livestock, which in turn can reduce the amount of methane emitted per head due to enteric fermentation (Eckard *et al.*, 2010). For example, Ramirez-Restrepo and Barry (2005) note that while methane emissions from cattle consuming perennial ryegrass are 24.4 g methane per dry matter intake (DMI), legumes such as sulla and lotus lower emissions to 19.7 g methane per DMI. This means that the carbon footprint of cattle grazing on natural grasslands is 7 kg of CO_2e per kg of beef produced (live weight), compared to improved pastures where the carbon footprint can be as low as 5.6 kg of CO_2e per kg (or 100 kg CO_2e per hectare compared to 80 kg CO_2e per hectare), which is even lower than the carbon footprint of beef production systems confined in feedlot in Uruguay (Modernel *et al.*, 2013). However, other publications have reported negligible decreases in methane emissions as a result of a transfer from perennial ryegrass to legumes (Dini *et al.*, 2012), so this is clearly an area where more research is needed. Nevertheless, for the purpose of this report, the assumption of Ramirez-Restrepo and Barry was adopted, leading to estimate that increasing the proportion of improved pasture from 16.8% today to 30% in 2030 could reduce methane emissions nationwide by approximately 0.7 million tons of CO_2e per year, or 5% of Uruguay's

Table 3. Environmental targets for Uruguay beef production addressing climate change, biodiversity and nitrogen pollution

Issue	Metrics	Baseline	Change	2030	Baseline to 2030
Production	kg LW/ha/year	102	↗ 25%	128	
Carbon footprint	kg CO_2/kg LW	20.8	↘ 25%	15.5	
Nitrogen	kg N/kg LW	66	↘ 27%	48	
Biodiversity	beef area (million ha)	11.1	→ ≈ 0%	11.1	

emissions from enteric fermentation. It should be noted that while other practices exist to reduce methane emissions, they frequently involve more micromanaged nutrition or the use of antibiotics, which would be considered contrary to the 'Uruguay Natural' brand.

Finally, increasing the amount of improved pasture is estimated to reduce the amount of nitrate run-off (from livestock manure) from 30% to 18%. Consequently, increasing the proportion of improved pasture from 15.4% today to 30% in 2030 could reduce nitrate leaching by 3,000 tons of nitrate per year.

Two other courses of action were identified for their efficiency in decreasing the carbon footprint and nitrogen pollution: nitrification inhibitors and trees for shade. Nitrification inhibitors have been particularly effective in countries with beef-grazing systems such as New Zealand, reducing nitrous oxide emissions by 64%-82% (Di & Cameron, 2002; Di *et al.*, 2010). Nitrification Inhibitors can also reduce other forms of nitrogen pollution, including nitrate (by 42%-76% in Di & Cameron's study, 2002) and nitrogen oxides (by 40% on average (Akiyama *et al.*, 2010). Furthermore, urease inhibitors have been shown to reduce ammonia emissions by an average of 75% by delaying the hydrolysis of urea (Trenkel, 2010). If 50% of grazing land devoted to beef production were to use nitrification inhibitors, the carbon footprint could be reduced by 0.3 kg of CO_2e per kg of beef produced or 40 kg of CO_2e per hectare, and Uruguay would avoid nitrogen losses of 24,250 tons per year.

Increasing the number of trees for shade is used across Uruguay to provide shade for livestock, protecting them from heat stress which can otherwise significantly reduce productivity levels (Torquato *et al.*, 2012; Silanikove, 2000). This practice could also help sequester carbon and further reduce net greenhouse gases emissions. Currently, about 78,000 hectares of grassland – less than 1% of the grazing area in Uruguay – have trees in Uruguay, sequestering 0.9 tons of carbon per hectare. Increasing the proportion of grazing area with trees to 10% would avoid additional emissions of 3.6 million tons of CO_2e per year. Due to lack of data, we are not able to estimate the potential increases in beef productivity due to increased protection from heat stress, so the productivity target estimated above should be regarded as conservative.

Table 4. Breakdown of the main strategies for reducing the beef sector's carbon footprint and their individual contributions towards GHG mitigation

Metrics	Baseline	2030 with and without additional measures				
		BAU	+Nitrification inhibitors	+Improved Pastures	+Trees for shade	All measures combined
Kg CO_2e/kg LW/year	20.8	-3.6	-0.3	-0.3	-0.9	15.5
Kg CO_2e/ha/year	2,330	-110	-40	-100	-330	1,750

Table 5. A breakdown of current and future loads of nitrogen pollution (by major nitrogen compound) under a business-as-usual and mitigation scenario. A combination of improved pastures and nitrification inhibitors could reduce nitrogen losses by ~30% per kg LW.

Parameters	Current		2030	Curent to 2030
Productivity (kg LW/ha/yr)	100	↗	130	
Area (millions ha)	11.1	→	11.1	
Manure production (tons N/yr)	145,850	↗	189,210	
Nitrate (tons N/yr)	41,060	↘	38,750	
Ammonia (tons N/yr)	14,590	↘	11,840	
Nitrogen oxides (tons N/yr)	14,590	→	14,590	
Nitrous oxide (tons N/yr)	3,520	↗	3,630	
Total N pollution (tons N/yr)	73,750	↘	68,810	
N pollution per kg beef (kg N/kg LW)	66	↘	48	

Breaking down average productivity and environmental targets into intermediate activity indicators enables a check to be made of the overall consistency of assumptions and helps question the technical feasibility of a selected course of actions. It is a crucial step that feeds into the policy debate, by opening up explicit discussions with all stakeholders.

Implementing the course of action

Identifying levers and roadblocks

The targets established for 2030 in the Uruguayan beef cattle system are ambitious, particularly given the focus on feeding by means of natural grasslands with low levels of supplements. The ambition is to increase production and maintaining or increasing share in an international market that is expected to become steadily more competitive. Technical change is needed that avoids the most common intensification pathways that inevitably lead to feedlots.

One of the strengths of the Uruguayan agricultural and food system is its robust inter-institutional framework. Uruguay indeed has a consolidated public R&D system as well as solid public-private organizations that promote technology adoption and beef consumption and provide guarantees of traceability, quality and safety.

At the same time, a number of roadblocks are likely to constrain the implementation of the above courses of action, and it is necessary to identify them right from the beginning in order to set actions intended to overcome them. This framework is illustrated in the Strategy Matrix below (**Table 6**). For each of the four categories of action, there are particular levers and roadblocks which in some cases are common for many categories.

Human capital was identified an important roadblock across categories. A large part of the improved practices depicted above require skills that may not be available at the farm level, especially since most of the technologies are process-based, rather than input-based. As road-

Table 6. Strategy Matrix for the transformation of the Uruguayan beef sector

PRODUCTIVITY	BIODIVERSITY	CLIMATE	NUTRIENTS
Target +25% productivity at farm gate	**Target** Native forest conservation	**Target** -25% kg CO_2/kg LW	**Target** -27% kg N / kg LW
Roadblocks • Lack of technology transfer capacity • Lack of labor skills • Farmer attitude and age • Farm infrastructure and water access R&D	**Roadblocks** • Stakeholders interests • Knowledge adoption and diffusion • R&D	**Roadblocks** • R & D • Cultural factors such as breed preference • Lack of financial incentives • Knowledge adoption and diffusion • Farmer training	**Roadblocks** • Enforcement of existing regulations • Knowledge adoption and diffusion • Farmer training • Stakeholders interests • Inter-institutional coordination • R&D
Levers to overcome roadblocks • Lever 1: Inter-institutional framework for technology transfer • Lever 2: Training programs (farmers) • Lever 3: Incentives to improve infrastructure, adopt better management practices and reduce financial risks	**Levers** to overcome roadblocks • Lever 1: Forest law based on incentives (1987) • Lever 2: Grazing management practices • Lever 3: Stewardship and environmental values	**Levers** to overcome roadblocks • Lever 1: Research to improvefeed conversion efficiency (genetics) • Lever 2: Increased market reach and value for Uruguayan beef • Lever 3: Data on GHG emissions and carbon footprint.	**Levers** to overcome roadblocks • Lever 1: Regulations on water quality standards and soil use and management practices (Water and soils law - 1981) • Lever 2: Inter-institutional coordination on water quality at the watershed level • Lever 3: Farmer best management practices • Lever 4: Incentives for adoption of new technology

blocks that are related to human capital across the four categories, farmers' age, interests, attitudes, preferences, and training were also mentioned. All these roadblocks are particularly challenging because they are linked to the decision process at the farm level. Unless individual farmers are convinced about the benefits of the proposed change in the way they manage farms, they will not adopt new technologies. Programs and interventions that are already in development might contribute to overcome such roadblocks.

An example of pathway implementation: a new strategy for technology transfer

Some of the levers identified in **Table 6** have been in place for some time already, such as the Forestry Law of 1987, which shall serve as institutional support for developing some of the strategies linked to biodiversity conservation. Some others were specifically designed to overcome roadblocks, such as the inter-institutional program for technology transfer currently developed by the Ministry of Livestock, Agriculture and Fisheries (MGAP). The new technology transfer task force for the beef sector aims at encouraging the adoption of new technologies and management practices by farmers and fill the gap between the average and the best performing farmers.

The technology transfer task force is led by the MGAP and includes a variety of organizations, such as the National Institute for Agricultural Research (INIA), the Agrarian Plan Institute (IPA), the Uruguayan Wool Secretariat (SUL) and the National Meats Institute (INAC). These institutions will have different roles: INIA for technological issues, IPA for capacity building, MGAP for the operational framework at the local level. Local private organizations are expected to operate as the beneficiary of the applied public funds, which will in turn be used for hiring the technical advisors.

Although there are barriers related to infrastructure, market development, risk management and others, this inter-institutional effort will focus primarily on technical assistance, disseminating technology and results obtained by the most efficient farmers. There is a large gain to be obtained by improving the decision-making process at the farm level, without the need for large investments in inputs. Low input beef production technologies are available and it is a matter of changing the decision-making process, reallocating inputs to affect productivity levels increasing profits as a result. It is also important that technical assistance be initially provided at no cost to the farmer so as to ensure that farmers have an incentive to continue using new technologies and practices over the long term. Previous work found that the positive impacts of an intervention (usually financed by international development agencies) were lost because there were no incentives for the farmers to continue improving their productivity levels once the program was finished (Kanter *et al.*).

Areas for further analysis

In the case of this pilot study on Uruguayan beef, the focus has been on the beef sector and on the productivity/environment nexus only. It already shows very interesting results that identify a practicable vision of a sustainable, more productive but still extensive beef sector. Nevertheless, other socioeconomic or environmental impacts could be assessed in a further development of the initiative, such as:

- the potential impacts of increases in feed from soybean at the expense of other natural ecosystems (in Uruguay or outside its borders, e.g. in the Brazilian cerrado if feed is bought from a neighboring country);
- the potential impacts of technical changes on jobs in the livestock sector, on incomes and on the attractiveness of the livestock sector in general;
- the potential impacts on biodiversity of an increased proportion of managed pasture among different types of pastureland.

The technology transfer task force will be developed in a progressive way, starting in 2016 with the goal of reaching a certain number of farmers and scaling up in the following years. It will be based initially in two or three different locations. In each one a base line and long term targets will be established. Because locations are different in terms of potential, the specific targets will be slightly different. The Beef Productivity Model utilized at the national level will be also used to evaluate the feasibility of productivity targets at the regional level.

In each of the selected locations an inter-institutional technical group will be leading the implementation plan. Each group will instruct, supervise, and evaluate a number of technical advisors; and each technical advisor will work with a group of farmers. The participating farmers will be linked to a local organization such as a cooperative.

The progressive development of the technology transfer task force will provide useful information about levers and roadblocks and enable to elaborate the Strategy Matrix. The above-depicted course of action is not an exhaustive list of the potential GHG mitigation strategies for Uruguay's beef sector, and as the GHG and other environmental targets are implemented, other mitigation strategies may emerge as better suited to a particular region.

For what concerns a more holistic exploration of sustainability transformation pathways, Uruguay is willing to conduct analyses of two other sectors that are at the core of its agricultural sector, and that are inter-related through the constraints on land use change as well as through flows of biomass or nutrients with the beef sector and with one another: rice production and dairy production. The soybean sector, from which more capacity to produce feed for the beef sector is expected, would also need to be studied.

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CHINA

In the case of China, the project was led by the Key Laboratory of Agricultural Water Resources, based at the Center for Agricultural Resources Research of the Chinese Academy of Sciences and by the China Agricultural University.

Country profile and main challenges

China, the world's most populous country, has to feed almost 20% of the world's population with only 7% of the world's arable land. Furthermore, it needs sufficient food at affordable prices, as the share of food remains high as a proportion of total consumer spending (about 35% of urban and rural budgets in 2012, according to the National Bureau of Statistics). However, the country now faces a decrease in the amount of arable land and water resources available for farming, along with a degradation in their quality, caused by a number of factors including urbanization, industrialization and intensive agriculture.

Meanwhile, the growing middle-class – especially in urban areas – is showing a rising demand for new types of food. This trend has stimulated national oil and meat consumption, which in turn has had a tremendous effect on the demand for land-intensive products such as oilseeds and feed, primarily soybean and maize, which is needed to supply the booming industrial livestock sector. During the past few decades, China has massively increased its food production and imports of agricultural products to keep pace with the dramatic increases in national demand. Since the country became a net food importer in 2004, its negative agricultural balance has increased on a daily basis.

Considering the demographic weight of the country, the stakes go well beyond the Chinese territory. Should China fail to maintain a certain level of self-sufficiency in agriculture, there could be disastrous consequences on global food markets and, ultimately, on other importing countries. The risks are also substantial for China. Despite the fact that its massive trade surplus theoretically balances its rising food imports, relying on global markets for food would put the population at greater risk in terms of price volatility. Tackling food security issues has been a real priority for the Chinese government since the beginning of the 21st century (Schwoob, 2015). The effort to increase domestic agricultural production to cope with the rising demand have been accompanied with significant increases in inputs such as water, nutrients and pesticides. The use of chemical fertilizers and pesticides, in particular, has been heavily encouraged since the 1970s, resulting in their overuse, which in turn has led to serious environmental damage as well as concerns about food safety and human health. Heavy metal pollution caused by accelerated industrialization is another serious issue to be added to the list of human health risks (Lu *et al.*, 2015).

The deterioration of soil, water and air quality may become even more critical by 2030, when China's population, its urbanization rate and consumption of animal-derived food per capita is expected to peak (Ma *et al.*, 2013a). China urgently needs to develop a course of action to sustainably intensify food production while minimizing food waste and GHG emissions, along with the development of efficient soil, water and nutrient management practices, China must also attempt to identify a course of action to manage changes in food demand.

The Chinese government has already recognized the fundamental importance of making agriculture more sustainable. In March 2015, the 'National Plan on Sustainable Agricultural Development 2015-2030' was published, putting special emphasis on guidelines linked to productivity, land resources protection, water use efficiency, pollution mitigation and ecosystem services provided by agriculture. A critical question that needs to be explored is how to translate these general guidelines into roadmaps for the whole agricultural and food chain. Given the scale of such a large country with very diverse types of agricultural production, the first step of the process was a scoping exercise to analyse the average national level statistics, with the objective of identifying the most critical characteristics of a transformation towards more sustainable agriculture and food systems.

A national pathway towards greater sustainability

Approach: exploratory scenarios to assess the efficiency of different courses of action

To develop a course of action for the agricultural and food sector, a baseline scenario was developed with BAU trends for population, urbanization rate and diet (S0), along with exploratory scenarios that simulated **(i)** technical improvements in crop and animal production (S1); **(ii)** dietary adjustments and a reduction of food waste (S2); and **(iii)** increases in food and feed imports (S3). For each scenario, single and combined impacts were evaluated for changes in inputs and efficiencies (agricultural land, nitrogen, phosphorus, water, etc.), nitrogen (N) and phosphorus (P) losses, and greenhouse gas emissions in 2030. The development of BAU and exploratory scenarios and their single and combined impacts enabled realistic targets to be established, along with their corresponding courses of action.

The national expert team projected requirements of food, feed, and N and P fertilizers using NUFER (NUtrient flows in Food chains, Environment and Resources use), a mass balance model that the team had developed for nutrient flows, stocks and losses across the food chain (Ma *et al.*, 2010, 2013 b). The model included seven main crop combinations (rice, wheat, maize, soybean, vegetables, fruits and grasses) and six animal categories (pig, dairy cattle, beef cattle, laying hens, broilers, sheep and goat), which together account for most of China's crops and livestock.

Plant-based and animal-based food requirements in scenarios for 2030 were calculated using FAO projected population and urbanization rates, information about rural and urban diets (NBSC, 2011), and parameters of food losses and food allocation during or between processing, transportation, and consumption sectors from literature and survey data. Feed requirement was calculated following IPCC guidelines (IPCC, 2006) and through the net energy requirement of animal production using the NUFER model. The IPCC provided the prediction of feed dry matter intake by ruminants, according to the net energy requirement. The NUFER model was developed to analyse nutrient use and losses in the food chain in China (Ma *et al.*, 2010), and also to analyse the feed requirements of different animal categories (pig, layer, broiler, dairy, beef and draught cattle, sheep and goat) (Bai *et al.*, 2013, 2014), based on the net energy requirement and feed composition per animal category.

The plant-based food and feed requirements were then aggregated to estimate the resources requirements (land, water and fertilizer) and environmental impacts (nitrogen losses, phosphorus losses and GHG emissions) of domestic crop and animal production. The land requirement was calculated from the plant-based products requirement and crop yield derived from the FAO database. The fertilizer requirement was calculated from the applied fertilizer rate per hectare and the land requirement for each crop species. The water requirement was calculated according to the water footprint of different agricultural products. Finally, GHG emissions were calculated according to the IPCC approach. In this study, only non-CO_2 GHG emissions were evaluated, mainly through the use of the IPCC Tier 1 method. The CH_4 emission from rice production was estimated to be 43.5 kg CH_4 per ton for rice (Gustavsson *et al.*, 2011) and the CH_4 emission through straw burning (around 20% of rice, wheat, maize and soybean straw is burned) was evaluated considering that 4.6 g CH_4 was emitted into the air when 1 kg of straw is burned (Gustavsson *et al.*, 2011). The CH_4 emission from enteric fermentation and manure management were derived from an IPCC report (IPCC, 2006). As N_2O emissions are affected by precipitation, the direct and indirect N_2O emissions of applied chemical fertilizer were calculated using emission factors and average precipitation.

Scenario 0 is the BAU situation. Under this scenario, there is no change in urban diets, which have remained fairly constant in recent years (NBSC, 2011). However, due to the rapid increase in rural incomes, the BAU scenario predicts that rural diets will reach the same levels of the urban population by 2030. As the Chinese government is encouraging intensive livestock production (MOA, 2011) with a high reliance on concentrated feed, under this scenario more cereals will be used as feed. The national expert team assumed that the percentage of feed concentrates would increase by about 30% compared with 2010 (a conservative estimate, as the total maize and soybean feed consumption rate has already increased by about 20-30% between 2010 and 2013 (FAO database).

Scenario 1 is based on S0 but incorporates technical improvements in crop and animal production. According to recent studies, crop yields of rice, wheat and maize could increase by 17%, 45% and 70% respectively by 2030 through the adoption of knowledge and technologies that are already available, without using more fertilizer or other inputs (Chen *et al.*, 2014). The Integrated Soil-Crop System Management (ISSM) practices simulated in this scenario involve agronomic measures such as planting appropriate crop varieties or hybrids at the right sowing dates and densities, and applying fertilizer according to crop demands and soil fertility. Such agronomic improvements still represent a hugely underutilized potential in China. Hence, since the main goal of the project was to assess near to medium-term interventions, above-mentioned numbers were used as 2030 productivity targets for the S1 scenario.

For soybean, vegetable and fruit production, it was assumed that yields could be increased by 25% by 2030 (Ma *et al.*, 2013b). The rates of ammonia emission and nitrate leaching from chemical fertilizer and manure use in soybean fields could be reduced by 50%, following improved nutrient management technology (Chen *et al.*, 2014). Meanwhile, fertilizer use in vegetable and fruit production could be reduced by 30%, primarily by avoiding over application of chemical fertilizers and manure (Yan *et al.*, 2013). Future livestock productivity can be significantly improved in China by introducing phase feeding in pig production (Niemi *et al.*, 2010), total mix ration feeding in cattle production (Kolver & Muller, 1998), sanitation improvements to reduce mortality rates, and by importing high performance breeding boars and bulls. Under S1, the yield of pig and broiler production is expected to increase by 20% by 2030 compared with 2010. For other animal categories, high production systems have larger technology gaps in comparison, for example, to farming systems in the US. The national expert team therefore assumed that productivity could increase by 40% for beef and draught cattle, sheep and goat, layers and dairy production. It was also assumed that N losses due to manure management could be reduced by 50% (Ma *et al.*, 2013a). Massive amounts of animal manure are currently discharged into ponds and rivers (Wang *et al.*, 2010), due to poor regulation and governance. However, as the first regulations for manure were recently released (SCOC, 2013), the national expert team assumed that the manure recycling rate would increase from 20% to 75% in 2005 to an average of 80% in 2030.

Scenario 2 is based on S0 but allows for dietary improvement. This scenario was designed to simulate a slowdown of the increase in animal-derived food consumption following broad adoption of the recommended Chinese dietary guidelines. These guidelines are based on a 2007 human nutrition survey by the Chinese Nutrition Society and the nutrient requirement standards of the World Health Organization. Recommendations include: **(1)** eating a range of foods with cereals as the staple; **(2)** consuming adequate amounts of vegetables, fruits, and tubers; **(3)** consuming milk, beans, or dairy or bean products every day; **(4)** consuming appropriate amounts of fish, poultry, eggs, and lean meat; and **(5)** reducing the intake of animal fat in the diet. If these recommendations are followed, the consumption of meat will decrease and that of milk, eggs, beans, and fruit will increase compared with 2005. The national expert team assumed that the

Table 7. The crop and animal productivity, food import rate and calculated food supply rate in China in 2010 and in 2030 according to different scenarios.

	Productivity (ton/hectare or kg of product/head)		Related products net import rate (%)		Diet (food supply rate, excluding feed and other ultimate stocks) kg dry matter/capita/year					
					Urban			Rural		
	2010, S0, S2, S3	S1, S1+2, S1+2+3	2010, S0, S1, S3	S2, S1+2, S1+2+3	2010	S0, S1, S3	S2, S1+2, S1+2+3	2010	S0, S1, S3	S2, S1+2, S1+2+3
Rice	6.5	7.7	0.2	10	101	101	80	131	101	80
Wheat	4.7	6.9	2.0	10	47	47	37	78	47	37
Maize	5.5	9.2	3.4	10	2.4	2.4	2	12	2.4	2
Soybean	1.8	2.0	84	84	3.0	3.0	15	5.1	3.0	15
Vegetables	23	27	-1.7	10	451	451	304	205	451	304
Fruits	11	12	-2.0	10	108	108	222	42	108	222
Grass	1.0	1.0								
Pig	73	88	0.9	10	50	50	21	22	50	21
Broiler	1.4	1.7	3.6	10	18	18	9.1	8	18	9.1
Beef and draught cattle	139	194	3.9	10	8.8	8.8	2.9	1.0	8.8	2.9
Sheep and goat	14	20	2.1	10	4.6	4.6	1.8	1.3	4.6	1.8
Dairy	2904	4065	7.1	20	52	52	130	4.4	52	130
Layer	9.4	13	0	10	30	30	17	6.8	30	17

changes in consumption would lead to proportional changes in production. Under this scenario, both urban and rural diets would change to reach the recommended levels by 2030.

This scenario includes another course of action focused on achieving a 20% reduction of food waste and losses by the end of 2030, through the increased use of refrigerator transportation trucks, improved food storage facilities and education campaigns to promote the prevention of food waste.

Scenario 3 is based on S0 but with increasing imports of plant-based and animal-based food and feed. According to the priorities established by the Chinese government, the self-sufficiency of maize, wheat and rice should not decrease below 90% (CSC 2014). In S3, it was assumed that the self-sufficiency in all plant-based and animal-based food and feed products would reach 90% in 2030, except for soybean and milk. The soybean import rate would stabilize at 84% (in 2010, China was already importing 60% of globally traded soybeans). Given the milk import rate increased rapidly after the melamine scandal in China, this scenario assumes that this import rate would reach 20% in 2030.

Identification of targets

The most challenging period for the Chinese food system will be around 2030, because both population and urbanization are expected to peak around this time. If China follows the current dietary trends (S0), the demand for cereals for human consumption will decrease by 14%, but the demand for animal-derived food, vegetables and fruits, and animal feed cereals and grass will increase by percentages of between 40% to 109%. A major challenge under this scenario will be to satisfy the requirement for fodder such as grass or alfalfa, which will increase by a factor of 1.8 compared with 2010.

Under this scenario, resource consumption increases significantly. The requirement for arable land for crop production is projected to increase by 1.4 times – which seems highly unrealistic as China is already facing challenges due to the scarcity of agricultural land. By 2030, the requirement for irrigation water will increase by a factor of 1.1, while that for nitrogen fertilizer will increase by 1.4 compared with 2010. Nitrogen use efficiency in the food chain (NUEf) will decrease from 10% in 2010 to 8% in 2030. Finally, GHG emissions (N_2O and CH_4) will increase by 1.3.

Results obtained from alternative scenarios indicate technical improvements in crop and animal production to be the single most effective intervention. Improvement of the genetic potential of crops and animals, integrated soil-crop system management, integrated livestock management and manure management may greatly improve the agronomic and environmental performance of crop and animal production systems. Under scenario S1, with 100% of the achievement rate (i.e. if technology and practices are scaled up at the national level), the projected requirement for cropland will decrease from 164 to 110 million ha, and from 555 to 396 million ha for grassland. The consumption of N and P fertilizers and water, and the emissions of GHG from the food chain are predicted to decrease by 42%, 7% and 17% respectively in S1 compared with S0.

The second most effective intervention is achieving dietary change and reducing food waste (S2). If the population follows the recommended Chinese food dietary guidelines, the projected food demand will increase by 478% for milk products and 35% for animal feed (cereals), but will decrease by 4% for eggs, 34% for meat, 3% for grasses, and 34% for plant-derived food (cereals) in 2030 compared with that in 2010. Under the S2 scenario (with 100% achievement rate) the projected demand for land and inputs will be reduced by 19% for cropland, 46% for grassland, 7% for N fertilizer, 26% for P fertilizer and 23% for water, while GHG emissions are predicted to decrease by 17%, all in comparison to the S0 scenario.

A combination of S1 and S2 is even more effective at decreasing the requirements for cropland, grassland and water as well as reducing GHG emissions by 28-62% in S1+S2, compared with those in S0. Furthermore, Nitrogen Use Efficiency and Phosphorous Use Efficiency could increase to 17% and 13% respectively in 2030.

If the S1 and S2 cannot be realized completely, the third intervention, S3, is a backup option to close the gap between the demand and supply of food and feed by increasing imports from other countries, which of course would also entail significant trade-offs for other countries to address. In this scenario, by 2030, 10% of vegetable and animal products, 80% of soybean and 20% of dairy products will be imported from abroad. Cropland requirement, grassland requirement, N fertilizer, water footprint and GHG emissions in China would decrease by 7-11% compared with those in S0. The overall impact of this scenario is less than that of the S1+S2 scenario.

The combination of all three major options (S1+S2+S3, with 100% achievement rate) would decrease the requirement for cropland, grassland, chemical fertilizer and water in China and reduce nitrogen and phosphorus losses and GHG emissions in China by 31-68% compared with S0.

Table 8. Targets for resources for the following scenarios: BAU, S1+S2, S1+S2+S3

	Unit	2010	S0	Change	S1+2	Change	S1+2+3	Change
Cropland	million ha	123	167	↗ +36%	96	↘ -22%	84	↘ -32%
Grassland	million ha	377	613	↗ +63%	232	↘ -38%	209	↘ -44%
N fertilizer	Tg	29,47	41	↗ +39%	23	↘ -22%	20	↘ -32%
P fertilizer	million m3	6,1	8,4	↗ +38%	3,7	↘ -39%	3,3	↘ -46%
Blue water	million m3	272	293	↗ +8%	214	↘ -21%	189	↘ -30%
GHG emission	Tg	893	1112	↗ +25%	782	↘ -12%	731	↘ -18%

Table 9. Targets for waste for S2, illustrated with food material flows in the food chain (% of dry matter) (numbers in brackets are 2010 figures)

Food item	Initial product	Food before processing	Food before distribution	Food available for consumption	Real human consumed products
Wheat	100	78	56	55	47 (46) ↗
Maize	100	5.9	5.6 (5.5) ↗	4.7 (4.4) ↗	3.8 (3.5) ↗
Rice	100	82	53	52	44 (42) ↗
Soybeans	100	8.3	6.1	5.2 (5.0) ↗	4.3 (4.0) ↗
Vegetables	100	85	82	66 (61) ↗	53 (48) ↗
Fruits	100	85	82	67 (62) ↗	54 (50) ↗
Pig meat	100		90 (80) ↗	77 (76) ↗	72 (70) ↗
Beef	100		90 (79) ↗	75 (74) ↗	70 (68) ↗
Mutton	100		90 (78) ↗	73 (72) ↗	68 (66) ↗
Chicken meat	100		90 (66) ↗	63 (62) ↗	59 (57) ↗
Egg	100		100 (91) ↗	87 (86) ↗	81 (79) ↗
Milk	100		100 (89) ↗	89	85 (84) ↗

Initial product: crop after harvest or live animals before slaughtering;
Food before processing = Initial product - post-harvest losses;
Food before distribution = Food before processing - processing losses;
Food available for consumption = Food before distribution - distribution losses;
Real human consumed products = Food available for consumption - consumption losses.

This step of the analysis illustrates the importance of examining average balances for a large country such as China and disaggregating this data into activity indicators for specific types of production. Such a process enables a more explicit discussion among stakeholders in the policy debate about the consistency and feasibility of different target levels and the different options available to attain these targets.

Implementing a course of action

The national expert team demonstrated in its analysis that through a scaling-up of existing technologies and practices, dietary changes and a reduction of food waste, China could radically alleviate the environmental issues caused by its food and agricultural sector, while at the same time increasing food productivity to meet future food demands. A national sustainable

Table 10. Strategy Matrix for the transformation of the agricultural sector in China

	CROP PRODUCTIVITY AND N USE EFFICIENCY	LIVESTOCK PRODUCTIVITY AND N USE EFFICIENCY	CONSUMPTION
	Target Increase productivity by levels indicated in Table 7	**Target** Increase productivity by levels indicated in Table 7	**Target** -35% meat, -28% cereal for human consumption
	Roadblocks	**Roadblocks**	**Roadblocks**
	• Poor scale-up of innovative technology transfer networks • Entrepreneurial skills / Risk aversion / Farmers age	• Small size of farms • Lack of enforcement of regulations/interinstitutional articulation i.e. Environmental protection bureaus with other bureaus • Lack of knowledge • Few economic incentives to improve feed quality and manure management	• Western influence on food habits • Lack of political willingness to influence consumption patterns
	Levers	**Levers**	**Levers**
R&D	• Lever 1: Comprehensive sets of research on farming practices, such as ISSM for other cropping systems	• Lever 1: Integrated sets of research on genetic, feed improvement and herd management	• Lever 1: Sociological research linking nutrition, diet and behavior
Action and institutions at the farm gate	• Lever 2: Innovative networks for technology transfer	• Lever 2: Innovative networks for technology transfer	• Lever 2: Good media coverage to convey government's messages
Policy, regulation and institutions	• Lever 3: Well-designed economic incentives to adopt new technology • Lever 4: Well-designed economic incentives to design sustainable farming system, such as cereals-forages rotation	• Lever 3: Well-designed economic incentives for manure management equipment and machinery • Lever 4: Deepen regulation on water quality standards and manure management practices • Lever 5: Well-designed economic incentives to support land-based animal production	• Lever 3: Responsibility of local health bureaus
Action of industry and market	• Lever 5: Reducing and recycling waste during harvest and processing	• Lever 6: Re-designing manure markets and manure application machinery markets	• Lever 4: Label and retail regulation
Actions and institutions at the consumer level			• Lever 5: Role of consumers associations, i.e. to reduce food waste
Co-benefits	BIODIVERSITY Target: -32% cropland	GHG EMISSIONS Target: -18%	N AND P REQUIREMENTS Targets: -32% N fertilizer, -46% P fertilizer

agricultural and food strategy could include the following actions:

1. accelerating knowledge and technology transfer in crop farming systems. There are already solutions to increase productivity and lower environmental impacts (e.g. Integrated Soil-crop System Management, crop rotation...) but more work is needed to accelerate the transfer of knowledge from research to practice, through better models for education, training and extension as well as more aggregated agricultural enterprises and services. Innovative networks already exist to address these challenges. For instance, the Science and Technology Backyard (STB) programme has established over 60 community-driven platforms for agricultural technology research and application in rural areas since 2009. Professors and graduate students from agricultural universities live in the STB villages and work with farmers to study, optimize and exchange agricultural knowledge, and to help farmers to adopt new technology. This model has demonstrated potential in both agricultural technology innovation and agricultural technology extension (Shen *et al.*, 2013). Similar initiatives should be further developed.
2. strengthening the institutional framework to improve manure management, to effectively enforce regulations on water quality standards and to support pasture-based livestock systems, for instance through economic incentives, adapted machinery and relevant markets.
3. improving feed quality, as feed is a major lever both to improve productivity and lessen the environmental impacts of livestock systems. Action should focus on: precision feeding depending on the production phase and time of the year, utilization of complementary nutrients and valorisation of uncultivated grassland to produce grass and legumes such as alfalfa.
4. policies and education strategies that promote a healthy diet and reduction in food waste and sociological research linking nutrition, diet, food waste and behaviour. Consumer associations are likely to play a significant role in educating the public to increase awareness of healthy diets and the importance of reducing food waste.

Areas for further analysis

From 2016 to 2017, the Chinese national expert team will develop this work further by conducting several case studies focusing on specific sub-sectors to refine the details of the courses of action needed to achieve the targets. They intend to focus primarily on two main sub-sectors:

- Maize production, which will drive the increase in fertilizer use in China over the coming years. A first assessment of the national level situation has already been conducted, establishing preliminary targets to transform the sector and improve its productivity and sustainability. However, further work is needed at the regional level because considerable differences exist in terms of farming practices. Four regions were identified with specific maize cultivation systems and specific pathways will be developed for these regions.
- Dairy production: Over the past decades, the growth of the dairy sector has been based mostly on the development of industrial production systems, which have huge consequences for N and P pollution. The demand for milk is likely to keep on growing in China in the coming years, and actions are needed to carefully monitor the development of the dairy sector and halt its environmental impacts.

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UNITED KINGDOM

The UK case study was led by Rothamsted Research.

Country profile

Agriculture in the UK represents 0.7% of the country's gross domestic product, while employment in agriculture accounts for only 1% of total employment (or about 430,000 people). However, the UK's agri-food sector, which includes production, manufacturing, wholesaling, retailing, and non-residential catering, accounts for £103 billion, or 6.8% of national global value added, and employment in this sector is 13.4% of the total workforce (or 2.73 million people) (DEFRA, 2014). In addition, agricultural land represents more than 70% of the total land area, making it a fundamental sector regarding environmental issues and ecosystem services. The UK is only about 60% self-sufficient in all foods (DEFRA, 2008) and the food trade deficit, which has grown almost continuously for the past two decades, reached £20.7 billion in 2014.

Therefore, reducing GHG emissions and increasing resource-use efficiency in food production and consumption, and reconstructing sustainable agriculture and food systems are among the main challenges faced by the UK. Among the international community, there is a growing consensus on the fact that business-as-usual food production is unsustainable and will cause increased soil degradation and environmental pollution (FAO, 2011). However, solutions vary from country to country on how to reconstruct a more sustainable food production-consumption system that uses fewer resources to produce more food. One specific issue that has been subject to in-depth investigation in the UK is the reduction of GHG emissions by restructuring agricultural systems to increase the area of land available to act as a carbon sink. According to a recent study, land sparing to allow habitat restoration to increase carbon sequestration may be possible if sufficient land can be freed up through increased crop yields: a continuation of the average rate of the past 40 years (1.3) would be sufficient. If such a yield improvement were achievable, the GHG emissions reduction from the agricultural sector alone would enable the UK to meet its GHG commitments of an 80% cut by 2050 in comparison with its level in 1990 (Lamb *et al.*, 2016). However, other studies have shown that a number of crops in Europe have already reached or are close to reaching their maximum biological yields (Brisson *et al.*, 2010; Cassman, 1999; Lobell, 2012). Therefore, more research is needed to assess efficient and feasible courses of action to reduce the environmental impacts of agricultural production in the UK while at the same time improving its self-sufficiency.

A national pathway towards greater sustainability

Approach: exploratory scenarios with upper and lower bounds

Exploratory scenarios were developed by the national expert team with the aim of: (i) assessing the potential gap between production and consumption in 2030 under different scenarios, and (ii) exploring the available leeway for improving food production systems and making them more sustainable.

In the first step of the scenario development, it was hypothesized that the UK population would increase from its current 63 million people to 71 million people in 2030 and that there would be no change in grassland and cropland areas, as was the case between 1992 and 2010 (**Figure 4**).

Apart from fruits, the yields of which are still rising, cereal, potato and vegetable yields appear to have peaked in the middle of the 1990s. It is not clear what has caused this plateau, although different hypotheses have been put forward (Brisson *et al.*, 2010; Cassman, 1999; Lobell, 2012). Given this uncertainty, the national expert team decided to follow the approach suggested by Lamb *et al.* (2016), setting a lower and an upper bound for future crop yields. The lower bound is based on the assumption that yields have already peaked and there is no room for improvement. The upper bound assumes that there is still potential for growth through improvement and innovation in agronomy and breeding (Reynolds *et al.*, 2012; Whalley *et al.*, 2006), and that yields could continue to grow at their average rates of the past 30 years (**Figure 5**). For vegetables and oilseed that did not show any obvious growth over the past 30 years, it was assumed that their future yields would remain the same as their current average yields.

Figure 4. Change in croplands and grasslands from 1992 to 2010

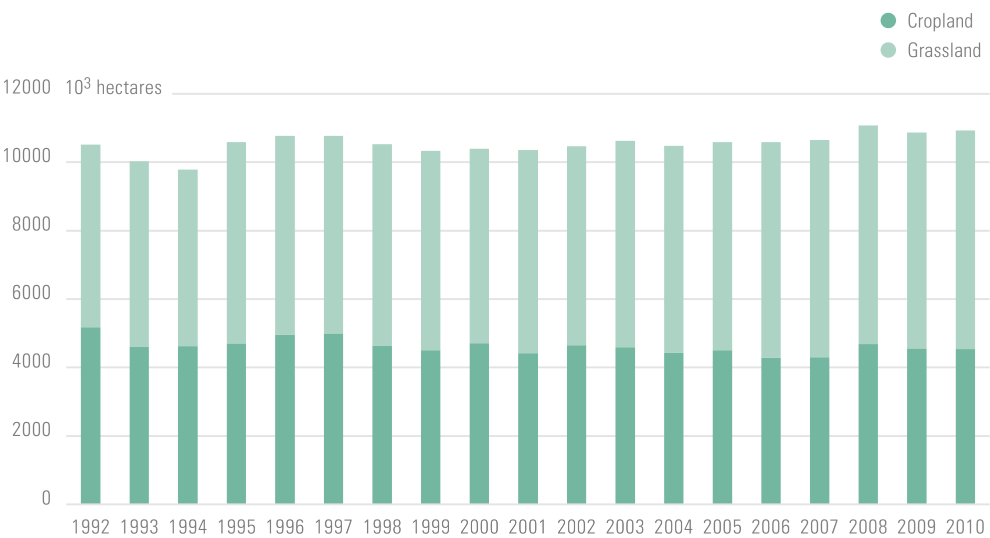


Figure 5. Change in yields of the six major crops and the upper and lower bounds set for the projected yield growth

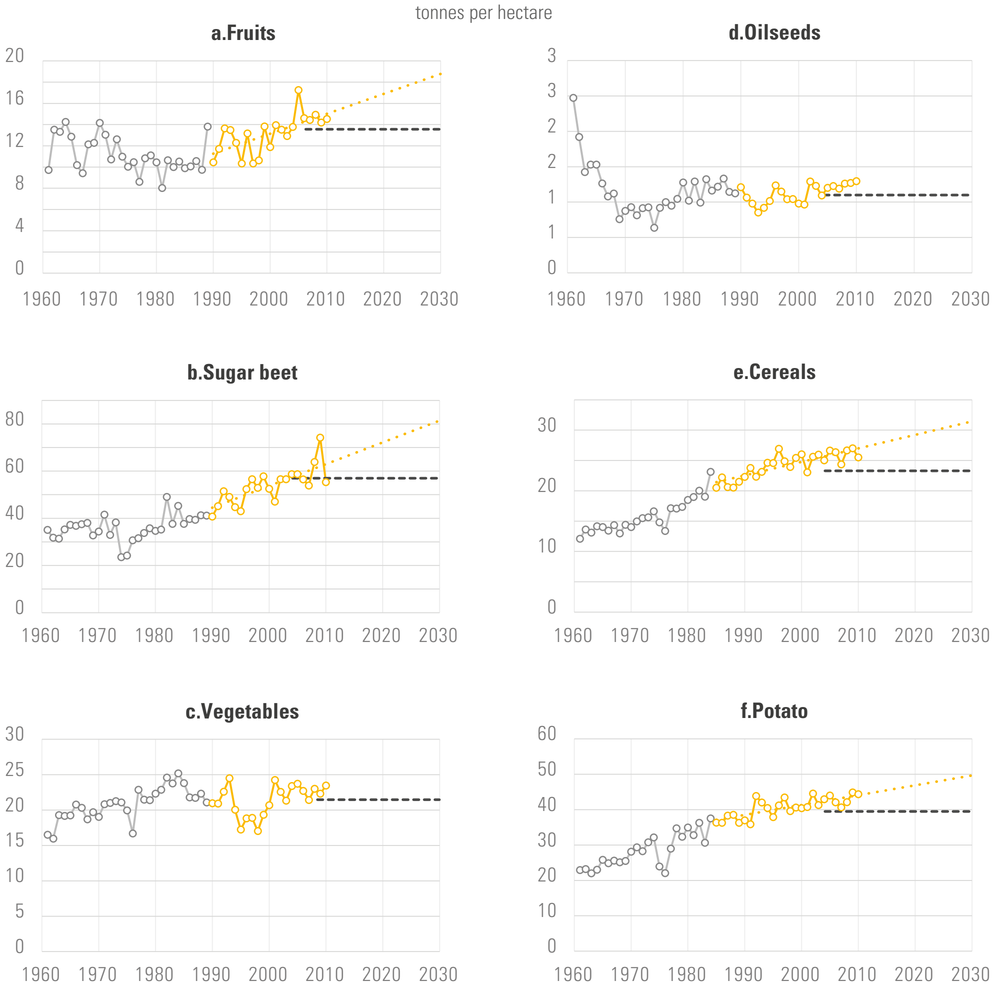
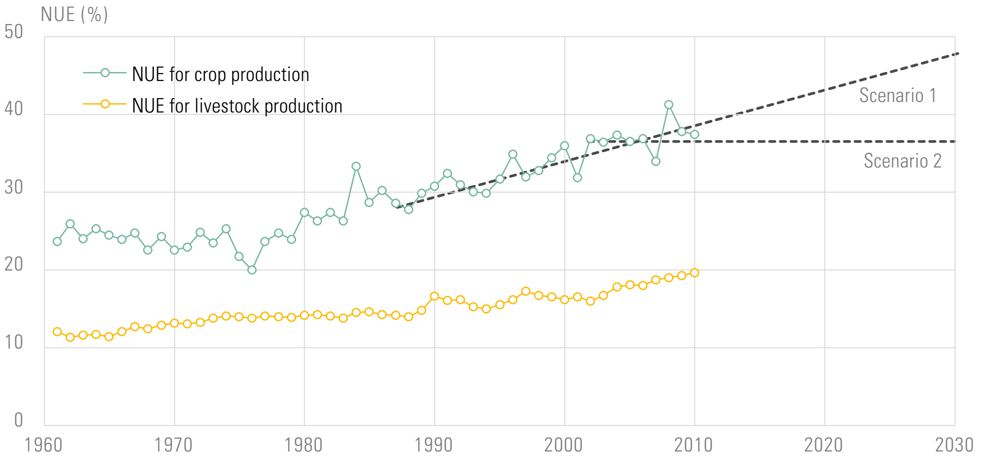


Figure 6. Change in nitrogen use efficiency (NUE) for crop and livestock production



For nitrogen use efficiency, the national expert team also considered two scenarios. The application of fertilizer in both croplands and grasslands has been in decline since peaking in the middle of the 1980s. This is largely due to the increase in nitrogen use efficiency (NUE). The hypothesis for the lower-bound scenario is that efficiency has peaked and will remain at the current value; the one made for the upper-bound scenario is that the efficiency will continue to increase at its average rate over the past 50 years through genetic improvement and/or technological invention, such as the application of nitrification inhibiters that slow nitrogen loss from soils.

Food waste in the UK has been the subject of many investigations. Based on the available data, post-harvest waste for each category was estimated to be: cereals 33%, oilseeds 11%, potato 40%, fruits and vegetables 32%, meat 19%, egg 25%, and milk 9%. Based on a study of the available literature, a 50% reduction in food waste by 2030 was determined to be achievable.

The national expert team first analysed how the change in yields and a reduction in food waste could affect self-sufficiency under different scenarios. In this report, only arable food crops were analysed and it was assumed that the cropland area will remain unchanged until 2030.

Identification of targets

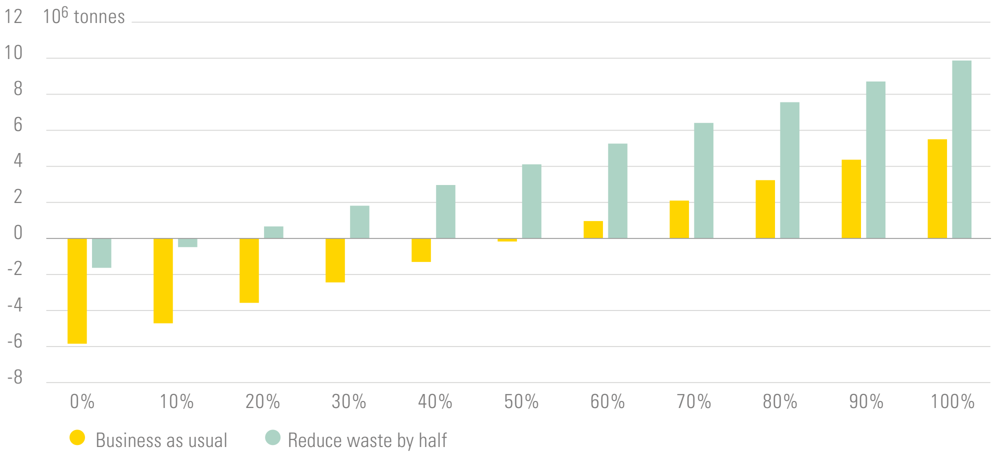
If there is no further growth in yields and no efforts are made to reduce food wastes (business-as-usual scenario), then overall self-sufficiency – measured in nitrogen intake – will decline from 75% to 65% in 2030 (**Figure 7**). A sufficient supply of all foods will depend on imports, as shown in **Figure 8**. While UK citizens may not consider this to be an unsustainable situation, an increase in overall import dependency also raises the possibility of the externalization of negative social and environmental impacts to other countries.

If food waste can be halved by 2030 compared to 2010, there will be a small surplus in food production if crop yields increase at approximately 70% of the average rates over the past 20 years (**Figure 9**). The production of cereals and sugar beet will exceed domestic demand, especially wheat and barley, which are the two most important crops in the UK. This will make land sparing possible to allow more forest and woodland restoration, so as to increase the country's level of carbon sequestration and help the UK meet its GHG commitments of an emissions reduction of 80% in 2050, in comparison with 2010.

The first conclusion that can be drawn from the development of these scenarios is that reducing

Figure 7. Overall self-sufficiency for arable food crops, with and without food waste reduction

The difference between production and consumption in terms of nitrogen in 2030 under different scenarios
(0%: crop yields do not increase; 100% crop yields increase at 70% of the average rates over the past 20 years)



waste by 50% is a more efficient solution to improve self-sufficiency without increasing environmental impact, whereas increasing yield appears to be more difficult.

Therefore, although efforts to increase resource-use efficiency should continue, the construction of a sustainable agriculture pathway for the UK requires considerably more focus on reducing waste in the food chain.

Unlike crops, livestock production systems have not shown any growth since the middle of the 1990s. If the anticipated increase in consumption by 2030 is to be met by increased domestic livestock production rather than imports, the only way to achieve this is for the increased grain production to be used as feed, assuming that significant grass yield improvement is not possible. Based on the literature, the grain requirements

Figure 8. Self-sufficiency of each food crop without reduction in food waste

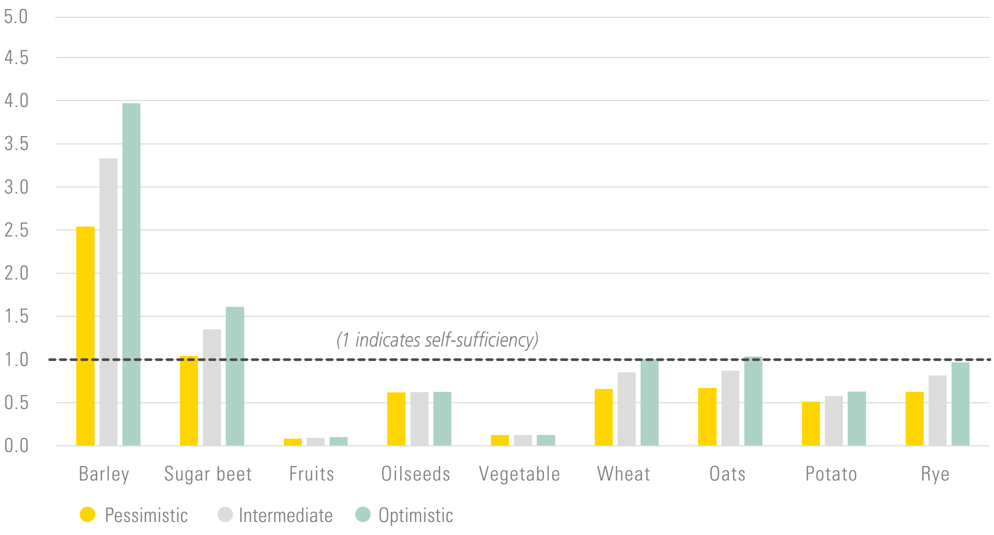
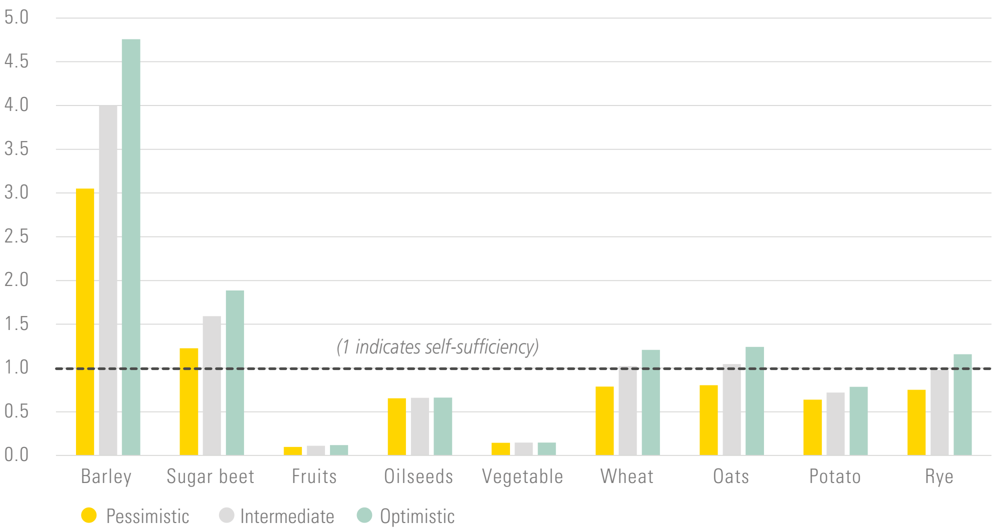


Figure 9. Self-Sufficiency of each food crop if waste is reduced by half in comparison with 2010



for the production of one kilogram of beef, pork, sheep, poultry, milk and eggs are estimated to be 10kg, 4kg, 4.5kg, 2.5kg, 0.4kg and 3.3kg, respectively. Therefore, the increased consumption of animal products will require an extra 4.0×106 tonnes of grain if food waste is not reduced, and 3.60×106 tonnes if waste can be reduced by half in 2030 in comparison with 2010. Unless grain yields continue to increase at a rate of at least half of the average rates of the past two decades, grain production will not be able to meet the increased demand under a business-as-usual scenario. This potential situation, however, can be significantly improved if the UK reduces food waste to reach this 50% reduction by 2030 in comparison with 2010. This could allow land sparing for approximately 50,000 ha, which could be used for forest and woodland restoration to increase carbon sequestration, without sacrificing food supply. For example, if land use change from cropland to woodland increases carbon sequestration by 4 tonnes of carbon per hectare per year, the spared land could capture up to 200,000 tonnes of carbon in one year. In the meantime, it would also reduce emissions of N_2O and NH_3 due to reduced fertilizer application.

Dietary changes can have a significant impact on self-sufficiency and managing the consumption of certain products could help avoid the externalization of environmental issues to other countries. Since 80% of barley is used for feed, reducing meat and sugar consumption would reduce the demand for barley and sugar beet. This would generate surpluses of both crops if the harvested areas remain unchanged. For other cereals, unless yields continue to grow at the average rates of the past 40 years, production will become insufficient by 2030 if no effort is made to reduce food waste. The national expert team estimated that a 50% reduction of waste by 2030 would mean that cereal production could be adequate even allowing for a yield increase of only half the average rates of the last 50 years. In contrast, the production of other crops will be insufficient. This could be addressed by either trading cereals for fruits and vegetables on the international market, or by converting barley and sugar beet fields to fruit and vegetable production.

The preliminary results of this analysis show that two courses of action should be favoured in the UK in terms of generating environmental benefits and obtaining self-sufficiency: the reduction of food waste and the reduction of meat consumption.

Areas for further analysis

Since reducing meat consumption increases the demand for plant-based foods, the assessment of the impact of such a substitution on GHG emissions must take into account the decreased GHG emissions resulting from a decrease in livestock production *and* the increased resource demands and GHG emissions resulting from an increase in plant-based food production. Since this report did not consider grasslands, the national expert team intends to investigate this area in detail in the next phase of the project. The technical references and pathways developed in the Uruguayan case study on how to obtain productive, but still extensive, livestock production systems could prove very useful in this regard.

The last step carried out in the two other case studies, namely the discussion of the main roadblocks and levers of transformation requires further development for the UK case study. For instance, the UK team did not consider food prices, which impact food production and trading in international markets. Further investigation is necessary because the reconstruction of sustainable agricultural systems must take into account the fact that importing certain foods can be more environmentally friendly than domestic production.

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MAIN CONCLUSIONS AND LESSONS LEARNED FROM PILOT CASE STUDIES

Building pathways

It is possible to build pathways with both economic and environmental benefits

The challenges of the coming decades are immense. Not only are nearly 800 million people still suffering from malnutrition but natural resources are being rapidly degraded, partly because of agricultural intensification. It has become necessary to launch a major deliberation process on how to implement national strategies that would enable countries to reach the intertwined goals of reducing hunger and achieving economic, social and environmental sustainability. These goals are not necessarily opposed but can be difficult to realize simultaneously. Establishing tools that enable the assessment of trade-offs and the monitoring of progress are therefore necessary.

In the case of the SDG2, indicators are currently being developed. For instance, an indicator on the "proportion of agricultural area under productive and sustainable agriculture" has been proposed (United Nations, 2016). The way this indicator is formulated itself raises crucial questions: how should "sustainable" agricultural practices be defined? It seems that agreement on this indicator will serve to mark only the beginning of more in-depth national discussions that will be needed to answer precise questions and to develop corresponding tools, in a global movement but with specific developments in each singular national situation.

There are reasons why indicators for SDG2 are particularly difficult to define. Agriculture is a multidimensional activity which does not only produce staple commodities that are necessary to human lives, but also maintains employment in rural areas, shapes the countryside and its resources and is a major provider of environmental services – while, at the same time, being also a major cause of environmental degradation. The purpose of this Agricultural Transformation Pathways Initiative is to demonstrate that despite these particularities of the agricultural and food sector, it is possible to build national transformative roadmaps adapted to the particular conditions of each country.

The three pilot cases of the initiative demonstrate that goodwill exists to achieve transition and that collective efforts have already been made at different scales and in different countries. It shows that it is possible to gather different stakeholders around the table to make them discuss and agree on a transformative roadmap, with detailed targets and strategic steps.

The pilot cases also demonstrate that options exist that have both economic and environmental benefits. A number of actions can increase productivity and alleviate environmental issues at the same time, demonstrating the global positive outcome of transformation and the compatibility of socio-economic goals and environmental protection. Evaluating the impacts of a given action in detail necessitates the specification of disaggregated activity indicators to feed national debates on what could be achievable (targets in each dimension) and on the consistency and feasibility of different technical options to reach targets (see first step of the analyses: setting targets and identifying a course of action). For instance, in Uruguay, improved pasture with legumes can increase beef productivity and decrease greenhouse gas emissions. It is fundamental that more research is conducted on this topic and that the results of actual experiments in the field are widely disseminated. Only by sharing this knowledge between regions and countries will global transformation be achievable for the agricultural and food sector.

Initiatives have to be taken at least at the national level

Another contribution brought by these first agricultural transformation pathways is to demonstrate that the initiative to build transformative strategies for a more sustainable agriculture has to be taken at least at the national level, notwithstanding other innovative changes coming from local stakeholders or necessary initiatives at the regional scale. We firmly believe that participatory processes are fundamental to inform national and sub-national strategies, to generate buy-in among stakeholders and to reduce non-technological barriers to transformation. Stakeholders from different regions and different scales must take part in the exercise and they will be crucial elements of success in the implementation phase. However, we believe that the exercise must be coordinated at the national level, because it is still at this level that most regulations and incentives are decided, and because many drivers of change or, conversely, many lock-in factors are situated at a national or supra-national scale.

While proposed scenarios and courses of action are not intended to replace political decisions by policymakers or economic agents, they provide a structured and detailed basis to inform the policy debate. Transformation pathways indeed do not only provide aggregate end targets (such as average emissions reduction), but also their translation into a concrete image of future activity and society that can be debated and questioned for its consistency and desirability, and a detailed sequence of action that can also be debated for its relevance and feasibility.

A wide range of tools are available to efficiently and affordably design courses of action

The approach that we propose for the establishment of agricultural transformation pathways is a general approach. Different methods can be used and it does not matter whether countries choose to start with an analysis of the whole agricultural sector and then focus on priority sectors (such as China) or decide to adopt a more bottom-up approach (such as Uruguay). There is a wide range of tools, from literature analysis and expert consultation to modelling that can be used to assess trade-offs and select the best performing courses of action. The NUFER approach developed at the national scale in China could for instance prove very useful to check the consistency across agricultural sectors in Uruguay once the approach developed in the Uruguayan beef sector has been extended to the main crops.

What the pilot case studies also demonstrate is that challenges are different from one country to another. Therefore, key indicators enabling targets to be set and the monitoring of progress towards more sustainable agricultural and food systems differ from one country to another. Countries ought to select the most appropriate indicators, *i.e.* the most representative of what would be a truly transformational pathway for their agricultural and food sector. Although the SDGs are global and need to be applied in all countries, priorities in terms of courses of action and monitoring frameworks must be established according to the specific situation of each country. Targeting priority sectors and priority actions is fundamental for taking prompt action and the triggering of transformation as soon as possible.

Common challenges

The pilot phase of the Agricultural Transformation Pathways initiative also illustrates important common challenges faced by countries with very different agricultural and food sectors.

Avoiding path dependencies

Exploring the possible futures that transformation pathways could engender the selection of no regrets strategies and the avoidance of path dependencies that would otherwise make future changes difficult (for instance once an economy has been developed, it might not be so simple to encourage the development of more sustainable models). Path dependencies can rapidly emerge because taking strategic steps always leads to:

- the dedication of investments to a specific area: invested amounts will be blocked and unavailable for other areas in the future. Decisions have to be made carefully in order to invest in long-term strategies. In addition, investing in a specific area at a given time can tie investors into having to regularly put more money in the same area (e.g. infrastructures that need to be maintained, etc.);
- the establishment of certain groups of actors and of certain business models or habits (e.g. food waste) which might not necessarily be the best options in the future. For instance, although many regions would need to increase their fertilizer usage to overcome productivity gaps, developing the fertilizer industry in a given region is likely to lead to the establishment of enterprises with the business model of selling more inputs. Such business models are then hard to put back into question once the desired consumption levels are reached. How to avoid unnecessary consumption peaks and "tunnel through" by encouraging directly efficient farming practices is a fundamental question regions have to ask themselves before taking strategic steps.

Building flexible long term strategies that can adapt to future situations is a fundamental challenge that this initiative aims to achieve.

Dissemination of knowledge

Another very important and common challenge illustrated by the case studies appears to be the dissemination of technology and farming practices. Bridging the gap between the best performing farmers and the rest is a challenge across all countries, no matter what stage of economic development they are at. The annual adoption rate of new technologies or new farming practices is extremely low in the farming sector (compared to other sectors of the economy for instance), especially for smallholder farmers (CGIAR, 2014). The reasons for this lie in the diversity of environments (i.e. adopting practices in one place will have different consequences in another), in the inevitably low level of standardization of practices and in the distance between farmers and innovation nodes (whether these nodes are comprised of groups of advanced farmers, researchers or entrepreneurs). Bridging this gap will necessitate the encouragement of all efforts that forge stronger links between research, extension services and other institutions promoting better technology and farming practices, and will also improve links between farmers.

Improved coordination of stakeholders
Finally, the pilot case studies demonstrated that public policies (public investments, norms and regulations, fiscal incentives...) must be aligned with these objectives, but that coordination between private and public actors and with civil society also plays a central role to catalyse change.

Restructuring food chains and food demand
A large number of countries are also likely to face a major challenge on the subject of food chains and demand. In China, it was demonstrated that targets could only be met through a significant reduction in food demand. In the United Kingdom, reduction in waste and meat consumption was identified as a major lever towards sustainability and food security. Targeting the whole food chain and taking prompt action to influence consumption will be necessary to transform the agricultural and food sector as a whole and achieve the SDGs.

THE WAY AHEAD

The results presented in this report are the preliminary results of pilot phases conducted in Uruguay, China and the United Kingdom. The three countries will continue developing and refining transformation pathways and implementation strategies in the future.

New countries joined the initiative in 2016. In the framework of the European Research Area Networking Cofund “FACCE SURPLUS” (a scheme designed to support long-lasting coordination of European research programmes), Rothamsted Research, IDDRI and Wageningen launched a project in March 2016. The project, “TSARA” (Towards Sustainable And Resilient Agriculture) will use the target-setting and backcasting approach to carry out detailed studies for the UK, France and the Netherlands. Teams in Poland (the Institute of Sociology of the Jagiellonian University in Krakow), Italy (The Desertification Research Centre of the University of Sassari) and New Zealand (Invermay Agricultural Centre) will also be involved in the project. TSARA will investigate means to support and develop pathways to assist the achievement of the UN Sustainable Development Goals (SDG) and targets, relying on farm typology, modelling, participatory approaches and backcasting.

The ambition of the Agricultural Transformation Pathways Initiative is to encourage other countries to take part in future, particularly in least developed areas. By forging national debates and international exchange, we believe that the initiative could outline the most important common challenges faced, propose ways to address these challenges through joint cooperative efforts and showcase successful examples for practical problem solving. It could also identify the global and regional policies and measures that are necessary to facilitate the implementation of domestic transformation strategies and lower their transition costs.

We hope the methodological approach and results of the case studies can become a touchstone for future work in this area and inspire other countries in the development of their own transformation pathways for their agricultural and food sectors. This report shall be a living document to which other national narratives will be added in future.

References

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