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Translating the Sustainable Development Goals into action: A participatory backcasting approach for developing national agricultural transformation pathways

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ABSTRACT

A new set of objectives for sustainable development are now in place, known as the Sustainable Development Goals (SDGs), and countries need to develop concrete policy roadmaps to achieve them. This is particularly challenging in the agricultural sector given the heterogeneity of local conditions, the diffuse nature of its environmental impacts, and the important interactions with various aspects of sustainable development – from education and poverty alleviation, to human health and the environment. And yet it is precisely because of these interactions that vibrant, resilient and sustainable national agricultural sectors are key to the SDGs' success. This paper presents a practical backcasting approach and methodological toolkit – developed by the Agricultural Transformation Pathways (ATP) initiative under the auspices of the Sustainable Development Solutions Network (SDSN) – for countries to develop policy roadmaps towards 2030 using local tools and expertise that could help transform national agricultural sectors in a way that is consistent with the SDGs. This approach is illustrated using the Uruguayan beef sector as a case study, where productivity and environmental targets were developed in tandem with a wide range of stakeholders in order to maximize productivity, while minimizing a suite of environmental impacts – from carbon footprint and biodiversity, to nitrogen losses. This marks the beginning of a new approach to achieving the SDGs in the agricultural sector: participatory target setting and pathway development across a number of areas crucial to sustainable development – all under a harmonized framework provided by the ATP initiative. We hope the methodological approach and results of the Uruguay case study will become a touchstone for future work in this area.

1. Introduction

In September 2015, the United Nations signed onto a new development agenda, with 17 new Sustainable Development Goals (SDGs) at its core. These goals (and the more specific 169 targets that constitute them) present a unified vision for making progress on key issues of social, economic and environmental concern by 2030. While they are global in scope, the actions these goals require call for concerted efforts at the country-level and below (SDSN, 2014). Consequently, each country needs to build a pathway towards the SDGs: a series of policy measures implemented over time with specific, achievable actions and outcomes at national and sub-national levels. And one sector of the economy that intersects with many issues of sustainable development is agriculture (Canavan et al. 2016).

A vibrant, resilient and sustainable agricultural sector will be

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crucial to achieving many of the proposed SDGs, as agriculture is a key factor in determining outcomes from poverty levels and food security, to health, gender equality, and a range of environmental issues. However, few countries have developed a clear understanding of how to make transformative changes in their often complex and diverse agricultural and food systems that would enable them to address these kinds of key cross-sectoral issues in a coordinated way.

This paper aims to present a practical approach for countries to build national roadmaps based on concrete courses of action that could transform their agricultural sector in line with the SDGs. This approach is illustrated using the Uruguayan beef sector as a case study. It not only shows that building transformation roadmaps is feasible, it also demonstrates the possibility for major economic, social and environmental co-benefits. We define "transformative" in this study to mean agricultural pathways that go beyond traditional agronomic priorities (e.g. increased yield, productivity etc.) and account for the broader array of SDGs relevant to agriculture.

2. Approach and methodology

The Sustainable Development Solutions Network (SDSN; an initiative of the United Nations to promote practical problem solving for sustainable development across all scales) established an Agricultural Transformation Pathways Initiative in 2014. This initiative brings together countries with a diverse set of agricultural contexts under the umbrella of an international coordination team that provides support in two important methodological areas: (i) developing realistic national and sub-national targets that are in line with the SDGs; and (ii) building technology and socio-economic roadmaps that enable countries to meet those targets. The initiative provides a harmonized, and interdisciplinary approach, inspired by extensive work on greenhouse gas (GHG) emissions from the energy, transport and building sectors in the world's fifteen largest economies as part of the Deep Decarbonization Pathways Project (DDPP, 2015) led by SDSN and the Institute for Sustainable Development and International Relations (IDDRI).

The first country case studies were conducted in Uruguay, China and the United Kingdom and will be followed by other countries representing a range of agricultural and food systems. Each country adopts: (i) a participatory approach involving a range of key stakeholders from government, academia, industry and farmer organizations, making use of local tools and expertise; (ii) a methodology based on "backcasting", where targets are fixed at some point in the future, with pathways developed for achieving that target by working backwards from it to the present (more detail in Section 2.2).

2.1. Involving key stakeholders

The first step in building an agricultural transformation pathway is to involve a range of stakeholders with links to the sector, including academic institutions, national research institutes, industry associations, farmer community organizations and government. Over the past decade, researchers and practitioners have repeatedly emphasized the importance of participatory approaches, especially for designing transitions towards sustainability (Bohunovsky et al., 2011; Vervoort et al., 2014; Weaver and Rotmans, 2006). By involving key stakeholders from the very beginning, we move beyond a traditional modeling exercise of sustainable transition narratives and aim to achieve three goals: (i) integrating local data and knowledge by consulting local experts and practitioners; (ii) fostering policy debate among these actors on the important issues facing the country; (iii) generating stakeholder buy-in, which is fundamental to overcoming a number of sociological and political roadblocks to transformation.

In the case of Uruguay, the project was a collaboration between 11 researchers from: INIA (Instituto Nacional de Investigación Agropecuaria), the main agricultural research institute; 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), with expert input from SDSN and IDDRI. Other academic, industry and farmer stakeholders were involved at different stages of the project via informal consultation and stakeholder workshops. Indeed, INIA's governance structure is relatively unique for a national agricultural research institute in that farmers are represented on their Board of Directors and play an integral role in defining research priorities, enabling close and constant interaction with INIA's researchers. Together, we worked to develop a set of targets for Uruguay's beef sector consistent with several of the SDGs that could become the basis for policy. Uruguay is a unique case in that there is a strong culture of collaboration and coordination among agricultural stakeholders, which was present prior to the ATP initiative. Consequently, building a team and executing the project in a way that was inclusive (in terms of stakeholder involvement) and comprehensive (in terms of subject matter) was relatively straightforward, making us confident that we were aiming at the right kinds of goals and desired policy changes.

2.2. Backcasting

The Uruguay team adopted a "backcasting" approach for this exercise based on the framework provided by the ATP initiative and adapted to local conditions (SDSN, 2015). Backcasting, in contrast to forecasting, sets targets at a future date based on expert judgment, best available technologies and other factors, with technical pathways subsequently developed for achieving those targets by working backwards in time towards the present. The central difference between backcasting and forecasting analysis is that the latter develops multiple futures from a common present while the former develops pathways to a single desired future, making it a more relevant tool for policy planning. In other words, forecasting explores what could happen, while backcasting articulates what might be a pathway to a desirable future. This is very much a problem-solving approach, as it enables users to set priorities, rank solutions and identify the steps that need to be taken (and when) in order to reach a desired outcome.

In certain cases, backcasting and forecasting approaches have been combined in the same study, allowing decision-makers to explore backcasting pathways under uncertainty – multiple plausible futures, each with their own challenges and opportunities (Kok et al., 2011; Robinson et al., 2011; Vervoort et al., 2014). We did not combine backcasting and forecasting at this stage of the project for two reasons: (1) the relatively short-term frame (to 2030) makes the development of multiple future scenarios less pressing than if we were backcasting from 2050 or 2100 (e.g. atmospheric CO_2 concentrations in the different Representative Concentration Pathway climate scenarios do not begin to significantly diverge until the second half of the 21st century – Van Vuuren et al., 2011); and (2) given the direct involvement of the Uruguayan Ministry of Livestock, Agriculture and Fisheries in the project, the goal at this stage was to develop a series of policy targets and measures that could be implemented in the near future, rather than a range of policy storylines to consider for long-term planning. That being said, as the project develops further, expanding in scope across more agricultural sub-sectors and longer time horizons, it will become increasingly important to consider combining backcasting and forecasting approaches.

Backcasting has long been identified as a practical methodology for building pathways towards sustainable development. As encapsulated by Robert et al. (2002), "without first defining a future "landing place" on the systems level, reaching sustainability is an unlikely outcome of any effort" (201). However, the bulk of previous studies have focused on the energy sector and greenhouse gas emission trajectories (Robinson 1982, Mulder and Biesiot, 1998, Anderson, 2001, Giurco et al., 2011). Studies using backcasting in the agricultural and food sector have only recently begun to emerge (e.g. Vervoort et al., 2014), and deserve further investigation. Moreover, backcasting for the agricultural sector is not as straightforward as for the energy sector. As highlighted above, several SDGs depend on the performance of agricultural systems. Consequently, national pathways for sustainable agricultural transformation cannot focus on a single global target (such as the 2 °C target adopted for climate change – DDPP, 2015), but instead must take into account and prioritize a range of targets that have to be adapted to the agricultural conditions of that particular country. The first step in building such a national pathway is to select appropriate agronomic, socioeconomic and environmental indicators that can evaluate and monitor progress in the agricultural sector, then determine their current levels and establish 2030 target values (Fig. 1).

The purpose of using locally-developed tools and experts as a basis for the Uruguay case (and other country cases) is two-fold: first, the data underpinning these tools is more likely to reflect actual conditions in Uruguay compared to the more generic modeling approaches embodied in tools such as global integrated assessment models. Second, the use of local tools increases the likelihood that local stakeholders have confidence in the credibility and legitimacy of the analysis, which also makes it more likely that the results of this case study become a foundation for Uruguayan agricultural policy over the long-term. Selecting the tools and indicators that form the basis of the methodology was itself a complex process, with several rounds of debate, tool evaluation, and constant attention to ensuring their alignment with ATP objectives. The Uruguay team decided to use models and methods that had already been developed and validated for the Uruguayan beef sector, adapting them for the purposes of the project (see Section 3). The rationale for first focusing on Uruguay's beef sector is described below.

2.3. Uruguay's beef sector

The Uruguay team decided to disaggregate the agricultural sector into its major sub-components and approach each one individually, as they believed it would simplify the exercise and ensure that the pathways developed were politically feasible. Other countries in the ATP initiative have taken a more top-down, sector-wide approach – neither ultimately affects the basic pillars of the approach described above. Uruguay's beef sector was deemed a priority for several reasons. The beef sector is a critical component of Uruguay's agricultural sector, responsible for approximately half of Uruguay's agricultural GDP, which is 8–9% of overall GDP. Moreover, for a country of just 3.4 million people, it supplies 5% of the beef on the global market (in terms of weight), making up 20% of the total value of Uruguay's exports ($1.5 billion) (Bervejillo, 2015). In addition to its economic importance, Uruguay's beef sector has a significant environmental footprint. The land devoted to beef production covers over two thirds of Uruguay's surface area, even though it has been displaced from some of Uruguay's most productive soils in recent years by crop production. It is responsible for approximately 75% of Uruguay's greenhouse gas emissions (with 55% of these emissions from methane (CH_4), and 45% from nitrous oxide (N_2O) (Piaggio et al., 2012). Consequently, any efforts to increase the sustainability of Uruguayan agriculture must have the beef sector at its core.

And yet despite this significant environmental footprint, the Uruguayan beef sector's international reputation is partly based on its commitment to certain stringent environmental and health quality standards (e.g. largely grass-fed, high sanitary and food

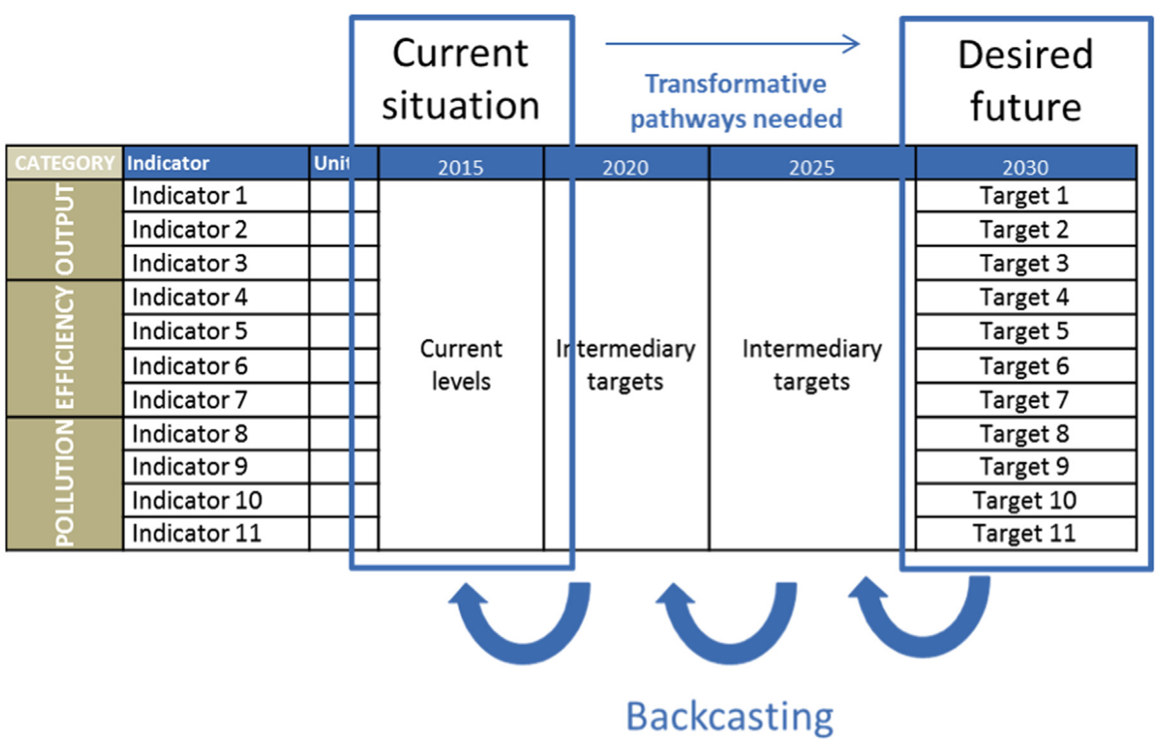

Fig. 1. Illustration of the backcasting approach, demonstrating how targets are developed and set at a future date and pathways are then subsequently developed for achieving those targets.

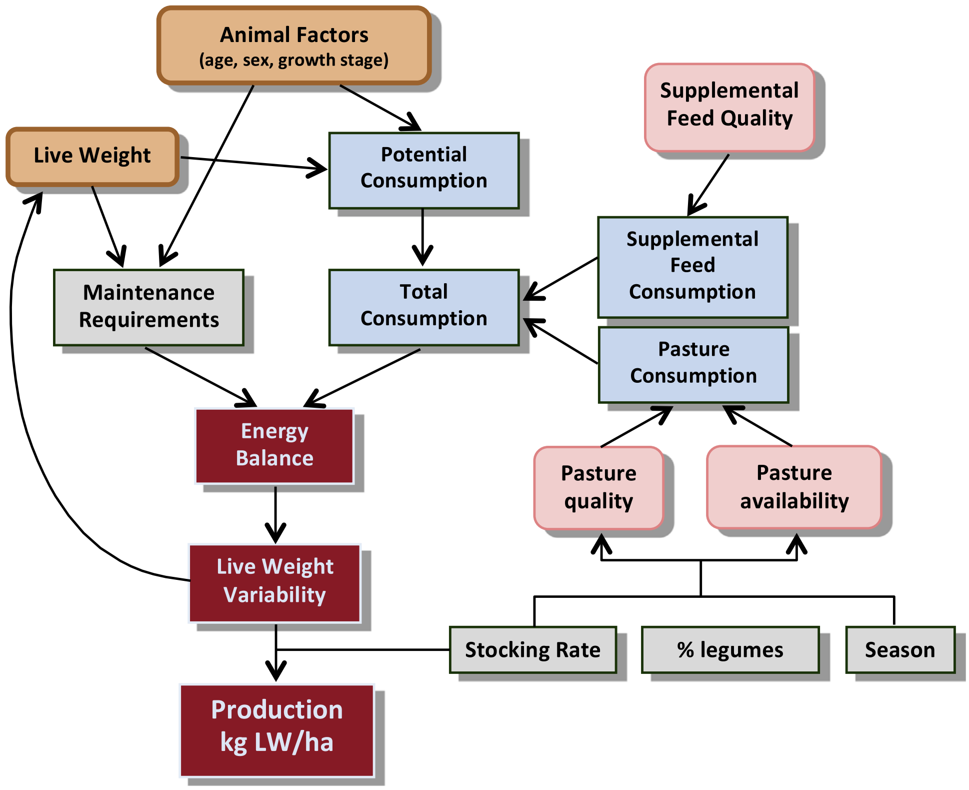

Fig. 2. General schematic of the beef production model used in the Uruguayan case study (adapted from Soares de Lima (2009)).

safety standards including zero use of antibiotics and hormones, and a mandatory traceability system), which is key to its niche in the global market. These attributes underpin the "Uruguay Natural" brand that is associated with Uruguayan beef. Therefore, the challenge at the heart of Uruguay's beef sector is a multi-objective optimization problem: how to increase productivity while staying true to the environmental and health traits that make Uruguayan beef such a highly valued global commodity. Furthermore, sustainable development is one of the main strategic guidelines for Uruguayan agricultural policies, creating a unique confluence of economic, environmental and policy interests that underpin the targets described below.

However, the current focus on the beef sector should be viewed as a first step in a longer process of developing a transformative pathway that accounts for all of Uruguay's major agricultural subsectors – from dairy production, to rice, rain-fed crops and forest plantations. Indeed, certain environmental issues are more relevant to these sub-sectors than the beef sector. For example, an expanding rice sector is stimulating demand for improved irrigation infrastructure (with implications for water use in a country increasingly susceptible to drought – World Bank, 2013); and soybean production, the most rapidly growing agricultural subsector in Uruguay, is the dominant driver of land-use change in the country (USDA, 2016). The Uruguay team is working towards studies on each of these agricultural sub-sectors, which will culminate in a sector-wide report and a suite of policy recommendations for how to set Uruguay's agricultural sector on a path consistent with the SDGs.

3. Developing a transformative pathway

Increasing beef productivity is a fundamental component of the Uruguay agricultural development roadmap, and therefore setting an ambitious productivity target for 2030 was the first step of the project (in kilograms of live weight (LW) per hectare). For this the Uruguay team used data from farms that are part of FUCREA (Federación Uruguaya de Grupos Crea, an organization that includes some of the most productive farmers in Uruguay) as a benchmark. The team set national targets for a number of parameters linked to beef productivity (improved pastures, weaning rate, feed supplements, etc. – see Section 3.2) that largely mirror the practices of average FUCREA farmers. These targets were used as inputs to a beef productivity model developed by Soares de Lima (2009), which subsequently estimated that national average beef productivity could increase from 102 kg LW/ha in 2012 to 128 kg LW/ha in 2030 – a 25% increase (see Section 3.2).

The team considered this 2030 target ambitious for a national average, particularly given the typical characteristics of Uruguayan beef cattle systems – dominated by natural grasslands with low levels of supplementary feeding (e.g. hay, silage, grains, vitamins and minerals). Many top performing farmers have adopted a basic set of management practices to reach such production levels: improved pastures, supplemental feeding, fencing to create smaller, more homogeneous and more manageable paddocks, and ensuring water and shade availability. Several of these strategies are implemented in the beef production model the team uses to generate the pathways for reaching the beef production target.

3.1. The beef productivity model

The Soares de Lima (2009) model was used to develop the beef production targets by setting a number of parameters linked to beef production (improved pastures, feed supplements, etc.) at levels that reflect common practices of highly productive farmers (such as those who are FUCREA members). This dynamic, farm-level model simulates beef cattle production systems across all stages of development (from cow-calf to slaughter), following the performance of individual animals across time. This includes simulation of nutritional requirements, herd dynamics, and different farm management strategies. These components constitute the core structure of the model. The model also has an economic component, which the team plans to use in future analyses. Fig. 2 is a simplified schematic of the model.

Farm-level dynamics in the model are determined by the balance between feed supply and demand. Feed demand is determined by the requirements of the entire herd, which is the sum of the individual requirements of each animal in the system. Feed supply is 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 purposes of this project, the team adapted the model by representing Uruguay's national beef production as a single unit of production that produces all the necessary female replacements to keep the system in production, including fattened cows for slaughter, and raises all the males to the point that they become finished steers ready for slaughter. While easier to model, this approach also oversimplifies Uruguay's beef sector, sacrificing granularity for simplicity (focusing on the "average" farm rather than a diverse range of farming contexts) – a trade-off the team was willing to make at the national scale, but that it plans to reconsider as the analysis is downscaled to specific sub-regions.

3.2. Productivity goals

The team considered two overarching strategies for increasing production: improving feed supply (without increasing the amount of land devoted to beef production – see environmental targets), and increasing the efficiency (i.e. turnover) of the entire system by slaughtering more cattle at a younger age. For improving feed supply, the team considered the following measures:

Improved pasture – Feed supply comes from the area of agricultural land devoted to beef production in the country. This area comprises natural grasslands and improved pastures. Legumes are a common choice to improve pasture for a number of reasons. First, they provide more nutrition, thereby accelerating animal growth rates. In addition, improved pasture also delivers important environmental benefits, including a two-fold climate benefit:

– *Carbon sequestration:* Legumes increase soil N content which drives grass growth, thus sequestering more carbon in the soil. In addition, they reduce nitrogen (N) losses while fixing N themselves.
– *CH_4 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 (Ramírez-Restrepo and Barry, 2005; Eckard et al., 2010).

The team decided a reasonable yet ambitious course of action would be for improved pastures to increase from 15.4% to 30% of total grazing area devoted to beef production by 2030. This could reduce 5% of Uruguay's emissions from enteric fermentation and sequester carbon equivalent to 100 kg CO_2/ha/yr (or 0.3 kg CO_2/kg LW/yr) more than natural grasslands.

Feed supplements – This involves integrating a variety of vitamins, amino acids, fatty acids and minerals into cattle diet that are typically not present in a regular grass-fed diet. Much of this can be provided by supplemental feed from grains, hay and silage. Similar to improved pastures, this accelerates animal growth rates, and thus reduces the age for first pregnancy as well as slaughter age. The team set a target of doubling the amount of feed supplements fed to young cattle by 2030. Achieving this target would require either producing supplemental feed domestically, or importing it from abroad. The former could have implications for Uruguay's environmental footprint (e.g. from increased fertilizer use), which would have to be accounted for in the sector-wide report.

Improved feeding will accelerate animal growth rate, thus increasing the efficiency of the reproductive cycle. To monitor the increase in turn over, the team considered the following intermediate targets:

– *Age at first pregnancy* – Accelerating the animal growth rate can reduce the average age of first pregnancy. The team set a target of moving from a current baseline where half of the heifers are two years old and the other half are three years old at first pregnancy, to one where three quarters of the heifers are two years old at first pregnancy by 2030.
– *Weaning rate* – Defined as the number of calves weaned divided by the number of cows that were intended for breeding the previous season (Anderson and Lewis, 2012). The team set a target of 77 weaned calves for every 100 breeding cows, up from a current level of 67 per 100.

These intermediate targets were used as inputs to the Soares de Lima (2009) beef productivity model to estimate national average beef productivity by 2030. They have the effect of reducing 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. Consequently, the model projects a 2030 national productivity value of approximately 128 kg LW/ha, up from the current value of 102 kg LW/ha (Table 1).

3.3. Environmental goals

In terms of environmental targets, the team's approach was to combine expert consultation and a literature review to develop the most ambitious environmental targets given the productivity goals Uruguay also wishes to achieve. First, the mere fact of intensifying production has been shown to reduce carbon footprint per animal and per hectare. Picasso et al. (2014) derived the statistical relationship between productivity and carbon footprint from a sample of 15 beef production cycles representing a range of intensification across Uruguay. They found that for every 10 kg increase in productivity per hectare, carbon footprint decreases by 1.2 kg CO_2e/kg LW and 36 kg CO_2e/ha. This dynamic largely stems from the fact that increases in intensification are often accompanied by an increase in production efficiency at the farm scale.

In addition, the Uruguay team developed targets for three environmental issues: carbon footprint (kg CO_2/kg LW), biodiversity

Table 1
Baseline values and 2030 targets simulated by the Soares de Lima (2009) beef production model. The end target (productivity) is the result of achieving a number of intermediate targets focused on increasing turnover and improved feeding.

Parameters	Description	Baseline	2030
End target	Production (kg LW/ha/year)	102	128
Related outcomes	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)	10.8	10.8

Table 2
Environmental targets for Uruguay's beef sector, focused on climate change, biodiversity and nitrogen pollution.

Issue	Metrics	Baseline	2030	Change
Production	kg LW/ha/year	102	128	25% ↑
Carbon footprint	kg CO_2/kg LW	20.8	15.5	25% ↓
Nitrogen	kg N/kg LW	66	48	27% ↓
Biodiversity	beef area (million ha)	10.8	10.8	0%

(beef production area, millions 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 allowed us to define targets for 2030 as follows: 25% decrease in carbon footprint, 0% expansion in the amount of land devoted to beef production, and 27% reduction in nitrogen losses (Table 2). They are described in detail below.

3.3.1. *Environmental target 1: carbon footprint*

In addition to the dampening effects of intensification and improved pastures on carbon footprint, the team evaluated several other strategies for further enhancing the environmental targets: reducing N_2O emissions through nitrification inhibitors and increasing the number of trees for shade (which also would sequester carbon). This is not an exhaustive list of the potential GHG mitigation strategies for Uruguay's beef sector. Indeed, as the GHG and other environmental targets are implemented, other mitigation strategies may emerge as better suited to a particular region.

Nitrification inhibitors – The main selected strategy for reducing N_2O emissions is the use of nitrification inhibitors, which have been effective in other countries with beef-grazing systems such as New Zealand, reducing emissions by 64–82% (Di and Cameron, 2002, Di et al., 2010). They work by suppressing nitrifying bacteria in the soil, which delays the oxidation of ammonium to nitrate. This reduces the amount of plant-available nitrate in the soil, which would otherwise fuel denitrification – the main biogeochemical process, in addition to nitrification, that forms N_2O. Nitrification inhibitors can also reduce other forms of N pollution, such as nitrate and nitrogen oxides (see below). If 50% of grazing land devoted to beef production were to use nitrification inhibitors, the carbon footprint could be reduced by 0.3 kg CO_2e/kg LW or 40 kg CO_2e/ha.

Increased tree planting – This practice is used across Uruguay to provide shade for livestock, protecting them from heat stress which can otherwise reduce productivity levels (Torquato et al. 2012). Cattle are particularly susceptible to heat stress due to their higher metabolic rate and low water retention compared to other livestock (Silanikove, 2000). In addition to providing shade, trees also sequester carbon as they grow that would otherwise end up in the atmosphere as CO_2. Currently, about 78,000 ha of Uruguay's grasslands have trees to provide shading for livestock, less than 1% of grazing area.

Assuming 600–650 trees per ha, sequestering 0.9 t C/ha, trees for livestock shading are already helping to avoid emissions of 0.26 million tons CO_2e per year. Increasing the proportion of livestock grazing with trees for shading to 10% would avoid additional emissions of 3.6 million tons of CO_2e per year (assuming that the trees continue to grow from when they are planted until 2030). Due to lack of data, the team were not able to estimate the potential increase in beef productivity due to increased protection from heat stress, so the productivity target estimated above should be regarded as conservative.

Overall, these measures are projected to decrease the carbon footprint of Uruguay's beef sector from 20.8 kg CO_2 eq./kg LW to 15.5 kg CO_2/eq. kg LW (Table 3). This is still significantly higher than the carbon footprint for the US beef sector (13.2 kg CO_2/kg LW), due to a higher proportion of US production situated in feedlots, which generally have lower carbon footprints than pasture-fed beef (Johnson et al., 2003; Desjardins et al., 2012). As described above, Uruguay's international reputation for pasture-fed beef with stringent environmental and health standards makes a transition to feedlot-dominated production highly unlikely.

3.3.2. *Environmental target 2: nitrogen*

The N targets for the beef sector are set in terms of N losses per head of cattle and per unit area. The current N footprint is approximately 66 kg N lost/kg LW/yr and 7.3 kg N lost/ha/yr. The 2030 targets for each of these metrics are 48 kg N lost/kg LW/yr and 6.3 kg N lost/ha/yr respectively. Achieving these targets would reduce N losses of approximately 26,500 t N/yr, equivalent to 30% of current N losses from Uruguay's beef sector. The two strategies used to achieve these targets are N inhibitors (both nitrification and urease inhibitors) and improved pastures (Table 4).

N inhibitors – Nitrification inhibitors were discussed above as a strategy for reducing N_2O emissions. However, they can also reduce other forms of N pollution, including nitrate (by 42–76% in some studies – Di and Cameron, 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 N inhibitors, Uruguay would avoid N losses of 24,250 t N/yr.

Improved pasture – Increasing the amount of leguminous pasture is estimated to reduce the amount of nitrate run-off from 30% of applied N to 18% of applied N (the applied N in this case being livestock manure and urine). Consequently, increasing the proportion of improved pasture from 15.4% today to 30% in 2030 could reduce nitrate leaching by 3000 t N/yr.

Finally, it should be noted that phosphorus (P) is also an important component of nutrient imbalances in livestock production, with its own suite of environmental impacts, particularly on water quality. While several strategies have been identified to reduce P pollution from livestock production, they are more applicable to more intensive production systems, particularly feedlots, which make up only a small part of Uruguay's beef sector (Sutton et al., 2013). Consequently, P mitigation strategies are not considered in this report. However, if the improved pasture target from this report is implemented, it will likely result in increased P fertilizer use, and so as policies are developed to put these targets into action P use efficiency strategies will have to be considered.

Table 3
Breakdown of the main strategies for reducing the beef sector's carbon footprint and their individual contributions towards GHG mitigation. "A.M." refers to additional measures beyond the reduction in carbon footprint from an increase in productivity as reported in Picasso et al. (2014).

Metrics	Baseline	2030 with and without additional measures				
		No A.M.	+Nitrification inhibitors	+Improved pastures	+Trees for shade	All A.M. 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 4
A breakdown of current and future 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, despite projected increases in manure production due to the increase in livestock production.

Parameters	Current	2030 mitigation
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)	3520	3,630
Total N pollution (tons N/yr)	**73,750**	**68,810**
N pollution per kg beef (kg N/kg LW)	**66**	**48**

3.3.3. Environmental target 3: biodiversity

The biodiversity target is the most simple in terms of metrics and strategy. The goal is for zero expansion in the amount of land devoted to beef production between current levels and 2030, meaning that the 10.8 million ha of grazing land remains constant over this period. While this is directly inspired by one of the initially proposed Sustainable Development Goals (which calls for a complete halt of forest conversion to crop or livestock agriculture by 2030 – SDSN, 2013), some may argue that simply increasing the proportion of improved pastures can also reduce biodiversity – by favoring grasses that thrive at higher levels of N captured by legumes. This is important to consider as policy is developed and biodiversity targets eventually set for Uruguay's entire agricultural sector.

4. Implementing the targets

4.1. Identifying levers and roadblocks

Uruguay's beef sector is supported by a robust inter-institutional framework that could be leveraged to implement the targets described in the previous section: a consolidated public R&D system and public-private organizations that promote technology adoption and beef consumption, domestic and internationally, providing guarantees of traceability, quality and safety. Farmers also have a long history of involvement in the sector's development via direct participation in public-private organizations. For example, as mentioned in Section 2.1, farmers play a key role in INIA's governance structure. Overall, as with the development of the targets and courses of action, implementation will require the involvement of a range of stakeholders (from farmers and researchers, to government and industry) to ensure their success.

Table 5
Strategy matrix for the transformation of Uruguay's beef sector.

Course of action			
PRODUCTIVITY	BIODIVERSITY	CLIMATE	NITROGEN
Targets, Levers and Roadblocks			
Target: +25% productivity → **Roadblocks**: ▪ Lack of technology transfer capacity ▪ Lack of labor skills ▪ Farmer attitude and age ▪ Farm infrastructure and water access ▪ R&D → **Levers to overcome roadblocks:** **Lever 1**: Inter-institutional framework for technology transfer **Lever 2**: Farmer training programs **Lever 3**: Incentives to improve infrastructure, adopt better management practices and reduce financial risks	**Target:** 0% land expansion → **Roadblocks**: ▪ Increasing agricultural production ▪ Lack of knowledge adoption and diffusion ▪ R&D → **Levers to overcome roadblocks:** **Lever 1**: 1987 forest law based on conservation incentives **Lever 2**: Grazing management practices **Lever 3**: Environmental values	**Target:** -25% carbon footprint → **Roadblocks**: ▪ Cultural factors such as breed preference ▪ Lack of financial incentives ▪ Lack of knowledge adoption and diffusion ▪ Lack of farmer training ▪ R&D → **Levers to overcome roadblocks:** **Lever 1**: R&D to improve feed conversion efficiency (genetics) **Lever 2**: Increased market reach and value for Uruguayan beef **Lever 3**: Data on GHG emissions and carbon footprint.	**Target:** -27% nitrogen footprint → **Roadblocks**: ▪ Lack of enforcement of existing regulations ▪ Lack of knowledge adoption and diffusion ▪ Lack of farmer training ▪ Lack of inter-institutional coordination ▪ R&D → **Levers to overcome roadblocks:** **Lever 1**: Regulations on water quality 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

Implementing the courses of action can be facilitated by a variety of policy levers that are currently at various stages of development. Conversely, a number of roadblocks currently hinder implementation, which need to be addressed for implementation to be successful. This tension is illustrated in Table 5. For each course of action, there are specific levers and roadblocks, with some cutting across categories. The successful implementation of transformation pathways depends on correctly identifying and subsequently addressing these levers and roadblocks. Table 5 illustrates a first attempt at doing this. However, it should be viewed as a "work in progress" that will likely change during the implementation process as more levers and roadblocks become apparent.

Several of the levers identified in Table 5 have already been in place for some time. The 1987 Forestry Law, which could serve as a basis for implementing the biodiversity conservation strategies, is a good example. Other levers are currently in the process of being developed, such as the inter-institutional program for technology transfer, explained in more detail below.

In terms of roadblocks, R&D is one that cuts across all courses of action, in spite of the relatively high level of public R&D investment in Uruguay compared to other Latin American countries. Human capital is another important crosscutting roadblock, which encompasses a variety of issues from a lack of training, to farmer age and preferences. This is a particularly challenging area as it is closely linked to farm-level decision-making – unless individual farmers are convinced of the benefits of new management practices and technologies, they will not adopt them.

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

With human capital a major roadblock, the Ministry of Livestock, Agriculture and Fisheries (MGAP) has set up a taskforce to develop a new technology transfer strategy for the beef sector based on the following ideas:

a) The technology transfer process in the beef sector needs be implemented in concert with a variety of organizations representing a range of important stakeholders, in order to maximize farmer uptake of improved practices and technologies. These organizations include INIA, the Agrarian Plan Institute (IPA), the Uruguayan Wool Secretariat (SUL), the National Meat Institute (INAC) and the MGAP.
b) The scope of the effort needs to match the ambition and timeline of the targets. New technologies and management practices need to be adopted by thousands of farmers for the transformation pathway to become a reality; otherwise the targets are unfeasible at the national level.
c) An increased emphasis on technical assistance (also known as agricultural extension) is necessary. Although there are roadblocks related to infrastructure, market development, risk management and other issues, this inter-institutional effort focuses on technical assistance, with the aim of disseminating technology and results obtained by the most efficient farmers to other farmers.
d) Technical assistance will be initially provided with no cost to the farmer to ensure that farmers have an incentive to continue using new technologies and practices over the long term. This stems from previous experiences where 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.

This plan for enhancing technology transfer will be progressively rolled out, starting in 2016 with a focus on a small subset of farmers in two to three locations. The goal is to scale up these efforts significantly in coming years. Baseline levels for productivity and environmental indicators will be established in these locations, as well as long-term targets (which will vary by location given differences in climate, soil fertility and other environmental and social factors). The Soares de Lima (2009) beef production model used to develop national targets will be downscaled to the regional level for the purposes of this project.

In each of the locations an inter-institutional technical group will lead implementation. Each group will instruct, supervise, and evaluate a number of technical advisors (hired at the local level), 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 participating institutions will have specific roles, with INIA responsible for technical issues, IPA focused on capacity building, and MGAP managing operations at the local level.

5. Conclusion

This case study marks the beginning of a new approach to achieving sustainable development goals in the agricultural sector: target setting and pathway development across a number of areas crucial to sustainable development – all under a harmonized framework provided by the Agricultural Transformation Pathways initiative. We show how combining an overarching methodological approach (backcasting) with local tools and expertise generates production and environmental targets that set the basis for concrete, transformative policies that could make them a reality. The next steps for the Uruguay team are to develop similar pathways for the other major agricultural sub-sectors. However, it should be noted that the Uruguayan case has unique features that make it a challenge to replicate in other countries: in particular, the combination of economic and environmental incentives that make sustainable development objectives a top government priority, and a tight-knit group of well-coordinated stakeholders that facilitate the translation of science to policy. Nevertheless, we hope the methodological approach and results of the Uruguay case study will become a touchstone for future work in this area and inspire other countries to develop similar pathways.

Dedication

We dedicate this paper and the entire Uruguay project to our co-author, colleague, and friend, Mario Mondelli, who tragically passed away as this paper was being written. We hope his spirit and belief in this project will drive it for years to come.

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