Annual Investment Report 2022

Climate investment in the food and agriculture sector in Latin America

The cases of biochar and protein transition in Argentina

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Project number

217002

Acknowledgements

The compilation of this report was supported with discussion and inputs from a number of practitioners and experts. We are particularly grateful for inputs from Fundación Torcuato Di Tella, SouthSouthNorth and Valoral Advisors.

The project is part of the International Climate Initiative (IKI), implemented by the Federal Ministry for Economic Affairs and Climate Action (BMWK) in close cooperation with the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), and the Federal Foreign Office (AA).

This report is an output of the DecarBOOST project. The views and assumptions expressed herein are those of the authors and do not necessarily reflect those of the funder or the other implementing partners of DecarBOOST.

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

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About the Annual Investment Reports in Latin America and the Caribbean

This report is the second of a series of three reports looking into investments needed to meet the climate mitigation objectives of the Paris Agreement in Latin America and the Caribbean (LAC). The report series focuses on private sector investment, and public policy instruments that can incentivise it, as private sector finance will need to be significantly scaled up to meet the investment needs of a transition to net zero emissions.

This second edition focuses on the agriculture and food sector, analysing the status of the sector's alignment with the objectives of the Paris Agreement and identifying investment opportunities that have the potential for transformational change to net zero emissions.

The report incorporates findings from Latin America—and the Caribbean when it comes to certain data points—and focuses predominantly on three countries of the region: Argentina, Brazil, and Peru. The analysis is mostly conducted for these three countries, but findings from the broader LAC region help provide context and highlight success stories for low and zero emissions developments. The two selected case studies in this report highlight investment opportunities in Argentina.

The analysis for this report was mostly conducted between March and July 2022. Developments occurring after this period have mostly not been included.

The next edition of this report series, to be released in 2023, will focus on investment opportunities in green hydrogen.

Summary

The goal of the Paris Agreement to limit global temperature increase to well below 1.5°C above pre-industrial levels will require transformational changes in all countries and sectors of the economy. This includes a significant reduction of agriculture, forestry, and other land use (AFOLU) emissions and an increase in carbon sinks, globally and in the Latin America region. Globally, food systems account for 80% of deforestation and 29% of global GHG emissions. In the Latin America and Caribbean (LAC) region, AFOLU emissions represent 46% of total emissions; the main drivers for deforestation and land-use change in the region are commodity agriculture and shifting agriculture, whereas the main source for agriculture emissions is livestock (Roe *et al.*, 2021).

Latin America is the world's largest net food exporting region. It accounts for 13% of agricultural goods and fish produced worldwide and contributes to 25% of the world's food exports. Agriculture represents 4.7% of the region's GDP and employed 14.1% of its labour force (FAO, 2018a; OECD-FAO, 2020). Latin America's strong dependence on the agricultural sector aligns with the urgency to adopt sustainable production practices to achieve the global climate objectives, untap the many opportunities that arise from a low-carbon development pathway and, last but not least, to maintain and even strengthen its role as a major producer and exporter of agricultural products in the future.

This transition will require both redirecting existing investment flows towards low-carbon alternatives and mobilising additional funds. The amount of investment needed is so large that both the public and private sectors have important roles to play and must collaborate. The government should aid and support investment by small-scale producers or other private sector investors through strategic policy decisions and specific investment incentives. The private sector should contribute by investing in technology, innovation and improved farming practices to minimise agricultural emissions. The private sector also plays an important role in the dissemination of knowledge and raising awareness, which is particularly important with regard to cultural habits in the area of food and nutrition.

Current investment flows and support policies in the food and agriculture sector

Governments' motivation to channel public funds into the agricultural sector are manifold and include, for instance, economic growth, employment creation and poverty reduction. GDP growth in agriculture has shown to be more effective in reducing poverty as growth originating in other sectors (FAO, 2018a). Government agricultural policies are usually a mix of income redistribution and the promotion of public goods. The countries of Latin America take different approaches to supporting their agricultural sector. While countries in Central America and the Andean region tend to rely heavily on subsidies for private goods, the countries of the Caribbean sub-region and the southern part of South America focus mainly on the provision of general services (World Bank Group, 2020).

The estimated total support, measured as the total value of all financial transfers to the agriculture sector, are relatively low for Brazil and Peru, and even negative in Argentina despite the size and importance of the sector for the economy. Brazil provides, albeit on a relatively small-scale, support to both consumers and producers. However, there are major differences between Argentina's and Peru's approach. While

Argentina shows positive consumer support values, taxes on exports of agricultural products lead to negative producer support values. Peru on the other hand, shows positive producer support values but negative consumer support values, due to tariffs on imports or other domestic prices. In countries like Argentina and Brazil, around half of total budgetary expenditure for the sector goes to general services in the agricultural sector, including agricultural R&D. This can, if spent in the right way, contribute to the competitiveness of sustainable and climate-friendly products and practices in the food and agricultural sector and thus speed up their update and market-penetration. In the case of Peru, there are large fluctuations in the country's support for general services.

These conditions can also have an influence on private and institutional sector investment, which are an important source of cash inflows in the agriculture sector in Latin America and the Caribbean. The South American food and agriculture sector in particular is attracting a growing number of domestic and foreign investors who want to become active in one of the few regions that has the potential to produce growing food surpluses and export them to the world. There is a clear trend of how investors' interest in the food and agribusiness industry has increased over the last decade and how the region is slowly transitioning from a major supplier of raw materials to a provider of more finished products. This is also confirmed by the fact that the stage of the value chain where most merger and acquisition (M&A) transactions and the largest volume are concentrated is the midstream stage, which includes post-harvest activities and processors.

Subsectors that would lead to a more sustainable food and agriculture sector, however, still attract relatively little attention from investors. These include, for example, the sub-sector seed and crop protection, animal health or solutions to reduce food waste.

The bulk of investments in the region is divided into i.) investments in farmland markets, in particular the purchase and/or lease of agricultural land for row crops, permanent crops and cattle, where South America's extensive arable land place it among the top three regional markets globally; and ii.) private debt, which is predominantly focused on structured trade finance and other financing solutions for commodity processors and traders.

However, the share of venture capital, investing in start-ups and early-stage companies developing innovative products and services in the AgTech and FoodTech sectors has steadily increased. This is a positive sign for the sector's emissions, as many of these companies are focusing on sustainable activities such as replacing animal-based products and ingredients with plant-based alternatives.

Paris-compatible and future proof investment opportunities in the food and agriculture sector

Defining Paris-aligned benchmarks for the food and agriculture sector is urgently needed but challenging, as the sector's emission sources and developments vary widely across regions and countries. Still, investors need clear sector-specific emissions targets in the food and agriculture sector to help them plan and support the transition to a more sustainable future. In response, a number of approaches to determine Paris-compatible investment flows have been proposed.

The EU Technical Expert Group (TEG) has made recommendations for a transition to more sustainable cropland and livestock activities, while also combining it with further requisites in order to deliver

substantial mitigation contributions. These requisites include reducing emissions from ongoing land and animal management, increasing CO_2 removals and storage in biomass through good land and animal management; and ensuring that the agricultural activity is not carried out on land that was previously deemed to be a 'high carbon stock' (TEG, 2020). Building on the recommendations of the EU TEG, another study concluded that no further investments should flow into agribusinesses that directly or indirectly contribute to deforestation or forest degradation, as well as agribusinesses that transport perishable agricultural products by air freight; and new investments in primary forest risk commodities should be carefully evaluated to ensure they do not contribute to deforestation or forest degradation (Kachi *et al.*, 2021). This aligns with the pledge to eradicate deforestation caused by agricultural commodities, in which more than 30 financial institutions (managing over USD 8.7 trillion in assets) are committing to removing deforestation caused by agricultural commodities from their investment and lending portfolios by 2025 (Race to Zero, 2021a, 2021b).

To identify potential investment opportunities, international guidance on sustainable investment criteria for the sector should be combined with information on where the highest emissions reductions potential lies. Sixty percent of AFOLU emissions in the region come from land use change and 40% from agriculture. Recent research highlights that the biggest mitigation opportunities in Latin America involve sustainable intensification practices that avoid deforestation and ecosystem conversion, as well as agriculture practices that additionally contribute to carbon sequestration (agroforestry, biochar from crop residues, soil organic carbon in croplands and grasslands) (Roe *et al.*, 2021; UNCCD, 2022).

Argentina, Brazil and Peru are all in the top 15 countries with the highest total cost-effective mitigation potential from land-based measures, globally. In the case of Argentina, the biggest mitigation potential comes from implementing sustainable agricultural practices such as agroforestry and biochar application, followed by demand side measures like reducing food waste or shifting to healthy diets (Roe *et al.*, 2021). For Brazil, the highest mitigation potential comes from forest restoration and protection, followed by agriculture mitigation measures that contribute to carbon sequestration. In Peru, over 80% of the country's potential is linked to reducing deforestation through measures to protect forest and other ecosystems.

Untapping two investment opportunities in Argentina

The analysis of the market potential and conducive framework conditions for investments in the production of biochar and alternative proteins, carried out in this report as part of a case studies for Argentina, revealed that these opportunities can have significant positive effects in the environment, while representing important economic opportunities in the country.

In both cases, the investment opportunities are focused on nascent markets that have grown in recent years and have promising growth forecasts. The selected investment opportunities thus include the chance to enter and develop new markets in the country. However, there is still limited research and development to support local production of both biochar and plant-based meat. Furthermore, consumption of both products is currently rather low, however, recent studies predict a significant increase in demand in the coming years.

The biochar case study looks into the production of biochar from crop residues and builds on the registered growth in the global production capacity over the last five years. The analysis highlighted the knowledge and empirical development gap, particularly when it comes to understanding the social and development implications of biochar. Successfully exploiting the market opportunity to produce biochar and promote its use to enhance soil carbon content in Argentina will require overcoming technical and economic barriers, creating the right policy framework, and addressing the existing finance gap. Public interest in biochar's potential to sequester carbon is growing, however, capacity gaps and limited data on the cost of its application remain the main obstacles.

To untap the investment opportunity for plant-based meat production in Argentina, national firms could, with adequate support from the public sector both through policy and budgetary transfers, effectively tackle technical challenges and substantially improve the production efficiency. But macroeconomic and cultural barriers remain as the most challenging ones. De-risking facilities can help reduce the cost of capital and facilitate investments; this could be partially supported by multilateral finance. Cultural barriers will also need to be addressed through awareness raising and information campaigns that allow shifting narratives to facilitate acceptance of alternative flagship products.

Key messages

In a Paris Agreement-compatible world, agri-food systems are not only expected to meet the consumption needs of people and animals, but also to contribute to multiple climate and development objectives simultaneously.

Policy support is needed to accelerate the uptake of both investment opportunities analysed in this report, for example by providing financial incentives for start-ups, promoting research and innovation in production chains, and encouraging users and consumers to further increase demand for both products. Private investments should be (re)directed to agribusinesses that are considering or have already made the shift to business models that minimise the climate impacts of their operations will allow both development and climate objective to be met in the long run.

Redirecting at least part of Latin America's foreign capital inflows from conventional activities to innovative solutions or products in the sector would be fully aligned with international guidance on making future investments compatible with the Paris Agreement.

There is significant investment flowing into the region but only a small share is flowing into innovative, more sustainable and climate-friendly alternatives. At the same time, there is already important public support, e.g., for research and development, that, if directed to the right purposes could play an important role in overcoming barriers in the region to further expand into new investment opportunities like the production of biochar and alternative proteins. These opportunities can not only bring economic benefits to the countries but are in line with reducing emissions and preventing climate change impacts.

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Abbreviations

AFOLU	Agriculture, forestry, and other land use
AOI	Agricultural Orientation Index
AuM	Assets under management
CAGR	Compound Annual Growth Rate
CAPEX	Capital expenditure
CDR	Carbon dioxide removal
CSE	Consumer Support Estimate
EC	European Community
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
EU	European Union
FADA	Agricultural Foundation for the Development of Argentina
FAO	Food and Agriculture Organisation
FDI	Foreign direct investment
FTDT	Fundación Torcuato Di Tella
GDP	Gross Domestic Product
GFI	The Good Food Institute
GHG	Greenhouse gas
GMO	Genetically modified organism
GSSE	General Services Support Estimate
HCS	High carbon stock
HCV	High conservation value
HNWI	High Net Worth Individuals
IDB	Inter-American Development Bank
IISD	International Institute for Sustainable Development
ILO	International Labour Organization

INTA	Argentina's National Agricultural Technology Institute
IPCC	Intergovernmental Panel on Climate Change
LAC	Latin America and the Caribbean
LTS	Long-term low greenhouse gas emissions development strategies
M&A	Merger and acquisition
MSCI	Morgan Stanley Capital International
MW	Megawatt
NDC	Nationally determined contributions
OECD	Organisation for Economic Co-operation and Development
PSE	Producer Support Estimate
R&D	Research and development
SDG	Sustainable Development Goals
TEG	Technical Expert Group
TSE	Total Support Estimate
UNCCD	United Nations Convention to Combat Desertification
USD	US dollar
VAT	Value added tax

1 Introduction

Achieving the goal of the Paris Agreement to keep the global temperature increase below 1.5°C above pre-industrial levels will require significant changes in all countries and all sectors of the economy. The Intergovernmental Panel on Climate Change (IPCC) suggests that in order to stabilize the global temperature rise to 1.5°C by 2100, global emissions need to peak around 2020, reach net-zero CO2 emissions (while minimizing methane and nitrous oxide) between 2040 and 2060, and achieve net-negative emissions after that (Mead, 2018; Roe *et al.*, 2021). While emissions from the AFOLU sector cannot be completely eliminated with existing technologies, the 1.5°C-compatible mitigation pathways will still require a significant reduction of the sector's emissions.

According to the recently published Global Land Outlook by the United Nations Convention to Combat Desertification (UNCCD), food systems account for 80% of deforestation, 29% of global GHG emissions and are the single largest cause of biodiversity loss on land. Furthermore, the AFOLU sector has a much higher contribution to emissions in Latin America, compared to world average levels. Whereas global AFOLU emissions represent between 15%–23% of total emissions, in the Latin America and the Caribbean (LAC) region this figure goes up to approximately 46% (Kahlen *et al.*, 2021). This directly correlates with the key role of the agriculture sector in the region's economies, as well as its overall land use structure. In the LAC region, almost half (47%) of the region's area is covered with forest (mostly primary forest), while another 36% is being used for agriculture (Roe *et al.*, 2021). The main drivers for deforestation and land-use change in the region are commodity agriculture and shifting agriculture, whereas the main driver for agriculture emissions is livestock (Roe *et al.*, 2021).

The LAC region currently accounts for 13% of agricultural goods and fish produced worldwide, produces one fourth of the world's food exports, generates global ecosystem services and supports millions of livelihoods in the region (OECD-FAO, 2021). The countries of the region are among the world's largest suppliers of important agricultural products such as soybeans from Brazil, coffee from Colombia, wine from Chile, beef from Uruguay, wheat from Argentina, bananas from Ecuador, fruit from Haiti and quinoa from Peru (Calvin *et al.*, 2015; World Bank Group, 2020). These are only some of the countries' flagship products, they all produce many more. The main attribute of the region is its diversity in landscapes, productive systems and the different actors that are involved (World Bank Group, 2020).

The agriculture sector represented 4.7% of the region's GDP in the period between 2017-2019 and in 2018, the sector employed 14.1% of its labour force. GDP growth in agriculture has shown to be more effective in reducing poverty as growth originating in other sectors (FAO, 2018a). Between 1990 and 2014, poverty in rural areas of Latin America decreased by nearly 20%. A key factor in this progress was the change in public policy from general consumer subsidies to targeted, conditional cash transfer programs which were first implemented in Latin American countries. Additionally, during economic downturns in the region, agriculture served as a protective measure during recessionary periods (Arias et al., 2017; World Bank, 2021e).

Given the strong reliance on the agricultural sector in the region, it is crucial to implement sustainable production methods in order for the sector to continue driving regional economic growth and long-term development. The sector needs to become a major net sink of emissions by 2050, while maintaining food security and livelihoods. In simpler terms, reaching net-zero emissions must be achieved in a way that aligns with the sustainable development goals, and studies have shown that it is possible. Some estimates suggest that transitioning to net-zero emissions could result in the creation of 22.5 million jobs in Latin America and the Caribbean by 2030. Despite the loss of 7.5 million jobs in fossil fuel-related industries and animal-based food production, the overall increase in employment would still be 15 million (Saget, Vogt-Schilb and Luu, 2020).

The population of the Latin America and the Caribbean region is predicted to rise from 650 million to around 760 million by 2050, which will likely lead to a greater demand for agricultural production and investments, and increased pressure on land use (UN, 2019). Other trends besides population growth that are highly likely to occur and impact the sector, either positively or negatively, are urbanisation, migration, income growth, changing tastes and dietary preferences, productivity growth, and emerging technologies. At the same time, climate effects[1] will have an increasing impact on the food and agriculture sector as a whole, with implications in terms of investment risks and livelihoods. Developments related to these trends present both opportunities and risks. Therefore, it is important that stakeholders anticipate and address them as early as possible to create the enabling conditions to exploit the opportunities and minimise the risks. The latter, by its very nature, also has an impact on investment activities in the sector: The food and agriculture system in the LAC region needs to evolve and embrace emerging investment opportunities resulting from a transition to a more sustainable, carbon constrained agriculture sector. LAC could become a "frontrunner" in the transition and remain competitive while also reducing economic risks.

To achieve the global climate objectives, to untap the many opportunities that arise from a low-carbon development pathway and to maintain and even strengthen the role of the LAC region as a major producer and exporter of agricultural and other higher value-added products in the future, substantial amounts of investments are required. This requires redirecting existing investment flows towards low-carbon alternatives as well as mobilising additional funds. The scale of the investment required is such that both the public and the private sector have important roles to play and need to work hand in hand.

Aside from channelling public investments in the agricultural sector, the public sector plays a key role when it comes to steering private investments through strategic policy interventions and targeted investment incentives (FAO, 2021b). Along with incentivising low and zero- emissions investments, policies are needed to ensure that investments no longer flow into technologies and activities that are not Paris-aligned. At the same time, the private sector plays an important role in minimising agricultural emissions through improved sustainable farming practices and by

[1] We recognise the significant impact of extreme events, such as droughts and floods, in the sector; as well as the importance of adaptation measures to respond to these events. However, the scope of this report is limited to investments opportunities and risks related to mitigation actions in the sector.

incorporating new technologies. For that, investors need a holistic understanding of the food system and its implications for the Paris Agreement goals. While some guidelines and standards exist for sustainable investments in the sector, they do not necessarily focus on the climate mitigation aspects of it (CBI, 2021).

This report aims to give an overview of current investment flows, covering both public expenditure and private investment, and support policies (Chapter 2). Chapter 3 gives insights into where investments should be directed to align the sector with a pathway towards Paris compatibility and ensure that it remains competitive in a carbon-neutral future and provides an overview of sector-specific Paris-compatible investment opportunities. Two investment opportunities (case studies) are examined in more detail in Chapter 4 to analyse conducive framework conditions and to formulate recommendations on how to scale-up investments in the selected area in the future.

2 Analysis of current investment flows and support policies in the food and agriculture sector

The food and agriculture sector plays a significant role in the economies of Latin American countries. In 2020, the contribution of agriculture, forestry and fishing to GDP was 5.9% for Argentina, 5.9% for Brazil and 7.7% for Peru (World Bank, 2021d). In 2019, over 14% of employment in the LAC region (excluding high-income countries) was in the agriculture sector (World Bank, 2020b). Among the countries analysed in this report, Argentina had the lowest percentage of jobs in agriculture at 0.1%, with Brazil at 9% and Peru at 27% (World Bank, 2020b). However, labour statistics, especially those focusing on highly seasonal or fluctuating activities, such as agriculture, have some important limitations (Rodrigues, 2007). For example, there are significant variations depending on the data source, as evidenced by the following example: According to data from the Agricultural Foundation for the Development of Argentina (FADA), 24% of all private employment in the country is within the agricultural chain. The large difference can be explained, at least in parts, by the fact that the calculation by FADA does not only include agricultural producers, but also transporters and commercial workers (A24, 2022).

Recently, the LAC region has established itself as a major producer of agricultural products. Despite having only 8.5% of the global population, it accounts for 13% of all agricultural goods and fish produced worldwide and 25% of their exports (OECD-FAO, 2020).

Table 1. Agriculture profile indicators of the three focus countries

	Agriculture value added	Employment in agriculture	Volume of agricultural exports	Main agricultural export products	Main crops produced
Unit	*% of GDP*	*% of total employment*	*Billion USD*	*% of monetary value of total exports*	*% of monetary value of total production*
Source	*(World Bank, 2021a)*	*(World Bank, 2021b)*	*(Statista, 2022)*	(OECD/FAO, 2021)	*(Statista, 2022)*
Year	*2020*	*2019*	*2020*	*2019*	*2019*
Argentina	5.9	0.1	37	Soybean (15%) Corn (12%) Meat (6%) Wheat (4%)	Soybean (56%) Wheat (16%) Maize (10%)
Brazil	5.9	9	97	Soybean (14 %) Meat (6%) Sugarcane (4%) Maize (3%) Coffee (2%)	Soybean (35%) Sugarcane (15%) Maize (13%) Coffee (5%)
Peru	7.7	27	8	Tropical fruits (3%) Grapes (3%) Coffee (2%)	Sugarcane (28%) Potato (14%) Coffee (10%)

Given the enormous economic value of these products for the region, domestic as well as foreign investors are showing keen interest in this sector, as the following chapters will show. To better understand investment flows in the sector it is worthwhile to get an overview of the predominant products and commodities in the agricultural sector, both in the region, as well as in the three focus countries of this report.

Major export commodities from the LAC region include soybeans, pork, maize, poultry, animal feed, sugar, coffee, and fruits and vegetables.

Brazil and Argentina have a strong focus on exporting agricultural products and are the top two exporters of agricultural and food products in Latin America and the Caribbean, with exports worth USD 97 billion and 37 billion respectively in 2020 (Statista, 2022).

Both countries have a large presence of export-oriented farms in their agricultural production. Despite this, a majority of farms in these countries are still owned and operated by families (75% in the case of Argentina) (FAO, 2021a).

In Argentina and Brazil, soybean is the most important export product of the sector. While soy was virtually non-existent in the Argentine agricultural landscape 30 years ago, it is now the country's most important crop. Together with the United States, Argentina and Brazil, are among the world's largest producers of soybeans (Areco Tradicion, 2021). Argentina is also one of the largest cattle producers in the world. However, in recent years this sector has experienced a decline, among others, due to government interventions. In 2018, in response to the economic turmoil caused by a sharp devaluation of the Argentinean Peso, the government introduced taxes on all exports, which directly affected the cattle sector (OECD, 2019). Other important agricultural export products in Argentina are corn and wheat.

Apart from soybean, important agricultural export products in Brazil include meat and sugarcane. The country is the world's largest producer and exporter of sugarcane; it supplies 50% of the world's sugar and is also a major bio ethanol supplier, a product derived from sugarcane (CNA, 2022). Brazil is also the world's leading coffee producer, accounting for 38% of the world's coffee beans, more than twice as much as the second largest coffee producer, Vietnam (FGV, 2021).

Peru is also an important exporter (sixth largest in the Latin America and the Caribbean), with exports worth USD 8 billion in 2017, with small farms responsible for the vast majority of food produced in the country (Statista, 2022). The export of agricultural products in Peru focuses mainly on tropical fruits, grapes, and coffee. In 2009, blueberries were not grown commercially in Peru; these were introduced in the country by export companies. Ten years later, Peru is the world's leading exporter of blueberries, valued at approximately USD 752 million in 2019 (Metlife Investment Management, 2020). Peru's avocado production has tripled in the last decade; the industry grew in direct response to overseas demand from the European Union and the United States, with total exports increasing from USD 85 million in 2010 to more than USD 750 million in 2020 (Metlife Investment Management, 2020).

2.1 Public expenditures and support policies

Key take-aways

- There is a long tradition of public sector intervention in the agriculture sector by LAC countries using a broad range of mechanisms and policy measures.
- Even though public expenditure in the sector is relatively low in relation to its contribution to overall economic added value in most LAC countries, governments, at least in some countries, allocate a significant amount of public money to support the sector.
- Through the use of market price support and budget transfers, the public sector has a crucial role to play in incentivising the consumption of sustainable and climate-friendly products and practices and discouraging the consumption of harmful products and practices.
- Much of the monetary support is spent on general services, including R&D, especially in Brazil and Argentina. If spent in the right way, it can contribute to the competitiveness and market expansion of sustainable and climate-friendly products and practices in the food and agriculture sector.
- Targeted policies to promote Paris-aligned investment in the food and agriculture sector are important and have already been implemented to a certain degree in the focus countries. In order to achieve the desired level of investment and the required emission reductions in this sector, these efforts by policymakers need to be significantly strengthened.

Given the important role the food and agriculture sector play for local economies in most of the countries in the region, it is accordingly of high importance to policymakers. Governments' motivation to intervene in the agricultural sector through public funding or targeted policy measures are manifold and include, for instance, poverty reduction, economic growth, employment creation but also generation of revenue for the state budget, especially in export-oriented countries. GDP growth in agriculture has shown to be more effective in reducing poverty than growth originating in other sectors (FAO, 2018). Government agricultural policies are usually a mix of income redistribution and promotion of public goods. Governments intervene for example to limit commodity prices, restrict imports or promote exports.

Within the LAC region, there are significant differences between countries in terms of public expenditures in the agricultural sector.

The Agricultural Orientation Index (AOI) is an indicator to assess the agriculture share of government expenditure in relation to the sector's share of GDP (World Bank Group, 2020). Caribbean countries belong to the group of countries in the region with a comparatively high AOI values, which means that the agricultural sector receives a comparably high share of government expenditure relative to its contribution to economic value. In general, public spending on agriculture relative to agriculture's contribution to the economy has been higher in the LAC region, including Argentina, Peru and Brazil, than in other developing regions but lower than in high income countries (Diaz-Bonilla, De Salvo and Egas, 2019).

Not only are there large differences in the amount of public spending, but also in the type of mechanisms used to spend these funds. The support policies in the agriculture sector vary across LAC countries and/or subregions. In Central America and the Andean countries, the government mainly provides financial support to the agricultural sector through subsidies for private goods. In contrast, the Caribbean countries and countries in the southern part of South America mainly use other types of payments, which are principally used for general services such as research and development or infrastructure projects (World Bank Group, 2020).

A classification often used to measure the nature and extent of public support is the Total Support Estimate (TSE)[2], which corresponds to the total value of all financial transfers from consumers and taxpayers to activities in the agriculture sector arising from policy measures and is the sum of support to producers, to consumers, and for general services (OECD, 2003).

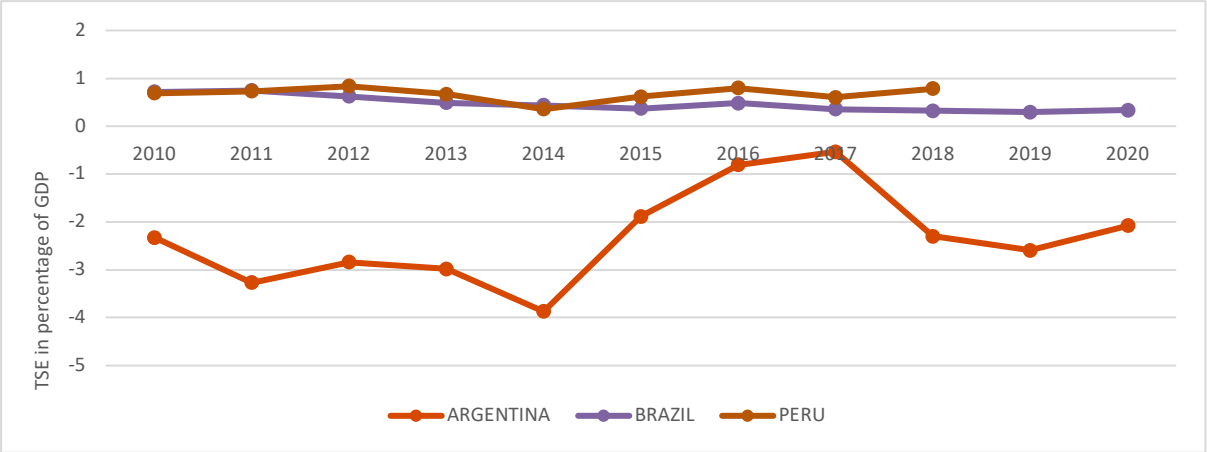
The level of support to the agricultural sector, reflected as TSE, is high in several LAC countries with low GDP per capita and large rural populations, e.g., Haiti, Nicaragua, Guyana, Bolivia, Honduras, or where agriculture, although a relatively small part of the economy, receives high levels of support, e.g., with the objective of maintaining food security for instance in El Salvador or Jamaica (Egas and De Salvo, 2018). At the other extreme are countries where agricultural support is less than 1% of GDP, e.g., Chile, Guatemala, Ecuador, Argentina, Brazil and Peru.

The TSE values for Brazil and Peru are relatively low and, in the case of Argentina, even negative despite the size and importance of the sector for the economy (Figure 1). The main reason for the negative value in Argentina is the taxes on the export of agricultural products, which translates into negative support for producers as a result of policies that have been erratic and biased against agriculture over the last 10 years. Only a few commodities, such as pork, have positive market price support in Argentina (OECD, 2019). Although Brazil and Peru have positive TSE values, they are still relatively low.

The basic element of support policy in Brazil consist of several price support mechanisms on the domestic market, including for instance, direct government purchases, with the aim to secure minimum guaranteed prices (OECD, 2020). Peru provides policies with significant support to producers through a variety of mechanisms, including trade policy measures, direct payments, and subsidized inputs, with consumers and taxpayers paying for these policies.

[2] Expressed as a percentage of GDP, the TSE expresses the "annual monetary value of all gross transfers from taxpayers and consumers arising from policy measures which support agriculture, net of the associated budgetary receipts, regardless of their objectives and impact on farm production and income, or consumption of farm products" (OECD, 2003).

Figure 1. Total Support Estimate (TSE) in percentage for the three focus countries



Source: IDB (2022)

When assessing the consumer support in these countries, a different picture emerges. Argentina and Brazil present positive values, while Peru presents negative values. The negative values indicate a transfer from consumers to producers through higher prices, either because of tariffs on imports or other domestic price support policies. The concern from the perspective of a national food security policy is that in the cases of close to zero or negative values for consumer support, consumers are paying higher prices to support domestic farmers, a situation that may particularly affect low-income consumers, who spend a proportionally higher percentage of their income on food items. In the case of Argentina and Brazil, the value of consumer support is positive, because certain commodity prices are subsidised by the government (OECD, 2021).

Support to general services in the agricultural sector in Brazil, which focuses mainly on research, development and innovation, accounted for 40% of the estimated total support in 2020, but has fallen since 2002 as a percentage of agricultural gross value added (OECD, 2020). The Brazilian development bank BNDES launched a programme to finance agricultural innovations ("Plano Inova Agro") for Brazilian agribusinesses, which includes measures to improve efficiency (BNDES, no date). In addition, the Brazilian Agricultural Research Corporation (Embrapa) conducts research on sustainable agricultural practices.

In the case of Peru, there are large fluctuations in the country's support for general services. This is explained, in part, by the implementation of the Sierra Rural Development project, commonly referred to as ALIADOS. This programme aims to improve the economic conditions of Peru's rural poor by supporting farmers and local organisations in the design, creation and consolidation of rural business plans and community-led sub-projects for territorial development (World Bank, 2020a).

Argentina is one of few countries assessed by OECD where most of the budgetary transfers are allocated to general services, accounting for around 60% of total budgetary support to the agricultural sector. The bulk of the expenditures on general services was spent on agricultural R&D, in particular with Argentina's National Agricultural Technology Institute (INTA), which has a mandate to conduct research on sustainable agriculture and provide capacity building as well as disseminate information and knowledge. In addition, inspection and control services, the public

institution for animal and plant health (SENASA) and the development and maintenance of infrastructure, especially irrigation and rural roads, was supported.

To date, public expenditures and support policies have, however, not led to a decline in sectoral GHG emissions. To achieve both sustainable development and climate objectives a significant shift is required in the way land is used and invested in.

Although sustainable land management practices and technologies can become profitable after three to ten years, targeted policy instruments are still needed to make these investments attractive to farmers, land managers and other investors, given the upfront cost they incur (IPCC, 2019).

Some progress has been made in this area in the focus countries, and some policies to incentivise the reduction of GHG emissions from agricultural activities exist. Argentina, Brazil and Peru all have a medium-term plan to reduce emissions in the agriculture sector, but none have a long-term perspective for the sector. Brazil's agricultural emissions reduction plan, the 'ABC Plan', has been in place for over a decade. In 2021, the government published an updated and extended 'ABC+ Plan' 2020–2030 (Government of Brazil, 2021). Argentina's National Cabinet on Climate Change approved the first sectoral mitigation plan for agriculture in 2019. Peru's agriculture mitigation measures are linked to its latest nationally determined contributions (NDCs) (Kahlen *et al.*, 2021).

Beyond this, however, it is important that governments increase efforts to reduce direct emissions from agricultural activities and significantly scale-up investments into sustainable agricultural practices, supported by sound policies.

For this, it will be important to identify and overcome some of the barriers to implementing climate policies. Fundación Torcuato Di Tella (FTDT) has identified the lack of long-term vision and approaches, policy inconsistencies as well as infrastructure deficits as some of the main structural barriers that narrow the degrees of autonomy and effectiveness for designing and implementing climate policies in Argentina (Fundación Torcuato Di Tella, 2021). In addition, FTDT identifies several other cross-sectoral issues that, if persistent over time, could hinder investment in decarbonisation. These include low growth rates of the economy, external indebtedness, currency devaluation, low foreign direct investment (FDI) levels and fiscal dependence on fossil fuels. Other barriers, so-called non-structural barriers, which FTDT identifies according to stakeholders consultation, could be addressed and/or removed at least partially through policy and regulatory reform (Fundación Torcuato Di Tella, 2021). These barriers are sector and even sub-sector specific and are thus described in more detail under each of the case studies presented in Chapter 4.

2.2 Private investment

Key take-aways

- A take-away from the analysis on private investment is that assessing low-emissions investment in the food and agriculture sector is difficult, as the activities are segmented into various categories, parts of the supply chain and data is often limited.
- The analysis has shown that the LAC region has been and still is very attractive to foreign companies and investors. However, the bulk of foreign investments, which for some countries

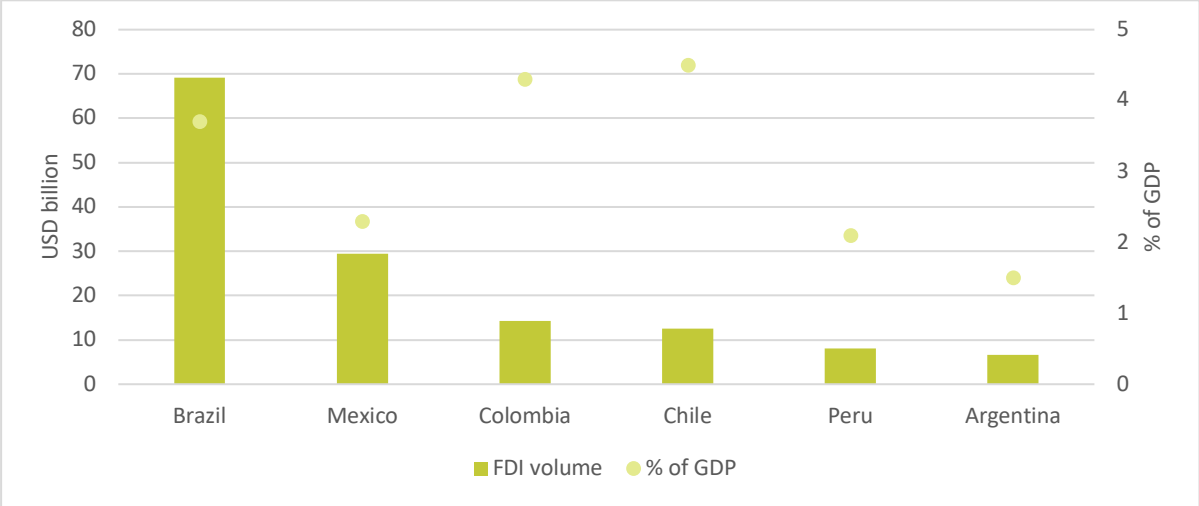
in the region represent up to 5% of their GDP, focuses on traditional activities, such as the extractive industries.

- Most of FDI inflows in the food and agriculture sector take the form of merger & acquisition (M&A) as opposed to greenfield investments, which is a sign that mostly the traditional and established subsectors are being targeted. Subsectors like animal proteins or fertilizer consequently account for large amounts of M&A volume, while subsectors that would supposedly contribute to a more sustainable and climate-friendly food and agriculture sector, such as animal health or reducing food loss & waste account for very low investment volumes.
- Even if investments in conventional areas like farmland for row crops, permanent crops, and cattle or investments in established companies operating along the food and agriculture value chain still dominate, investments in start-ups and early-stage companies that develop innovative products and services in AgTech and FoodTech are constantly growing.
- The increasing interest from foreign companies and investors in participating in midstream activities can be seen as a sign that the region is transitioning from being a main commodity supplier to also occupying with the handling and processing of agricultural products. Covering larger parts of the food and agriculture value chain also comes with increased responsibility for prioritising sustainable and climate-friendly practices.
- Given the important role of global players and companies play in this sector, defining and implementing global investment decision criteria is essential for making the LAC food and agriculture sector Paris-compatible and future proof.

The South American food and agriculture sector is attracting a growing number of domestic and foreign investors who want to become active in one of the few regions that has the potential to produce growing food surpluses and export it to the world. At the same time, private and institutional investments are an important cash inflow for the agriculture sector and national economy.

An important source of investments is Foreign Direct Investment (FDI), defined as "cross-border investment in which an investor resident in one economy establishes a lasting interest in and a significant degree of influence over an enterprise resident in another economy" (OECD, no date). FDI can take two forms: company establishment (greenfield investment) or merger and acquisitions (M&A). The decade ending in 2019 saw the highest ever FDI inflows to Latin America and the Caribbean, reaching an all-time high of around USD 345 billion in net inflows (in 2019), equivalent to almost 4% of the region's GDP. Brazil received by far the largest inflow of FDI (43% of the total) followed by Mexico (18%). Chile and Colombia are the countries in which FDI inflows represent largest share in GDP, with around 4.5% (ECLAC, 2020). In Argentina and Peru FDI inflows account for 1.5% and 2.1% of total GDP, respectively. The next figure shows total FDI inflows as well as their percentage of GDP for selected LAC countries. In 2020, the region received USD 145 billion in FDI, equivalent to 2.4% of regional GDP (World Bank, 2021c).

Figure 2. Foreign direct investment inflows for selected countries in Latin America and the Caribbean



Source: ECLAC (2020); World Bank (2021c)

The sectoral composition of FDI inflows in the region shows that services and manufacturing have been the most attractive sectors over the past decade, accounting for 42% and 39% of total foreign capital inflows, respectively. Foreign investment in natural resources and agriculture recorded high levels at the beginning of the decade and then declined to their lowest levels between 2015 and 2018. However, 2019 showed an increase, mainly due to growing investments in Brazil, Chile, Colombia and Mexico (ECLAC, 2020).

The countries that invest in Latin America and the Caribbean and the sectors they focus on tend to vary by sub-region. In South America, where there are many natural resources, a large portion of FDI goes towards industries such as extractive industries, agriculture, forestry, and fisheries. In Ecuador and Bolivia, for example, FDI in these sectors made up 54% and 46% of total FDI respectively. In the Caribbean, however, the majority of FDI is concentrated in the service sector, specifically in the tourism industry (ECLAC, 2020).

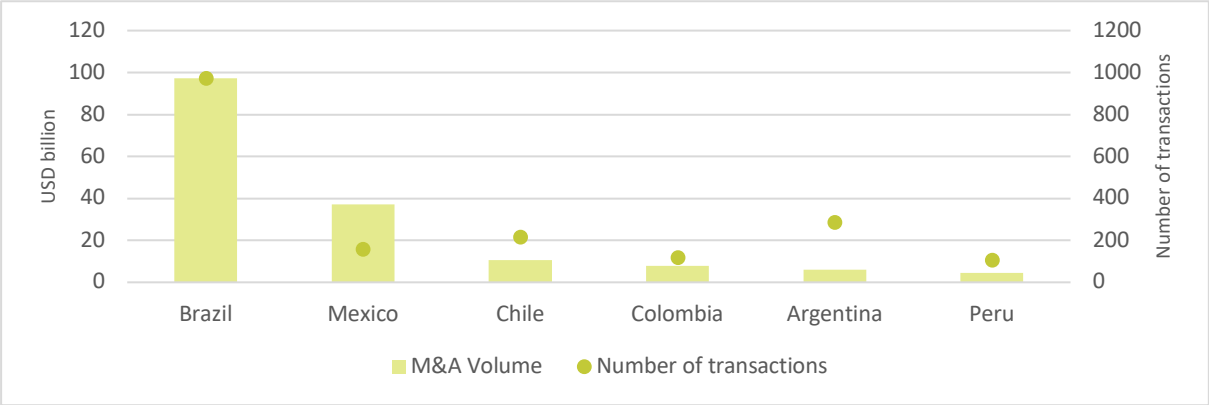
The sources of FDI in the region remained similar over the past decade, with companies from Europe and the United States being the largest investors, making up 82% of the total inflows in 2019. Europe had a significant presence in the Southern Cone, particularly in Brazil, while the United States was the main source of investments in Mexico and Central America (ECLAC, 2020). However, it is hard to accurately identify the origin of the funds as some countries, such as China, often channel their investments through other countries, making it difficult to track. A study suggests that 80% of Chinese investment that flowed into Brazil in 2016 came through third countries like Luxembourg and the Netherlands (Perez Ludeña, 2017).

Recently, rising interest among institutional investors has fuelled a large number of M&A transactions in the LAC food and agribusiness sector, both driven by domestic and foreign investors. In terms of investors, more than three-quarters (84%) of the M&A volume is accounted for by strategic players from across the food and agriculture sector and 7% by trading houses, which should be distinguished from strategic players as their investment focus is largely on grain

production and logistics and, to a lesser extent, biofuels. However, new players have entered the M&A market, including private equity firms, sovereign wealth funds and even pension funds (Valoral Advisors, 2018).

As shown below, Brazil ranks first in terms of cumulative M&A transactions between 2010 and the second quarter of 2022 in the food and agriculture sector. Brazil has the highest number of transactions with 972 M&A deals (48% of all transactions in the region) and also the largest transaction volume with USD 97 billion (58% of the total transaction volume in the region). Mexico is second in terms of transaction volumes (USD 37 billion), representing 22% of total transaction volume in the region. The country with the second highest number of transactions is Argentina, with 284 deals and 14% of total transactions in the region. Peru ranks sixth in the region, both in terms of transaction volume as well as number of M&A deals. The six countries shown below account for 96% of the total volume or 91% of the total transactions in Latin America.

Figure 3. M&A activity in the food and agriculture sector for selected countries in Latin America (January 2010 through May 2022)



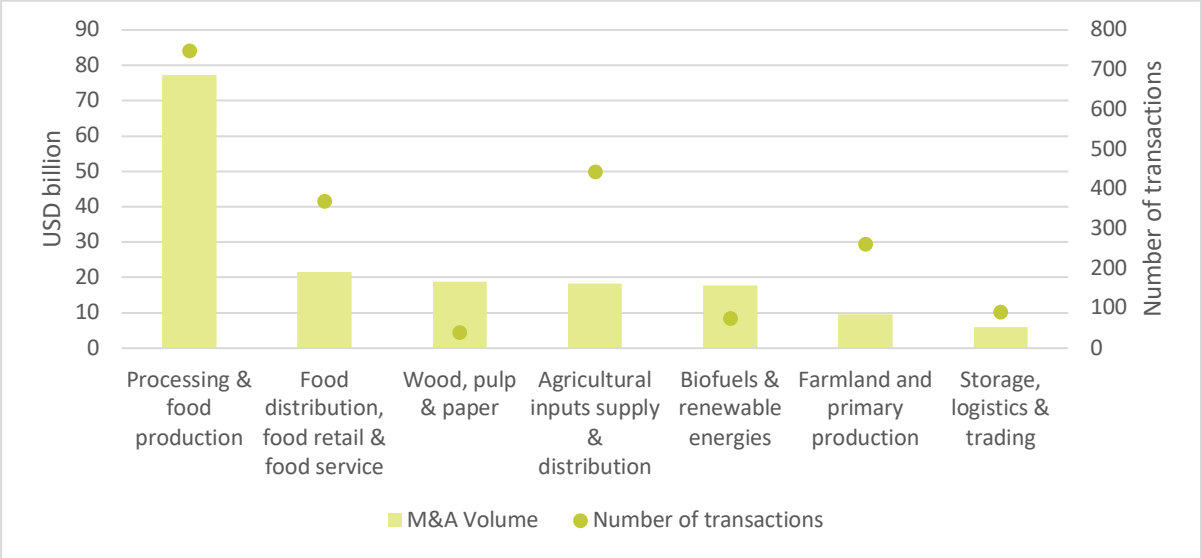
Source: Valoral Advisors (2022)

Figure 4 on the next page presents the M&A activity by the main sectors in food and agriculture in Latin America over the period from 2010 to the second quarter of 2022. The sector with both the highest transaction volume (USD 77 billion) and the highest number of transactions (747) in the region is the *processing and food production* sector as strategic players and private equity firms look to increase presence in the growing regional consumer market. The sectors *agricultural inputs supply and distribution* and *food distribution, food retail and food services* are also of great interest to investors, with the latter having the second highest transaction volume and the former the second highest number of transactions. In these segments in particular, there is considerable interest on the part of foreign companies to expand their presence in the region and to adopt established local brands and products (World Bank Group, 2020).

Investor interest has also been generated in a number of other niche areas in the region. Some examples of specific agricultural sub-sectors that have attracted foreign investment in certain countries within the LAC region include fish feed production for aquaculture in Ecuador, opportunities in the aquaculture industry in Brazil and Chile, fruit companies in Peru and Chile, poultry in Colombia, beef in Uruguay and Paraguay, and the animal protein business, specifically

dairy, in Chile (Valoral Advisors, 2018). It is also worth noting that the wood, pulp and paper sector has by far the largest average size of transaction, which is mainly attributed to the pulp and paper manufacturing subsector. The average transaction in this subsector is USD 1.2 billion, which is about twice as much as the second-ranked subsector in terms of transaction size.

Figure 4. M&A activity in the food and agriculture sector by main sector in Latin America (January 2010 through May 2022)



Source: Valoral Advisors (2022)

To better understand investors' priorities in this area, it is helpful to look at investment flows through merger and acquisitions by subsector (see Table 2). The subsector with the largest transaction volume is *alcoholic beverages* (in Processing & food production) with an M&A volume of USD 3.4 billion, followed by *sugar, feed and biofuels* (in Biofuels & renewable energy) with an M&A volume of USD 1.8 billion. Other relevant subsectors include *packaged food and animal protein (in* Processing & food production), *pulp & paper manufacturing* (in Wood, pulp & paper) and *fertilizers* (in Agricultural inputs and supply & distribution).

Figure 5. Subsectors in the food and agriculture sector with the highest M&A transaction volume in Latin America (January 2010 through May 2022

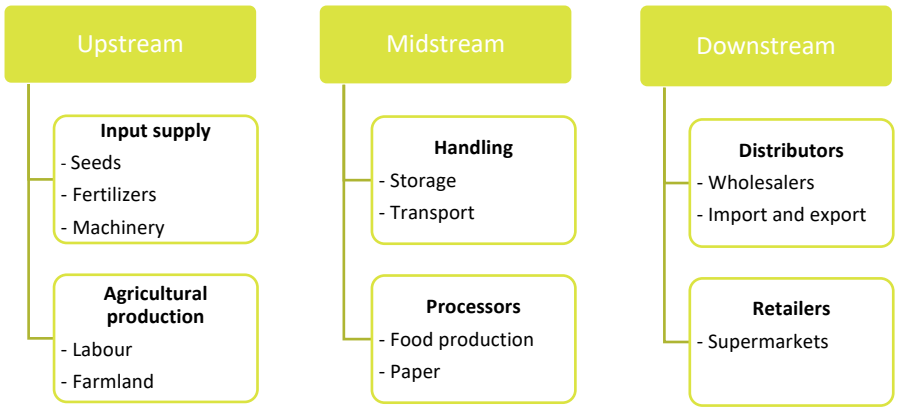
Main sector	Subsector	M&A Volume (USD billion)
Processing & food production	Alcoholic beverages	3.4
Biofuels & renewable energy	Sugar, feedstock & biofuels	1.8
Processing & food production	Packaged food	1.7
Wood, pulp & paper	Pulp & paper manufacturing	1.5
Processing & food production	Animal protein	1.3
Agricultural inputs and supply & distribution	Fertilizers	1.2

Source: Valoral Advisors (2022)

While subsectors with a higher environmental impact, such as animal protein and fertilizers, belong to those subsectors with highest M&A volumes, other subsectors that would lead to a less emissions-intensive food and agriculture sector, attract relatively little attention from investors. These include, for example, the sub-sector *seed and crop protection* (107 transactions with a total volume of USD 3 billion), *animal health* (15 transactions with a total volume of USD 0.2 billion) or *solutions to reduce food waste* (8 transactions with a total volume of USD 0.01 billion).

Another way of looking at the sector's investments in the region is by splitting them into the stages of the value chain production, namely up−, mid− and downstream, as shown in the figure below. The *upstream* stage covers all the primary agricultural production, including input supply. The *midstream* stage includes the post-harvest and processors activities (including food and paper production), and the *downstream* stage entails the activities of final disposition to consumers (including wholesalers, import, export and retailers).

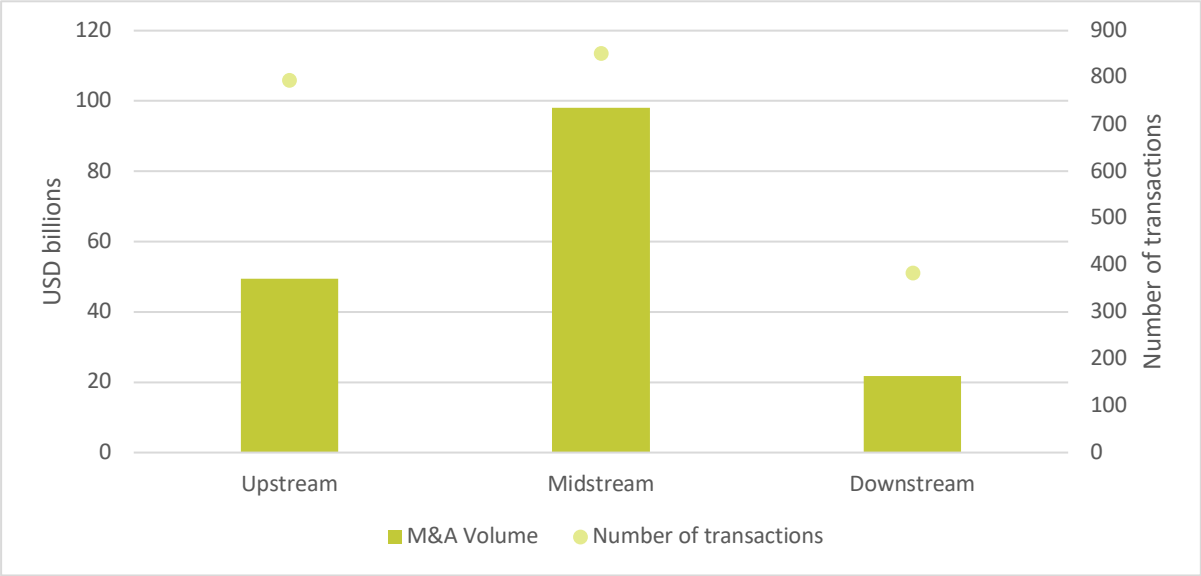
Figure 6. Parameters for classification of a process in the agricultural value chain



Source: Gloy (2005)

Figure 6 also presents a classification of the M&A activity in the food and agriculture sector by main stages of the value chain in the region. The classification is made by number of transactions and by volume in USD. The stage of the value chain production that concentrates the greatest number of transactions and volume is the *midstream* stage with 851 deals and a total transaction volume of USD 98 billion (with *alcoholic beverages* as the main sub-sector in terms of volume with USD 3.4 billion). This is followed by the *upstream* stage with 793 number of transactions and USD 49 billion transaction volume (being *sugar, feedstock & biofuels* the subsector with the highest volume at USD 1.7 billion), and the *downstream*, as the stage with the lowest number of deals and transaction volume.

Figure 7. M&A activity in the food and agriculture sector by main stages of the value chain production in Latin America and the Caribbean



Source: Author's calculation based on data from Valoral Advisors (2022)

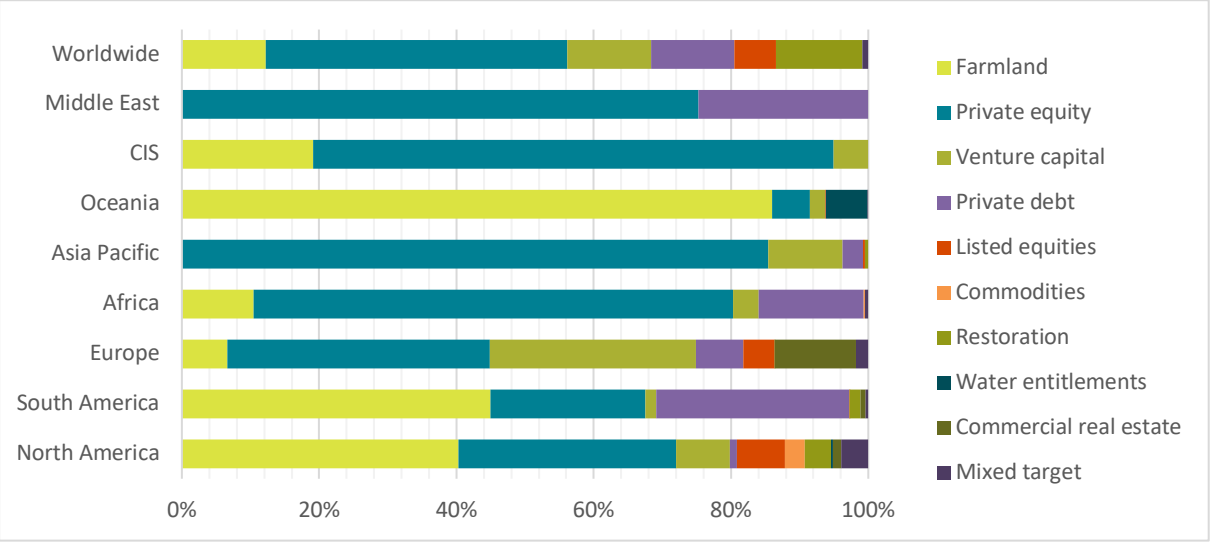
This picture is also reflected in the analysis of the green bond market in Latin America and the Caribbean. First agricultural companies are debuting in the green bond market, where the only four bonds issued in LAC are all from Brazil. Agriculture's share in the overall regional bond market is thus still comparably small. This is, however, nothing particular to the LAC region as, relative to its share of GHG emissions, agriculture is also globally by far one of the least funded green bond sectors (CBI, 2019). In the future, green bonds could and should play a more important role as they represent a powerful mechanism to finance sustainable agriculture. For example, the private sector could issue green bonds to larger agricultural producers, while financial institutions could group smaller projects together and finance them through green bonds.

A clear trend can be seen of how in the last decade, the interest of investments has been focussing mostly on the processor's activities and in the primary production. LAC is known as an important net exporter of food and agricultural commodities globally, but in recent years the processing of the commodities and the food production has taken a significant interest from investors in the region. The figure above summarises the asset allocation from these funds by geographical region.

Over the past two decades, attractive structural supply and demand trends have led to private and institutional investors putting more capital into the various asset strategies of the sector. The number of investment funds specialised in food and agriculture assets, excluding forestry funds, globally jumped from 41 in 2005 to over 800 in 2022 (Valoral Advisors, 2022)[3].

[3] Valoral Advisors' survey only covers a small portion of funds available in the market. It focuses specifically on investment funds that are managed by private asset managers, invest in assets related to the food and agriculture industry, and are available to a variety of investors, including retail investors, high net worth individuals (HNWI), and institutional investors. Many commodity and equity hedge funds are not included in the survey. Additionally, it does not take into account direct investments by sovereign wealth funds, pension funds, government agencies, or funds that are not open to investors.

Figure 8. Breakdown of investment funds specialised in food and agriculture by investment target and main regional focus (Percentage of total AuM USD billion) as of May 2022



Source: Valoral Advisors (2022)

From this perspective, it is clear that farmland and private equity are the main investment targets in the sector, although the composition varies greatly by region. The farmland category includes funds that invest in the acquisition and/or lease of farmland for row crops, permanent crops and cattle. Private equity includes funds that invest in established companies operating in the food and agriculture value chain.

South America, along with Oceania and North America, is one of the top three regional farmland markets for institutional investors. These regions have extensive arable land and market mechanisms that generally attract private and institutional capital. Unlike Oceania, the US and South America have a more diversified profile in terms of investment targets, which is reflected by the market volume for other investment types such as private debt, covering funds that provide structured trade finance and other financing solutions to companies in the sector, mainly to commodities processors and traders (Valoral Advisors, 2018).

The important role that investments in farmland for crops and cattle play in the LAC region underlines the need to prioritise sustainable and climate-friendly practices in investments. The latter has not been done sufficiently so far, as the analysis of FDI and M&A has shown.

The figure above shows selected examples of low-emissions investment areas in a sector that contribute to the achievement of both sustainable development and climate objectives. Chapter 3 below provides more detail on Paris-compatible and future proof investment opportunities in the sector.

Table 2. Examples of investment areas and main sources of capital in the AFOLU sector

Asset or activity	Capital provider
Low emissions investment areas	
Afforestation and reforestation	Governments, local forest rights holders, lessees, concessionaires, forest projects/management company
Agroforestry	Non-timber forest product businesses, farmers, traders
Sustainable forest management	Forest owners, forest managers, concessionaires, lessees, traders
Recovery of degraded pastures	Farmers, SMEs, landowners, lessees
Sustainable land management	Farmers, cooperatives, land-use planners
Biopesticides and biofertilizers	Farming companies
Seeds and breeding technologies	Farming companies, farmers, cooperatives
Climate-smart machinery and irrigation	Agribusinesses, farmers, cooperatives

Source: Kahlen et al. *(2021)*

A positive development to highlight is the constantly growing share of venture capital, covering investments in start-ups and early-stage companies that develop innovative products and services in the AgTech and FoodTech area. Entrepreneurs from Latin America have a reputation for their creativity and ingenuity in finding solutions to the various challenges in the food and agriculture industry in the region, hence the steady growth of AgTech and FoodTech start-ups in Latin America and the Caribbean. Argentina and Brazil have established themselves as the leading AgTech centers in the region. This can be seen as a result of the relatively large governmental spending on R&D in the sector in these two countries. The rise of AgTech centers is resulting in a significant growth of local communities that consist of entrepreneurs, farmers, agricultural businesses, educational institutions, government organizations, and other industry participants. These start-ups are part of a larger regional ecosystem of entrepreneurship that is expanding and causing disruptions in various industries, including row crops, permanent crops, livestock, forestry, and the entire food and agriculture industry from production to processing and services (Valoral Advisors, 2018).

3 Paris-compatible and future proof investment opportunities in the food and agriculture sector

3.1 Paris-aligned investment guidance

This section aims at providing an overview of where investments should be directed to align the food and agriculture sector with a pathway towards Paris compatibility and ensure that it remains competitive in a carbon-neutral future. 1.5°C-compatible emissions pathways for the agriculture and land use sector can vary widely across regions and countries, so a "one size fits all" set of criteria to define sector investments that are compatible with the Paris Agreement is challenging. However, there is clear evidence that greater and more responsible investments in the sector are needed to significantly reduce emissions in the sector and thus avoid global temperature increase while contributing to the sustainable development goals (e.g., enhanced food security and nutrition, reduced poverty).

The role of the agriculture and land use sector in the above-mentioned pathways is quite different from that of other sectors in which emissions are largely coming from fossil CO_2. In particular, because in the agriculture sector nitrous oxide and methane from e.g., fertilizer use and livestock are difficult to abate and comprise the largest and most potent share of agriculture emissions (Mead, 2018; UNCCD, 2022). At the same time, the land use sector can potentially act as a sink for GHG emissions, although the feasibility of large-scale CO_2 removal is still subject to multiple technical, economic and environmental constraints (Kachi *et al.*, 2021).

Where feasible, benchmarks help guide progress in the sector in the short, medium and long term. In the immediate future, the main focus is to stop deforestation and establish a foundation for further transition. In the mid-term, key objectives include reducing emissions, increasing carbon sequestration through extensive reforestation, increasing efficiency and productivity, and decreasing waste. In the long-term, these efforts must continue and expand in scope (Kachi *et al.*, 2021).

Criteria to define which investments can be considered Paris Agreement compatible

Studies have started looking into the sustainability of investment flows in the sector. In the following, a selection of relevant classification approaches is described.

In 2020, the EU TEG made recommendations to the European Commission on the technical screening criteria to be included in the EU taxonomy for Sustainable Finance in the agriculture sector. The proposed criteria can be aggregated in two main categories: those related to cropland (including perennial, non-perennial and rice crops) and those related to livestock activities (Annex 1 contains a summary of the proposed sustainable agricultural measures).

For cropland measures, the TEG gives recommendations regarding the crop of choice (including requisites for crop rotations in non-perennial crops); soil management practices; rice cultivation approaches; nutrient management; land conversion criteria and waste management practices. For livestock related measures, the list includes recommendations for animal health management; animal feed alternatives; manure management; permanent grass management; and soil management (TEG, 2020). Further, the proposed taxonomy also requires agribusinesses or farms to comply with three additional criteria to be recognised as delivering substantial mitigation contributions:

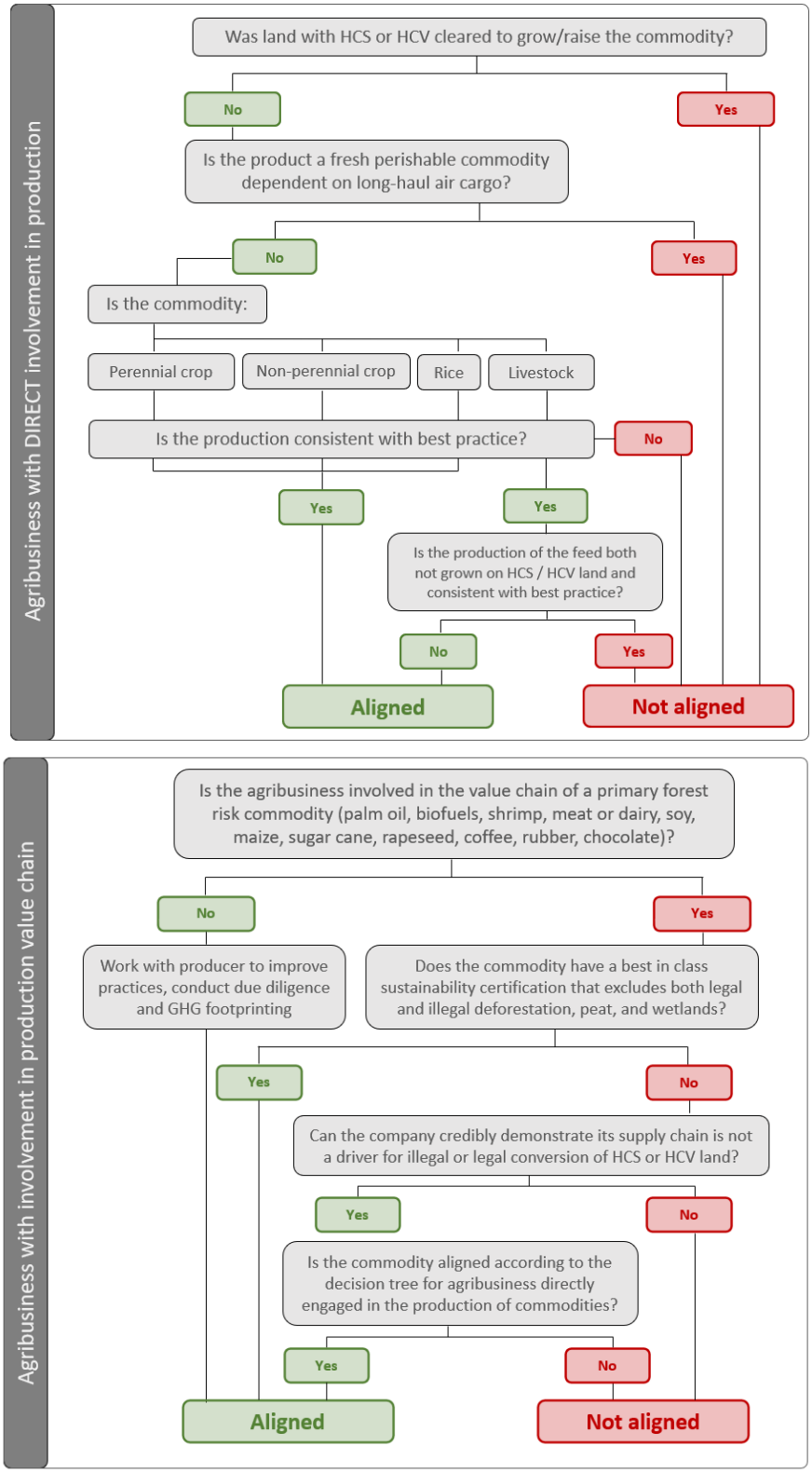
i) reducing emissions from ongoing land and animal management;
ii) increasing CO_2 removals and storage in above- and below-ground biomass through good land and animal management; and
iii) ensuring that the agricultural activity is not carried out on land that was previously deemed to be a 'high carbon stock' (TEG, 2020).

Although the set of proposed criteria is yet to be adopted by the European Commission, these recommendations provide a solid basis and standard for best practice and sustainability in agricultural activities worldwide. Not all the categories listed under the cropland and livestock related measures are common investment options for the private sector, therefore the discussed alternatives are only meant as an overview of good practices, potentially Paris-aligned, that can be looked at when considering new agribusiness investments.

Building on the recommended EU taxonomy for Sustainable Finance in the agriculture sector, Kachi *et al*. (2021) make a first proposal to guide development bank investments in the agriculture and land use sector to support the transition towards a more sustainable pathway. The paper proposes a rating system that divides agribusinesses into four categories according to their consistency with the Paris Agreement mitigation objectives (Kachi *et al.*, 2021). For this, the authors split agribusiness companies in the food sector into two broad categories: companies directly involved with the production of agricultural commodities on the farm, and companies that engage in other parts of the value chain such as food processing, transport, wholesale and retail.

For each category, a decision tree helps evaluate whether investments in the sector can be considered "sustainable" based on several factors, including its direct or indirect association with deforestation and/or forest degradation; the nature of the crop, whether it requires air freight to reach to its destination; and its consistency with best practice to minimise emissions on the farm, as shown in Figure 9 on the next page.

Figure 9. Decision trees to evaluate agribusiness's alignment to the Paris Agreement



Source: Own elaboration based on Kachi et al. *(2021)*

Based on these decision trees, agribusiness companies are then rated "aligned", "partially misaligned", "mostly misaligned", or "misaligned". Each rating includes recommendations as to whether to continue investing, invest with additional requirements and/or to stop investment.

Below is a summary of the main considerations and recommendations from the paper, which can be used to inform future investment decisions in the sector:

- Agribusinesses that directly or indirectly contribute to deforestation or forest degradation, with particular risks for land of high carbon stock (HCS) or high conservation value (HCV), are considered "misaligned" and should not receive further investments.
- Agribusinesses that transport perishable agricultural products by air freight (i.e., with very high carbon footprints), represent only a very small proportion of the overall food system, and are not a factor in guaranteeing food security. These agribusinesses are therefore also considered "misaligned" and should not receive further investments.
- New investments in companies producing primary forest risk commodities[4] should be carefully evaluated to ensure they do not contribute to deforestation or forest degradation, and that they are in line with best available practices (e.g., minimising soil carbon loss, nitrous oxide and methane emissions, for example based on EU TEG recommendations described above).

Investment risks associated with this sector greatly depend on the company, commodity, and the geographic location of the company's production. However, a recent IISD study on the State of Standards and Investments in Sustainable Agriculture points out that agribusinesses that are compliant with best agriculture practices and sustainability standards can result in operational advances which improve business profitability. Incorporating social and environmental considerations in agribusinesses can also help investors meet their due diligence requirements, which mitigates financial risks as well (Voora *et al.*, 2022).

Given the dispersed nature of emissions sources and diversity of actors in the food and agriculture systems, particularly in developing countries, it is not possible to have a list of individual measures that are in all contexts Paris Agreement aligned and where private investment should *in all cases* flow to. However, in general, new private investments should contribute to agribusinesses that consider transition risks beyond the physical ones of having more frequent and extreme weather events (e.g., policy and legal risks, technology risks, market risks, etc.) or to agribusinesses that are considering or are already in the process of shifting to business models that minimise the climate impact of their activities, helping to address such risks.

3.2 Investment gaps and opportunities

To identify sustainable investment opportunities[5] in the agriculture and land use sector in Latin America, international guidance on the type of investments that can be labelled Paris Agreement compatible (Chapter 3.1) should be combined with information on where the highest emissions reductions potential lies. AFOLU emissions in the LAC region are currently estimated to be at ~2.2

[4] Products often linked to deforestation and land use change include palm oil, biofuels, shrimp, meat and dairy, soy, paper/timber, sugarcane, maize, rapeseeds, rubber, chocolate and coffee.
[5] We will focus on investment opportunities that impact those parts of the value chain that affect the region. This includes products for the domestic market, but also those that are exported to other regions.

$GtCO_2eq$/year, with 60% of them due to land use change and 40% to agriculture. The main drivers for deforestation and land-use change are commodity agriculture and shifting agriculture, whereas the main driver for agriculture emissions is livestock production. About 47% of the region's area is covered with forest (mostly primary forest), and another 36% is being used for agricultural purposes (Roe *et al.*, 2021).

A recent study to estimate the mitigation potential and feasibility of several land-based measures indicates that countries that have a high share of forest cover and/or have high meat production and consumption levels have a high relative mitigation potential and could prioritise mitigation measures like protecting forests, restoring forests, shifting to less meat-intensive diets, and carbon sequestration in agriculture. This is relevant for countries like Brazil, Colombia, Mexico, Argentina and Bolivia (Roe *et al.*, 2021). Further, in countries where a high share of forest cover is combined with low fossil fuel emissions (e.g., when the power sector relies on hydropower resources instead of coal or gas), the cost-effective potentials lead to a "surplus potential", this means that the estimated mitigation potential is greater than the total country emissions. This is the case, for example, for Guyana, Suriname, Bolivia, Peru, Colombia, Brazil, and Costa Rica (Roe *et al.*, 2021).

According to the same study, the biggest mitigation opportunities in the region involve sustainable intensification practices that avoid deforestation and ecosystem conversion, as well as agriculture practices that, in addition, contribute to carbon sequestration (agroforestry, biochar from crop residues, soil organic carbon in croplands and grasslands, see Table 4) (Roe *et al.*, 2021). The highest cost-effective mitigation potential in Brazil comes, by far, from forest restoration and protection, followed by agriculture mitigation measures that contribute to sequester carbon. In Peru, over 80% of the country's potential is linked to reducing deforestation through measures to protect forest and other ecosystems. In the case of Argentina, the biggest mitigation potential could be achieved when implementing sustainable agricultural practices such as agroforestry and biochar application, followed by demand side measures like reducing food waste or shifting to less meat-intensive diets[6] (Roe *et al.*, 2021).

[6] The estimates in the study include emissions reductions from diverted agricultural production due to the adoption of sustainable healthy diets, but excludes emissions reductions from potentially avoided land-use change.

Table 3. Selected measures and maximum mitigation potential in the agriculture sector

	Measures	Technical mitigation potential	Regional focus
Agriculture and soils	Agroforestry	5.6 $GtCO_2e/y$	Russia, Canada, **Brazil,** Indonesia, US, EU, Australia, Tropical countries
	Improved livestock management (enteric fermentation & manure management)	0.3–0.5 $GtCO_2e/y$	China, India, Brazil, EU, US, Australia, Russia, Argentina, Mexico, Colombia, Paraguay, Bolivia
	Nutrient management	0.3–0.5 $GtCO_2e/y$	Developed and emerging countries (China, India, Brazil, EU, US, Australia, Russia)
	Increased soil organic carbon content (croplands & grasslands)	2.5 $GtCO_2e/y$	China, EU, US, Australia, Brazil, Argentina, India, Indonesia, Mexico, Sub-Saharan Africa
	Improved rice cultivation	0.2–0.3 $GtCO_2e/y$	China, India, Indonesia, Bangladesh, Vietnam, Thailand, the Philippines
	Biochar from crop residues	2.4 $GtCO_2e/y$*	China, EU, US, Australia, Brazil, Argentina, India, Indonesia, Mexico, Sub-Saharan Africa
Demand	Dietary change	2.3 $GtCO_2e/y$	Developed and emerging countries (US, EU, China, Brazil, Argentina, Russia, Australia)
	Reduced food waste	0.9 $GtCO_2e/y$	China, Europe, North America, Latin America

Source: Based on Roe et al. (2021)

* Up to 10.1 $GtCO_2e/y$ when including fossil fuel substitution effect

In Argentina, Brazil and Peru, the land use and forestry sector represents an important source of emissions. The NDCs of the three countries therefore explicitly cover emissions of the sector but all are very ambiguous as to what the sector's contribution will be in terms of emissions reduction, in achieving those NDCs. In general, these countries should avoid relying too much on LULUCF (land use, land-use change, and forestry) sinks to achieve their climate targets given the high chance of carbon loss through deforestation and eventual competition for land.

Argentina and Peru are currently implementing mitigation policies aligned with the above-mentioned findings, aimed at reducing deforestation and/or increasing carbon sequestration. The ForestAr 2030 initiative in Argentina aims to establish a comprehensive discussion and plan to preserve natural forests through sustainable forest management. This will be done by implementing the National Plan for Forest Management with Integrated Livestock Production (MBGI), which focuses on combining forestry and livestock production activities (Climate Action Tracker, 2022a). In Peru, the decline in deforestation between 2016 and 2019 is credited to the efforts of the National Forest Conservation Program (Climate Action Tracker, 2022c). Brazil on the other hand, initially set up a range of anti-deforestation policies that proved very effective between 2005 and 2012. However, since then, the government has rolled back several of these environmental policies and deforestation rates have continued to increase at a worrying pace (Climate Action Tracker, 2022b).

4 Case studies

To analyse conducive framework conditions for these investments and to develop recommendations for how to untap certain investment opportunities, it is advisable to look at them individually to reflect the specific circumstances and diversity of the region and its food systems. Two investment opportunities are analysed in the following chapter. In the selection, care has been taken to ensure that they are relevant mitigation options in the focus countries and that both a supply-side and a demand-side investment opportunity are represented. Both case studies focus on one country (in this case Argentina),

4.1 Case study I: Enhancing soil carbon content and use of biochar in Argentina

4.1.1 The context

This case provides a very succinct characterization of opportunities for enhancing soil carbon content and the use of biochar in Argentina from a scientific, technical and economic perspective. The objective is to help define the broader conditions under which the use of biochar could be integrated into national climate policies and measures and present the investment opportunity in biochar to the private sector.

This case study looks into investment opportunities for biochar production and its use to enhance soil carbon content in Argentina. The findings of this case study are based on the assessment of the scientific, technical and socio-economic literature available and consideration of the economic, social and environmental implications of the implementation of practices to applying biochar to soils. This analysis helps identify existing knowledge, implementation gaps, present the case for private investment in biochar and formulate recommendations for the government to stimulate the use of biochar in national climate change strategies that contribute to the achievement of sustainable development, the NDCs and facilitate green recovery plans.

What is biochar?

Biochar is a type of charcoal made by burning biomass in an oxygen-free environment. It is high in carbon and is often added to soil to improve its quality, boost plant growth, and increase crop yields. IPCC defines biochar as a solid carbonized product from thermochemical conversion through pyrolysis (heating with limited air). The term biochar is used herein only to refer to materials that have been produced under process conditions in which relatively easily mineralizable organic materials are converted to more persistent forms by heating to above 350°C with limited air through a gasification or pyrolysis process. The IPCC guidance does not deal with pyrolytic organic materials that result from wildfires or open fires and is applicable only for biochar added to mineral soils (Samaniego *et al.*, 2021).

The energy released during the pyrolysis can be partially utilized (approximately 30% of the total energy) in the processing plant or nearby facilities. This production characteristic makes it attractive

to be installed in industrial parks where energy use is more intensively required. The production of a ton of biochar, from 4 tons of dry base biomass, allows generation of about 5 MW of energy (Samaniego *et al.*, 2021).

According to the IPPC, biochar is referred to as a carbon dioxide removal (CDR) technology. CDR technologies represent options to actively remove CO_2 from the atmosphere and represent an important component in the future technology mix in many Paris Agreement compatible scenarios. In those scenarios, they compensate for remaining emissions in sectors where technologies for achieving zero GHG emissions are not available. However, the IPCC underscores that the potential accessibility of CDR technologies should by no means delay other types of actions to combat climate change or lead to slower or fewer GHG reductions compared to a situation without them (Samaniego *et al.*, 2021). CDR options should be additional to all other policies and measures that are available now and should not be used as a justification for inaction today.

Contribution to the achievement of the SDGs

The full impact of using technologies for Carbon Dioxide Removal (CDR) on achieving sustainable development, particularly in Latin American and Caribbean countries, is not yet well understood. However, an initial effort has been done to examine the effects of biochar on the United Nations' Sustainable Development Goals (SDGs) specifically in Argentina. The potential implications identified for the SDGs are likely to differ markedly depending on the assumed scale of intervention and contexts of its deployment. It is expected that large scale deployment of biochar would have several synergies with the SDGs in Argentina. In particular, we identified direct synergies with reaching zero hunger (SDG 2); creating decent work and economic growth (SDG 8); supporting industry, innovation and infrastructure (SDG 9); promoting responsible consumption and production (SDG 12); and contributing to climate action through emissions reduction (SDG 13).

Implementation of large-scale biochar would be expected to have physical side-effects and socio-economic or political implications eventually affecting the delivery of SDGs. Physical side-effects in particular relate to land-use alternative uses and food security; water quality and availability; health; energy; economic productivity; infrastructure needs; and effects on biodiversity. Socio-economic or political implications include economic and cultural impacts; opportunity costs; significant financial requirements; political consistency among sectors (Samaniego *et al.*, 2021).

Biochar can potentially improve water and fertiliser holding capacity at the root zone, increase soil biological productivity, and in-situ absorption of pesticides. Biochar deployment increases yields and have positive impacts, but there are potential risks during its development. Achieving beneficial outcomes and avoiding social and environmental harm requires more research and policy-specific impact assessments that should take local conditions into account.

Table 4. Potential impacts and risks of enhancing soil with biochar

Positive Impacts	Negative Impacts
• Enhanced soil properties and increasing yields (food supply) • Technological know how (dev, construction and operation) • Long-term C sequestration • Lower N2O and CH4 emissions • Higher soil water balance's • Potential on other crops • Biochar pyrolysis for power generation • Other valuable co-products: wood flavoring and adhesives • Direct and permanent jobs (construction, application)	• Logistics costs and environmental impacts of raw material and biochar transportation • Lower albedo and radiative forcing

Source: Own elaboration based on Vivid Economics (2020)

4.1.2 Global and regional trends

According to Mittal and Prasad (2022), the global biochar market was valued at $170.9 million in 2020. That same year, the Asia Pacific region accounted for 70.2% of the biochar market. This is attributed to the growing livestock and agriculture sector in the region. Currently, at the global level China and the United States are the frontrunners in using biochar for agricultural purposes (Cha *et al.*, 2016).

According to Valoral Advisors (2021), based on the European Biochar Industry Consortium, biochar production capacity in Europe recorded a significant growth in the last decade. By the end of 2020, the biochar production capacity in Europe reached over 20.000 metric tons, growing fourfold, from less than 5.000 metric tons in 2015, and doubling from 2018 to 2020.

The method of pyrolysis was responsible for generating the most revenue in the biochar industry in 2020. This is the most widely used technique for producing biochar, and it also produces other valuable products like bio-oil and syngas that can be used as a source of energy. According to the above-mentioned report, the use of biochar in soil amendment was the biggest market in 2020. This is due to increased government funding for agricultural activities in developed and developing countries, where biochar is being used to improve soil fertility. Additionally, farmers are becoming more aware of the benefits of using sustainable products to enhance soil quality and crop yield, which has led to an increase in sales of biochar for soil amendment applications.

In the Latin American region, there is still a significant knowledge and empirical development gap around CDR technologies, including biochar (although so far this is where most of the scientific research has focused on, compared to other CDR technologies). Considering the early stage of development of biochar in the region and the few empirical case studies, deploying the technology at scale would still require further research to e.g., explore synergies and challenges with other national development goals, as well as to understand costs and investments needs for biochar to become a feasible mitigation alternative (Samaniego *et al.*, 2021).

Current status in Argentina

The current status of enhancing soil carbon content with biochar in Argentina was assessed considering three different dimensions: i.) scientific and technical knowledge, ii.) consideration and adoption in planning, and iii) empirical application.

In general, the analysis shows a significant knowledge and empirical development gap. As expected, efforts on climate change mitigation are primarily focused on emissions reductions through the replacement of fossil fuels production and use in Argentina. Deforestation is also being addressed, separately. Carbon removal efforts are so far only considered in a largely incipient manner. The broader implications of biochar, in contributing to delivering or hindering sustainable development efforts are so far insufficiently explored and understood. Further, Argentina faces a persistent climate finance gap; thus, the decision on the potential development of biochar would require accurate abatement costs information and careful consideration of implementation risks in order to avoid misallocation of scarce resources. More comprehensive research and technical development efforts are still needed.

Table 5. Current status of knowledge and development for biochar in Argentina

Assessment dimensions	Scoring	Evidence for Scoring
Scientific and technical knowledge		Academic research on "biochar as soil enhancer" is still incipient in Argentina.
Mainstreaming in government planning		No explicit mention to biochar as soil enhancer in Argentinean policies and development plans. However, there are some incipient efforts to evaluate the direct effect of biochar on soil carbon.
Implementation of initiatives and projects		No specific initiatives (small / large-scale projects) were identified, but some nascent interest shown by private actors to look at biochar production.

Not developed | In development not directly / partially related to CDR | Less than 10 articles / Programs not yet implemented / Small-scale initiatives | More than 10 articles / Programs in execution or executed / Complete large-scale initiatives

Source: Own elaboration based on Samaniego et al. (2021)

Scientific and technical knowledge

Academic research on the "biochar as soil enhancer" subject is still incipient in Argentina, and only a limited number of articles have been disseminated. The application of biochar is being studied and tested in experimental applications in Argentina. The discussion is focused especially on its use in the livestock sector, but it is still preliminarily being analysed in which areas and methodologies it is feasible to obtain a significant mitigation response by reducing emissions or by capturing carbon in soils. In addition to technical studies on the effect of biochar on soil properties, economic studies are also necessary in order to evaluate the potential extension of this practice massively to farmers (Samaniego *et al.*, 2021).

Mainstreaming in government planning

No explicit mention of biochar as a soil enhancer was identified in Argentinean policies and development plans, nor are there specific programs on the subject. In fact, the use of biochar has not been considered in the list of mitigation actions or technologies for the AFOLU sector identified in Argentina in the wide range of studies examining opportunities in that sector (Samaniego *et al.*, 2021). Biochar was recently included in the IPCC guidelines to provide guidance for inventory compilers (IPCC, 2019). This technology would be considered as a Carbon Capture and Storage strategy. However, there are some soil carbon sequestration programmes in cropland and grazing lands:

- INTA-Minagro: Soils Observatory ("Observatorio Nacional de Suelos")
  One of the main actions of the soils observatory is the monitoring of the carbon content of agricultural soils, through a sampling methodology that considers the different agroecological regions and productive systems. With this information, Argentina prepares and periodically updates the national carbon stock map, complying with the national needs and the demands of the international agenda related to sustainable development goals. This survey is also part of the SISINTA program (http://sisinta.inta.gob.ar/).

- INTA -Minagro: the SISLAC ("Sistema de Información de Suelos de Latinoamerica") initiative and GSOCmap in partnership with FAO
  SISLAC is a regional initiative promoted and sponsored by the Global Soil Partnership, which involves CIAT, EMBRAPA and 20 national institutes in Latin America. The system is developed through state-of-the-art methods and tools of Digital Soil Mapping.

Simultaneously, private sector representatives and NGOs are moving forward in terms of studies and decision support systems oriented to reducing carbon emissions and estimating soil carbon changes in agriculture.

Implementation of initiatives and projects

No large-scale biochar projects have been identified in Argentina. However, LERA S.A. is a company located in Concordia, Entre Rios province, Argentina, that produces bio pellets (wood chips) and is strongly interested on migrating to biochar production, depending on the carbon market price trends in Argentina and Annex I countries in Europe (Samaniego *et al.*, 2021).

Investment opportunity assessment

At the regional level, several studies have been developed, most of them are technical studies also focused on the impact of biochar on soil properties. Gallo-Saravia, Lugo-Sierra and Barrera-Zapata, (2018) evaluate biochar as substrate alternative in tomato crops in Colombia. From an economic and environmental perspective, they conclude that using 20%-50% of biochar can represent significant savings for the producer (less use of substrates), while also giving utility to agro-industrial waste (converted to biochar).

Other global studies show that although biochar implies high upfront costs, its agricultural applications provide long-term economic benefits. An economic assessment carried out by Keske *et al.*, (2019) concluded that biochar application for agricultural purposes in Canada, had a 99% probability of becoming profitable (Allohverdi *et al.*, 2021). The potential benefits of using biochar are determined by the increased revenue from higher crop yields, particularly in growing beets and potatoes. The use of biochar made from forest biomass waste, such as black spruce, has been found to increase crop yields (Marshall *et al.*, 2019). When biochar is produced from waste biomass, it is typically economically beneficial. However, the economic analysis in this study is based on field research trials, which means there is still some level of uncertainty and the potential production values may vary.

Iswaran, Jauhri and Sen (1980) applied biochar during the cultivation of pea and mung bean in Indian climatic conditions and found that adding 0.5 tonne/ha biochar in the field increased the yield of peas by 160%, and in mung beans by 122%. According to a study by Kishimoto and Sugiura (1985) adding biochar to soybean crops grown on volcanic ash loam increased yield by 151% when using 0.5 tonnes/ha of biochar. When using biochar at rates of 5—15 tonnes/ha, the yield increased by 29% to 63%. Another study on maize crops revealed that mixing cow manure-derived biochar with sandy soil at rates of 0, 10, 15 and 20 tonnes/ha significantly increased the yield of the crop by 150% and 98%, respectively. This study also found that applying cow manure-derived biochar to sandy soil not only improves crop yields, but also improves the physical and chemical properties of the soil (Uzoma *et al.*, 2011; Panwar, Pawar and Salvi, 2019).

In addition to the income generated by the biochar itself, which can be used for various purposes, there are also by-products produced during the production of biochar such as bio-oil and heat. The heat is often utilized in the biochar production process to maintain a closed loop system, and the bio-oil is typically sold as a separate product (Valoral Advisors, 2021).

It is also important to note that using soils as a carbon sink creates a more economically sustainable approach to waste management (Chan *et al.*, 2007) and also represent two revenue streams: 1) lower cost of biomass supply, due to savings made from the reduced cost of biomass disposal and 2) from the carbon credits that account for the carbon captured and stored in the char. Further, according to Haeldermans *et al.*, (2020) "biochar price is the most important determinant of a biochar production plant's feasibility, motivating the need for economic and market research on biochar prices in function of biochar characteristics, to reduce fluctuations in widely varying biochar prices".

This case study aims at providing an overall assessment of the economic opportunities for investments in producing biochar and applying it as a soil amendment. At the producer level, adding biochar at a rate of 10 tonnes/ha every 5 years, considering that the literature review shows that yield responses to biochar persisted for 5 to 10 years (Cornelissen *et al.*, 2018; Kätterer *et al.*, 2019), increases potato and sweet potato yield by about 20% (assumptions included are detailed in Table 6), achieving a return on investment in a range that varies between 8 and 14% depending on the stability of yield increase during the five-year period. Incremental biochar yield and cost together with the distance from biochar production sites are the most important determinants of a biochar application's feasibility result.

Table 6. Producer feasibility - Assumptions

Crop:	Potato – sweet potato	
Planted area	*Has/year*	*1000*
% Area with biochar application	*%*	*100%*
Biochar application rate	*Ton/has/year*	*10*
Frequency of biochar application	*year*	*5*
Proportion of compost fertiliser supplement	*ratio*	*1*
Base yield	*Ton/has*	*35*
Incremental yield	*%*	*20%*
Yield with biochar	*Ton/has*	*42*
Net crop producer price	*USD/ton*	*250*
Biochar input cost - unit	*USD/ton*	*450*
Input cost of biochar/compost pellet - unit	*USD/ton*	*25*
Transport cost to cultivation area - per unit	*USD/ton/km*	*0,15*
Transport distance	*km*	*100*
Cost of transport biochar to cultivation area	*USD/ha*	*30*

Source: Own elaboration

At the investor level (biochar plant facility), the installation of a 1,000 ton/year biochar production plant requires an approximate investment (CAPEX) of 1,000,000 USD, producing an organic-mineral pellet from biochar and compost (see main assumptions in Table 7 below). For the biochar plant to be viable, the price of biochar cannot be below USD 350. Thus, as expected, the biochar price is the most important determinant of the production plant's feasibility.

Table 7. Biochar plant feasibility - Assumptions

Investment	1.000.000 USD	
Installed capacity	Ton/year	1000
Use of installed capacity	%	90%
Woody biomass used for biochar production	ton MS/ton biochar	4
Cost of biomass for biochar production - unit	year	5
Cost of biomass for biochar prod.	USD/ ton MS	30
O&M cost of biochar plant - unit	USD/ ton biochar	80
Transport – variable cost	USD/ton/km	0,1
Transport - distance	km	50

Source: Own elaboration

The techno-economic assessments done in Argentina for the production and application of biochar provide important information for sustainable development in the industry, which is valuable for all stakeholders such as policymakers, investors, industry leaders, forest owners, and farmers.

Additionally, using biochar to improve soil fertility can create a market for a large portion of organic waste produced by the forestry and agricultural sectors, making it necessary for all interested parties to work together to develop the industry.

Impact analysis of biochar application in fruit tree plantations

In Argentina's agricultural sector, biochar would mostly be applied to degraded soils due to high tillage practices, such as intensive horticultural crops, and non-degraded soils of intensive fruit tree production. Also, its use could be extended to large areas of degraded soils under agricultural production or livestock use. In the latter, biochar use could be more restricted due to the cost-benefit relation. For the purposes of this study only the fruit tree area will be considered for potential large-scale biochar deployment (Samaniego *et al.*, 2021).

In Argentina there were over 530 thousand hectares of fruit trees planted in the year 2016, as indicated in the third Biennial Update Report 3 (Government of Argentina, 2019) from 2019.

Table 8. Share per type of crop - Year 2018

Crop	Share of cultivated area
Oilseeds	38.5%
Cereals	30.4%
Fodder crops	21.2%
Forests and forests implanted	3.3%
Industrial crops	2.4%
Fruit trees	1.4%
Legumes	1.0%
Vegetables	0.,4%
Aromatic, medicinal and spices	0%
Greenhouse	0%
Flowers	0%
Other	1.5%

Source: FAO Argentina – Agricultural Census (2018b)

The planting of fruit trees covered 1.4% of the total planted area in the country, with more than 500 thousand has, showing the highest geographical concentration in the province of Mendoza, where almost 38% of the total surface was planted, followed by the province of Tucumán with 10.3% and San Juan with 10.1% (Samaniego *et al.*, 2021).

Under this study, two scenarios are considered, as well as an initial baseline scenario:

- Baseline Scenario: Business as usual - without biochar application
- Scenario 1: Biochar application on up to 25% of the fruit tree planted area with pellets of 10% biochar mix. The fruit tree planted area was forecasted to grow at about 1.5% annually over the period 2020-2050
- Scenario 2: Biochar application on up to 60% of fruit tree planted area with pellets of 50% biochar mix. The fruit tree planted area was forecasted to grow at 2.0% annually over the period 2020-2050.

An assumption of 5 ton per ha per year dose of organic-mineral fertilizers in the form of pellets was adopted. In Scenario 1 those pellets present a 10% biochar mix as indicated, while in Scenario 2 the mix increases to 50% biochar (Samaniego *et al.*, 2021).

The estimated investment to produce biochar for agricultural purposes varies depending on the type and quality of biochar to be produced. For example, "pure" biochar, or in combination with composting of organic waste, also known as "organic-mineral" fertilizers (with a certain mix of biochar) (Samaniego *et al.*, 2021).

The installation of a 1,000 ton/year biochar production plant requires an approximate investment (CAPEX) of 600,000 USD. If the objective is to produce an organic-mineral pellet from biochar and compost, an additional investment of 400,000 USD is required for composting and pelleting processes, therefore reaching an amount of 1,000,000 USD per 1,000 tons biochar/year facility[7]. A curve with efficiencies in investment over time for scenarios 1 and 2 was assumed due to synergies of increased activity, technology maturity and development of the value chain. Scenarios 1 and 2 would totalize approximately 100 and 900 million dollars investments respectively for the period 2020-2050 (Samaniego *et al.*, 2021).

Regarding employment, it is estimated that a 1,000 ton per year biochar plant would generate 4 direct jobs[8], resulting in approximately 425 jobs by 2050 in Scenario 1 (equivalent to 2 direct jobs per thousand hectares of biochar application) and around 6,000 jobs by 2050 in Scenario 2 (equivalent to 10 direct jobs per thousand hectares of biochar application). Jobs generated during biochar application on plantations could not be quantified due to lack of information. The application of biochar on soils could sequester up to 2.5 $MtCO_2e/yr$ by 2050, considering only its application in fruit trees.

[7] Biochar plant CAPEX assumptions from interviews with sectoral experts and industry players
[8] Biochar plant employment generation assumptions from interviews with sectoral experts and industry players

Table 9. Impact of biochar CDR deployment on key variables

	Potential GHG emissions (sequestered)	Avg. Investment requirements	Cost	Net changes in employment created		Contribution to GDP	
	Mega t CO2 /yr	MM USD/yr	USD / tCO2	Δ # jobs / '000 ha	# jobs created/ Mega tCO2 seq	Δ MM USD GDP/'000 ha	Δ MMUSD GDP / Mega t CO2 seq
Baseline	No biochar deployment in baseline scenario						
Sc 1	0.1 (avg) 0.2 (2050)	3 (avg)	25.4	+2 industrial	102 industrial	+0.10	110
Sc 2	1.5 (avg) 2.5 (2050)	30 (avg)	19.3	+6 industrial	77 industrial	+0.35	84

Source: Own elaboration

Note: MMUSD refers to million US dollars

4.1.3 Barriers

The biochar production option has a number of limitations, most related to the nascent state of the negative emission technology. The industry needs to gain maturity in terms of regulations and integration in national climate change plans, knowledge and education, technological advancement, cost of biochar production technology and scale, and the development of markets and commercialization.

While public interest in the potential of biochar to sequester carbon and enhance soil fertility is growing, the main obstacles for the use of biochar in Argentina, according to the multi-stake holders' dialogues held by DecarBOOST in Argentina, are the lack of knowledge about its benefits as an amendment and the cost of its application. Thirdly, the interviewees did not perceive the carbon market as a source of additional revenue.

Regarding the "lack of local studies" and its "limited availability due to low production in the country", opinions were more dissimilar. In fact, foreign literature exists on its use, although it would be necessary to understand its advantages and forms of application adjusted to local conditions. In addition, the scarcity of local jobs would also be a barrier to be considered. On the other hand, diverse stimuli for its production would increase adoption of biochar use.

The availability of biochar depends on the installed production capacity, as well as on the distance to the manufacturing sites and its cost/benefit ratio. In both scenarios where biochar is added, the required biomass to produce biochar and the required waste to produce compost, are both well within the limits of availability in Argentina, as estimated by the WISDOM report (FAO-INTA, 2009). In addition, the biomass supply must be relatively close to the processing plant.

A major issue is the energy consumption needed during the pyrolysis for biochar production, as well as the source of this energy. Further, a barrier highlighted by experts was the location of production plants. The production process of biochar generates energy (exothermic process) that

needs to be used or "sold" in the vicinity of the production unit. This particular feature of generating energy makes it sensible for it to be produced in an industrial zone to take advantage of "kilometer zero energy".

Therefore, the location of biochar production units depends on the combination of these two variables: close supply of biomass and close energy demand.

4.1.4 Recommendations

The following recommendations aim to enable better informed decision-making on the potential deployment of biochar in Argentina. These recommendations are divided into technical and economic research and development; business development; policy framework; and finance.

From the technical and economic research perspective, given the complexities and remaining uncertainties associated with the deployment of biochar, further research and capacity building is needed. Pilot projects should be carried out well in advance of a large-scale deployment phase in order to achieve technology development and cost reduction. Research in the field of integrated assessment models is needed at the national and sectoral level to have more accurate estimates of the mitigation potential, as well as in-depth cost-benefit analysis for biochar producers. Further, a more detailed assessment of potential synergies and trade-offs with the SDGs can help inform policy development in a way that maximises synergies, while minimising or managing potential negative impacts.

Regarding business development, a comprehensive plan is necessary to identify opportunities and address challenges for widespread adoption. This plan should include the formation of a trade group and committees focused on specific areas such as expanding markets, marketing for producers, education, evaluating feedstock resources, environmental and agricultural applications, identifying niche markets, and regulation and permitting for production facilities. Additionally, connections between industry leaders, researchers, investors and market developers should be established.

An analysis of potential international demand for biochar production at competitive prices is key, in particular in Asian markets. The current global conflict context has had significant implications on agriculture production and food security. The use of biochar could represent an option to increase yields in agriculture partially alleviating the constraints on fertilizer availability in the medium-term. Further, an analysis of the potential for generating an additional income flow resulting from mitigation of GHG emissions and eventually carbon removal at scale should be carried out.

Developing a supportive policy framework for biochar production and consumption is key. An overall assessment of the technical and economic feasibility should be embedded in the framework to be provided by long-term strategies elaborated by Argentina, including next generation of NDCs and long-term development strategy. In addition, integrated policy impact assessments are needed to understand potential policy designs to mobilize biochar and the implications on the SDGs. The government could play an active role in the shaping and guiding of the research, development and deployment, nationally, regionally and internationally (Samaniego *et al.*, 2021).

Argentina faces a persistent finance gap (that was accentuated by the pandemic). The decision on the potential of biochar development would require accurate abatement costs information and careful consideration and assessment of implementation risks and barriers. To address the need for additional resources, it is necessary to create collaborative platforms and programmes with common requirements that meet international climate finance standards.

Finally, further research is needed on the uncertain consequences of the implementation of the biochar as a CDR approach in Argentina. In particular, research should aim to evaluate biomass feedstock availability; potential locations for biochar plants, as well as crops and regions for biochar application (including both intensive and extensive crops); screening and analysis of relevant technologies and processes for biochar production.

More on the technical side, studies are needed to further determine the optimal dose and composition of biochar pellets for each crop type and each region where it could be applied, the safety production and handling of biochar, as well as the correct application rates on soils. This can be informed by studies on soil nutrients, pH and other relevant soil properties by main crops and regions. Additional studies on other potential uses of biochar beyond agriculture (e.g., remediation of effluents, remediation of contaminated soils, etc.) are also key to ensure market growth and stability over time (Samaniego *et al.*, 2021).

More financial data, particularly revenues and profit margins, will be key to economic projections. For this, it is important to take into account the logistics requirements and costs of biochar deployment, the potential power generation from biochar plants and its use in industrial micro grids. The analysis of the impact of biochar application on crop yields by crops and regions will also contribute to the economic evaluation of biochar. So will the evaluation of employment impact and the modelling of incremental cash flows due to GHG emission reductions.

4.2 Case study II: The plant-based meat market in Argentina

4.2.1 The context

Interest in alternative proteins has been continuously increasing during the last few years, with more and more companies and investors joining what has by now become a global trend. Some forms of alternative proteins have already been marketed for a few decades (e.g., plant-based dairy), while others have not yet reached a commercial stage (e.g., cultivated meat). In the last few years, they have also gained prominence in the context of discussions around the need to decarbonize the global food system.

What are alternative proteins?

Alternative proteins come in different shapes and sizes. The alternative protein market is divided into two big groups: plant-based protein and cultivated protein (also known as cultivated meat).

The plant-based protein market is also divided in two: plant-based dairy[9] is so far the most established and developed market, and plant-based meat[10] the most incipient one. The latter consists of products based on different plant proteins, mostly soy and pea isolates, as well as mycoproteins sourced from fungal biomass. All of these alternatives have different characteristics, including taste, price, and state of technological development (Clayton and Specht, 2021).

Cultivated meat, on the other hand, is produced from animal stem cells, and it is the most incipient technology within the alternative proteins market. So far, there is proof of concept and some successful pilot programmes, but no large-scale commercial applications (Byrne and Murray, 2021) exist. More research is needed to improve the production process and bring costs to a viable level. Current estimates suggest that costs could be cut by up to 99.5% through process optimization and economies of scale, reaching price parity with conventional meat products by 2030 (Sinke and Odegard, 2021).

This case study will focus on plant-based meat, which has already been successfully introduced to the market, and is now experiencing a strong growth phase. For this reason, the investment opportunities in this segment are more tangible in the short term compared to alternatives such as cultivated meat, and the wider societal benefits of its adoption are also clearer.

The climate argument

There is a strong climate rationale behind the shift towards alternative proteins. Meeting the temperature targets of the Paris Agreement will require a deep transformation of our production and consumption systems. Current research suggests that demand-side measures will be necessary to bring AFOLU emissions onto a 1.5°C compatible pathway (Springmann *et al.*, 2018). When accounting for the entire value chain, including land use change effects, demand side mitigation options (mainly diet shifts and reduced food waste) could provide up to 9.5 $GtCO_2eq/yr$ reductions, almost as much as all supply-side mitigation options for the sector combined (IPCC, 2022).

Another important pressure factor for the AFOLU sector is its key role in development and food security. Given that the world's population is expected to reach 10 billion by 2050, it will be impossible -considering current dietary trends- to keep emissions from agriculture, forestry and other land use (AFOLU) in line with the Paris Agreement. Notably, if crops that are currently used for animal feed and biofuels were consumed by people, there would be up to 70% more calories available in the global food system, which could feed an additional 4 billion people (Stoll-Kleemann and Schmidt, 2017). Current research suggests that it could be possible to achieve this while halting deforestation and reducing emissions, but it would require substantial changes in production and consumption patterns (Searchinger *et al.*, 2018; Boehm *et al.*, 2021). This

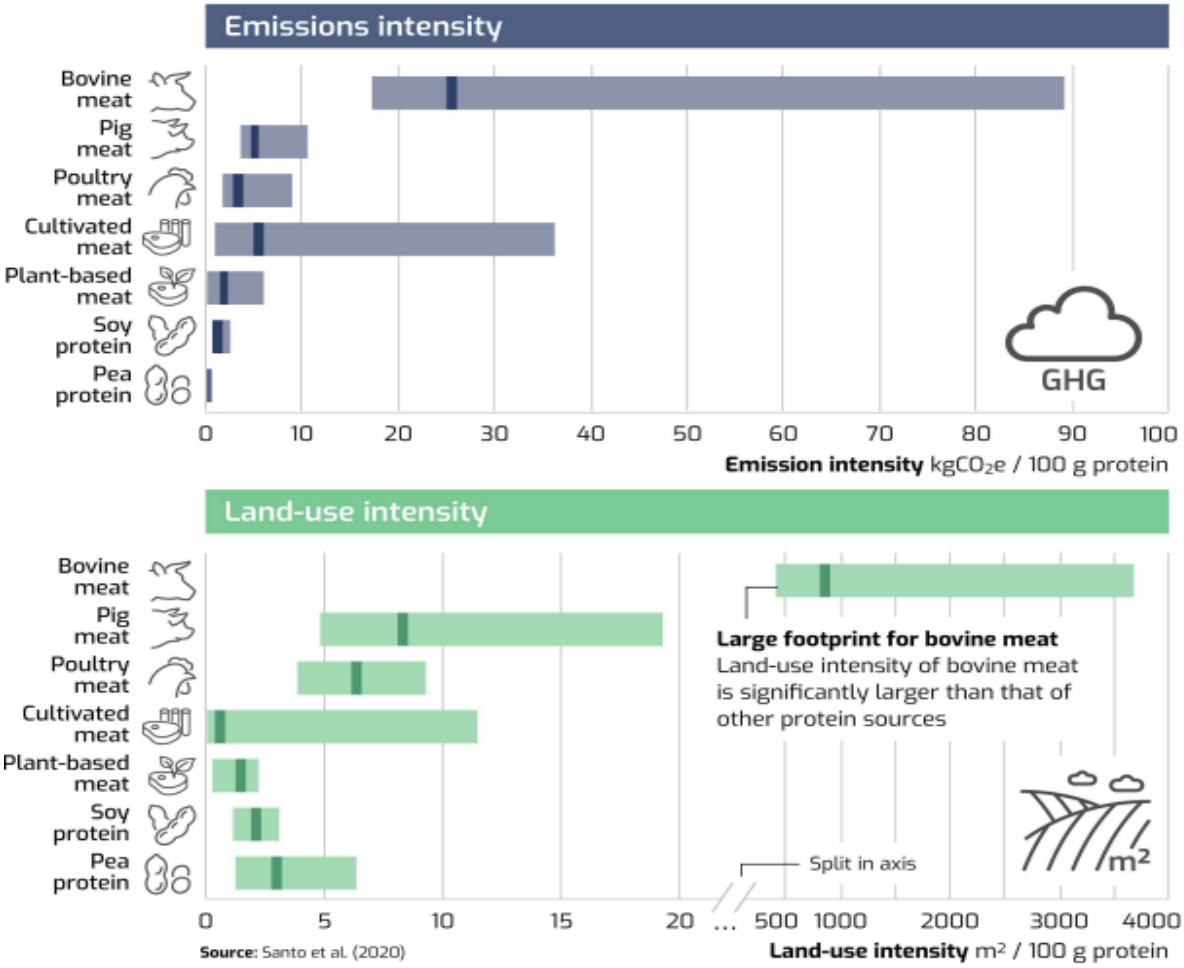
[9] These include plant-based alternatives to milk, cheese, butter, yogurt, cream and other dairy products. Major alternative ingredients include soy, wheat, almonds, coconut, and peas.

[10] This segment includes plant-based alternatives to beef, poultry, pork, fish, shrimp, and others. Major alternative ingredients include soy, peas, wheat, chickpeas, sunflower and rice.

necessarily involves a dietary shift towards more plant-based food and alternative proteins (MSCI, 2022). In short, a protein transition is just as crucial as an energy transition.

Plant-based proteins are one of the cornerstones of the protein transition. On average, the production of plant-based meat emits 3.4 kg CO_2eq per 100 grams of protein, while beef production emits 84 kg CO_2eq for the same amount (Poore and Nemecek, 2018). Non-ruminant meat production has a substantially lower footprint than beef, but still, a switch to plant-based alternatives would imply a 30-36% emissions reduction for non-ruminant meat, and 85-90% reduction for ruminant meat (Breakthrough Energy, 2020).

Figure 10. Environmental footprint of different protein sources



The benefits of plant-based proteins extend beyond climate change mitigation. A diet shift towards more plant-based proteins would contribute substantially to food security and development goals, by increasing the amount of available calories in the global food system and avoiding feed-to-food conversion losses (Bashi *et al.*, 2019). This would result in decreased demand for agricultural land and water.

The economic argument

Beyond the negative climate and wider environmental impacts of livestock and especially ruminant meat production, countries that depend heavily on animal protein exports have an additional incentive to diversify their production matrix. According to recent research (Marquardt *et al.*, 2022), transition risks can become a real threat for exposed producers. Two types of risks stand out: first, trade partners with ambitious climate policies could impose carbon tariffs for imports (external market risk). Second, consumer preference change amid the rise of alternative proteins can render animal protein less competitive (exogenous risk). This can be aggravated by rising input prices, such as grains for feed, due to external factors such as extreme weather events, competition with biofuel, and geopolitical factors such as instability in major producing regions, not only for commodities but also inputs such as fertilizers.

Transition risks in the agricultural production sector, and in particular conventional meat and dairy are a real threat to the profitability of these products. In line with this, a 2022 study by MSCI found that publicly listed companies generating more than 50% of their revenue from alternative proteins had on average 95% lower value-chain climate transition risk. Their modelling exercise suggested that if all analysed companies would shift to mostly generating revenue from alternative proteins, there could be USD 295 billion of avoided market cap loss in a 1.5°C climate scenario (MSCI, 2022). Many big food industry players have already recognized this and have already started the shift to alternative products. These are signs that the protein transition is already underway.

There is also substantial employment creation associated with the protein transition. According to the ILO, the plant-based agriculture industry could employ 19 million additional full-time equivalent employees in Latin America by 2030 compared to 2020 levels, assuming increased AFOLU decarbonization efforts in the region. In some regions, the direct employment effects of the protein transition could prove bigger than those of the energy transition (Saget, Vogt-Schilb and Luu, 2020). The structural nature of the required transformation is also likely to carry significant indirect effects such as workforce development and job transitioning (Marquardt *et al.*, 2022).

4.2.2 Global and regional trends

The global market

The plant-based protein market has shown exponential growth and forecasts are promising. In the US, for example, where year-on-year growth reached USD 7 billion in 2020, a 27% annual increase (Good Food Institute, 2021b). Similar trends followed in Europe, where market volume has doubled within two years, reaching USD 4.35 billion in 2020 (Ho, 2021b). Looking forward, Ernst & Young for example anticipates a substantial reconfiguration of the protein system towards high shares of alternative proteins in the next 10 to 20 years (Dongoski, 2021). Many major consulting firms have also come up with market analyses and reports. These make the case for alternative proteins and argue that there is a significant market opportunity there, yet to be tapped.

Most forecasts estimate that Asia will dominate the plant-based protein market. Bloomberg Intelligence, for example, expects that by 2030, Asia will comprise 57% of sales with a value of USD

64.8 billion. Europe and North America would follow with USD 50 billion, while Latin America would reach about USD 8-9 billion (Bartashus and Srinivasan, 2021).

This growth expectation is also reflected in the development of investments over the last decade until today. The plant-based protein segment raised around USD 2.2 billion in investments in 2020 alone (Gaan, 2021). A report by Ernst & Young puts the value of investments in alternative proteins as a whole for the period 2010-2019 at around USD 16 billion (Dongoski, 2021). Research by The Good Food Institute (GFI) puts that number for the period 2010-2021 at USD 11 billion, with USD 6.3 billion going into plant-based proteins (see Table 10) (Good Food Institute, 2021a).

Table 10. Investments in alternative protein sources

	Total invested capital 2010-2021	Invested capital 2021	1-year growth
Total alternative protein	11.1	5	1.6x
Plant-based	6.3	1.9	0.9x
Fermentation	2.8	1.7	2.9x
Cultivated	1.9	1.4	3.3x

Source: GFI State of the industry report (2021

Note: Values expressed USD billion

	Number of investors	Number of companies	Largest round*
Plant-based	350	300	700
Cultivated	120	40	161

Source: E&Y (2021

** Values expressed USD million*

The first quarter of 2022 saw a modest reduction in investments in the alternative protein market, reaching USD 991 million. However, according to GFI, this can be reasonably explained by prevailing market and geopolitical turmoil and aligns with funding reductions registered across companies globally. During this period, the companies raising major rounds were located in Israel (Redefine Meat, Remilk), China (Starfield Food Science & Technology), Singapore (Next Gen Foods), and the U.S. (Wildtype and MycoTechnology) (Good Food Institute, 2021a).

The perspectives indicate that there are still substantial investment opportunities. According to a report by BNP Paribas (2021), the plant-based protein segment will require between USD 11 and 28 billion just to develop its extrusion (processing) capacity. True investment needs for the sector are likely to lie far beyond these estimates. Other estimates suggest that at least USD 150 billion a year will be needed to transition the whole food system (Oken *et al.*, 2022).

The global industry is quickly developing, with the US in the lead. There are more than 1000 firms currently active in the alternative protein market (Dongoski, 2021). About 800 companies around the world focus on plant-based foods that aim to replace animal products. These companies range

from small start-ups to large multinational food companies and conventional meat companies (Gaan, 2021).

Currently, the most established firms in the plant-based protein segment are US based. Continued investments are also allowing for a rapid product development and market expansion by pioneer firms (Marquardt *et al.*, 2022). As the market matures, investors such as Temasek and Softbank have started to pour significant sums into firms such as Memphis Meats, Growthwell Group and Impossible Foods. This last firm alone raised USD 700 million only in 2020 (Dongoski, 2021).

In 2021, there were many developments in the food industry which show how key actors perceive the potential of alternative proteins:

- The CEO of Cargill, the global food industry giant, has announced that the company is preparing for a serious shake-up, as consumer demand for alternative proteins is growing. Their own projections show plant-based proteins reaching 10% penetration in the US market by 2024-25. Cargill also began manufacturing their own plant-based meat products (Ellis, 2021).
- Brazil's JBS, the largest meat processing company (by sales) in the world, has purchased Vivera for USD 410 million. This Dutch firm is the third largest plant-based meat company in Europe. This is part of the meat giant's move towards alternative proteins (Ho, 2021a).
- A JBS subsidiary called Planterra Foods launched a new venture for fermented plant-based protein using a pea and rice protein blend (Gaan, 2021).
- Unilever announced a target of EUR 1 billion in plant-based meat sales for the next five to seven years (Gaan, 2021).
- Brazilian meat company Mafrig has expanded its presence in the plant-based meat segment through a new joint venture called PlantPlus Foods with presence in North and South America (Gaan, 2021).
- The world's second largest meat company (after JBS), American giant Tyson Foods, announced plans to reformulate its Raised & Rooted products to be 100% plant-based (Gaan, 2021).

Demand shift

Demand for proteins is changing. One of the major drivers of growth in the alternative proteins market is demand shift, that is, the increase in total demand of alternative proteins relative to animal proteins. While the market for alternative proteins remains marginal in size when compared to animal proteins, demand projection models show a stagnation of global per capita demand for the latter, especially beef (OECD-FAO, 2021). In contrast, the market for alternative proteins is in an upward trend, although with significant regional differences.

The reasons behind this demand shift are different motivational factors. One of the biggest drivers are concerns for the environmental and climate sustainability of the food industry and specific products such as animal meat and more specifically beef. Another important motivational factor is the concern for animal welfare and health effects of different animal products (Collier *et al.*, 2021; Hielkema and Lund, 2021; Kopplin and Rausch, 2021; Milfont *et al.*, 2021). These types of factors

are complex to quantify and therefore not included in demand projections, but they could prove decisive in shaping both the traditional and alternative protein market's outlook. So far, we have found several indications of changes in consumer preference already happening, as shown below.

Figure 11. Regional developments and trends in consumer preference change

In Europe and North America:

A study by Hielkema and Lund (2021) found that 50% of the European population is willing to greatly reduce their meat consumption.

According to the FAO Agricultural Outlook (2021b), 6% of Germans and 5% of U.S. Americans are already vegetarian.

In Europe and North America, aggregate animal protein demand could peak by 2025 with sufficient regulatory support (Witte *et al.*, 2021).

In Asia:

A study found that economic development and rising incomes are leading to value-seeking behaviour in food choices, which is fuelling a growing interest in sustainable consumption and alternative proteins. These types of products can in principle account for half of all new spending until 2030, or up to USD 2.2 billion (Skinner et al., 2021).

In South America:

One study found that 90% of the population are willing to increase their consumption of alternative proteins (Ho, 2020), while another found that number to be 70% (Spencer, 2019).

In Argentina, a study by Union Vegana (Union Vegana Argentina, 2020) found that 12% of the population are either vegan or vegetarian, and another 12% consider themselves flexitarian.

Another poll found that up to 60% of Argentinians are considering giving up beef because of the ongoing economic crisis in the country (Salomon, 2020). While this is not particularly related to a preference change, it can still be a factor for higher adoption of alternatives if the alternatives are more affordable.

While alternative proteins can be considered a substitute product for animal proteins, it is not yet clear how demand for both types of proteins will interact. As population and income levels across the world rise, it is expected that demand for proteins will continue to increase, and to what extent alternative proteins will complement or replace animal proteins will be determined by multiple factors. Among the most relevant ones are when alternative products reach price and taste parity, and whether increased climate action will affect the competitiveness of animal proteins (Dongoski, 2021). Research shows that plant-based proteins are on the verge of becoming equal in terms of taste, appearance, and texture (Lamas, 2021) as well as price (Tubb and Seba, 2019).

For now, these trends will likely not have a substantial impact for the animal protein market. However, it is clear that in the medium term, the appearance of close alternatives with significant advantages in almost every front (such as emissions, water and land use, consumer health, animal welfare, price) will be a serious competition in the protein market (Ellis, 2021).

The Latin American market is still nascent but following global trends. Investments are already flowing into vanguard firms in the region, in anticipation of market opportunities. According to some estimates, investments in this subsector could reach a value of USD 300 million by 2025, with a compound annual growth rate (CAGR) of 12.4% (Mordor Intelligence, 2021). Brazil is the biggest market in the region by revenue share, followed by Argentina.

The plant-based meat market in Latin America is still relatively concentrated, with only a few firms dominating the industry, including several domestic firms as well as US-based ones. The landscape of firms includes several innovative start-ups, such as Tomorrow Foods in Argentina, or Fazenda Futuro in Brazil, as well as established players from the meat industry such as JBS and Mafrig in Brazil who are looking to diversify in response to market opportunities (Marquardt *et al.*, 2022).

This high level of concentration is characteristic of emerging markets (Yaman, 2019). At this stage, companies and products that emerge in the Latin American market are associated with new technologies or production processes. It is expected that as the market develops in the region, value chains are likely to become more disrupted through the emergence of specialized companies aiming to tackle specific value chain bottlenecks such as processing technology and formulation (Yaman, 2019). The process of value chain disruption is a key step in the development of the plant-based meat market, where innovative companies focus on solving key technological challenges and improving production processes, and large, highly capitalized companies can focus on reaching scale in output (BNP Paribas, 2021).

The investment opportunity in Argentina

Firms in the region are concentrated in specific parts of the value chain. Based on data from the GFI, the distribution of firms along the value chain has been plotted in Table 11, and it was found that in Latin America, firms are concentrated mid- to down-stream in the ingredient optimization, formulation and manufacturing segments[11]. The lack of firms in the upstream segment means that most producers in the region are dependent on imported inputs, such as protein isolates, which has a negative impact on costs. Argentina features a modern and highly developed agricultural industry and could potentially become a net exporter of these products (Marquardt *et al.*, 2022).

[11] The results of this analysis are not conclusive and therefore need to be taken with caution. This is partly due to data limitations, including uncertainties related to how comprehensive data collection is, and how frequently it is updated. In addition, only up-y and mid-stream segments of the value chain are covered in the dataset. This prevents the analysis from providing a full view of the value chain.

Table 11. Description and data of different value chain segments of plant-based meat

Value chain segment	Process	Description
Upstream	Sourcing and optimization	Selecting of the source material, and adaptation to the end use. For plant-based meat uses, a priority is improving the protein content of crops.
	Growth and harvest	Producing source material.
Midstream	Fractionation	Isolating protein from raw material
	Formulation	Incorporating raw materials to form a product with the nutritional profile, texture, colour and taste of meat.
	Texturing	Structuring the mixture of ingredients into an appropriate form through processes such as extrusion.
Downstream	Domestic retail	Domestic distribution and sale of products
	International retail	Exporting products to international markets

Source: Good Food Institute (2021a)

This suggests that one of the biggest market opportunities for Argentina could be in the upstream sector, both in the optimisation and the production of crops. This regional insight is also in line with global perspectives: a survey of industry experts conducted by the Boston Consulting Group showed that most believe the biggest market opportunity in plant-based meat lies in crop optimization, followed by formulation, texturing, and extraction (Witte *et al.*, 2021).

Pea protein has been identified as a prime candidate to fuel the expansion of plant-based meat. This is because of its low price and environmental impact, as well as its perceived positive health effects (such as lack of allergenic and estrogenic effects). Pea crops can also be integrated into current crop cycles as cover crops or in rotations. They could contribute to nitrogen fixation and help reduce fertilizer use, thereby reducing both costs and GHG emissions of agricultural production.

Table 12. Comparison of alternative proteins in terms of price and environmental impacts

Product type	Price	Environmental impact	Competitiveness	Challenges
Soy protein	2 USD/kg	Low	Well-developed product with major investments along value chain	Consumer concerns about safety of GMO's and allergenic and estrogenic effects
Pea protein	5 USD/kg	Low	It shares soy's advantages in terms of environmental impact and low price, but it also has an advantage because of its non-GMO and non-allergenic nature.	The protein content of pea is around 24%, which means that there is a substantial by-product that needs to be allocated
Insect protein	41 USD/kg	Low	It has the highest shares of feed to weight ratio and can be raised on low-value agricultural by-products.	It is currently costlier than meat, and the taste is a barrier for adoption
Mycoprotein	13 USD/kg	Medium	It has a high protein and fibre content, as well as low fat. Its taste is neutral, and its texture is close to meat when mixed with eggs	The feedstock is currently expensive, and there is low acceptance of the product since it's legally required to be labelled as "mould"
Cultured meat	300 USD/kg	High	This product has not yet entered the market, but it is expected to be cost competitive in the next ten years	The process is still very energy intensive and substantial improvements are still required in the production technology for it to reach cost competitiveness
Whey protein	7.5 USD/kg	Medium	This is a well-established and accepted product, and can be very versatile due to its neutral taste	There is increased competition from the dairy-free industry which has lower environmental impact and no animal welfare concerns

Source: Bashi et al. (2019)

According to research by McKinsey, public interest in pea protein is also the highest compared to other alternative proteins, followed by cultured meat. Search query data shows a CAGR of 30% in the period 2004-2019. If existing challenges are overcome, it is likely that pea protein will lead the alternative protein market in the short and medium-term (Bashi *et al.*, 2019).

The market for pea protein is also on the rise, currently valued at USD 1.7 billion, and projected to grow at a CAGR of 11.9% and reach USD 2.9 billion by 2027. Companies in the pea protein segment include some food industry giants[12], but so far Latin America remains underrepresented. Global demand is fuelled by new plant-based foods coming into the market. This is leading to supply instability and higher prices (Markets and Markets, 2020). This presents a clear market opportunity for Argentina to become a key player in the global pea market, helping to develop a healthy ecosystem of domestic plant-based meat firms, while mitigating transition risks for the agricultural sector and getting closer to its climate targets.

Argentina is particularly well suited to become a key producer of pea protein, due to its highly developed agricultural production system and research environment (Viton, Castillo Leska and Lopes Teixeira, 2019). The country also features ideal growing conditions for peas, which leads to both a price and quality advantage (Hommel, 2020). Argentina is currently the 9th largest pea exporter worldwide, and one of the largest in the southern hemisphere. However, production levels still remain below demand and have significant potential for growth (Hommel, 2020).

4.2.3 Barriers

Technical aspects

There are several technical challenges in the current production of pea protein which could present attractive opportunities for investors:

1. The first key issue is the need for crop optimisation: most crops currently used for plant-based meat have been bred for maximum oil and starch production, which makes them inefficient and expensive for plant-based meat producers. Through selective breeding, these could potentially be optimized for higher protein contents, thus improving the resource to output ratio (Clayton and Specht, 2021).

   Optimized crops would have other benefits along the value chain. They could simplify manufacturing processes by allowing for less intensive fractionation, and they could improve the conditioning process by selectively increasing desirable traits such as gelation capacity, water and fat binding capacity and flavour. All of this has the potential to substantially reduce costs and input intensity (Clayton and Specht, 2021).

[12] The key players in this market include Rouquette Freres (France), DuPont (US), Glanbia PLC (Ireland), Kerry (Ireland), Ingredion (US), Puris (US), Emsland Group (Germany), Yantai Shuangta Foods Co., Ltd (China), The Scoular Company (US), Burcon (Canada), Shandong Jianyuan Group (China), ET-Chem (China), AGT Food and Ingredients (Canada), The Green Labs LLC. (US), and Axiom Foods, Inc. (US) (Markets and Markets, 2020).

2. A second issue is that to reach commercial viability, food developers need to find a commercial application for pea starch, which currently makes up 60% of the source material volume and is not needed for the process (Markets and Markets, 2020). Manufacturing waste is also responsible for approximately 39% of food waste in developed countries (Mirabella, Casellani and Sala, 2014). Revalorizing side streams, that is, finding high value uses for this waste, can also help reduce food system emissions and improve sustainability (Clayton and Specht, 2021).
3. Another major hurdle in the plant-based meat segment is extraction and processing capacity. This is related to the shortage of raw materials, but also to the capital-intensive nature of the production equipment required. For this same reason, texturizing also remains a significant bottleneck. The result is that producers struggle to keep up with sales growth and prices remain high. Once input supply stabilizes and quality increases, economies of scale have the potential to drastically increase supply while reducing consumer prices. This can in turn unleash demand and expand consumer access (Witte *et al.*, 2021).
4. Finally, a lack of information on best practices seems to challenge the development of pea farming in Argentina, despite ideal conditions for production. However, due to high profitability and security in trade deals farmers are still venturing into the business. It is expected that once the market is established enough, best practices will be widely adopted (Hommel, 2020).

The key to capturing market share in this segment will be developing higher-protein pea crops and improving processing technology to lower costs and improve output quality, especially taste. Some firms are already looking to tap this opportunity: the French firm Roquette has announced a joint venture with the Israeli seed breeding company Equinom to develop high-protein high-yield pea varieties. These non-GMO seeds will have the potential to be grown and marketed worldwide, and could provide a substantial boost to the segment (Roquette, 2018).

Macroeconomic aspects

Macroeconomic instability increases the cost of capital. Since 2018, Argentina has seen an escalating economic crisis, which slowly developed into a monetary crisis. As a result, and with inflation levels of >50% annually, the country has developed a dual-currency economy. In an effort to protect the value of the Argentinian peso and prevent capital flight, the government has severely restricted the operation of exchange markets. Both the economic crisis and the fiscal and monetary responses to it contribute to increasing the cost of capital in the country, which negatively impacts investment.

This is a real barrier to investment in Argentina, especially for international investors. While there is no quick solution to it, this barrier could be mitigated by taking a page from the Argentinian energy transition playbook. To incentivize investment and lower costs during its renewable energy auction rounds, the Argentinian government together with the World Bank set up a multi-layered-guarantee system to protect producers (Menzies, Marquardt and Spieler, 2019). Setting up a similar government-funded trust fund with a multilateral finance backstop system could help accelerate private investments in plant-based meat and lower the cost of capital.

Policy aspects

Fiscal policy reforms are needed to accelerate investment. The combination of political and forex risks in Argentina, plus the inherent risk associated with investment in new technologies and markets can severely hinder investment in plant-based meat. To mitigate these risks, in addition to guarantee schemes, fiscal or financial incentives for activities in the plant-based meat segment are needed. During the RenovAr programme, special tax conditions were applied to specific technologies to incentivize their development. These included tax credits for purchased assets, relief from import duties and national income tax, early VAT recovery, extended tax computation period and accelerated depreciation (Menzies, Marquardt and Spieler, 2019). All or some of these policy tools should be considered for plant-based meat to accelerate its development and position Argentina in the global alternative protein market.

A second policy reform area is food safety regulation. For many novel food products, the current global regulatory environment is still vague and fragmented. This can discourage innovative producers who might be unsure of how long, expensive, and how successful it will be to get their products approved. Plant-based meat, for example, sparked a re-evaluation of standards of identity, which establish the necessary characteristics of a product to be labelled in a certain way (Gaan, 2021). Clarity on how different products are produced, marketed and labelled is also key to increasing consumer confidence in alternative proteins. National food safety agencies need to streamline the regulations for the approval of plant-based meat products, providing certainty for both consumers and producers (Banker, 2021; MSCI, 2022).

Signalling long-term commitment through climate strategies and targets can improve investor confidence. Support policies for plant-based meat can go a long way in promoting growth, mitigating high reversal risks associated with regime change. To show that support for this nascent industry is not going to vanish after an administration change, Argentina should formalize its support for plant-based proteins. This could be done by including them in its international climate commitments and strategies, like its NDC and LTS; as well as in its national climate change action plans. A further step in this direction which might be needed to minimize reversal risks would be to enshrine these commitments in national law. The climate argument for plant-based proteins is strong, and it could prove valuable to help Argentina reach its climate and development goals. A long-term commitment could also facilitate leveraging public international finance.

Public support for R&D is needed. As in every nascent industry, there are gaps in fundamental research areas that need to be filled to foster the development of the domestic market. The government can help kickstart local research into technical challenges of the sector in two ways: first, by making informational resources more available; research tools and public databases can help increase participation and solve key challenges. Second, grants for research and development can help effectively address technological challenges and advance the transformation (Breakthrough Energy, 2020).

Political and cultural aspects

Opposition from incumbent industries can increase the political cost of action. While many companies in the animal protein sector have already started a move towards alternative proteins,

pressure from lobby groups can be expected. The dispute has so far focused on product labelling, where traditional industries have been vehemently arguing that plant-based alternatives should not be labelled as milk, dairy, or meat. This has already happened in the US and in Mexico (Ho, 2020), and it can be expected in Argentina once the alternative protein industry develops further. Especially in countries where agricultural production represents a significant share of the domestic economy, a structural transformation of the sector needs to be carefully planned. The portrayal of alternative proteins as opponents of animal proteins may increase resistance from incumbent firms, lobby groups and the wider public. A narrative shift is needed to address this and reduce conflict, where alternative proteins are presented more as an economic opportunity for the sector, a mitigation strategy for climate, and a new source of revenue for the government. Aligning incentives of key stakeholders, the public sector and climate action will be key to enable the success of alternative proteins.

Barriers to consumer acceptance of alternative proteins can be significant. High levels of consumer acceptance will be needed for a widespread adoption of alternative proteins. This process can be hampered by a series of factors associated with novel foods. So-called 'motivational barriers' to consumer preference change include food neophobia; lack of knowledge and skills of consumers on how to integrate these products into their current diets; taste and price; as well as cultural values and language used to talk about meat alternatives.

On a global level, research shows that price and taste are the most relevant variables for determining consumer preference, and that on this front, plant-based meat products are quickly moving in the right direction. However, the link to cultural values is of particular importance in the Argentinian context, where meat production and consumption is perceived as part of the population's identity and embedded in national traditions. Addressing these barriers can prove more challenging as they require a change in behaviour, which will need to be supported by public and private sectors. For example, not only by making the alternatives available in the market, but by creating campaigns to start shifting narratives or creating the space for other products to become flagship products, not competing but contributing to sustain the country's position as global—animal, but potentially also plant-based—protein provider.

In addition, comparative labelling can help highlight both the health and climate benefits of alternative products compared to animal proteins. Establishing a new product and building consumer confidence will in all cases require time and information but making relevant information more available to consumers can go a long way.

4.2.4 Recommendations

The opportunity in the plant-based protein market is growing. As the market develops, more and more companies and investors are jumping in. The protein transition is already underway, but there are still substantial opportunities to be tapped. The plant-based protein market has shown exponential growth and forecasts are promising, with estimates by major consultancies reaching up to USD 290 billion in sales by 2035. There are more than 1000 firms currently operating in the market, with the US on the lead.

Market growth estimates are supported by evidence of a demand shift, with consumers choosing alternatives to animal protein based on animal welfare, health, and climate concerns. However, price and taste remain the most important variables to determine demand. In the coming years, plant-based meat is expected to reach parity with animal products. The climate and wider environmental benefits of a shift towards more plant-based meat are clear, as its production requires significantly less use of land and water and incurs in fewer GHG emissions. A transformation of global food systems will be required to reach global climate goals, and plant-based proteins can play a role in this transition.

The regional market in Latin America is still nascent but following global trends. Our analysis shows that firms in the region are concentrated in the midstream segment of the value chain and are dependent on imports for inputs. Producing inputs domestically can help lower costs and develop the Latin American plant-based meat market. Argentinian producers could expand into the upstream segment of this industry by developing high-protein crops such as peas. This could not only supply domestic markets but could also develop into a new export market for an industry that is poised for high growth in the coming years.

However, successfully tapping this market opportunity will require overcoming technical, macroeconomic, policy and cultural barriers. With adequate support from the public sector, innovative Argentinian firms could successfully tackle technical challenges and substantially improve the efficiency and production capacity of plant-based meat in the country. Policy support can have a big impact in accelerating the transition and giving the Argentinian market an edge over competitors. Important steps are the inclusion of alternative proteins in sectoral and climate policies, streamlining of food safety regulations, and providing financial incentives for start-ups and innovative producers.

Macroeconomic and cultural barriers are a real obstacle. De-risking facilities can help bring down the cost of capital and facilitate investments. These can be partially backed by multilateral finance (the WBG has already done so for renewable energy in Argentina). Cultural barriers will need to be overcome too: first among producers, which could benefit from hedging their transition risk, and second among consumers, who will need time to familiarise and accept alternative protein products.

5 Conclusion and key messages

In a Paris Agreement-compatible world, agri-food systems are not only expected to meet the consumption needs of people and animals, but also to contribute to multiple climate and development objectives simultaneously.

Policy support is needed to accelerate the uptake of both investment opportunities analysed in this report, for example by providing financial incentives for start-ups, promoting research and innovation in production chains, and encouraging users and consumers to further increase demand for both products. Private investments should support agribusinesses that are considering or have already made the shift to business models that minimise the climate impacts of their operations will allow both development and climate objectives to be met in the long run.

Redirecting at least part of Latin America's foreign capital inflows from conventional activities to innovative solutions or products in the sector would be fully aligned with international guidance on making future investments compatible with the Paris Agreement.

There is significant investment flowing into the region but only a small share is flowing into innovative, more sustainable and climate-friendly alternatives. At the same time, there is already important public support, e.g., for research and development, that, if directed to the right purposes could play an important role in overcoming barriers in the region to further expand into new investment opportunities like the production of biochar and alternative proteins. These opportunities can not only bring economic benefits to the countries but are in line with reducing emissions and preventing climate change impacts.

The following key messages related to climate investment in the food and agriculture sector in Latin America can be derived from the report:

- To remain competitive and become a "frontrunner" in the transition to a more sustainable, carbon constrained agriculture sector, the food and agriculture system in the LAC region needs to evolve and embrace emerging investment opportunities in the sector.

  The food and agriculture sector in the LAC region will be confronted by trends that are highly likely to occur and that will influence the sector, such as population growth, urbanisation, migration, income growth, changing dietary preferences, productivity growth, emerging technologies, and climate impacts. Developments related to these trends present both opportunities and risks. Therefore, it is important that stakeholders anticipate and address them as early as possible to create the enabling conditions to exploit the opportunities and minimise the risks.

- Governments have a crucial role to play in incentivising the production and consumption of sustainable and climate-friendly agricultural products and practices; however, the degree to which public interventions are currently being geared towards supporting climate and transformational activities to date is still relatively low.

  The widespread use of market price support mechanisms and the significant amount of budget transfers financed through public expenditures in the LAC agricultural sector allow

governments to influence both production and consumption patterns of agricultural products. To date, however, there is little evidence that these intervention mechanisms are used to encourage sustainable and climate-friendly activities or discourage environmentally harmful activities.

- The strong focus on public support for general services, as a share of total support for the agricultural sector, can be seen as a positive sign and represents favourable conditions for the needed support for R&D on innovative and climate-friendly agricultural products.

  In countries like Argentina and Brazil, around half of total budgetary expenditure for the sector goes to general services in the agricultural sector, including agricultural R&D. This can, if spent in the right way, contribute to the competitiveness of sustainable and climate-friendly products and practices in the food and agricultural sector and thus speed up their update and market-penetration.

- There are substantial capital inflows from foreign investors into the region and, to a lesser extent, its food and agriculture sector. These investments, however, focus predominantly on traditional activities as opposed to more sustainable and climate-friendly alternatives.

  Regional capital inflows from foreign investors target, to a large extent, traditional activities such as the extractive industries. Foreign investments into the food and agriculture sector mostly take the form of merger and acquisition, as opposed to greenfield investments, and also focus on more established subsectors with little investment volumes flowing into more sustainable and climate-friendly food and agriculture sectors, such as animal health or reducing food loss & waste.

- There are signs of alternative markets picking up as investments in innovative solutions to addressing the diverse challenges in the food and agricultural sector are constantly growing, albeit still at a relatively low level.

  While investments in traditional areas such as farmland for row crops, permanent crops, and cattle, and investments in established companies in the food and agriculture industry continue to be prevalent, there is a growing trend of investments in start-ups and early-stage companies that develop new and innovative products and services in AgTech and FoodTech. These start-ups are part of a larger regional ecosystem of entrepreneurship that is expanding and causing disruptions in various sectors, including row crops, permanent crops, the livestock industry, forestry, and the entire food and agriculture industry from production to transformation and services.

- To identify Paris Agreement-compatible investment opportunities in the sector, international guidance should be combined with information on where the highest emissions reductions potential lies.

  International guidance points at investments that support best practices while also ensuring no (direct or indirect) contribution to deforestation or forest degradation. Complying with best practices, both in social and environmental aspects, also helps investees meet their due diligence requirements and reduce financial risks. At the same time, research shows that the biggest mitigation opportunities in the region involve sustainable intensification practices, as well as agriculture practices that contribute to carbon sequestration (e.g., agroforestry, biochar

from crop residues, soil organic carbon in croplands and grasslands, etc.). These findings are aligned with current policies being implemented in Argentina and Peru, mostly focused on reducing deforestation and increasing carbon stocks. However, this is yet to be reflected in the countries' national climate targets.

- Two case studies of Paris Agreement-compatible investment opportunities in Argentina based on international guidance and mitigation potential estimates: Enhancing soil carbon content and use of biochar and investing in the plant-based meat market in Argentina.

  The analysis revealed that investing in the production of biochar and plant-based meat in Argentina can have positive effects in the environment, while representing important economic opportunities. However, there is still an important capacity and financing gap as these opportunities require high upfront investments and specific technologies that are not yet readily available.

  - There is a significant knowledge and empirical development gap for biochar production based on crop residues in Argentina, as the need to better understand the broader implications of biochar in delivering or hindering sustainable development efforts. The case study builds on an important growth in the global production capacity of biochar over the last five years. Further research is needed to evaluate biomass feedstock availability, potential locations for biochar plants, as well as crops and regions for biochar application.
  - Argentina's agricultural industry can become a net exporter of alternative proteins if national firms receive adequate support from the public sector to tackle technical challenges and improve production efficiency. The investment opportunity on alternative proteins builds on the global market growth over the last decade, as well as the new shift in demand for proteins around the world and at the regional level. Investments in alternative proteins in Argentina can help avoid transition risks linked to consumer preference change (reflected as reduced meat consumption) but cultural barriers will need to be addressed through awareness raising and information campaigns that facilitate acceptance of alternative flagship products.

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Annex 1

Table 13. Summary of sustainable agricultural measures proposed by EU Technical Expert Group

Cropland related measures	**Crop choice and rotation**: • Sowing of cover crops using a locally appropriate species mixture with at least one legume and reducing bare soil to cover at least 75% at farm level per year. • For non-perennial crops, at least a five crop rotation including at least one legume • Residue management
	Soil management: • Prevent soil compaction • Management of carbon-rich soils (avoiding deep ploughing; avoiding row crops and tubers; maintaining a shallower water table in peat and arable land) • Avoid waterlogging and compaction on drained soils • Maintain permanent grassland • No burning of arable stubble (except where authorities grant an exemption for plant health reasons)
	Rice paddy management: • Shallow flooding • Mid-season drying event • Off season straw
	Nutrient management: Nutrient management plan to optimize fertilization and improve nitrogen use efficiency
	Structural elements with mitigation benefit: Conversion of low productivity land (e.g. along field edges) into woodland to increase carbon sequestration and protect against soil erosion
	Waste management: Minimize post-harvest loss
Livestock related measures	**Animal health planning:** Better health planning and management (develop a health management plan, improve hygiene & supervision at parturition, improve maternal nutrition in late gestation to increase offspring survival, improve fertility management, selection for improving both methane and ammonia emission efficiency)
	Animal feeding: • Feed additives to reduce enteric CH_4 emissions of ruminants • Precision and multi-phase feeding techniques, where the nutrient requirements of groups of animals (or individual animals) are targeted in feed formulation • Feed imported to the farm must be sourced responsibly and must demonstrate that the production of feed did not take place in deforested areas with high carbon stock or high biodiversity value
	Manure management: • Cooling and better storage of liquid manure • Covering and sealing slurry and farm-yard manure storage to reduce CH_4 and NH_3 emissions • Separating solids from slurry (mechanical or chemical approach) • Composting and applying solid manure • Slurry acidification by adding strong acids to the slurry to achieve a pH of 4.5-6.8 to reduce CH_4 and NH_3 emissions • Apply low-emission application technology for slurry and manure
	Permanent grassland management: • Pasture renovation (when productivity declines, reseed the pasture) • Remove animals from very wet fields to reduce compaction • Maintain permanent grassland • No ploughing of permanent grassland
	Soil management: No burning of arable stubble (except where authorities grant an exemption for plant health reasons)

Source: TEG (2020)