GLOBAL CORPORATE STOCKTAKE: AGRICULTURE SECTOR

October 2023

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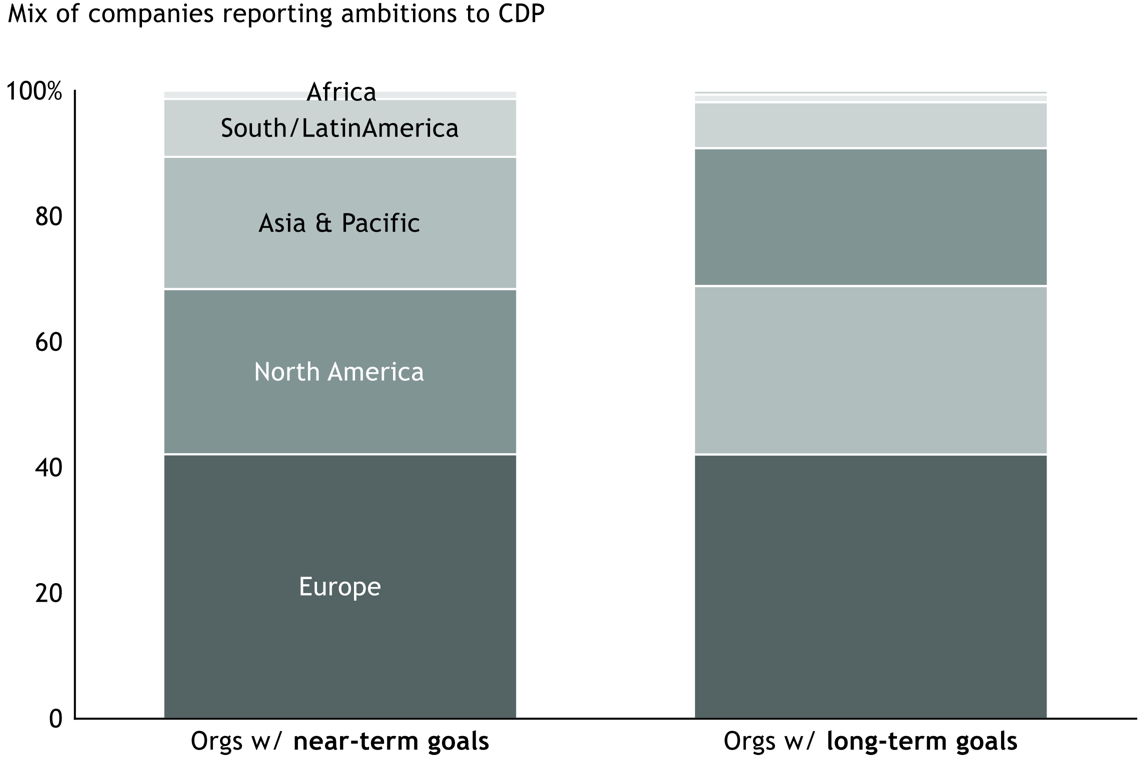
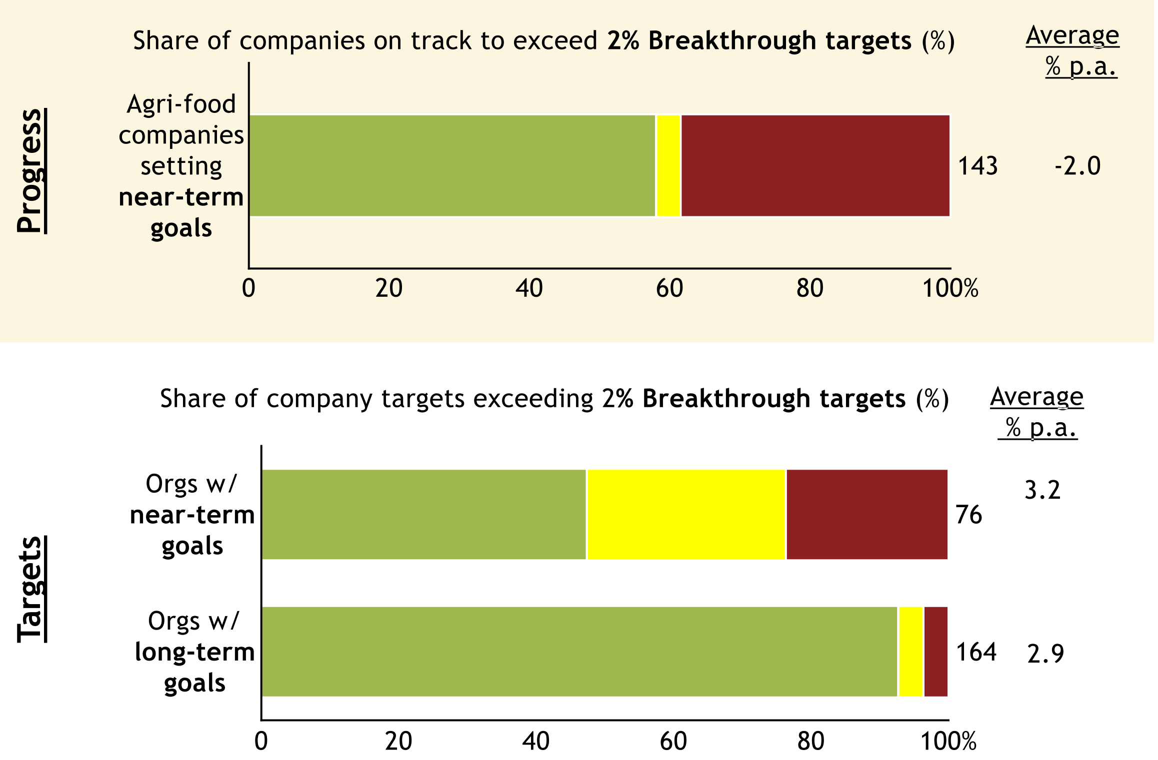
Agri-food organizations reporting to the CDP are exceeding Breakthrough Agenda targets

Legend: Company performance vs. Breakthrough *Missed target (<80%)* *Near miss (80-100%)* *Hit target (+100%)*

EU-based agri-food orgs represent ~40% of those setting targets despite significant production in Americas and APAC



Of those reporting, a majority have both made progress and set goals that exceed Breakthrough targets



Note: Annual reduction ambition shows the % reduction a company will need per year in order to reach their target from the base year (includes underway, new, or revised targets); near-term defined as target year before 2030; Priority countries selected based upon highest emission countries from 2022 Global Carbon Project Data; % reduction refers to an annual percentage and does not take into account compounding; IEA Agenda goals account for Scopes 1+2 only
Source: 2022 CDP Climate Questionnaire Data; 2022 Global Carbon Project; 2023 Breakthrough Agenda

This approach anchors towards food production and **not holistic food system transformation**

Executive Summary: The State of the Transition in Agriculture

Dimension of sector	**Reductions in land use change**	**Mitigation of on-farm livestock emissions**	**Mitigation of on-farm crop emissions**
Future decarbonization scenario	Deforestation, the degradation of coastal wetlands, and peatland burning halts; biodiverse carbon sinks are restored	Tested technologies to reduce methane emissions within livestock farming are adopted across regions	New farming practices increase yields and scales carbon removals
Indicators of progress towards accelerating decarbonization	Growing demand for beef, soy and palm oil create **powerful economic incentives for the conversion of forests and other natural ecosystems** to agriculture **Measures to improve supply chain integrity or enforce deforestation bans are progressing but have not yet reached technical or commercial maturity,** requiring significant investment in a sector stretched by thin margins and exacerbated by siloed, uncoordinated approaches to-date	Intensifying production can reduce methane per unit of beef, but many **producers lack the capital, specialized labor, and know-how to implement** Feed additives to tackle enteric emissions are advancing, but their **long-term ability to reduce emissions remains unproven and the increased costs they pose to farmers remain a challenge** While the adoption of anaerobic digesters has grown over time, they are too capital intensive for many farmers; the optimal spreading and storage of manure is challenging across a **fragmented farming industry**	Despite potential to improve long-term yield and soil health, **regenerative agriculture practices create economic risk for farmers** – both through short-term yield drag and upfront capital investments **While adoption of regenerative agriculture practices has grown, most producers lack access to key inputs, technical assistance, and willingness** to implement new practices with unclear long-term yield benefits Nitrogen use efficiency and other measures show **potential to reduce fertilizer emissions, but inputs and technical needs vary by region,** posing challenges to system-wide adoption

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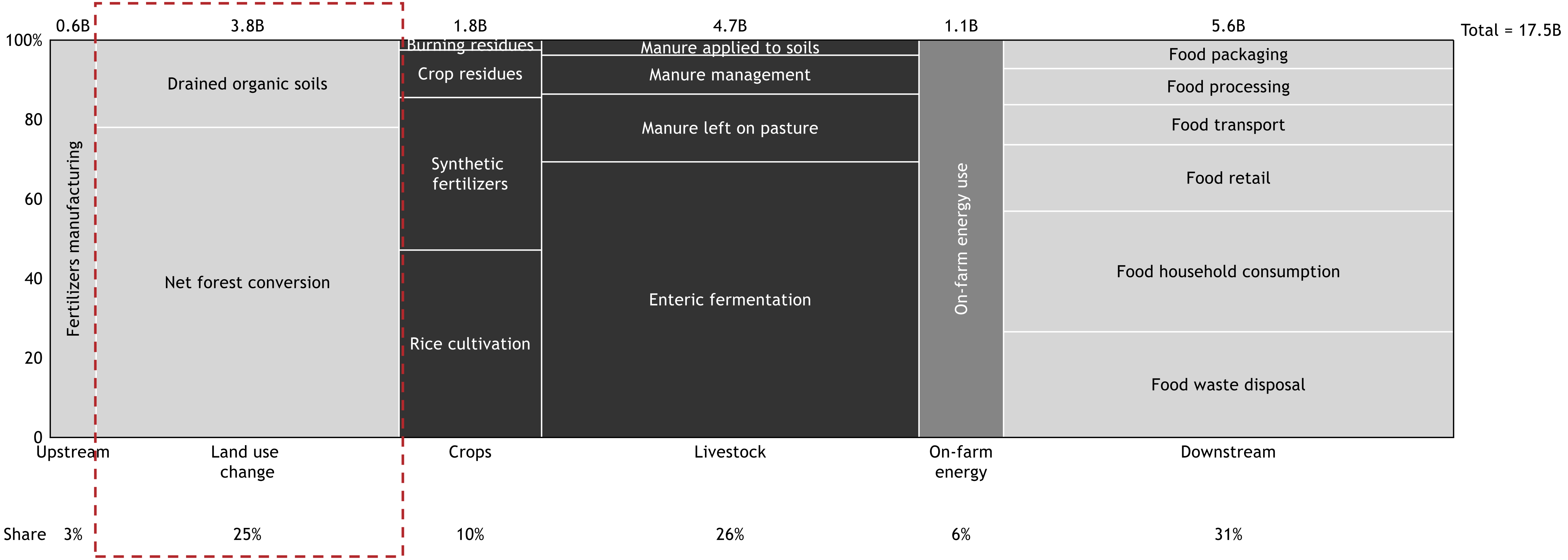
Land use change emissions come from converting non-agricultural land to agriculture, generating emissions from deforestation and peatland drainage

01 **02 LAND USE CHANGE** 03 04

Legend *(from farmer perspective)* *Scope 1* *Scope 2* *Scope 3*

Global GHG emissions from the agri-food system (T, CO2-equivalent)

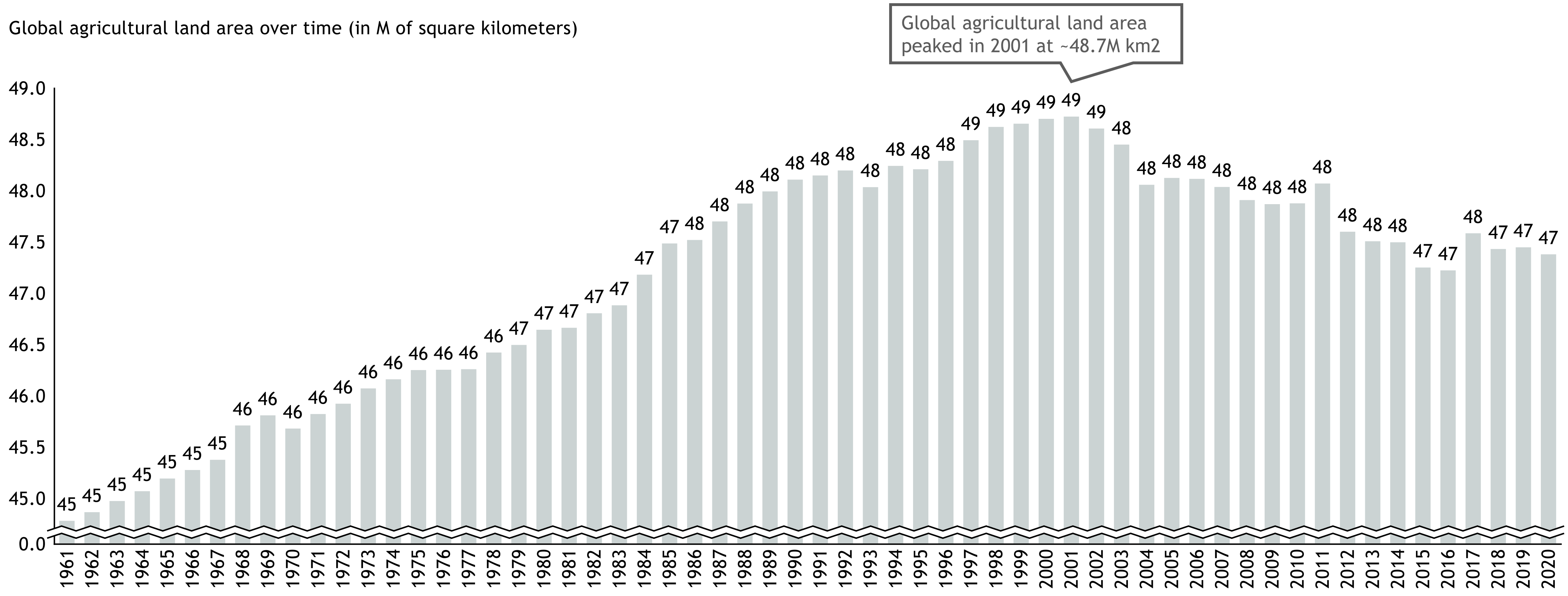


Note: Land use change and Farm gate emissions measured using FAO Stat emissions totals data; Pre- and post-production emissions measured using FAO Stat emissions shares data
Source: FAO Stat

Global agricultural land area has grown steadily, peaking in 2001, before declining over the past two decades

Global agricultural land area has grown at ~0.2% p.a. from 1961-2000, peaking in 2001 before demonstrating consistent declines of ~0.1% p.a. from 2000-2020

Global agricultural land area over time (in M of square kilometers)



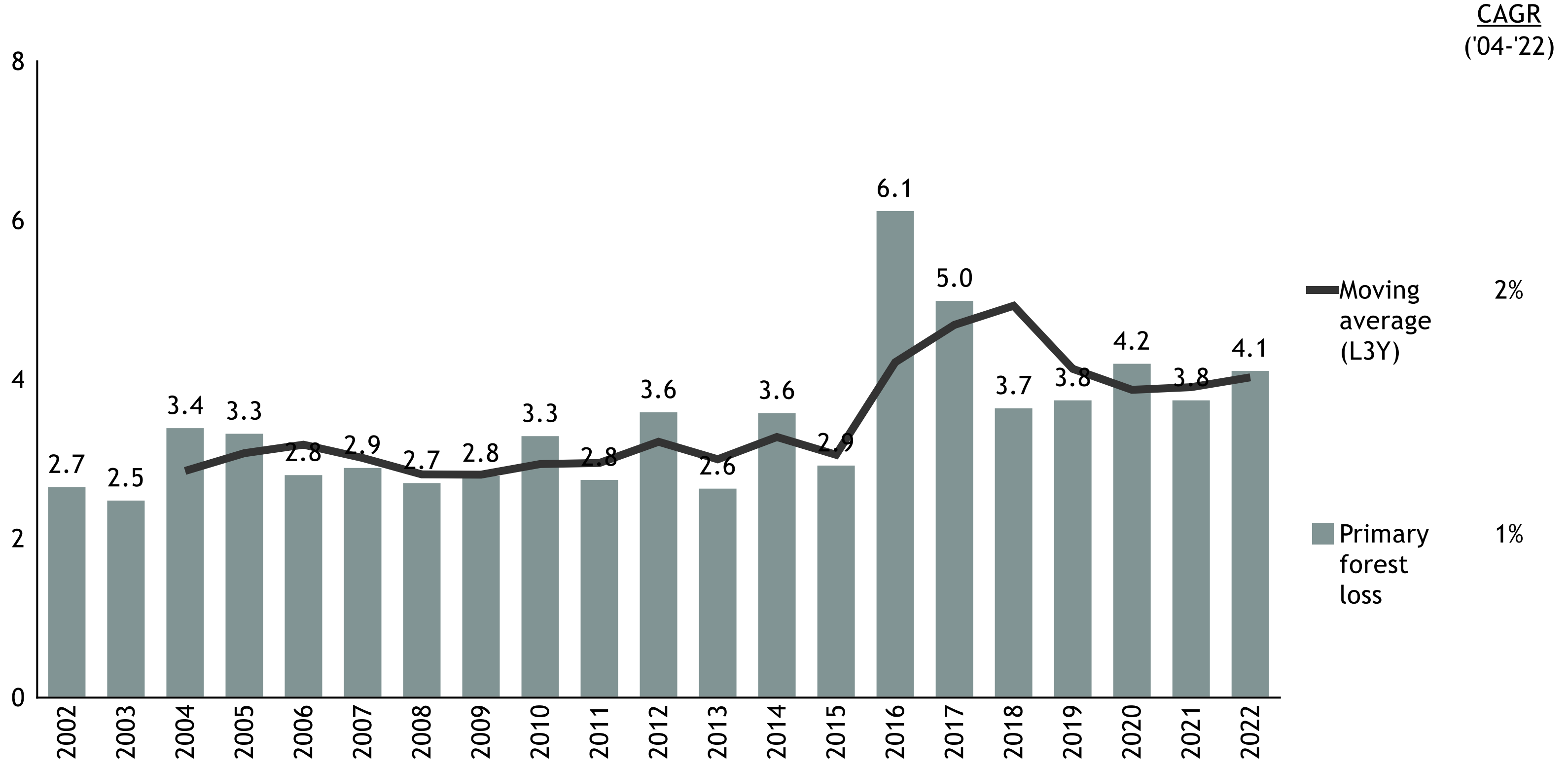
CAGR ('61-'00)	CAGR ('00-'20)
0.2%	-0.1%

Source: World Bank

“It is great to see flat-lining in deforestation rates over the past few years, but given agricultural demand I am not sure deforestation has reached its peak yet”

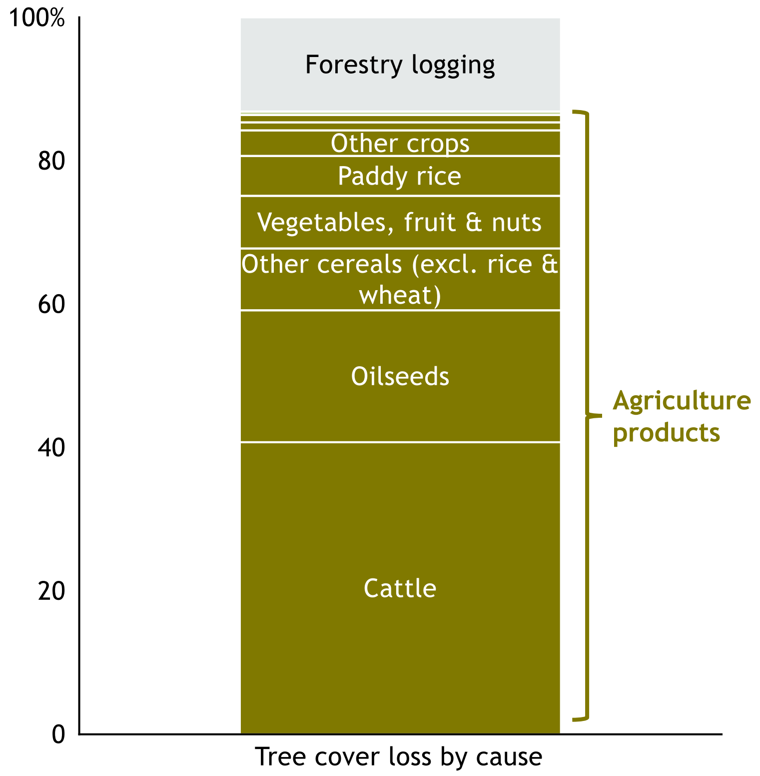
Excepting a spike in 2016-2017, tropical primary forest loss has grown slowly but steadily since 2002

Tropical primary forest loss (in M of hectares)



Agricultural products are causing ~85% of this deforestation

Share of tree cover loss by cause (%, 2019)



Note: Title quote is from Environmental Impact Lead Global Public Affairs, Agri-food-provider #3
Source: World Resources Institute, Corporate interviews

“EU regulation has prompted discussions with many suppliers about whether they need to consider deforestation of the land their supply chains rely on”

The EU enacted regulation banning deforestation and forest degradation practices in June 2023

- Regulation **applies to all products containing: cocoa, coffee, palm oil, wood, soy, beef** (and derivates like furniture, chocolate candies)
- Any operator or trader who places these commodities on the EU market, or exports from it, **must be able to prove that the products do not originate from recently deforested land or have contributed to forest degradation**
- The **new regulation** has been met with positive feedback by the press, academics, and NGOs

The Washington Post
Climate and Environment
E.U. seeks to block import of commodities that drive deforestation

REUTERS
EU proposes law preventing import of goods linked to deforestation

GREENPEACE
Glimmer of hope for EU anti-deforestation law

SBTi incorporated its FLAG guidance in September 2022 to address land use change in emissions goals

- The launch of the Forest, Land, and Agriculture Science Based Target Setting Guidance (SBTi FLAG) in September 2022 is the **first framework for addressing emissions from land use change**
- SBTi FLAG guidance **requires companies to eliminate deforestation from their value chains by 2025**
- FLAG provides mitigation pathways for major commodities with significant carbon footprints including beef, chicken, dairy, leather, maize, palm oil, pork, rice, soy, wheat, timber, and wood fibers
- While more than 410 FLAG companies have already committed to or set emissions reduction targets through the SBTi, **few accounted for land-based emissions prior to this new FLAG guidance**

Note: Title quote is from Global Partnerships / Multi-Stakeholder Platform Lead, Agri-food provider #2
Source: Science-Based Targets Initiative (SBTi), European Commission, Lit. search, Corporate interviews

"Only a small share of Fortune 500s actually have sufficient zero-deforestation commitments; for most companies, the commitments just aren't good enough"

Coca-Cola

- Coca Cola has included soy and timber in its "global sustainable sourcing priorities"
- **Safeguards against deforestation** are built into the company's Principles for Sustainable Agriculture (PSA)
- Coca Cola has **discontinued products that use palm oil** or ensured they are Roundtable on Sustainable Palm Oil (RSPO) certified

Kellogg's

- In 2018, Kellogg's announced the expansion of its Global Sustainability Commitments to include a goal of working towards 100% reusable, recyclable, or compostable packaging by the end of 2025
- As of 2023, **97% of Kellogg's' timber-based packaging came from recycled or certified sustainable content, up from 65% in 2018**

Walmart

- Walmart has set the goal to **become a "regenerative company" through several key goals and metrics,** such as:
  - 100% of palm oil in Walmart private-brand products sourced with no deforestation or conversion by 2025
  - Walmart private brand products made of pulp, paper, and timber will be sourced deforestation and conversion-free by 2025
  - 100% of soy in Walmart private-brand products sourced as deforestation and conversion-free by 2023 in accordance with their Forest Policy
  - 100% of fresh beef sold by Walmart Inc. sourced as deforestation and conversion-free by 2025 in accordance with their Forest Policy

MARS

- Mars is accelerating efforts to **stop deforestation and conversion of natural ecosystems in Mars supply chains** identified as most at risk for driving deforestation
- Mars has begun with these commitments: **deforestation-free Palm Oil, Pulp, and Paper by 2020 and Beef, Cocoa, and Soy by 2025**

Nestlé

- Nestle is **targeting a 100% deforestation free supply chain by 2025,** reaching 99% in 2022 for each of their meat, pulp and paper, soy and sugar primary supply chains and with goals for coffee and cocoa to be added to the list of priorities for deforestation-free status by 2025
- Nestle has **identified palm oil as the greatest opportunity for improvement,** with 95.6% assessed as deforestation-free in 2022

Carrefour

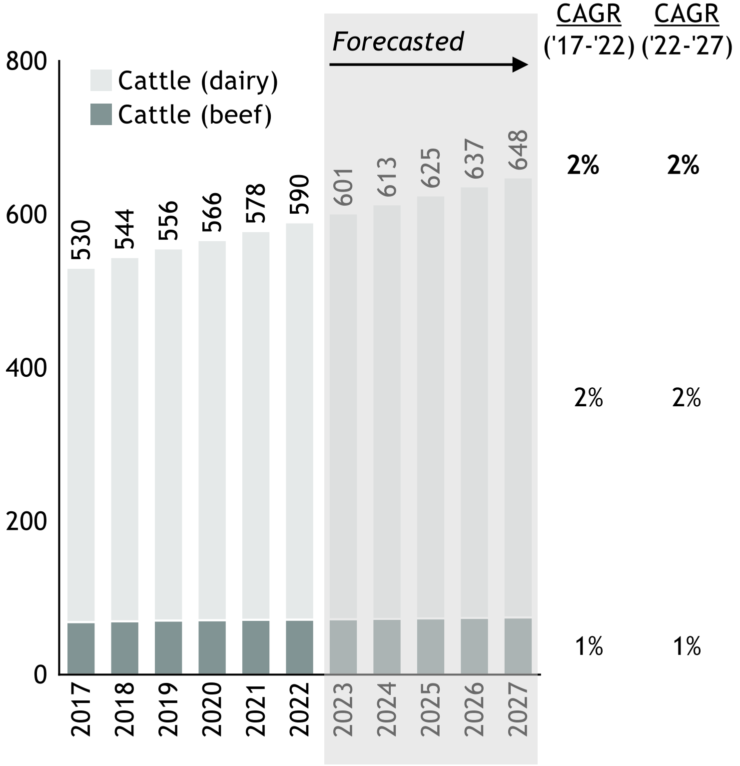
- Carrefour committed in 2010 to the implementation of a **sustainable forests action plan for products linked to deforestation by 2020**
- This commitment **included Palm Oil, Soy, Wood & Paper, and Brazilian Beef**

Note: Title quote is from Owen Bethell, Environmental Impact Lead Global Public Affairs, Nestle
Source: Lit. search, Corporate interviews

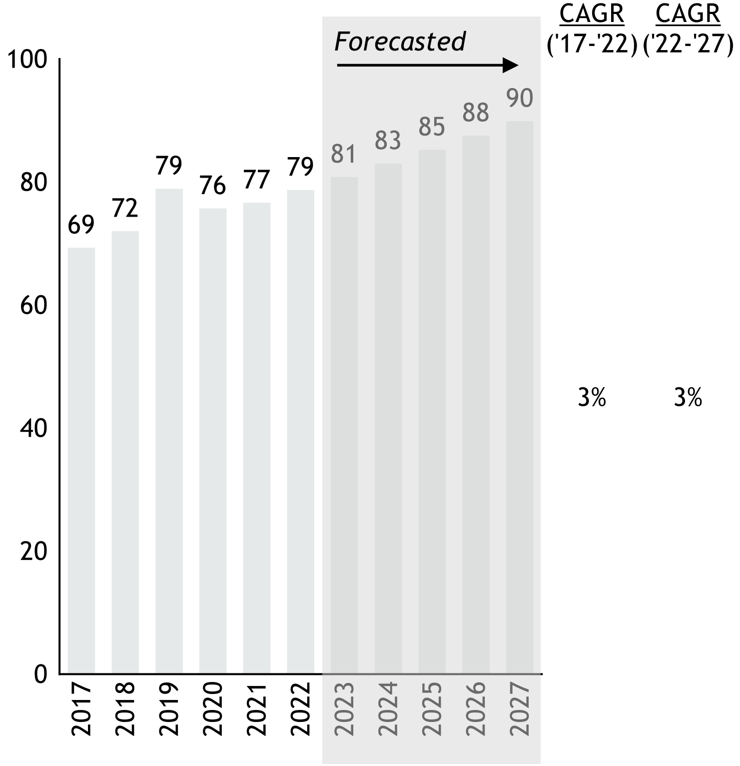
"Actors are creative when given the right economic incentives; we need to tackle underlying drivers of deforestation if we are going to change behavior"

Cattle and palm oil production have grown steadily over the past five years and are expected to continue to grow at a similar pace for the next five years…

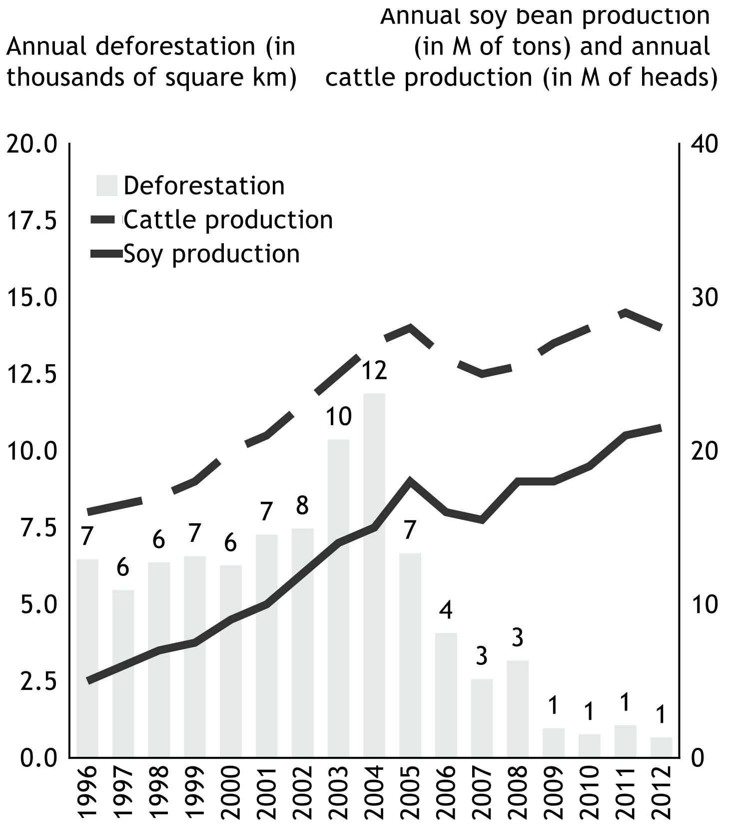
Millions of metric tons of cattle produced globally



Millions of metric tons of palm oil produced globally



…but productivity can still increase alongside reduced deforestation*



Note: Title quote is from Director of Sustainable Business, Agri-food provider #1; (*) Adapted from a study of the Mato Grosso State in Brazil from 1996 to 2012

Source: OECD-FAO Agricultural Outlook, FAO Stat, USDA, Reuters, Nepstad DC, Boyd W, Stickler CM, Bezerra T, Azevedo AA. Responding to climate change and the global land crisis: REDD+, market transformation and low-emissions rural development. *Philos. Trans. R. Soc. B Biol. Sci.*368(1619),20120167 (2013), Corporate interviews

The incentives for deforestation largely outweigh the costs

Overview of benefits or penalties

Logging and proceeds from timber are profitable

- **Stumpage prices are what loggers pay for the right to harvest** standing timber on someone's land
  - This transaction is where a landowner can profit from logging / timber
  - After this transaction, downstream revenue benefits loggers and other downstream actors
- Factors like the species of trees, the quality of those trees, the volume of those trees, distance from the logger's timber mill, the ease of logging at the site, and timing of harvest all affect stumpage prices
- Ultimately, **landowners can expect to receive 50% of the value of the logs**

There are few penalties for deforesting today

- **None of the world's 5 highest deforesting countries have introduced major penalties** for deforestation
  - Russia: Russian laws threaten fines but define those fines on a case-by-case basis, with a maximum of ~$80 USD per acre
  - US: No financial penalties
  - Canada: Landowners who deforest "may face any of several stiff penalties"
  - Brazil: While deforestation rates have declined under Lula, the Bolsonaro administration curtailed enforcement of deforestation penalties, leading to soaring rates of ecosystem destruction
  - Indonesia: Indonesian laws threaten fines for deforestation but define those fines on a case-by-case basis

There are minimal financial benefits to preserve lands

- Various **financial incentives** schemes incentivize **land preservation:**
  - E.g., Conservation easement schemes: Income tax deductions to landowners for conservation, upon donation or sale
  - E.g., Land management grants: Healthy Soils Program (HSP) in the US provides grants for sustainable farm practices
- But there is **uncertainty** regarding **financial returns**
  - Funding for grants vary annually - e.g., US Greenhouse Gas Reduction Fund needs state approval for discretionary funds
  - Applications sometimes require full project proposals, which may require spending
  - Continuation of financial incentives can be uncertain - e.g., biodiversity conservation schemes if an at-risk specie is delisted

Financial implication per acre

~$500-$5,000 earned per acre logged

~$80 penalty per acre logged

~$50-$75 per acre preserved

Source: Lit. search

"We must ensure carbon market incentives for preservation and reforestation have direct impacts on farmers' and land owners' businesses"

Current carbon pricing schemes do not cover land-use change

- The most robust carbon pricing scheme in place today is the EU's **Carbon Border Adjustment Mechanism (CBAM)**
- CBAM incorporates a few key elements:
  - EU importers of goods covered by the CBAM registers with national authorities where they can also **buy CBAM certificates, priced based on weekly emissions trading scheme (ETS) allowances**
  - EU importer **declares the emissions embedded in its imports and surrenders the corresponding number of certificates** each year
  - If importers can prove that a **carbon price has already been paid during the production of the imported goods, the corresponding amount can be deducted**
- The CBAM and corresponding ETS implemented in the EU **only consider carbon that has already been emitted,** introducing allowances, trades, and pricing to create financial accountability for emissions
- Other forms of carbon transfer, including carbon credits, offsets, and other mechanisms that cover avoided emissions, are not included

Carbon pricing markets for 'avoided carbon' are nascent

- **'Forest carbon offsets'** include a metric ton of CO2 equivalent (avoided or newly stored emissions) **purchased by GHG emitters** for compensation
- This market is currently based on **projections** on carbon threats to forests by **firms with vested interests**, which can lead to **mistrust**
  - Pachama sold credits for forests not under threat or where deforestation had actually risen
  - In the Democratic Republic of the Congo, 400 farming families were displaced due to a replanting project by oil firm Total
- **High upfront costs** and **long lead times** further disincentivize investors, but **innovation in carbon pricing mechanisms** is addressing this barrier
  - For example, 'Climate Forward' credits allow investors to receive credits earlier in afforestation projects (vs. after carbon sequestration), which can be sold to firms mitigating emissions for future projects
- Avoided deforestation credits are based on counterfactual baselines that are **difficult to prove**
  - Carbon credit rating agencies have found **projects frequently overstate their baseline emission projections**
  - According to IPCC, forest carbon credits must be priced between $50 and $200 per metric ton, much higher than the current average price of ~$5 per metric ton
- **Carbon project developers** are finding ways to **lower costs** for **landowners**
  - EP carbon developed the 'Forest Carbon Works' app, which allows tree measurements for carbon projects on smartphones and reduces inventorying costs for smaller landowners

Note: Title quote is from Senior Director of Marketing, Agri-food technology provider #3
Source: EP source, IPCC AR6 synthesis report, Climate Forward Initiative, European Commission, Lit. search, Corporate interviews

"All actors have a role; in many markets, the economic viability of reforestation is unclear, so demand to change existing trends is not there yet"

Reforestation is growing

- **27M hectares** of forest area has been restored from 2010 to 2020
  - Progress slower than Bonn Challenge targets set in 2011
- Reforestation relies on both **passive** (i.e., natural regeneration) and **active** (i.e., planting of seedlings) efforts
- **Active re-planting is growing** in importance because threats to forests - droughts, fires etc. – is making **natural regeneration less sustainable**
  - Nursery grown seedlings are now required for ~60% of reforestation efforts in US

However, key barriers across the supply chain are limiting the pace required

Seed supply

- Lack of access to seeds is driven by **viability issues** and **poor species variety**
  - In US, 3B+ seedling production needed to reforest 64M acres by 2040, >2x of current levels
- Limited **seed storage** adds to this problem
  - More than half of the world has no known seed banks

Environment

- Enlisting funders is hard due to **long lead times** and **higher price** compared to other credits
  - It takes up to 2 years to prepare land and more 1-2 years until seedlings are ready for sale
- This also leads to **misallocation of time** towards **fundraising**
  - On average, global forestry teams spend more time fundraising vs securing land and staff for projects

Financing

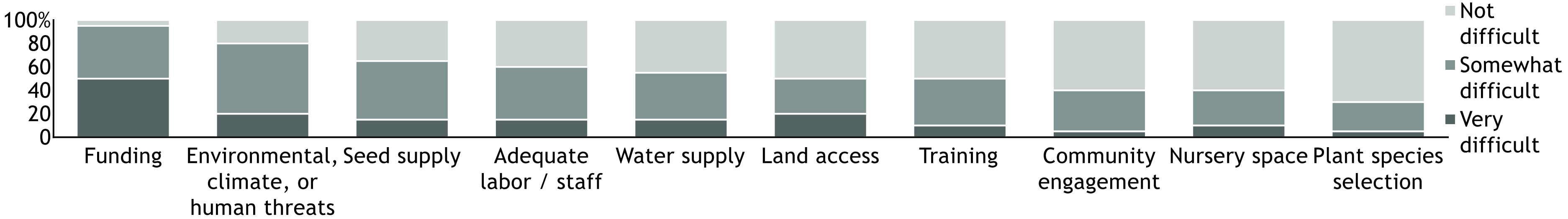
- Extreme weather patterns lead to **physical disruptions** or **render land unusable**
  - In Brazil, more forest fires occurred by Sept 2022 than all of 2021, amid high deforestation
  - USFS was only able to reforest ~20% land, given rise in wildfires

Workforce

- Shortage of staff is driven by **physical** and **seasonal nature** of the work, leading to attrition
- **Lack of training** or specialized teams increases the skill gap
  - Local knowledge is high but advanced forestry skills (seed zones, genetic diversity, seed storage) is lacking

Challenges faced by restoration teams worldwide

Based on a survey from Terraformation with 230 forresters from 63 different countries and in-deoth interviews with 70 forresters from 29 countries



Note: Title quote is from Director of Sustainable Business, Agri-food provider #1; Charts sourced from Terraformation – based on a survey with 230 foresters from 63 different countries and in-depth interviews with 70 foresters from 29 countries
Source: Terraformation , Climate Action Reserve, American Forests, Corporate interviews

As climate change impacts growing regions and seasons, agricultural lands are shifting, causing additional deforestation

Spotlight: Brazil

Climate change is causing global shifts in agricultural land use

- Climate change has led to rising temperatures, **shifting seasons** and **erratic weather** patterns
- This is affecting agricultural land by physically **disrupting farms** or **decreasing productivity**
  - EU experienced an estimated **~€5 billion** of **agricultural losses** linked to climate change in 2015 (>60%+ of all drought-linked losses)
  - **Agricultural yields** could **decline by up to 30% by 2050 globally** in the absence of adaptation
- As a result, a **growing number of farming families** have been forced to **leave or move** their farm operations
- Climate change is thus **decreasing land viable for agricultural use,** leading to further deforestation

Brazil's agriculture sector is affected by high temperatures and low rainfall …

- Brazil's leadership in **soybean and maize production** depends on **predictable rainfall** in the Amazon-Cerrado agricultural frontier
  - **~50%** of agriculture sector is **concentrated** in Cerrado- Amazon frontier; **~90%** depends on **rain for irrigation**
- Over the last 20 years, **agricultural land has been expanding** into areas **with lower soil moisture**
- As a result, **28%** of agricultural lands are **no longer in an optimal climatic range** and have decreased productivity
  - Expected to **continue rising up to ~50% by 2030** and ~**75% by 2060** as the region gets hotter and drier

…which has increased deforestation and farmland displacement

- This decrease in productivity and shift in land use **requires farmers to adapt** (e.g., new practices like double-cropping corn and soy in one season etc.)
- However, **agricultural intensification practices** are increasingly **becoming less feasible** on existing land, increasing pressure on **farmers to deforest more land**
  - Deforestation is further exacerbated by extreme weather patterns such as drought
- **Adaptation without deforesting more land** is thus needed to enable restoration and preservation

> *"If farmers don't have the time [to mitigate or adapt to the change in climate], they invest in more* ***space****. Farmers need to understand that deforesting in the face of climate change is like getting rid of your air conditioners before an upcoming heatwave."*
>
> Woodwell Climate

Source: "Climate Change and the future of food", UN foundation; Policy Department for Structural and Cohesion Policies 2021, "Climatic limit for agriculture in Brazil", Nature Climate Change 2021

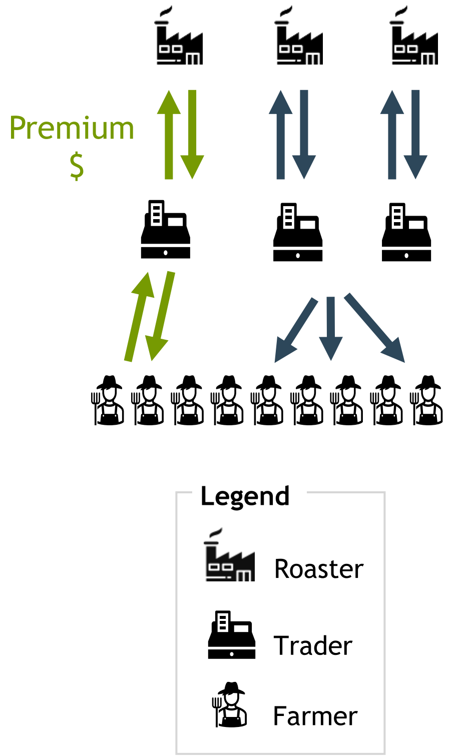
"If we are unable to measure how much carbon is released or sequestered on a given parcel of land, we cannot create the right incentives to change behavior"

What is traceability?	• **Traceability helps to determine if a product or service downstream in the value chain was associated with deforestation** further upstream in the value chain • As regulations and SBT requirements become stricter (e.g., polygon mapping on the table for EU deforestation law), business leaders across the value chain (including land owners, farmers, traders, FMCGs, and retails) can **progressively increase traceability across supply chains** to comply
What are the benefits?	• **Allows organizations to measure actual carbon footprint** and to account for progress made • Allows to **prove deforestation-free supply chain** (needed for regulatory / SBT) and is future-proof for any additional traceability needs from government / investors / others
What are the challenges?	• Farmers would **not necessarily gain additional income** – Smallholders risk exclusion for not being able to comply with requirements • **Depending** on implementation method to achieve traceability, **an incremental cost is required**

How can we implement traceability?	• Organizations can **implement traceability in different ways**, e.g.
	  – Set a **progressively more stringent set of standards towards suppliers**, who will need to adhere to supply
	  – Limit supply to **a few districts** to be able **to target support to farmers**
	  – **Have long-term supplier contracts**, who can invest in dedicated communities to increase ESG progress
	  – **Vertically integrate** farmers within supply chain
	  – Increase **volume of certified products** to increase impact
	• In general, **resources need to be enabled for procurement teams** to drive supplier impact

What are the costs?	• **The costs depend on how traceability is implemented:** from 0 if strict supplier standards are set to significant costs if certifications are involved • **This cost is expected to decrease over time** as data standards and technologies are more standardized and data is shared more freely and easily

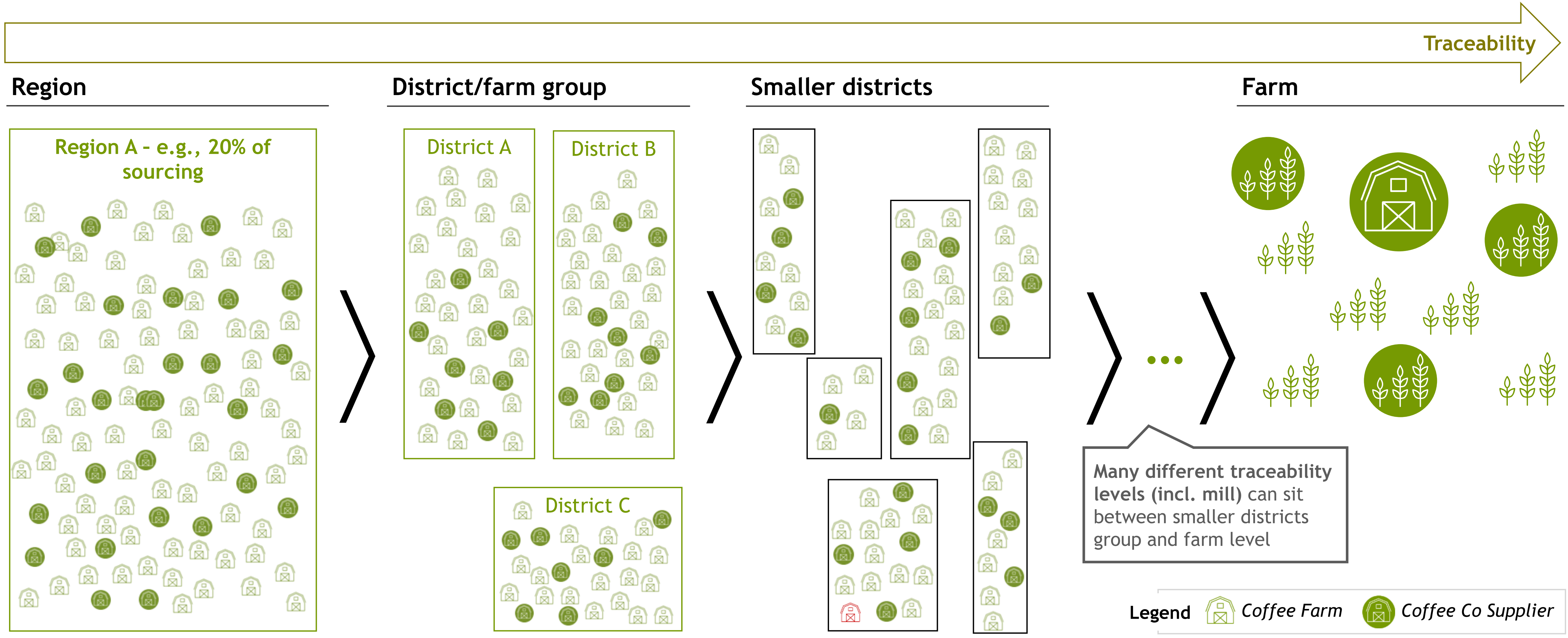
Traceability Example: Coffee Co



Note: Title quote is from Senior Director of Marketing, Agri-food technology provider #3
Source: Lit. search, Corporate interviews

There are different levels of traceability that can exist, but given a sporadic and decentralized value chain, farm-level monitoring is necessary

/ILLUSTRATIVE



Various technologies can enable deforestation monitoring and supply chain traceability at the farm-level; satellite monitoring is most promising

	Initiative	Satellite monitoring	Agronomist sampling	Field sensors	Tool (e.g., Cool Farm Tool)
Description		• **Remote monitoring** of field to follow-up on tree density through satellites • **Min. 6 cloud-free images** per year required to estimate tree biomass • **Easily scalable** approach	• **On-ground sampling & analysis** of soil and crop conditions through agronomists • **Sampling & analysis at start of project,** updated annually depending on the parameters monitored incl. soil organic matter, soil pH, nutrients	• **On-ground sensors** to monitor soil, crop and environmental conditions incl. weather, soil pH, nutrient quality • **Continuous observation** possible if sensors & analysis tools are available and farmer had training on operation of tools	• **Online tool** for farmers and agri-food companies to **benchmark and assess their greenhouse gas emissions, water management and biodiversity** • **Immediate results and feedbacks** that helps farmers to define **an action plan** and to track **performance** at the farm level
Already used by		Acorn, Rabobank, Fairtrade, Rainforest Alliance Certified ...	Acorn, Rabobank, puro.earth, Fairtrade, Rainforest Alliance Certified ...	ARABLE	Starbucks, Nestlé, MARS, Unilever
Agriculture training	Agro-forestry	Satellite monitoring of # shade trees	Monitoring of # shade trees		Input from farmer: # of shade trees
	Fertilizer reduction	Remote sensing data and advanced machine learning **(still nascent)**	Nutrient testing in laboratory (incl. N, P, K)	Monitoring of soil nutrients with potential for AI to predict fertilizer requirements	Input from farmer: Type & the amount of fertilizer
	Yield improvement	Remote sensing data and advanced machine learning **(still nascent)**	Monitoring of crop size, density, health, soil organic matter	Monitoring of soil condition with potential for AI to predict yield improvement	Input from farmer: Harvested Yield and marketable yield product weights
Biochar	Biochar production		Monitoring of biochar organic matter content **(still nascent)**		
	Fertilizer reduction through biochar		Nutrient testing in laboratory (incl. N, P, K)	Monitoring of soil nutrients with potential for AI to predict fertilizer requirements	
Reforesting	Reforestation of depleted land	Satellite monitoring of # trees	Monitoring of # trees		Input from farmer: Take into account # trees

See deep dive

Source: Lit. search

Polygon mapping with satellite imaging can track & verify farm-level progress but requires upfront costs for each boundary and field, limiting adoption

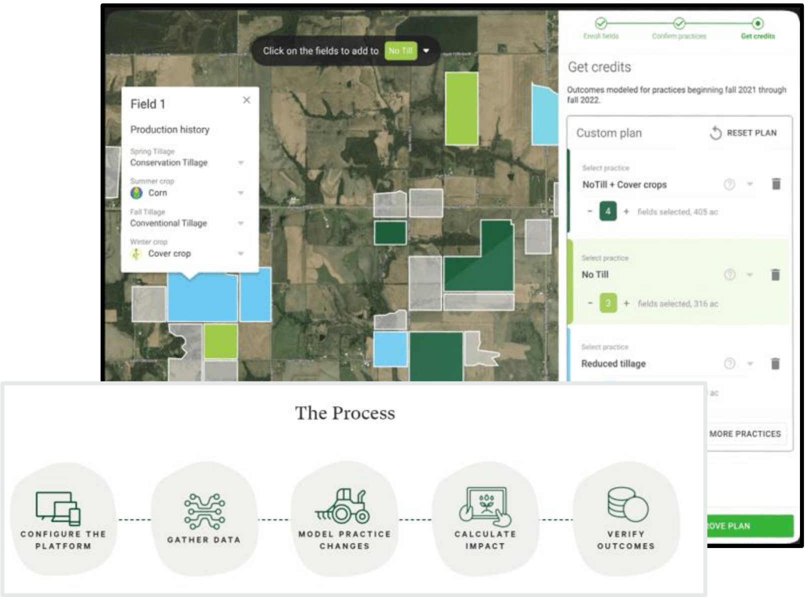
Polygon mapping is one way of gaining farm-level traceability and tracking ESG progress, and key players are leveraging this

- Polygon maps is a form of location data, defined by a series of coordinates, which are interconnected into a shape. They are **used to map regions or farms**
- Polygons can then be **used to track progress on specific sustainability areas** (e.g., deforestation, tillage, cover crops, crop rotation)
- **The cost for boundary mapping is roughly £0.20-£0.60 per boundary** (i.e. field), so mapping an entire farm would depend on the number of fields
  - This needs to be **done thoroughly once**, and afterwards only need to be updated if there's a shift (e.g., shift of ownership, shift of purpose of land)
- The **cost of mapping activities within fields** are **higher** and priced per ha
  - This needs to be **done more frequently** (typically automatically) to track progress
  - **Costs will scale with hectares covered**, so larger areas are more cost effective
- **A number of companies are offering** these services (e.g., Regrow, Agreena), and **key CPG players** (e.g., Nestlé, Cargill) are already **leveraging polygon mapping**

Nestlé | Cargill | BARRY CALLEBAUT | Unilever

Example: Regrow

regrow



Regrow's OpTIS is a **remote sensing platform that collects and verifies sust ag practices** automatically. Based on this, soil carbon and GHG calculations are done

Source: Lit. search

However, focusing regulation on supply chain transparency alone will be insufficient to combat deforestation; positive incentives are equally important

*“**We need to broaden regulatory efforts in a way that does not just penalize deforestation.** Other countries and parts of the world are spreading the ‘good stuff.’ **We must create a two-tiered system that has both consequences for deforestation and rewards for preservation and reforestation.** Some of the voluntary initiatives and coalitions that are popping up are a good start, but **there is opportunity to improve these ‘positive’ reinforcement mechanisms too.**”*

Environmental Impact Manager – Global Public Affairs & ESG Engagement, Agri-food provider #3

Source: Corporate interviews

"Countries understandably react negatively if policies penalize their economically important commodities; we must empower communities instead"

Spotlight: EU

The EU has pushed restrictions on palm oil to curb deforestation

- To meet its climate targets, EU has added regulations to **palm oil production** – a land-intensive crop
  - Palm oil was responsible for one third of Indonesia's 25M acres of deforestation
- In 2019, European Union Deforestation Regulation (EUDR) was aimed at **reducing emissions** and **preventing** firms from **trading deforestation-linked commodities**
  - First of its kind by banning products tied to deforestation from supply chain
- **The EU** has also enforced **multiple programs** to **boost local production** and **control the supply chain**
  - E.g., imposing duties on Indonesian biodiesel

Restrictions have disproportionately impacted big exporters

- Palm oil is the **main agricultural export of Indonesia and Malaysia**
  - Generated ~9% and ~3% of Indonesia and Malaysia's 2019 exports respectively
- EU restrictions are being **contested by these exporters**, who are calling them discriminatory and ineffective
  - They claim national policies are already in place to foster sustainability practices

The net impact of these restrictions is mixed due to low global coordination

- These measures can simply **shift exports to countries with more relaxed measures** – including India, China and Pakistan
- Moreover, **smallholder farmers** may be disproportionately affected and bear the **costs of meeting new due-diligence** standards
  - Adequate training and investment assistance can result in sustained impact for these farmers

*"With the supply chain approach and policies, **maybe Europe will be sourcing from areas without land use risk but then this risk is just going to go elsewhere - different countries or different regions - that don't have the same kind of requirements**. So, it certainly has an impact. But I don't think it's a silver bullet by itself."*

Director, Carbon Programs and Strategy, Agri-food provider #4

Note: Title quote is from Owen Bethell, Environmental Impact Lead Global Public Affairs, Nestle
Source: Reuters; Lit. search, Corporate interviews

Increasing the value of standing forests, greater supply chain transparency, and international coordination will determine the rate of land use change globally

Economics of deforestation

- Deforestation remains one of the largest sources of food emissions today, with the rate of primary tropical forest loss increasing slowly but steadily over last two decades
- Deforestation is likely to continue given the combination of **economic incentives, while** alternatives for intensifying production or restoring ecosystems require knowledge and capital to implement. There are also **limited consequences for deforestation in many parts of the world**
- **Growing regions are shifting** due to climate change, and could **result in additional deforestation** as new arable area overlap with primarily forested areas

Law enforcement and supply chain transparency

- Technologies are available today to verify zero deforestation production, with satellite imaging and polygon mapping proving to be the most promising, but **upfront costs to map and monitor each farm have led to limited uptake**
- Tracing agricultural commodities back to the farm, both for potential law enforcement as well as for private supply chain tracking, is challenging and time-intensive, **given complex and decentralized supply chains for many of these inputs**

International coordination

- Voluntary and regulatory measures are creating pressure to raise supply chain standards in some cases, although the lack of consistent **global definitions and monitoring systems for zero deforestation will delay implementation**
- But **uncoordinated, piecemeal efforts on the demand side will likely have limited impact at a global level** given the strong underlying incentives and potential for resource shuffling
- Carbon payments are also generating **new revenue streams for businesses and farmers willing to commit to lower carbon practices; but progress will likely be limited without coordinated global efforts to incentivize the protection and restoration of forests and peatlands**

Government policy needs to improve economics against deforestation, pave standards for tracking, and facilitate domestic and international coordination of policies

Incorporating avoided carbon into markets and pricing

- **Pricing avoided carbon and building a market to incentivize protection and restoration of forests and peatlands is necessary**, but these markets are underdeveloped today
- Building on models like the EU ETS and CBAM cap-and-trade and pricing schemes, respectively, **credits for avoided carbon that can be traded and built into pricing schemes will enable governments to change the underlying economics of deforestation** for land-owners and farmers, countering the economic incentives driven by agriculture and logging

Auditing and standard setting for deforestation

- Given the lack of data on deforestation to date, **no auditing standard has yet been established** to enforce these procedures universally
- **Establishing an international set of standards for what constitutes deforestation, preservation, and reforestation as well as auditing to hold actors accountable to these standards** will pave the way for both public policy to monitor deforestation and private supply chain tracking

Domestic and international government coordination

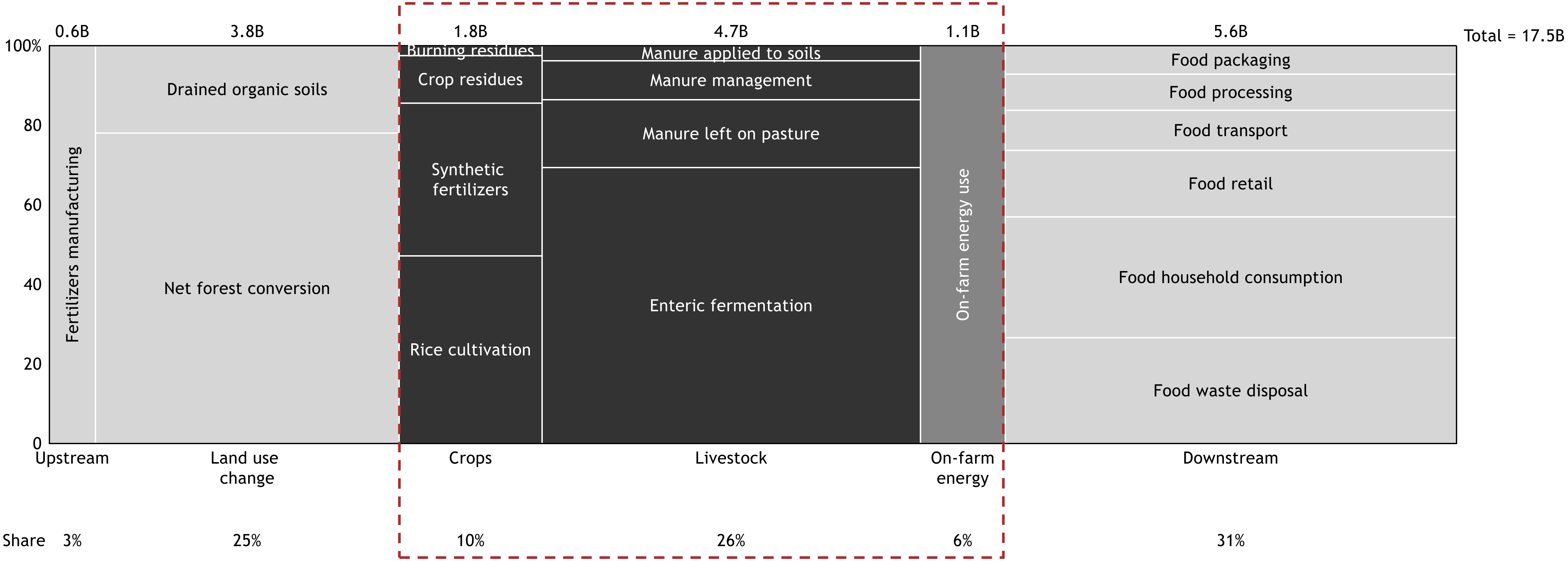
- Governments need to play a role in pushing conservation and restoration of lands and better enforcing domestic laws and regulations to halt illegal deforestation
- **Domestic policies that require compliance with zero-deforestation standards, in the form of financial penalties high enough to outweigh potential benefits from deforestation, are a first step** for governments to control practices within their own borders
- In parallel, **governments must coordinate internationally with key trading partners to restrict trade of deforestation-inducing commodities like beef, palm oil, and soy so that deforestation is eliminated rather than displaced** with trade of these commodities with less restrictive jurisdictions that allow for deforestation

Agriculture: Table of Contents

On-farm emissions constitute ~42% of all agri-food system emissions from growing crops, rearing livestock, and operating farm machinery

Legend *(from farmer perspective)* *Scope 1* *Scope 2* *Scope 3*

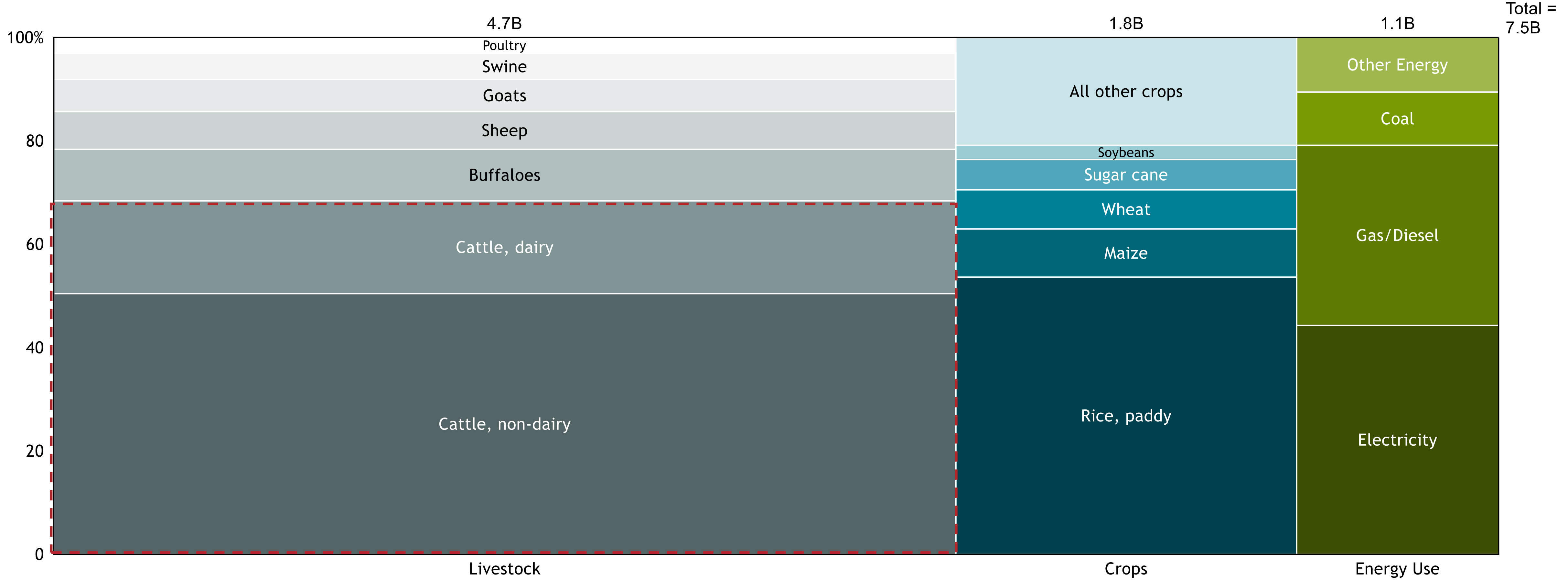
Global GHG emissions from the agri-food system (T, CO2-equivalent)



Note: Land use change and Farm gate emissions measured using FAO Stat emissions totals data; Pre- and post-production emissions measured using FAO Stat emissions shares data
Source: FAO Stat

Within on-farm emissions, beef and dairy cattle contribute ~43% of total emissions

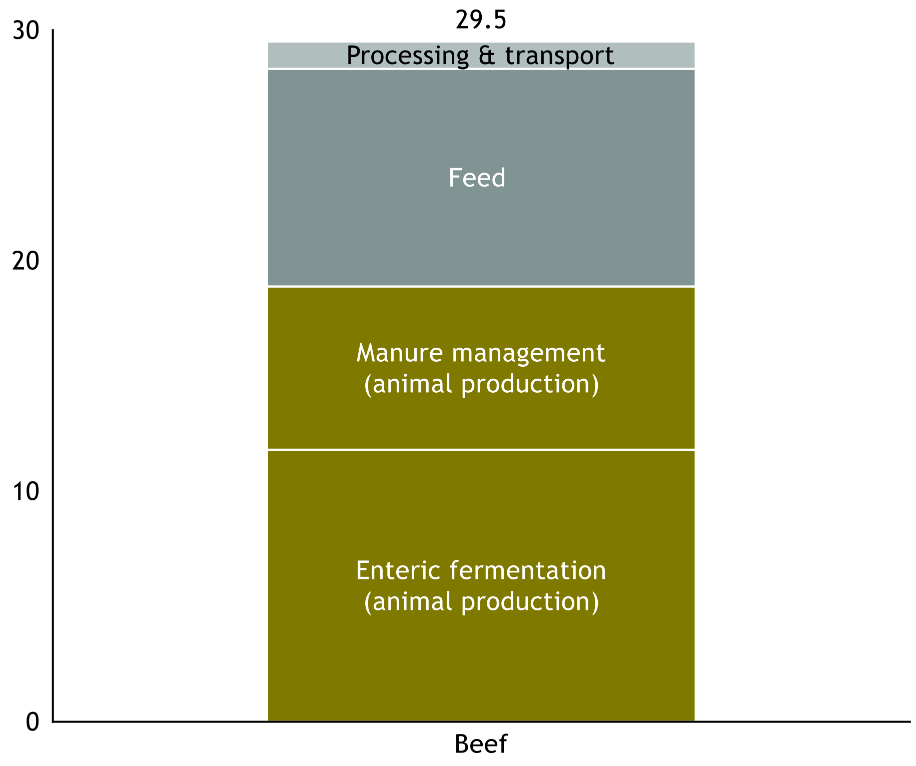
Global GHG emissions from the on-farm emissions (T, CO2-equivalent)



Source: FAO Stat

For beef and dairy cattle, most emissions are generated from enteric fermentation and manure practices

Emissions factor for 1 kg of carcass weight
(kg CO2e / kg animal, North America)



Animal production

~64%
of livestock emissions

- Enteric methane from natural ruminant digestive processes
- Manure and related methane and nitrogen emissions

Feed

~35%
of livestock emissions

- N_2O leaching from soil
- Fertilizer, lime, and pesticide manuf. emissions
- Tractor diesel emissions
- Drying energy
- Production and use of fertilizer for managed pastures
- Production of hay for supplemental feed

Processing and transport

~1%
of livestock emissions

- Energy for electricity and heat during direct processing
- Emissions from transport of livestock

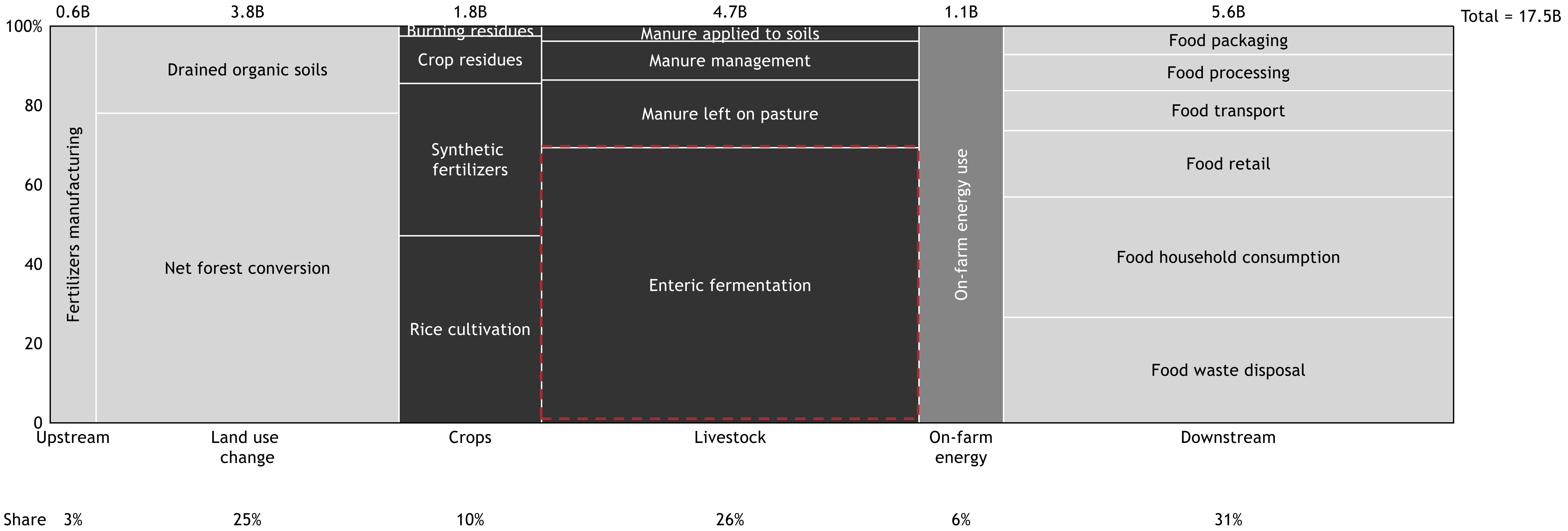
Key areas of livestock supply chains include feed conversion ratios, growth metrics, natural animal biology, and manure

Note: Beef feed percent includes both grazing and row crop emissions, North America data, Ranges reflect beef, chicken, pork, and eggs life cycles
Source: GHG Emissions from pig and chicken supply chains (FAO); GHG Emissions from ruminant supply chains (FAO)

Enteric fermentation constitutes ~65% of total livestock emissions in the agri-food system

Legend *(from farmer perspective)* *Scope 1* *Scope 2* *Scope 3*

Global GHG emissions from the agri-food system (T, CO2-equivalent)



Note: Land use change and Farm gate emissions measured using FAO Stat emissions totals data; Pre- and post-production emissions measured using FAO Stat emissions shares data
Source: FAO Stat

Enteric fermentation is a process where methanogens use H2 and CO2 to create methane

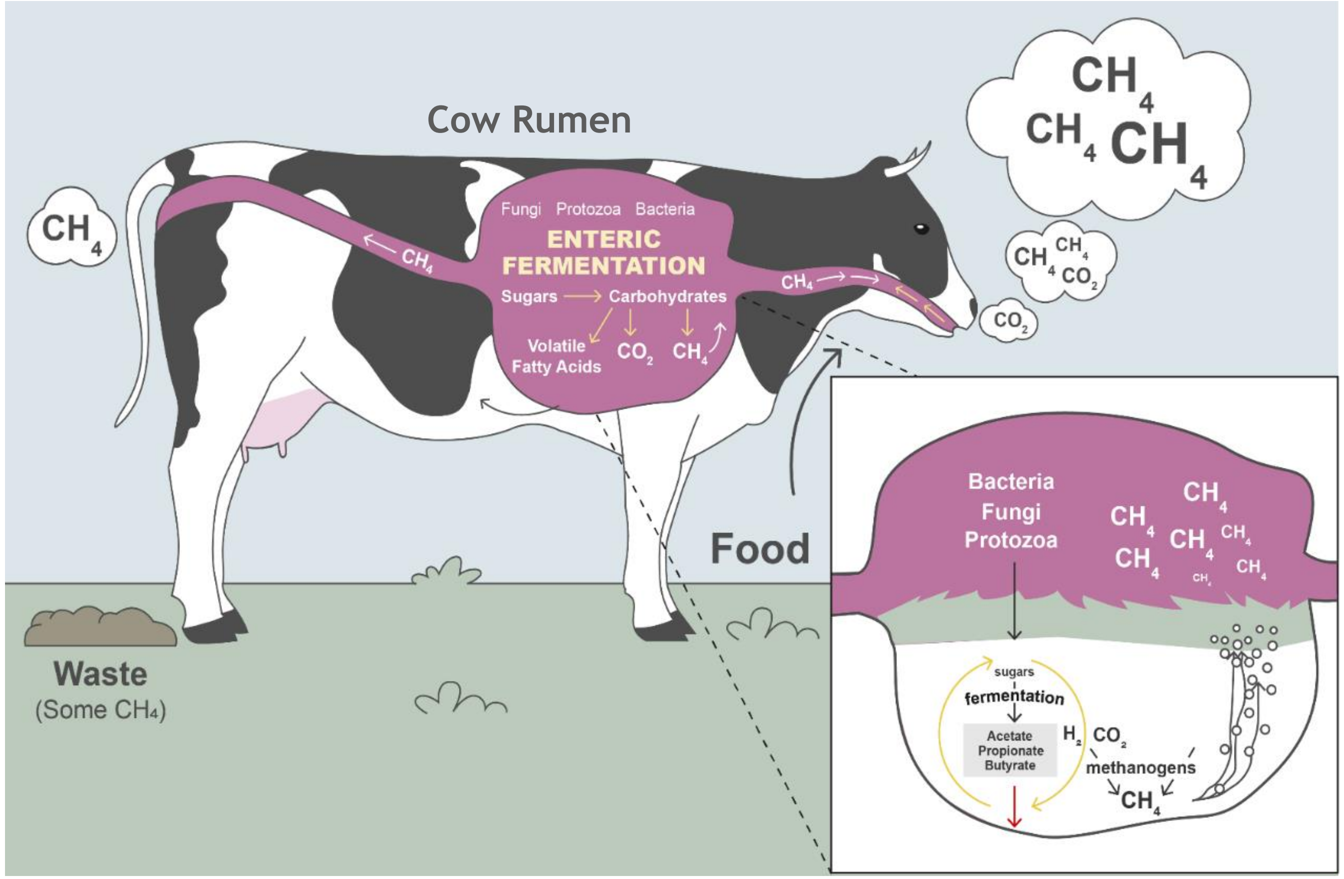
Methane is a byproduct of the enteric fermentation process

Ruminants have a **four-chambered stomach** that **allows them to digest fibrous plant material** like grasses and hay

The first and biggest chamber is the **rumen**, where the **microorganisms** (bacteria, fungi and protozoa) **break down the sugar and starch from plants through fermentation**

- **Enteric fermentation** is the process when **bacteria break down complex carbohydrates into simple sugars**. The end product include **volatile fatty acids (VFAs)** as well as gases, such as **carbon dioxide** and **methane**
- Methanogenesis happens in the rumen, where **methanogens utilize** predominantly **H2** and **CO2** as substrates **to produce methane**
- **VFAs are absorbed through the walls of the rumen** and transported to the liver where the animals use them for energy

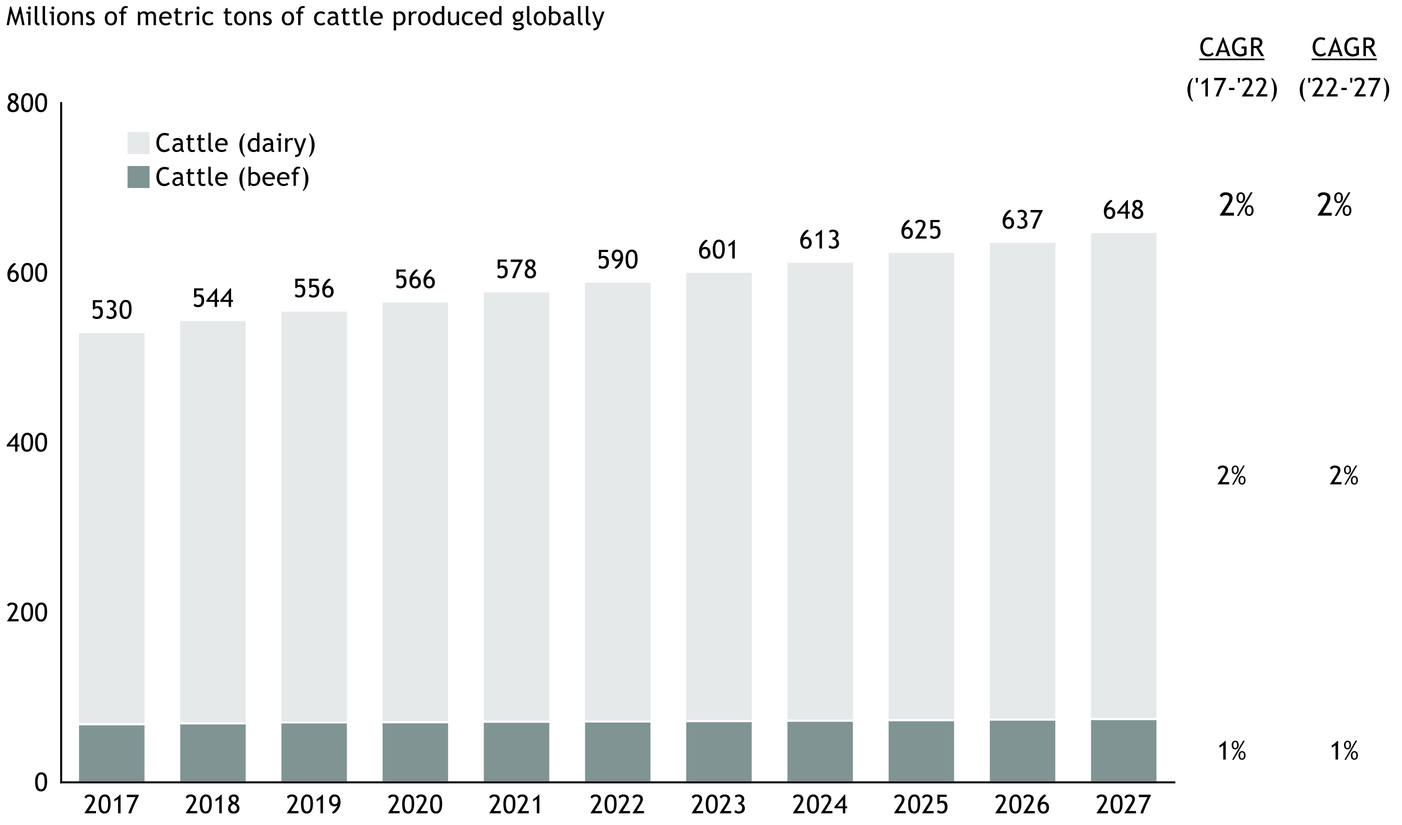
Methanogens use H_2 and CO_2 to produce CH_4 (methane), which then is belched by cattle into the atmosphere



Source: University of Nebraska; Let's Talk Science; Lit. search

However, beef and dairy consumption has grown 2% annually, which will continue through 2030; emissions will grow at similar rates without action

Beef and dairy consumption has grown steadily over the last five years and is expected to grow at a similar pace through 2030



Source: OECD-FAO Agricultural Outlook

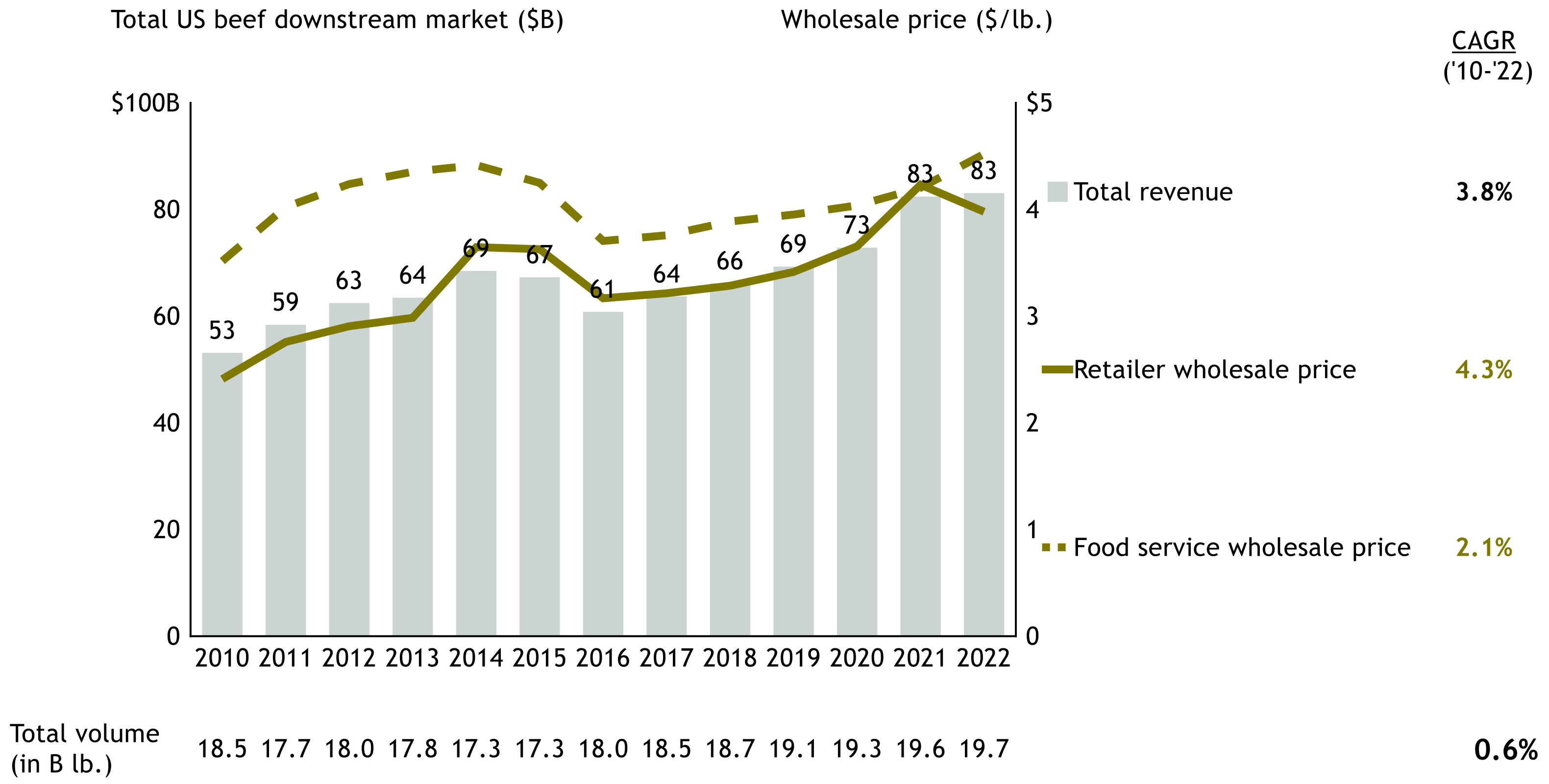
Commentary

- Beef and dairy consumption are expected to increase **in the coming years as the global population continues to grow**
- That said, **per capita consumption is expected to remain flat,** meaning on average individuals will maintain existing rates of beef and dairy consumption
  - In developed economies, per capita consumption is decreasing over time
  - However, in developing economies, per capita consumption has been increasing

Steady revenue and underlying price growth in the beef market reinforce demand trends and subsequent emissions trends

Spotlight: US

The downstream beef market has grown ~4% YoY, driven by price increases with relatively flat consumption



Note: Downstream market size is based on wholesale price (the price that retailers and food service providers pay to procure beef)
Source: Meat Demand Monitor, USDA Economic Research Services, Euromonitor, GlobalData, Technomic

The market is expected to remain resilient

- Increasing prices have not affected consumption across beef products, signaling **low levels of price elasticity**
- Approximately 80% of consumers expect to **increase or maintain their beef consumption** in the future
- Even during a recent period of high inflation, consumers **did not appear to meaningfully trade down to lower-cost proteins** (e.g., chicken and pork)
- Consumers who purchase meat are critical to retailers – grocery baskets containing beef are **more than twice as valuable** as the average basket

Alternative protein development will be critical in combatting rising demand for beef and dairy products

"There are nutritional needs that must be met by consuming beef and dairy, and it is unpopular for the government to regulate beef and dairy volumes or to tax them. ***However, if we can offer alternatives to beef and dairy that encourage diet shifts without 'penalizing' those seeking meat and dairy, then we can start to shift the demand curve even though those products will never completely go away."***

Environmental Impact Manager - Global Public Affairs & ESG Engagement, Agri-food-provider #3

Source: Corporate interviews

“The problem is too big for a single pathway; we need a broad suite of emissions reduction products and system-wide enablers” (1 of 2)

NON-EXHAUSTIVE

LEVER	Production intensification	Tropical plants	Feed additives
Mitigation mechanism	Intensification is achieved by **decreasing age and increasing bodyweight** at slaughter, which reduces total emissions per kg of meat Key intensification strategies are **higher quality pasture** (e.g., Legume/Brachiara pasture, improved N-fertilized Guinea grass) and **transition to feedlot system**	Increasing **easier-to-digest sources of carbohydrates,** is an effective way to **reduce methane emissions** This way, **tropical plants** (such as legumes[2] and grass) can **mitigate from 10 - 25%,** given the presence of **tannins, saponins and starch**	Adding **feed additives alter cattle’s digestive microbiome**, reducing emissions - 3-NOP - Lemongrass - Nitrates - Probiotics[3] - Vegetable oils - Ionophores - Tannins
Mitigation potential[1]	20-50%	10-25%	10-40%
Implementation challenges	Low **capital** availability Lack of specialized **labor and know-how**	**Little implementation challenges** were seen, as similar strategies were implemented and studies indicate it’s relatively low cost	**Prohibitive costs** for most extensive cattle ranchers (+80%[4] of production) **Labor and resource** requirements for correct dosage **Lack of research** on **tropical** settings **No additional productivity benefits**
Cost	**CAPEX** of USD ~**$100-1,500** per ton **OPEX** of USD ~**$25-550** per ton per year (or OPEX of USD ~$1.30-2.20 per CW[5])	**CAPEX[6]** of USD ~**$100-400** per ton **OPEX** of USD ~**$100-260** per ton per year (or OPEX of USD ~$1.73-1.77 per CW[5])	**CAPEX[6]** of USD ~**$250-1,000** per ton **OPEX** of USD ~**$50-130** per ton per year (or OPEX of USD ~$0.43-0.58 per CW[5])

Note: Title quote is from Kosta Stavreas, Chief Commercial Officer, Rumin8; (1) Estimates not directly applicable to all agriculture economies (2) E.g.: Leucaena leucocephala and Desmanthus leptophyllus (3) E.g.: native ruminal microbes (NRM), Chordicoccus furentiruminis, Prevotella albensis, Succinivibrio dextrinosolvens, and Saccharomyces cerevisiae yeast (4) % of slaughters (5) CW = kg of carcass weight produced (6) Doesn’t include CAPEX to recover pastures
Source: Lit. search, Corporate interviews

“The problem is too big for a single pathway; we need a broad suite of emissions reduction products and system-wide enablers” (2 of 2)

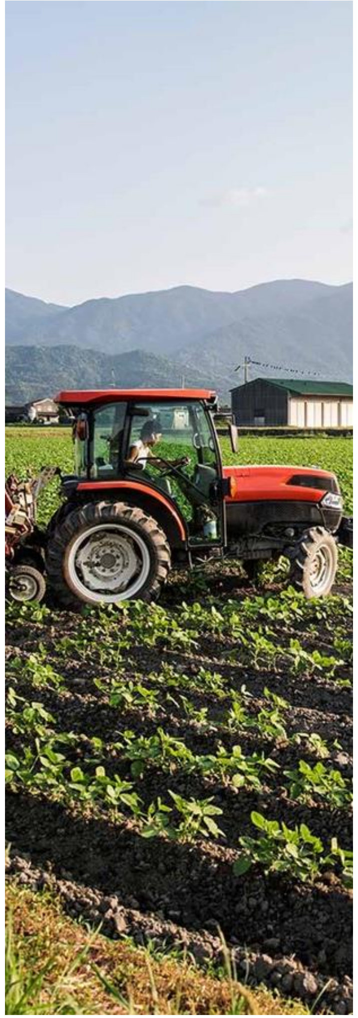
Legend ◔ *Worst* ● *Best*

/ NON-EXHAUSTIVE

LEVERS		Red seaweed feed additive	Anti-methanogen vaccine	Wearables reducing methane emissions	Selective breeding
Mitigation mechanism		Red seaweed (**Asparagopsis**): adding 0.5% of AT into the cattle feed **reduces methane production** by **up to 98%**	Vaccination could make **antibodies inhibit the methanogens, reducing production of methane** in the rumen	Main tech available is **ZELP’s** cattle mask It claims to **capture 50-60% of methane emissions**, converting them to CO2 and water	**Selective breeding** (cross breeding or within breeds) of **cattle with higher feed conversion efficiency** reduce methane emissions - Breeding does not impact[2] feed intake, growth and carcass output
Mitigation potential[1]		~55%	20-35%	25-30%	10-30%
Implementation challenges		**Production needs to be close to farms**, as it can lose its properties over time Need to **develop** aquaculture techniques in **ocean and land-based systems globally**	Science behind the vaccine is still **early-stage development**	Tech was prototyped and awarded, but **isn’t at commercial scale** **Uncertainty** on whether **producers** and **herds will adapt**	Solution is in the **early stage** Selection on other **breeding criteria has larger production gains**, increasing opportunity cost
Technology maturity		Startups launched products in 2022, mainly in NZ and AUS	Expected time to market in 4 to 6 years	Technology will be available for customers in 2023	Best case semen will be available in 2025
Scalability	**Technology certainty**	◑	◔	◕	◔
	Cost at scale	●	◕	◔	◔
	Disruption to rancher model	●	●	◑	◑

Note: Title quote is from Kosta Stavreas, Chief Commercial Officer, Rumin8; (1) Estimates not directly applicable to all agriculture economies (2) Measuring for Residual Methane Emissions can assure the breeding produces cattle with similar feed intake, growth rate and carcass output
Source: Lit. search, Corporate interviews

Increasing production intensification has potential to reduce methane intensity, but producers lack capital to invest

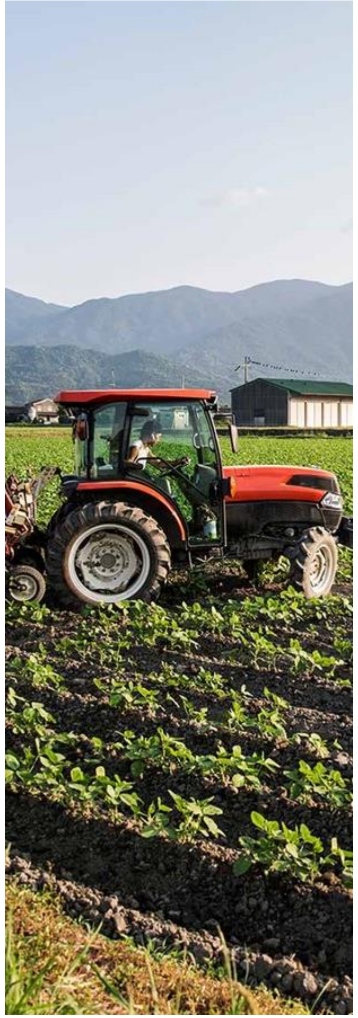


*"On the enteric emissions side, **feed and diet intensification is key.** We need to find ways to **reduce methane emissions** to reach the 1.5 degrees scenario. Massive efforts are being focused on answering what the new technology will be in the toolkit for the dairy industry. This area continues to be a big challenge. **Some of what's being looked at** is **extremely capital intensive."***

Director, Carbon Programs and Strategy, Agri-food provider #4

Source: Corporate interviews

Low levels of specialized labor in remote areas and the limited availability of technical assistance make it difficult to transition practices



"Specialized technology solutions may not be appropriate or feasible in areas with lots of small-holder farming communities, such as in India *– making on the ground community engagement will be more impactful.****"***

Owen Bethell, Environmental Impact Lead Global Public Affairs, Nestle

Source: Corporate interviews

Different farming practices also have distinct needs and are not necessarily able to adopt the same emissions reduction technologies

Feedlot cattle

- When cattle are grown **on a feedlot the primary focuses are efficiency and growth of the animal**
  - The main purpose of feedlots is to help the animal reach a certain weight as efficiently as possible through steady, high-energy diet
- The longer they are in the feedlot, the more their **diets become concentrated with grains and high-energy products**
  - This diet along with cortisol from stress, allows the cattle to gain weight exponentially in the feedlot, making the overall harvesting process fast and cost-effective

Grazing cattle

- **Grazing cattle spend most of their lives eating grass** and foraging in pastures
- Grazing cattle **can either be grass-fed or grain-finished**
  - Grass-fed cattle only eat grass their entire lives
  - Grain-finished cattle eat grass for most of their lives and are then “finish” with grain and corn before they are harvested

Source: Lit. search

Tropical plants have shown to reduce CH_4 emissions reduction by 10-25%

Embrapa **Case Study: Embrapa**

Overview

- **Description:** Research corporation devoted to developing technologies, knowledge and technical-scientific information aimed at Brazilian agriculture, including livestock
- **Founded:** 1973
- **Headquarters:** Brasilia, Brazil
- **Ownership:** State-owned and affiliated with the Brazilian Ministry of Agriculture
- **Employees:** 9,790

Milestones

1976
- Embrapa[3] established PROPASTO[4], a program that included **on-farm experiments of mixed legume-grass pastures** in Acre state

2000
- Implemented on 1 farm

2015
- Implemented on 2K farms and 137 K Ha (average farm size of ~68 Ha)

2019
- Embrapa launched a new variant of the forage peanut, BRS Mandoboi

Activities

Reducing methane emissions by 20-25%

- **Methane** is produced as a **byproduct** of the **digestion of complex carbohydrates** such as cellulose
- **Increasing** the share of **easier-to-digest sources of carbohydrates**[1], such as in some tropical plants, is an effective way to **reduce methane emissions**
  - Additionally, legumes also fix nitrogen, which reduce costs and increase protein concentration on pasture
- **10-25%[(a)] decrease in methane yield**[2] has been recorded with the **usage of tropical grasses and legumes** on cattle's diet

Driving large-scale adoption of mixed legume-grass pastures

- Between **2000 and 2015**, Embrapa promoted a forage peanut[5], a **successful case**[(b)] of large-scale adoption **of mixed legume-grass pastures**
- **Cost:** CAPEX of ~R$1.3K - 2K per ha, and yearly OPEX of ~R$100 per ha
- **Productivity:** 1.5x productivity increase[7] after ~3 Years
- **Profitability:** ~R$ 300 – 400 of yearly profit per Ha (8x the ~R$ 40 baseline profit); break even in 2 – 4 years

Note: (1) Source (a) indicates that the methane reduction is related to the presence of tannins, saponins and starch (2) g CH4/kg of dry matter intake (3) Brazilian Corporation for Agriculture Research (4) Program for Reclamation, Improvement and Management of Pastures in the Brazilian Amazon (5) forage peanut cultivar Belomonte (Arachis pintoi) (6) as estimated by source (b), at 2018 prices; Doesn`t include cost of technical assistance. Includes transportation of inputs, increased labor, costs from fencing and the implementation of rotational grazing. (7) Meat carcass per hectare per year. There were also improvements in stocking rate and slaughter age (source (c)) | Source: (a) Ku-Vera et al. (2020) (b) Zu Ermgassen et al. (2018) (c) Embrapa

“The challenge for adoption of feed additives is creating a compelling economic case for farmers; for now, downstream players will drive momentum”

Feed additives alter cattle’s digestion, reducing CH_4 by up to 40%; impact varies widely between additives

- **Feed additives** are **usually mixed** into the **TMR**[1], thus being inadequate to “pure” grazing systems
- **They alter cattle’s digestive microbiome** and methanogenesis, reducing emissions
  - They also can provide health and productivity benefits

Feed additive	Methane reduction
3-NOP	~40%[g]
Lemongrass	~33%[f]
Nitrates	~26 – 32%[d]
Probiotics	~20%[h]
Vegetable oils	~12 – 18%[d]
Ionophores	~0[a] – 15%[b][c]
Tannins	~10%[k]

Availability of low-cost additives to producers may take decades, and long-term impacts are not proven

- **Sheltered cattle troughs** are the **main infrastructure needed,** and these are accessible, however:
  - **Costs of feed additives are prohibitive**[d] for most producers, so they **won’t be viable at scale until the prices are lowered** and/or **producers increase profits**
  - **Ionophores** have been **used since 1970s**[j] and yet **are not affordable** for most producers on grazing systems
  - E.g., 3NOP could cost ~$100 per ton to administer, Ionophores could cost ~$20 per head to administer
- Cost is not the only challenge, though:
  - **Long-term impacts are not yet proven** – feed additives may only have short-term benefits
  - **Dosage is critical** and implementing it correctly is especially **challenging on grazing systems**[e], which account for >80% of production[i]
    - E.g.: incorrect dosage of nitrates can lead to hypoxia, dyspnea and even death of the animal[d]
  - **Research and applicability** on tropical settings is **not well -established** [2] [d][l]

Note: Title quote is from Kosta Stavreas, Chief Commercial Officer, Rumin8; (1) TMR = Total Mixed Ration. Ionophores can be used in “pure” grazing systems (2) E.g.: Source (e): practices to apply nitrates are complicated in pastoral systems in the tropics, since forage quality varies with season; Source (c) “the application of ionophores in grazing systems is not widespread, because most of these operations are not equipped with the resources required (bunks, carrier feed, trucks, labor, etc.)

Source: (a) Dallantonia and Berchielli (2023) (b) Appuhamy et al. (2013) (c) Marques and Cooke (2021) (d) Ku-Vera et al. (2020) (e) Embrapa (2015) (f) Vázquez-Carrillo et. al (2020) (g) Araújo (2020) (h) Pittaluga et. al (2023) (i) ABIEC (2022 - page 42) (j) Embrapa (2006) (k) FAPESP (2022) (l) Congio et al. (2021), Corporate interviews

3NOP Example: For example, 3NOP at feedlots has shown emissions reduction potential with minimal impact on consumers but requires operational change

Intervention	**3NOP at feedlot**	-30% CH_4	A feed additive that blocks formation of CH4 in cattle rumen, administered with routine supplements		Currently approved for use on dairy cattle in the EU, and expected to be approved by the FDA in Q2 2024	
Example end-to-end improvement	Input providers	Cow-calf	Feedlots	Packers	Demand channels	Consumers
Economics (costs)			• Spend ~$50 / head on 3NOP and receive (at least) ~$50 more when selling steer (3% increase in operating costs, recouped)	• Pay ~$50 more per steer, or ~$6.25 more per primal for output (3% increase per primal)	• Pay 2% more per lb., or ~$0.08 per case-ready item	• Pay <1% more, or $0.02 per 0.25 lb. burger
Operational / behavior change	• Manufacture 3NOP and set procurement mechanism with purchasers	No change	• Feedlots incorporate 3NOP into diet, with routine mixed rations	• Packers adjust operations to accommodate 1 sort or 1 shift of cattle • Systems developed to keep cattle separate from arrival and segregated during processing	• Retailer develops strategy (e.g., new marketing or labeling) to pass cost through to consumers	• Consumers opt to purchase sustainable beef
Verification	• Invoice documents purchase of sustainable input by feedlot	Not required	• Cattle are penned and handled separately • Cattle receiving 3NOP in rations are tagged with a unique identifier (e.g., RFID ear tag)	• All beef from 3NOP cattle tracked (e.g., barcoding system for all parts) from processing to boxing	• Retailer leverages packer records for validation, markets / labels product as sustainable	• Consumer trusts sustainability labeling

Economics are inset

Significant change for several stakeholders

Traceability required

Source: Lit. search

Early studies indicate red seaweed feed additives can also inhibit production of methane in digestive systems

Red seaweed was seen to reduce methane production

- Red seaweed, also known as **Asparagopsis taxiformis (AT)**, contains a natural compound called **bromoform**, which can **inhibit the production of methane** in the digestive system of cattle
- Studies show **varying results** from **9% to 98%[2] reduction in methane emissions**, depending on amount administered, duration of experiment and cattle breed
  - 0.5% AT shows the best results, **ranging from 26%[4] to 75%[1]** reduction

There are scientific and logistical limitations to widespread use

- There is a **limited number of studies** on the topic, specially considering **in vivo experiments**
- Red seaweed (AT) grows mainly in **Australia, New Zealand, Hawaii and the Pacific Islands**, making its availability and mass production a **challenge for global expansion**
- AT's **properties have a brief half-life**, losing its effects if stored for a long time[3]
- One study show **reduction in feed intake**, that may lead to weight reduction[4]

Results from academic studies vary

AUTHORS	Duration	Results (% of AT in feed)
Roque et al. (2021)	147 days (broken into 63 days, 21 days, and 63 days)	0.25% (Low), **50.6%**, **45%**, and **50.9%** reduction 0.5% (High), **74.9%**, **68%**, and **73.1%** reduction
Kinley et al. (2020)	90 days	0.05% (Low), **9%** reduction 0.10% (Mid), **38%** reduction 0.20% (High), **98%** reduction
Stefenoni et al. (2021)	112 days, broken into 4 periods; 28d total, 21d for adaptation and 7d for data and sample collection	0.25% (LowAT), no reduction 0.5% (HighAT), average **55%** reduction in CH4 in period 1 and 2; period 3 and 4 with no difference
Roque et al. (2019)	63 days, broken in 3 periods of 21-days each	0.5% (Low), **26.4%** reduction 1.0% (High), **67.2%** reduction

Note: For the development of this study, only in vivo experiments were considered | Source: (1) Red seaweed (Asparagopsis taxiformis) supplementation reduces enteric methane by over 80 percent in beef steers, Roque et al. (2021) PLOS ONE; (2) Mitigating the carbon footprint and improving productivity of ruminant livestock agriculture using a red seaweed, Kinley et al. (2020); (3) Effects of the macroalga Asparagopsis taxiformis and oregano leaves on methane emission, rumen fermentation, and lactational performance of dairy cows, Stefenoni et al. (2021); (4) Inclusion of Asparagopsis armata in lactating dairy cows' diet reduces enteric methane emission by over 50 percent, Roque et al. (2019); Financial Times (2021)

Several promising startups are developing red seaweed-based methane reduction solutions

FutureFeed
Nature. Science. You.

- FutureFeed was born out of an **IP partnership** between **CSIRO**, **Meat and Livestock Australia**, and **James Cook University**

mla MEAT & LIVESTOCK AUSTRALIA · CSIRO · JAMES COOK UNIVERSITY AUSTRALIA

- FutureFeed **holds the global IP rights** to the technology of red seaweed as a supplement – they **promote the use Asparagopsis** across the globe through:
  - Research and development;
  - Certification and standards,
  - Providing regulatory pathways; and
  - Marketing
- There are **9 licensed companies around the world**[1] producing the supplement

BLUE OCEAN BARNS

- Blue Ocean Barns (BOB) is an American startup the sells **Brominata™**, a **red seaweed-based supplement** basef of AT
  - Brominata^{TM} is both **USDA Certified Organic** and **Generally Recognized as Safe** (GRAS)
- By 2030, BOB expects to **grow enough to supplement all 100 million cattle** in the US

Blue Ocean Barns production facilities

V0LTA GREENTECH

- Volta Greentech is a **Swedish greentech company** on a mission to **reduce methane emissions** from the world's **cows**
  - A **feed supplement** which when **fed at a daily dose of 100 grams**, **reduces** cows' enteric **methane emissions** by **up to 90%**
- The company is **developing a scalable, sustainable, and automated land-based** red seaweed **cultivation system**

World's first methane reduced beef launched in Swedish supermarkets in 2022

Note: (1) companies located in Australia, New Zealand, USA and Europe
Source: FutureFeed, Blue Ocean Barns, Volta Greentech, Lit. search

Companies launching feed additives are utilizing credit inset models to support economics at launch

	Elanco / DSM	Blue Ocean Barns	Mootral
Additive	• Bovaer is a **feed supplement that includes 3-NOP** and claims to **reduce enteric methane emissions by ~30%; awaiting US approval**	• Brominata is a red **seaweed-based supplement** made of asparagopsis that claims to **reduces enteric methane emissions by ~80%**	• Mootral is a **natural feed supplement** made of garlic and citrus extract that claims to **reduce enteric methane emissions by ~30%**
Credit system/ verification partner	• Credits will be posted on Athian, **a marketplace** that connects ranchers to credit buyers • Verification of credits is **not yet clear** • **Prioritizing inset** options	• Credits are **Verra certified and registered on the VCS registry** • **Inset and offset options** - credits have been **purchased by major CPG companies** outside the beef supply chain	• “CowCredits” are **Verra certified and registered on the VCS registry** • **Inset and offset options** - buyers include **U.S. coffee chains and a dietary supplement producer**
Emissions reduction validation	• Unclear validation mechanisms; potential methane emissions reduction factor supported by **trial results that used GreenFeed** machines for measurement	• Credits subjected to a rigorous validation process by an ISO-accredited third-party verifier, including **gas readings from GreenFeed machines**	• Methane emissions reduction factor calculated via **data supported by peer-reviewed publications**
Additional approvals / partnerships	• Bovaer is already available in Brazil, Chile, and Australia; **Elanco will be responsible for the US commercialization, approval process**, and product supply	• GRAS approved; authorized by the California Department of Food and Agriculture (CDFA) for **commercial use the supplement as a digestive aid**	• CowCredits are eligible under the **Carbon Offsetting and Reduction Scheme for International Aviation** (CORSIA)

Source: Blue Ocean Barns; Farm Progress; Ministry for Primary Industries; Mootral

Anti-methanogen vaccines have been studied for 20+ years and could come to market by 2030

agresearch
āta mātai, mātai whetū

Case Study: AgResearch

Company overview

- **Description:** AgResearch is a New Zealand based research center aimed at enhancing the value, productivity and profitability of the agri-food and agri-technology sectors
- **Founded:** 1992
- **Headquarters:** Lincoln, Canterbury, New Zealand
- **Ownership:** One of New Zealand's Crown Research Institutes (CRIs), which are corporatized government entities charged with conducting scientific research
- **Revenue (2022):** $107.4M

Technology overview

Anti methan-ogen vaccine

- Vaccine containing the **antigen will stimulate the animal's immune system**, which will create **antibodies**
- Antibodies will be **secreted into the saliva** and **enter the rumen** when the animal swallows
- The **antibodies will bind on to the methanogens and inhibit their function**, reducing the amount of methane formed

Activities

Building on decades of research

- Since the early 2000s, more **than 10 studies have been done**, both with in vitro and in vivo experiments, to understand if a **vaccine could be a viable way to reduce** cattle and sheep **methane emissions** – none have shown strong consistent positive results
  - Despite some having shown promising results, the **great variety in methods** is **impedes full comparison of results from different studies** in an appropriate and repeatable way
- **Benefits** of having a **vaccine solution** will be:
  - Low frequency intervention
  - Doesn't require a change to farm system
  - Vaccination is an accepted farm practice
  - No chemical residues in saleable products
  - Applicable to all farmed ruminants (cattle, sheep, deer, goats)

Showing a path to a vaccine

- AgResearch has seen that **antigens can result in a reduction of methane formation** in the test tubes
- AgResearch is currently **selecting among ~400 antigens for the vaccine;** the antigen needs to **inhibit the growth and function of the methanogens** in the rumen

Source: Lit. search

Organizations are investing in methane-absorbing wearables as a breakthrough technology to tackle enteric cattle emissions

zelp **Case Study: ZELP**

Company overview

- **Description:** ZELP (Zero Emissions Livestock Project) is a British startup, that has developed a methane-absorbing wearable device for cattle
- **Founded:** 2019
- **Headquarters:** London, United Kingdom
- **Ownership:** Private
- **Latest Funding Round (Series A):** $1M in September 2021

Technology overview

Methane-absorbing wearable for cattle

- ZELP's oxidation technology works by **routing the methane exhaled by cattle** through a **catalytic mechanism** arranged within a **patented energy recovery-system**

Activities

Reducing methane emissions

- The **methane gets oxidized**, resulting in a **combination of CO_2 and water vapor**, which significantly reduces its contribution to global warming
- The **energy recovery system**, allows the device to **repurpose the energy from the continuous methane oxidations**, greatly **reducing the need for batteries**
- Besides methane oxidization, ZELP's product also comes with **24/7 advanced herd monitoring technology,** enabling heat detection, welfare alerts, generating farm insights

Bringing tech to market at-scale

- ZELP technology will be **available for customers in 2023;** founder Fracisco Norris has said price may **start at ~$80/animal/year**, in a subscription model
- In **March 2023**, ZELP received a **USD $4.8M grant** from the Bill and Melinda Gates Foundation to develop its tech

Source: Bloomberg; ZELP; Bill and Melinda Gates Foundation

Selective breeding could also reduce 10-30% of methane emissions, but the availability of measurement technologies is a barrier to adoption

Finding the ideal cattle to breed requires the measurement of multiple metrics...

- Some cows have a higher **feed conversion efficiency** (FCE) - meaning they **absorb more energy from** feed; this characteristic ultimately increases the animal's weight and **decreases what is discarded as methane** and manure[1]
- Studies in Australia[(a)] and Ireland[(b)] suggest this selective breeding can reduce methane **by up to 24-30%**, while other studies [(d)] indicate an **impact of 10-20%**
- Careful measurement of "Residual Methane Emissions" (RME) requires monitoring body size, feed intake, and methane output **to ensure the right cattle are selected**

...however, measurement technology is at an early stage, bringing cost and logistical challenges

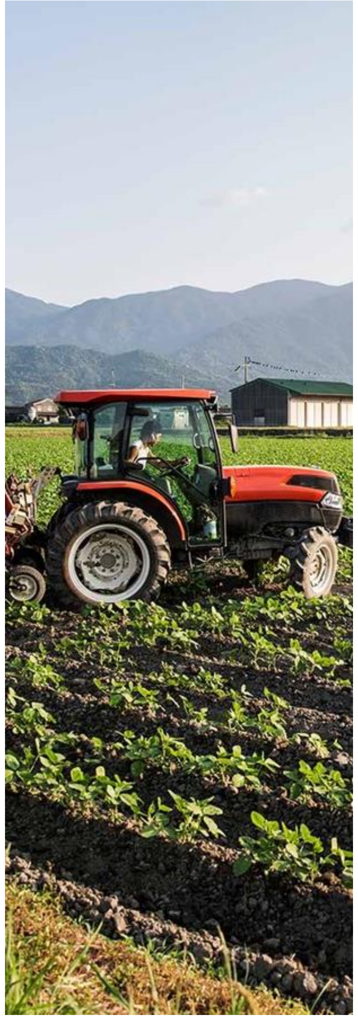
Methane emissions being measured by GreenFeed(b)

- **Options**[2] **for measuring** methane **at scale are limited**[(c)]
- Australian authority[(a)] recognized that **selecting for methane won't optimize production** and that it may not be in small producers' economic interests

Solution is promising, but the current state of measurement technology makes adoption infeasible in the short term

Note: (1) Jevons paradox might become a problem as source (a) indicates as a risk that "Increased feed conversion efficiency may result in an increased stocking rate, which may then increase methane emissions in total" (2) Besides options on source (c), Zelp's emerging tech claim to measure methane | Source: (a) Government of Western Australia (2022) (b) Irish Agriculture and Food Development Authority (2022) (c) Haas (2021, Animal – page 7) ; (d) NZACCC 2023

Administration of feed additives requires specialized feed systems and trained labor to ensure proper dosage but could be difficult for some grazing systems



*"**Measurement, monitoring, reporting, and verification (MMRV) is a big challenge** in administering feed additives. There are many technologies out there with many strengths, but they **each have fatal flaws as well – not the least of which is the trained labor required to use them.**"*

Chief Commercial Officer, Agri-food technology provider #1

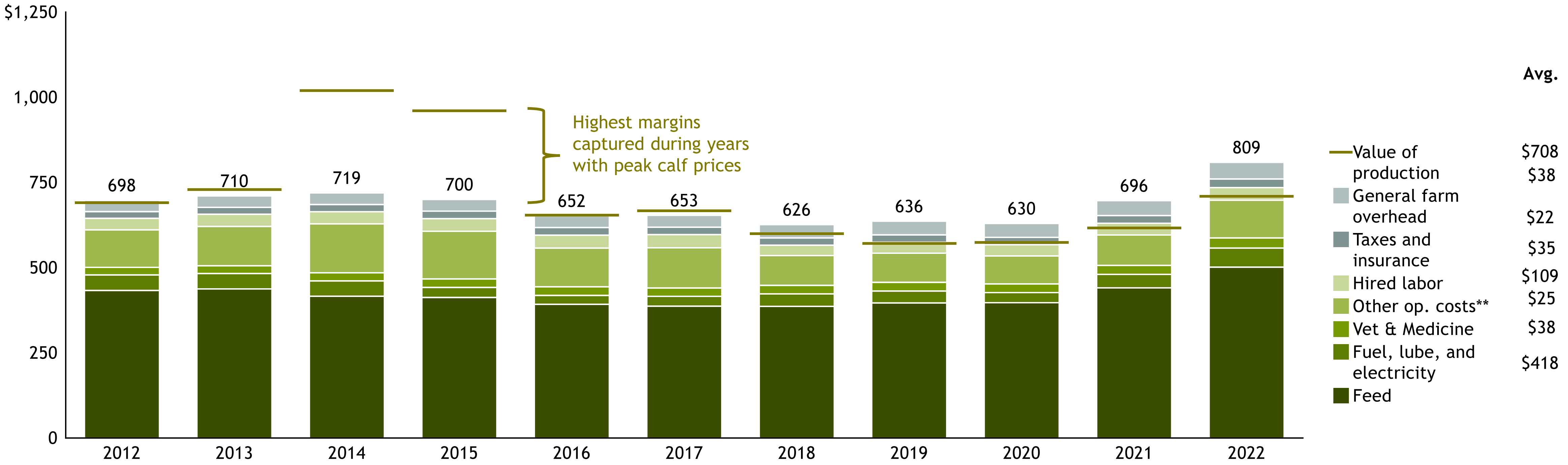
Source: Corporate interviews

However, cattle operations are often at or below breakeven – costs to manage emissions must be absorbed elsewhere in the value chain

Spotlight: US

Cow-calf operations returns, per cow* ($)

Excludes opportunity cost of unpaid labor, use of land, and capital recovery of machinery & equipment



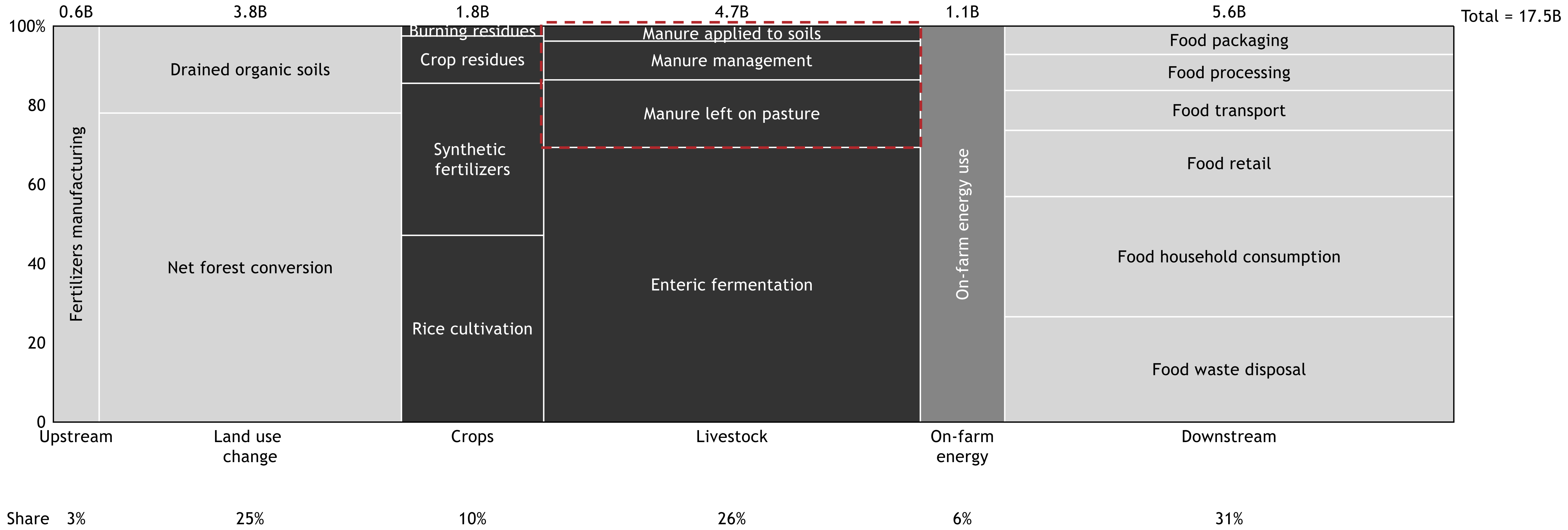
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Avg.
Gross margin	$80	$108	$391	$354	$97	$109	$65	$28	$39	$20	$12	$118
Net margin	-$7	$18	$300	$260	$3	$13	-$26	-$66	-$56	-$80	-$99	$24

Note: *Based on USDA survey of cow-calf operations with average annual gross production value of ~$700 per calf in 2022; stocker / backgrounders likely experience higher returns depending on size of operation. **Includes bedding and litter, marketing, custom services, repairs, interest on operating capital, costs assoc. with cattle for backgrounding
Source: USDA Cow Calf Return analysis

Manure emissions contribute ~35% of total livestock emissions, from leftover manure breakdown, anaerobic storage conditions, and suboptimal spreading

Legend *(from farmer perspective)* *Scope 1* *Scope 2* *Scope 3*

Global GHG emissions from the agri-food system (T, CO2-equivalent)



Note: Land use change and Farm gate emissions measured using FAO Stat emissions totals data; Pre- and post-production emissions measured using FAO Stat emissions shares data
Source: FAO Stat

Land owners and farmers are pursuing several practices to combat pasture-based emissions

/ NON-EXHAUSTIVE

LEVER	METHANE EMISSIONS MITIGATION: Stocking management	Forage management	CARBON EMISSIONS CAPTURE: Silvopastoral systems (SPS)
Mitigation mechanism (Not additive between levers)	**Avoids overgrazing** and **soil damage emissions**, while also improving **productivity, reducing methane emission per kg** of meat **Medium stocking is optimal** for carbon footprint (CF)[(b)] - **~3.3 AU[4]/Ha** was indicated[(b)] to be the one with the **lowest CF**, which is more than **more than 3 times**[5] the stocking rate of an **average pasture**	Similarly, **avoids overgrazing** and **soil damage emissions**, while also improving **productivity, reducing methane emission per kg** of meat **Rotational grazing** method seems[(f)] to be **optimal** in terms of carbon footprint[(a)(c)] - Pasture is **divided into paddocks** in which **animals are moved**, allowing for greater pasture recovery and nutrient supply[3] Grazing timing is critical. This way, **measurement and optimization of forage height** are important practices	Integration of **animal, pasture, and timber production** can compensate for enteric CH4 emission by **facilitating carbon storage as soil organic carbon and timber**[(e)] - It might also reduce enteric methane[(a)]
Mitigation potential[1]	**22 - 35%** CH4 reduction[2] [(a)]; with the **potential of temporarily being carbon sinks due to soil carbon sequestration**		Insufficient[(a)] evidence for enteric methane mitigation, but nascent research field suggests that **SPS can be carbon sinks**[(e)]
Implementation challenges	Low **capital** availability (savings and credit) Lack of specialized **labor and know-how**		**High upfront investments** with **long payback period**[(a)(d)]
Cost	**CAPEX[6]** of USD ~**$50 - 250** per ton Additional OPEX of ~$0, if know-how and qualified labor are in place		Highly contingent on context (biome, tree species, etc.)

Note: (1) Only some estimates are directly applicable to the Brazilian context (2) g CH4/kg of average daily gain (3) Source (c): "grass was grazed at the inflorescence emergence, providing the animals with a balanced supply of proteins, carbohydrates, vitamins and minerals" (4) 1 AU = Animal Unit = 450 kg of live cattle bodyweight (5) Pasture recovery and forage management are also needed for this impact (6) Includes machine rental for ploughing, application of inputs, electric fencing, installation of water system | Source: (a) Congio et al. (2021) (b) Oliveira et al. (2020) (c) Bartoni et al. (2022) (d) Arango et al. (2020) (e) Resende et al. (2019) (f) FCRN (2017) (g) US EPA / AgStar

Proper stocking and forage management can improve ranching carbon footprint by reducing enteric emissions and increasing carbon sequestration

Pasture management prevents overgrazing and raises productivity

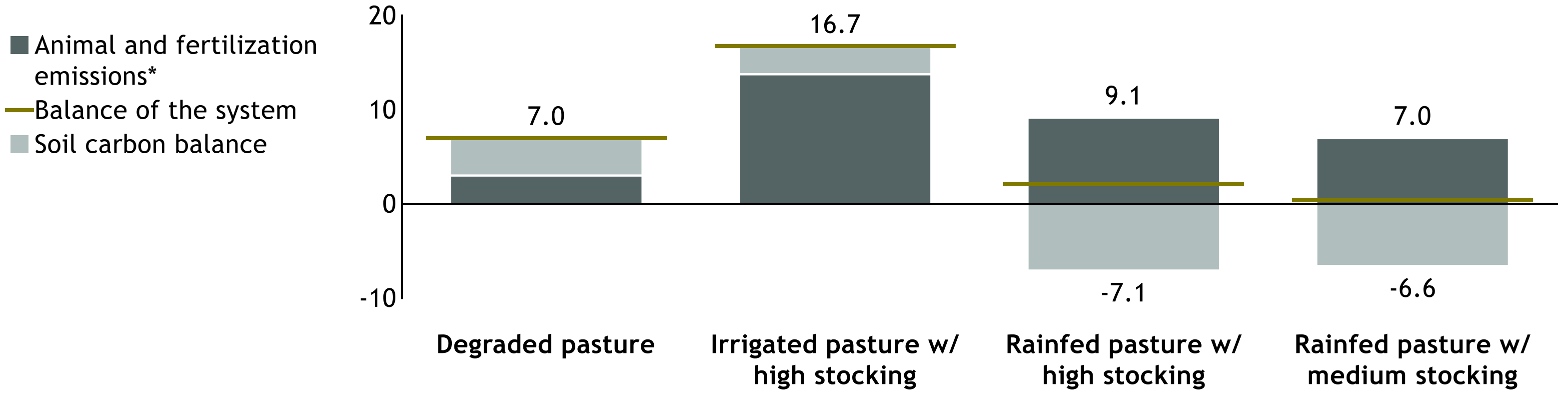
- **Overgrazing reduces** soil **carbon sequestration**

Image of an overgrazed pasture (d)

- **Proper stocking and forage management** can **prevent overgrazing** while also **increasing productivity**, leading to a **22 - 35% CH4 emission reduction**[1] (a)

Experiments(b) on the Atlantic forest indicate that stocking and forage management may improve the carbon footprint

Emissions by type of pasture in the experiment
(Tons of CO2eq per hectare per year(b); negative values = net sequestration)



	Degraded pasture	Irrigated pasture w/ high stocking	Rainfed pasture w/ high stocking	Rainfed pasture w/ medium stocking
Stocking rate (AU/Ha):**	1.4	6.6	4.2	3.3
Productivity (kg carcass/ha/year):	117	767	480	366
Grazing system:	Continuous	Rotational	Rotational	Rotational
Soil additives:	None	Lime, N, P, K	Lime, N, P, K	Lime, N, P, K

Note: (*) CH4 emissions from enteric fermentation, N2O and CH4 emissions from N fertilization and animal wastes (**) 1 AU = 450 kg of live bodyweight (1) g CH4/kg of average daily gain
Source: (a) Congio et al. (2021) (b) Oliveira et al. (2020) (c) Bartoni et al. (2022) (d) AG Canada (2017)

Silvopastoral systems (SPS) can increase productivity with net sequestration but are not financially viable

SPS store carbon and can increase productivity...

- SPS helps neutralize the impact of enteric CH4 emission by **facilitating carbon storage as soil organic carbon and timber**[(a)]
- Several experiments[(a)] in the Southeast of Brazil show **early evidence that SPS provides net sequestration of carbon**:

Studies	Resende et al. (2019)	Torres et al. (2017)	Rocha et al. (2017)[2]
Sequestration[3] (tons of CO2eq per hectare per year)	~2.7	~10.9 - 19.3	~2.8 - 8.0

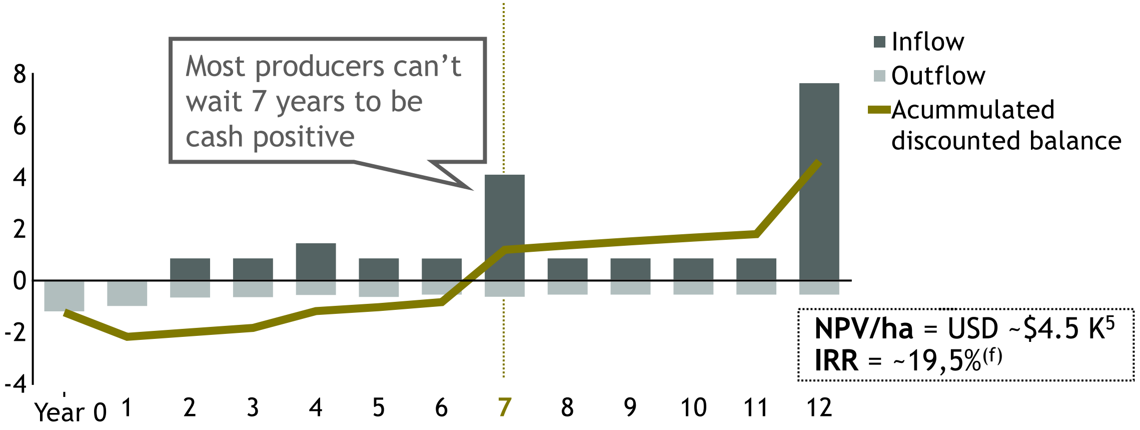
Image of a farm with SPS (e)

- Also, SPS can **improve animal thermal comfort**, thus **increasing the productive performance** of beef[(d)]
  - Thermal discomfort compromises food intake

... yet the related costs are prohibitive[(b)(c)]

- Studies vary widely, but most indicate **high investments over multiple years are needed to receive a meaningful return**[(f)]:

Cashflows of silvopastoral system - case study[(f)4]
(Thousand USD $ per hectare[5]; cattle beef and eucalyptus; farm in MT state)



- **SPS systems are premised on increased stocking rates, putting pressure on the need to deforest** additional land and make space for these systems

Note: (1) Paraphrase (2) Rocha SJSS, Schettini BLS, Alves EBBM (2017) Carbon balance in three silvopastoral systems in the southeast of Brazil (3) Metrics differ on the usage of C sequestration or soil organic carbon (source (a), page 10) (4) Adapted from source (f). These are not universally adequate figures, only directional ones. Thorough estimates are necessary for each context (biome, tree species, etc) (5) Corrected from 2014 to 2022 with IPCA | Source: (a) Resende et al. (2019) (b) Arango et al. (2020) (c) Congio et al. (2021) (d) Lemes et al. (2021) (e) IDB (f) Santos and Grzebieluckas (2014) (g) Embrapa (2014, page 282) (h) Revista Brasileira de Planejamento e Desenvolvimento (2018) (i) Gonçalves et al. (2021) (j) Schettini (2017)

Agri-food giants are reducing livestock emissions through feed additives and stronger manure management

Case Study: Nestle

Overview

- **Description:** multinational food and drink processing conglomerate whose products include baby food, medical food, bottled water, breakfast cereals, coffee and tea, confectionery, dairy products, ice cream, frozen food, pet foods, and snacks
- **Founded:** 1866
- **Headquarters:** Vevy, Vaud, Switzerland
- **Ownership:** Public (SIX: NESN)
- **Revenue (2022):** ₣94.424B

Targets

2023
- Reduce factory water use by 6M m^3

2025
- Reduce GHG emissions by 20% vs. 2018
- 100% deforestation free supply chains
- 20% of ingredients from regenerative agriculture

2030
- Reduce GHG emissions by 50% vs. 2018
- 20% of ingredients from regenerative agriculture
- 100% of key ingredients to be produced sustainably

Activities

Tackling enteric fermentation

- Working with external partners, **Nestle is exploring the use of feed supplements, wearable devices, improved nutrition and immunological approaches** that decrease enteric methane production, but do not negatively impact the yield of milk or animal welfare and health
- For example, in the United States, Nestle is facilitating research to assess the efficacy and the human, animal and environmental health and safety aspects of a **seaweed-based feed supplement, which has the potential to reduce enteric methane emissions significantly**

Streamlining manure mgmt.

- In parallel, Nestle is looking at **scientific approaches to reduce emissions related to manure management and feed production**
  - Nestle tests and validate technologies in their research farm network prior to rolling them out across supply chains.
- For example, in the United States, **Nestle is rolling out vermicomposting, which uses worms to naturally degrade manure with lower methane production** – replacing the need to capture and store the gas
  - The worms also remove up to 99% of wastewater contaminants and generate castings that can be used as fertilizer to improve soil health
  - This practice targets one of the largest sources of emissions on many dairy farms.

Source: Nestle, Lit. search

"Manure management is important but challenging - high density of cattle stock can lead to a lot of manure, but there's not a lot of hectares to spread it"

/ NON-EXHAUSTIVE

LEVERS	Anaerobic digestion	Solid storage	Manure drying practices	Decreased manure storage time
Mitigation mechanism	**Microorganisms** break down organic matter **in the absence of oxygen** Designs include covered anaerobic lagoons, plug flow digesters, and complete mix digesters	Storage of manure for several months in piles or stacks with a **dedicated storage facility** Typical in colder climates	Any method to **reduce the liquid content** of manure to achieve a solids content of 13% or more Commonly used so that the manure can be **stored or transported** easily	**Limiting amount of time manure is stored in anaerobic conditions** Suitable for warmer climates and farms with large land area
Relative methane reductions				
Behavior change and implementation challenges	Manure should be managed as a liquid or slurry and **collected as a single location** **Pretreatment** may be required to reduce the size of the feedstock and remove contaminants **Needs infrastructure** to process, transport, and destroy or use biogas and digestate products **Requires staffing** for regular maintenance and management May be subject to **permitting requirements** High initial **expenses**	Surrounding land needs to be **well-drained** with vegetated filter strips around the drainage area **Pest and odor control systems** are required Local and state **laws** dictate how manure storage facilities are **constructed and managed**	**Requires specific equipment and infrastructure** depending on the manure drying technique Must **optimize heat and volume of manure** to decrease drying time and ammonia emissions Must be **regularly monitored** so dry manure can be removed and fresh manure can be added to the system There may be local, state, or regional **permitting requirements**	Needs **sufficient and appropriate land to apply manure** (e.g., cropland, grassland, woodlands) May require **alteration of the farm's nutrient management plan** Must **schedule frequent land applications** for some crop rotations as we must **avoid frozen or wet ground**, which could cause runoff and water quality issues Increased land application requires **more dedicated labor**

Notes: Title quote from Director, Carbon Programs and Strategy, Agri-food provider #4
Source: EPA

“Biogas digesters can reduce emissions on farms quite significantly and provide a source of cheap and even free energy for local communities”

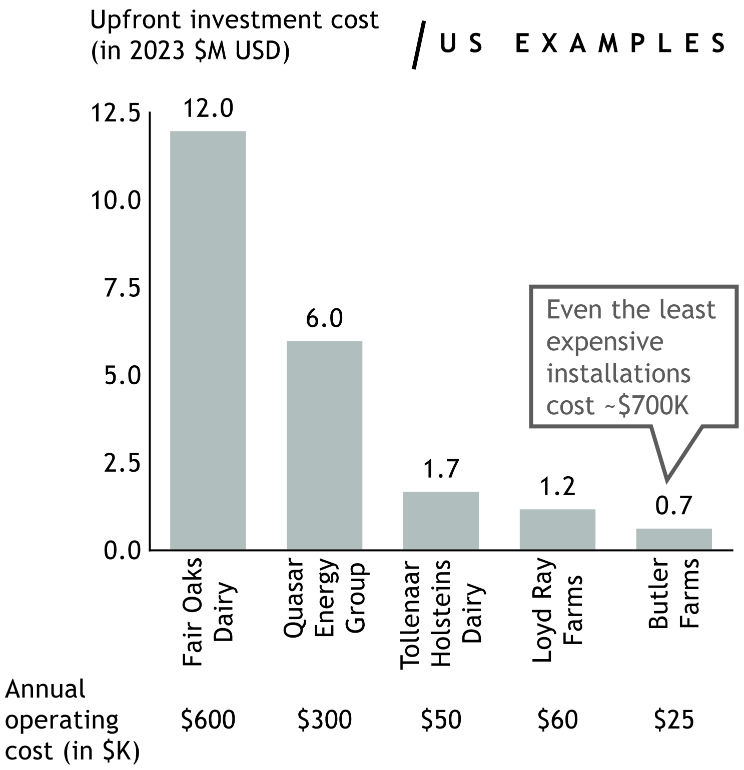
Biogas technology has been proven in agriculture…

- Biogas is **created when animal waste or manure decomposes**
- Biogas technology has been proven in food processing and water treatment
  - **In agriculture, biogas recovery systems are already used** at hundreds of farms and are technically feasible at thousands more
- Anaerobic digesters are closed systems that **capture the emissions from this natural process to produce biogas**
- Biogas recovery is **proven and easy to measure** compared to other emissions reduction solutions, providing **greater flexibility to secure financing to install**

…and has extensive benefits[1] for farmers and the climate…

- **Diversified farm revenues**
- **Rural economic growth**
- **Conservation of agricultural land**
- **Energy independence**
- **Sustainable food production**
- **Farm-community relationships**

…but requires high upfront investment and ongoing operating costs

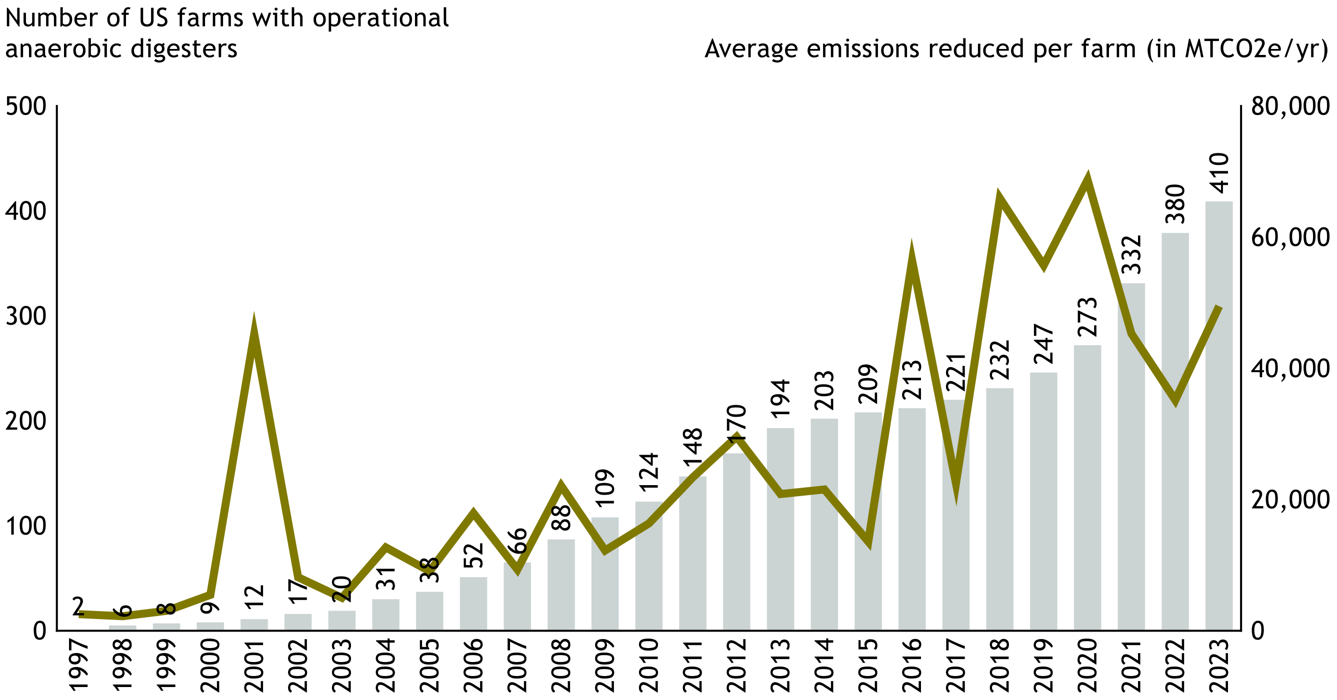


Note: Title quote is from Owen Bethell, Environmental Impact Lead Global Public Affairs, Nestle; (1) Details on each of these benefits in the appendix
Source: US Environmental Protection Agency (US EPA) / AgStar, Corporate interviews

As anaerobic digester adoption has increased over time, per farm emissions have declined

Spotlight: US

The number of US farms with operational anaerobic digesters grew at a 10% CAGR from 1997 to 2023, with average emissions reductions growing too



Share of total US farms that could adopt ADs	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	3%	4%	5%	5%

Source: AgStar Livestock Anaerobic Digester Database

Commentary

- Anaerobic digesters are **primarily adopted on dairy farms**
- With 10% CAGR of adoption, **emissions reductions achieved per farm also grew at a 12% CAGR from 1997 to 2023**
  - The efficiency and impact of anaerobic digester technology has improved over time
- While only ~5% of US farms have adopted ADs as of 2023, the rate of adoption has been **growing steadily over the last two decades**

Increasing production intensification, using feed additives, and adopting appropriate manure management practices will determine the rate of emissions reductions on the farm

Sustainably intensifying production

- **Intensifying production can reduce methane intensity** – particularly on dairy farms in developing markets, but producers lack the capital to invest
- **Low levels of specialized labor in remote areas and limited availability of technical assistance** make it difficult to transition practices
- **Interventions to sustainably intensify production vary by cattle operation, with centralized, concentrated, dairy and feed operations having unique needs from grazing, ranchland operations,** further limiting the ability to aggregate demand for specialized labor, formal education, or technical assistance

Using feed additives

- Enteric fermentation contributes ~45% of on-farm emissions; **feed additives like 3NOP have the potential to reduce methane by up to 40%,** but the long-term viability has yet to be proven and has not been verified
- Red seaweed, anti-methanogen vaccines, wearables, and selective breeding are the main emerging solutions to reduce enteric fermentation, but **technologies are still at an early stage, with viability at scale still unproven and costs prohibitively high despite questionable productivity benefits**
- Implementation requires a centralized feeding system and a trained workforce to ensure the right dosage, which **could prove to be difficult for certain types of grazing systems**

Addressing manure-based emissions

- Manure storage and spreading contributes 20% of on-farm emissions, with **solutions including proper spreading techniques, shortening storage time, and ensuring correct feed balance;** these require changes in practices, the buildout of enabling technologies (e.g., remote soil sensing), and capital to implement
- Anaerobic digesters that convert methane emissions to biogas can create valuable revenue streams for farmers, generate energy, and reduce emissions, but **these solutions are highly capital intensive**, ranging from ~$0.5M-$15M in initial CapEx in the US, depending on facility size

Governments must provide a balance of financial and technical assistance to a fragmented base of farmers and producers to encourage adoption of livestock emissions reduction practices

Providing resourcing for production intensification

- Farmers and producers need more financial support to justify the capital investments required **to pursue production intensification**
- Alongside direct funding and subsidies, **governments can aggregate demand from disparate farmers and producers to organize specialized labor trainings and offer technical assistance programs** that enable small operations to tap into communal resources

Scaling feed additives

- **Governments can provide direct funding towards R&D capital investments** in feed additives, red seaweed, anti-methanogen vaccines, wearables, or selective breeding practices to help dismantle technical barriers, demonstrate viability at scale, and bring down upfront and ongoing costs associated with these practices
- **In parallel, governments can provide specialized labor trainings to ensure farmers and producers can use the centralized feeding systems required** to administer proper dosages for many additives

Enabling stronger manure management

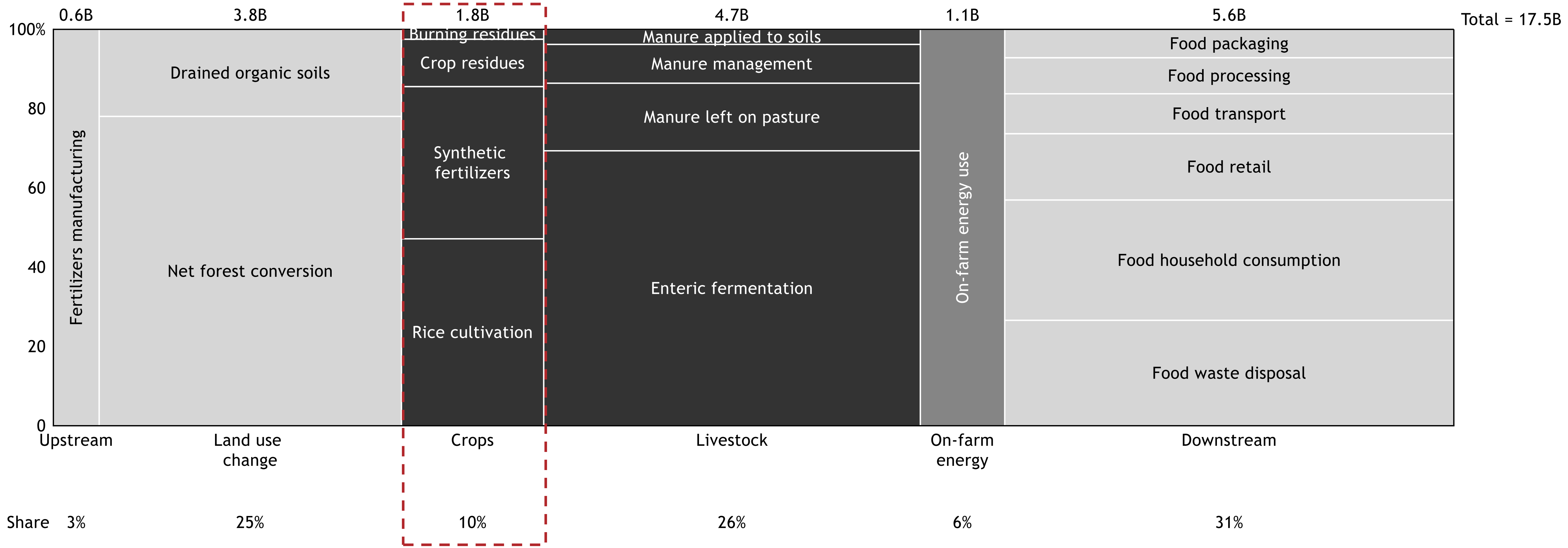
- Similarly, farmers and producers need more direction financial support to justify the capital investments required **to pursue certain manure storing and spreading practices, such as anaerobic digesters**

Agriculture: Table of Contents

On-farm crop emissions constitute ~10% of total emissions in the agri-food system

Legend *(from farmer perspective)* *Scope 1* *Scope 2* *Scope 3*

Global GHG emissions from the agri-food system (T, CO2-equivalent)

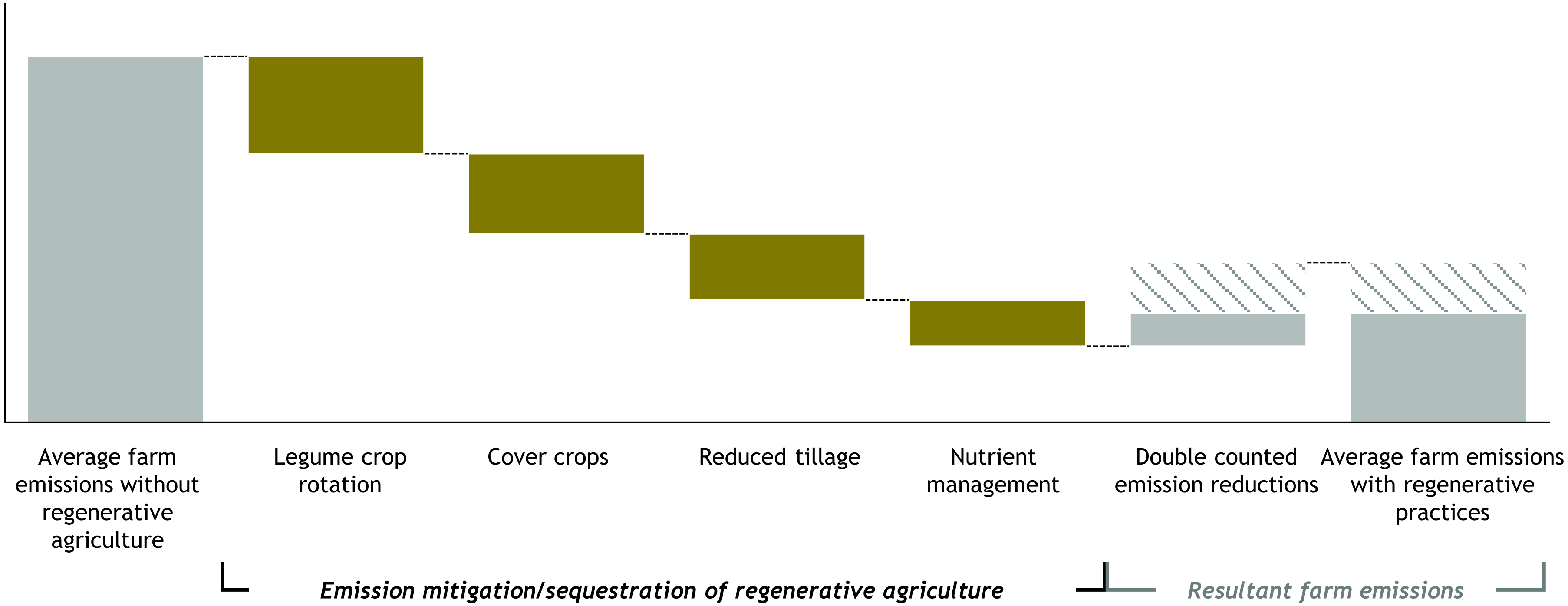


Note: Land use change and Farm gate emissions measured using FAO Stat emissions totals data; Pre- and post-production emissions measured using FAO Stat emissions shares data
Source: FAO Stat

Regenerative agriculture scales carbon removals, increases farm resilience and climate adaptation, and improves other environmental and social factors

Illustrative example of emissions reduction potential from regenerative agriculture practices

Average annual Ontario farm emissions and mitigation potential from regenerative agriculture practices per hectare by 2030[1] (tCO2e / yr / ha)



Additional regenerative agriculture benefits

- Regenerative practices such as no till farming and cover cropping **reduces erosion and water pollution**, producing healthier soils
- Biodiversity enables **added variety of crop** for surrounding communities and **greater resilience to market volatility and extreme climate events**
- Long-term, **farmer livelihood is increased** through reduced costs and improved crop yield and quality

Note: 1) Used the average CAGR 0.9% growth of agricultural emissions from 1990-2020 to grow the estimated per hectare emissions from 2011 data; 2) Estimates based on average cost observed across USDA EQIP practice scenarios across multiple states in combination with EQIP incentive rates and US Soil Health example farms; 3) Buffer year added to break even estimates
Source: Nature United, Master NCS Report, 2021; USDA EQIP Practice Scenarios; USDA EQIP Incentives; US Soil Health Partnership; World Economic Forum

Regenerative practices typically reduce yields in the short-term but result in long-term improvements in profitability

Case study context

- Published in 2018
- Assessed soil organic matter, insect pest populations, corn yield, and profit for each corn farm
- Sample of 20 corn farms across the United States
  - Farms were ranked on regenerative vs. conventional agriculture practices

Regenerative practices led to a 29% decrease in crop yield…

Farmers need time to learn and implement new practices efficiently

Soil being reconditioned to new practices results in disruption to the farm

Lower use of synthetic fertilizers and pesticides may result in reduced soil health and additional pest issues in the short term

However, regenerative farms were 78% more profitable than conventional farms

Fewer costly inputs, like fertilizers, and machinery for techniques like tilling, are needed

Certifications of **higher-value product** enable farmers to receive higher premiums

Diversified income streams from biodiversity allowed for better consistency of cash flows

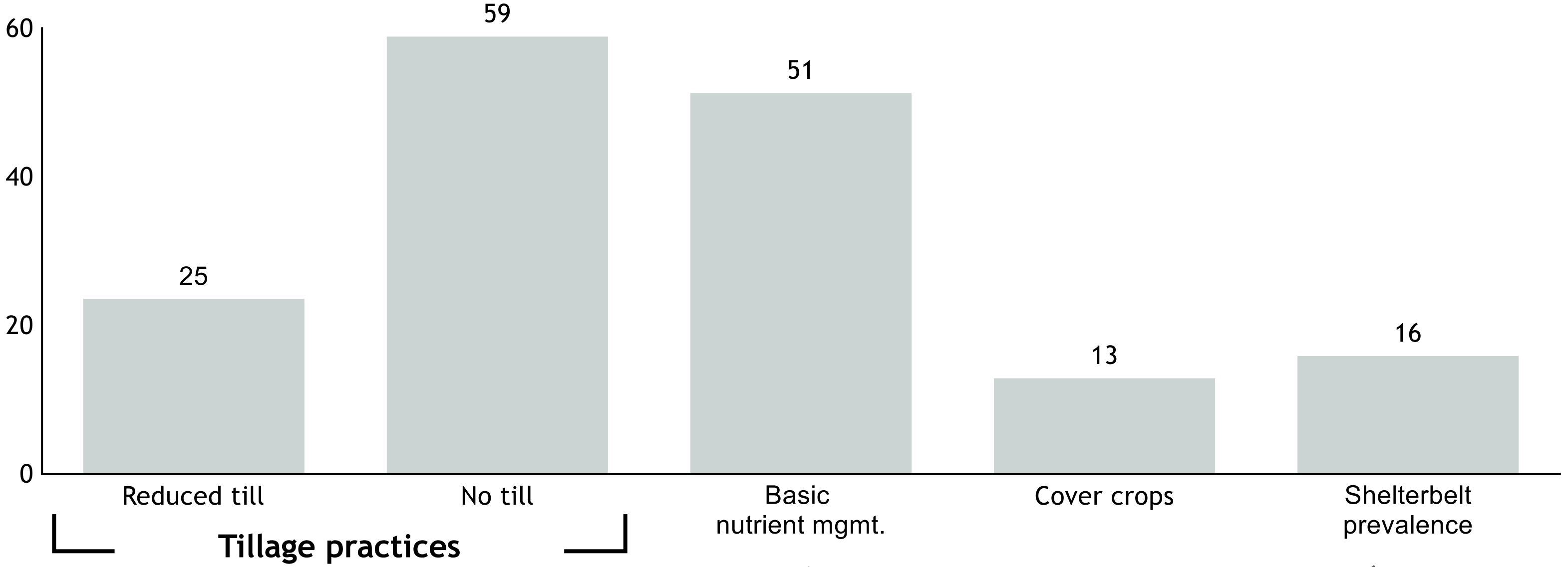
Short-term pressures outweighed long-term benefits and prevented farmer adoption due to high start-up costs or a lack of understanding

Source: LaCanne CE, Lundgren JG. Regenerative agriculture: merging farming and natural resource conservation profitably

Given short-term yield losses, farmer adoption of regenerative agriculture practices has remained low

No till has the highest level of adoption (60%); minimal adoption across other pathways

Current est. Canada adoption rates

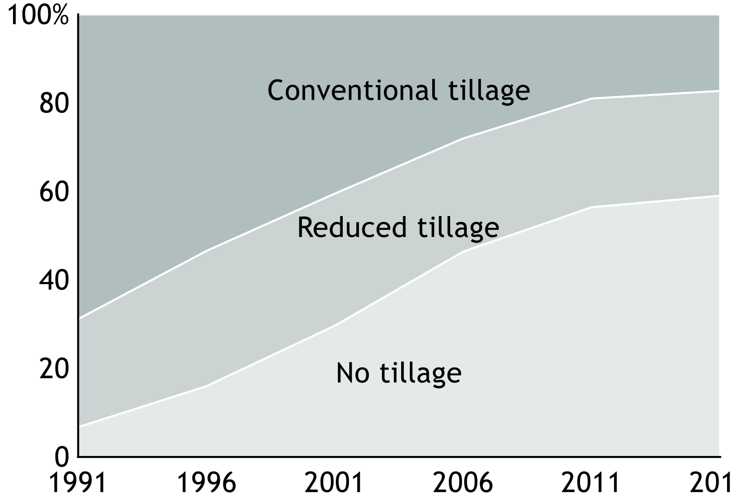


Bas: basic supply matching, limited monitoring, field level resolution
Int: monitoring, supply manipulation (variable in-field rate applications)
Adv: monitoring, extensive supply manipulation, sub-field resolution

% of operations that have planted or have shelterbelts

Reduced till practices are peaking

Percentage of cropland under specific tillage practice



'80s: new technologies (seeding + roundup) released, paired with erosion problems and political awareness

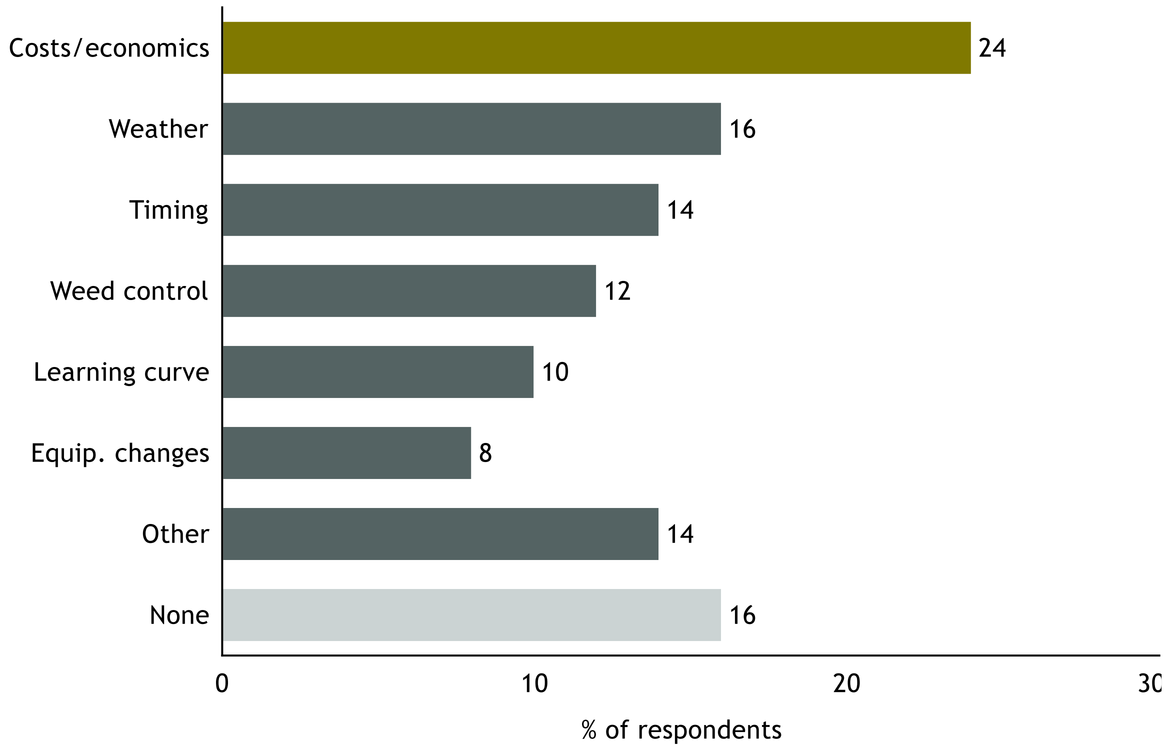
'90s: adoption driven by large farmer associations promoting yield benefits

Note: Adoption rates taken directly from Nature United report and may be misinterpreted
Source: Statistics Canada. Table 32-10-0408-01 Tillage practices used to prepare land for seeding; Top Crop Manager, Conservation tillage through the decades, Bruce Barker, 2015

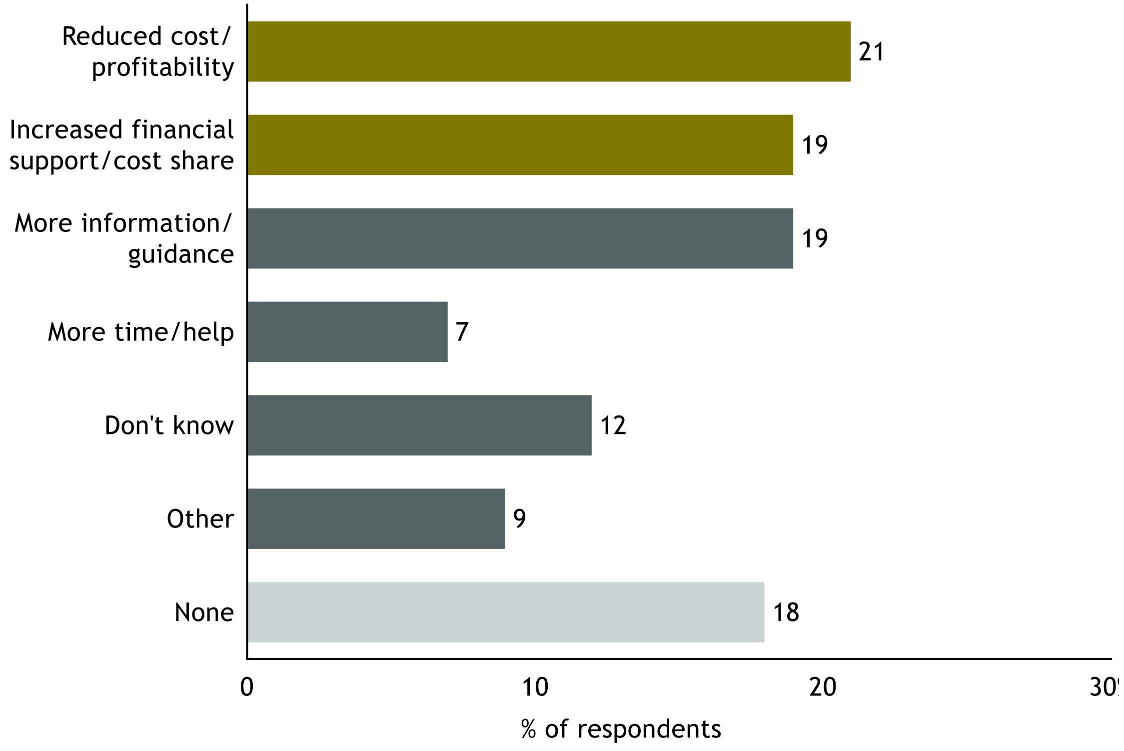
Farmers are unlikely to scale adoption if they are expected to bear all upfront costs and associated risks

Economic barriers are amongst the biggest challenges to regenerative practice adoption, according to a 2021 survey of Iowa farmers

Main challenges to soil health practice adoption



Farmer needs to adopt additional soil health practices

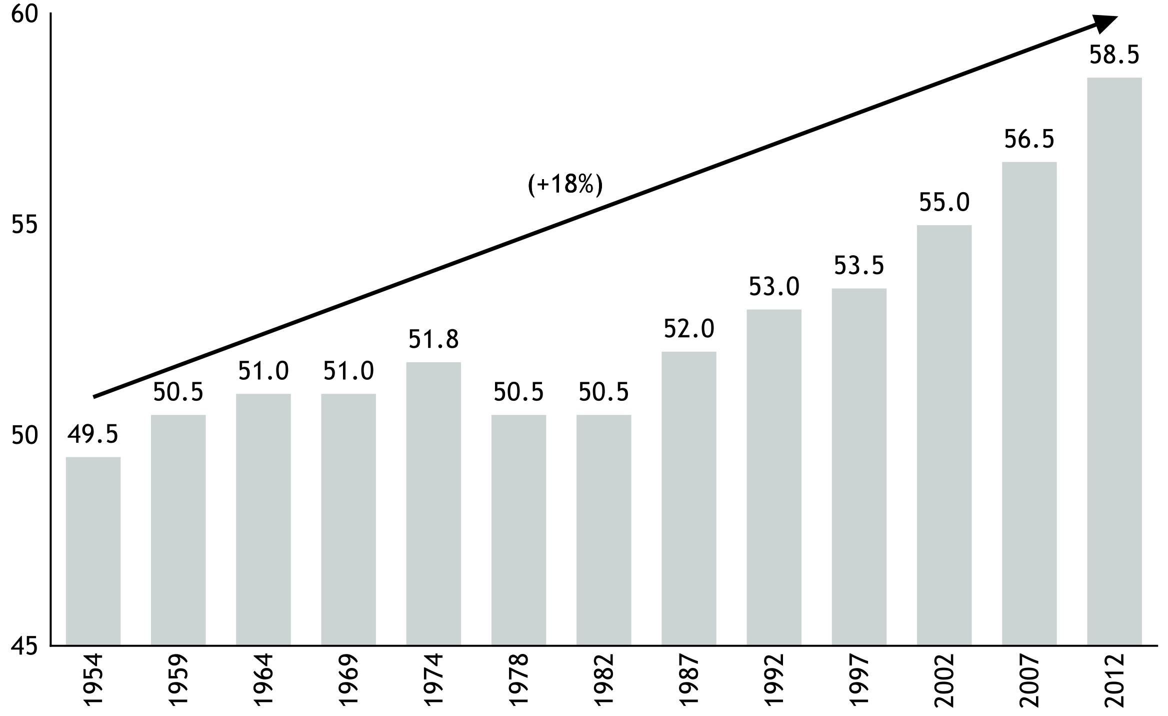


Note: 2021 survey of 100 Iowa farmers
Source: [1] The EDF; [2] Transforming food systems with farmers: A pathway for the EU (WEF, 2022); [3] New York Times – Companies' climate promises face a wild card: Farmers

Moreover, many farmers prioritize the short-term when managing operations, given an aging population and the prevalence of rented or leased land

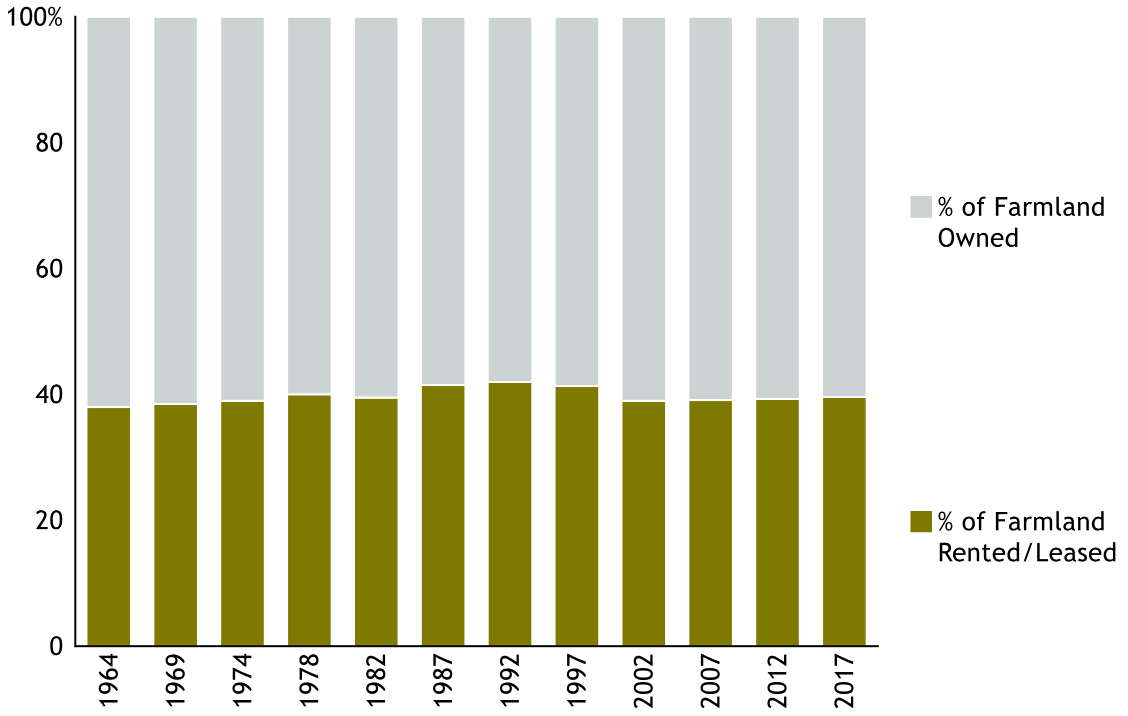
As farmers age, their focus on the short-term increases as they prepare for retirement

Average age of US farmers over time



~40% of farmers that rent or lease their land must prioritize payments to their landlord

% of US famland acres that are owned vs. rented / leased



Source: USDA; National Agricultural Statistics Service; Census of Agriculture

“Growers are not typically comfortable with new practices; we must bring the best available data to the farmer so they can make informed decisions”

Learning new skills

- Technical knowledge about regen-ag is **co-developed with research institutes**
  - **Social learning is crucial in dissemination of technical & experiential knowledge**, and is brought about by formally involving communities (collective decision making, establishing social norms etc.) and sharing early adopter success stories (increase in yield, reduction in cost etc.)

Access to inputs

- **Access to regen-ag compliant inputs** via co-operatives, NGOs & Government collaborations **enhances switching ease**
  - e.g., organic manure, HYV seeds for crop diversification, saplings for agroforestry, CRM machineries etc.

Favorable economics

- Improved farmer income and affordability via **productivity-boosting initiatives** (e.g., off-season crop diversification) enable smoother transitions even without incentives
  - **Tangible offtake commitments/ contracts** (e.g., upfront payment guarantees, volume commitments) builds long-term trust by helping farmers offset upfront costs **(increases affordability)**

Reliable yields

- **Demonstrated improvement in soil health, water table / quality etc.** and impact on yield and productivity enhances long term trust and social acceptance of practices
  - e.g., via regular soil testing, field surveys etc.

*“We don't have a pipeline of talent even if incentives were created properly. We've **trained everyone to be commercial**, **not necessarily conservation agronomists**. It is a very different skill set.”*

Director, Carbon Programs and Strategy, Agri-food provider #4

Convincing farmers to change their behaviors and build a resilient value chain is a long-term multi-step process

Note: Title quote is from Pivot Bio; Pre-monsoon dry sowing is a technique which facilitates sowing before monsoon enables growing 3+ crops in a year
Source: Lit. search, Corporate interviews

“There’s opportunity with new technologies, but the economic, data, and technical support capacity at a commercial scale doesn't really exist”

ESG considerations

- More volatile / cyclical weather events
- Pressure for decreased GHG emissions for Ag + Food
- Increased social pressure and regulation on crop inputs
- Net change in demand for biofuels
- Net change in demand for feedstock

Economics

- Proliferation of new ownership models
- Digital sales channels
- Diminishing returns of differentiation within/across sectors
- Consolidation/partnerships across value chain
- Continued grower consolidation
  - Disintermediation of owner & operator

Data analytics

- Continued need to minimize downtime/maximize productivity
  - e.g., predictive maintenance
- Need for agronomic decision-making support
- Need for documentation of farming practices
  - e.g., traceability, carbon sinks

Technology

- Growth in automated and/or autonomous equipment
  - Continued labor shortage challenges
- Electrification of farming equipment
- Potential push for shift in form factor/swarm farming
- Technology decoupled from base equipment

“We've got this hammer, and everything looks like a nail because we've only got 3 or 4 solutions that we're trying to apply to all situations - this has been true for almost half a century. We need to find ***opportunities to help farmers*** *decarbonize on a broader scale. They need more solutions that are* ***less capital intensive*** *upfront.”*

Director, Carbon Programs and Strategy, Agri-food provider #4

Multiple priorities and external pressures result in farmers having different financial needs, preferences, and risk profiles. There must be flexibility and autonomy about the practices they implement

Note: Title quote is from Director, Carbon Programs and Strategy, Agri-food provider #4
Source: Lit. search, Corporate interviews

Farmers would need to learn new skills to implement these practices, and lack both the willingness to change behaviors and access to technical assistance

*"We need the USDA Natural Resources Conservation Service (NRCS) to modernize its position to adopt a more systems-based approach. These changes will **help deliver key information to farmers about new regenerative agriculture practices and afford opportunities for stronger technical assistance that are critical to adoption."***

Pivot Bio

Source: Corporate interviews

Farmers don't have access to quality inputs and equipment necessary to scale regenerative practices

"Farmers don't have the same access to investments for regenerative agriculture practices, such as those focused on nitrous oxide compared to the programs available for soil carbon. In the same way the USDA has directed investments towards MMRV for soil carbon, ***they should do the same for other practices to ensure farmers have access to quality inputs and equipment necessary to scale regenerative practices for nitrogen management."***

Pivot Bio

Source: Corporate interviews

Moreover, the incentives that will drive down these costs for farmers often are unable to reach them due to the presence of intermediaries

Source: Corporate interviews

*"Only **one third or maybe 50% of the incentives** are **getting back to the farmer** who is tasked with making the changes. You've got so many other parties involved in creating the solutions (e.g., project developers in the voluntary carbon market). They're important for tracking progress, quantifying GHG emissions, etc because that's a **specialty that farmers certainly don't have**. It's not necessarily bad because obviously you want these companies involved, incentivized, and compensated, but it continues to be a challenge. **Farmers are ultimately fronting the capital** needed for the transition and are **seeing far less of that shared pie than they should.**"*

Director, Carbon Programs and Strategy, Agri-food provider #4

Strong ecosystem support and technical assistance can enable adoption of agroforestry

BCI Better Cotton Initiative

Spotlight: BCI

Overview

- **Description:** Better Cotton Initiative (BCI) is a non-profit, multistakeholder governance group that promotes better standards in cotton farming and practices across 21+ countries
- **Founded:** 2005
- **Production:** Accounted for 14% of global cotton production in 2017
- **Retail Partners:** H&M, GAP, IKEA, and Levi Strauss

Targets

Telangana
- Cotton is grown in ~**56% of the cultivated area** in the state

Issues
- **Mono-cropping and inefficient irrigation practices** have led to
  - **Soil erosion** and degradation
  - Decrease in **plant health and diversity**

Solution
- **Agroforestry** was identified as it can
  - **Prevent soil erosion** by limiting flow of rainwater and wind
  - **Increase plant health** by improving soil carbon content

Barriers
- Low availability of high-quality saplings
- High establishment costs
- Low tree survival rate

Activities

Annual technical trainings
- Refresher trainings were offered to provide the knowledge required for long-term behavior change and drop-off prevention
  - Ex: Annual refresher on sapling maintenance can improve survival rate

Organize external support
- Government operated private nurseries provided high-quality saplings
- Local implementation partners provided expertise and developed supply ecosystem (saplings at reduced costs)

Results

OUTCOME
- ~3500+ farmers adopted AF
- ~140k saplings planted
- 73% tree survival rate in first year

IMPACT
- 17% **reduction** in use of **synthetic fertilizers**
- 30% **fall** in **pesticide use**
- 7% **increase in yield**, 21% **improvement in income**
- 42% **decline in soil erosion**, 4.4kT CO2 sequestered

Source: BCI Study on "Better Cotton and Sustainable Land Management Telangana"

The financial sector is best positioned to manage many of the financial risks associated with introducing regenerative agriculture

Recap: Impact of adoption on farmer cash flows

Contract begins (Y0) | Practice adoption (Y1) | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y8 | Y9 | Contract ends (Y10)

Stack of services for farmers

New debt/ debt savings	• New debt to pay for capital investments (e.g., equipment) prior to adoption and ability to refinance debt on new terms • Loan terms provide attractive farmer economics (i.e., lower-than-market interest rate, relaxed underwriting requirements, etc.)
Crop insurance savings	• Enrolled farmers receive lower premiums contingent on practice adoption
Input cost savings	• Enrolled farmers receive discounts on input costs in early years of adoption
Additional farmer de-risking	• Add'l payments / guarantees are necessary to ensure that farmers' cash flow will never be reduced by adoption (e.g., pre-payment for credits for carbon, water, etc.)
Non-financial services	• Including substantive technical assistance and MRV at no cost to the farmer, centrally coordinated and conveniently delivered

Lines denote in which years the services are delivered

Note: For renters, changes in lease terms (e.g., longer term, renter incentives) may be needed to deliver this stack
Source: Lit. search

However, most regenerative ag initiatives lack participation from financial actors

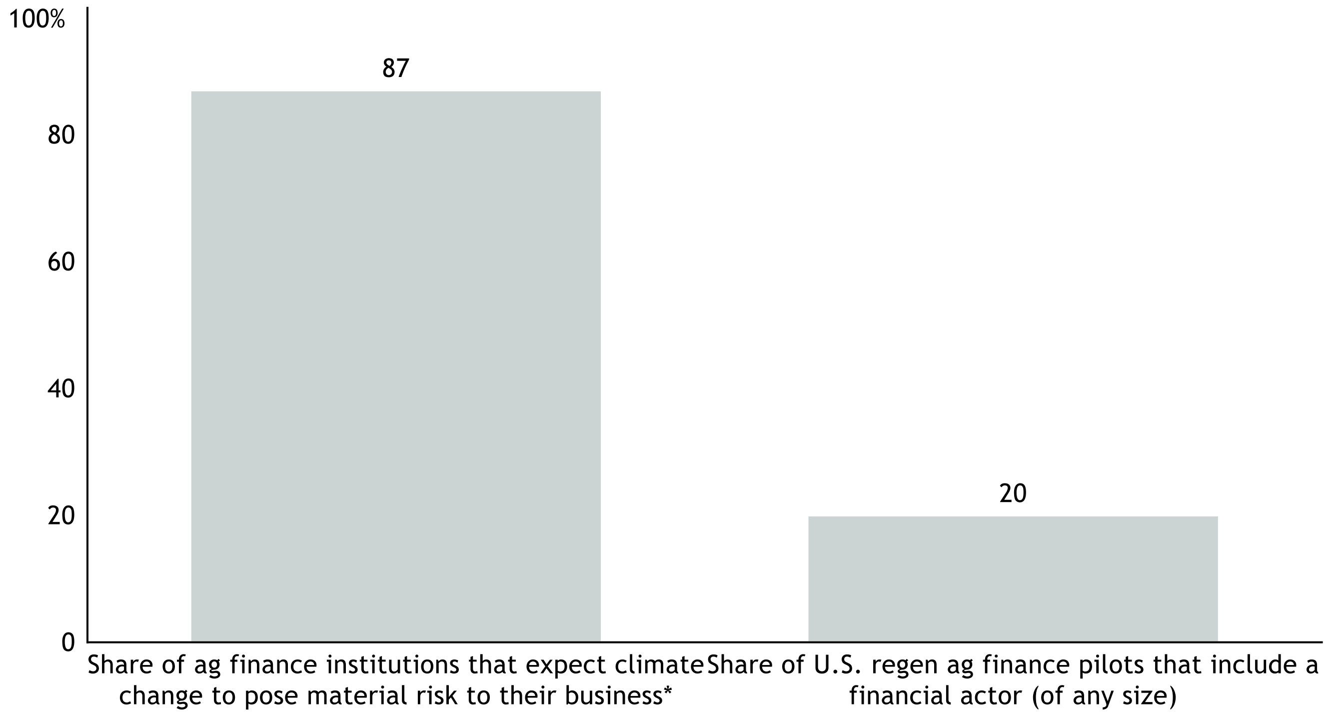
Ag lenders and insurers stand to gain from supporting farmer adoption of regenerative ag.

Lenders and insurers are facing **increasing physical risks** due to climate change

Geographic and sector concentration are increasing risk factors for lenders and insurers

Better soil health reduces risk from pests, droughts, and floods and creates **potential savings for lenders and insurers**

However, financial actor participation in regenerative agriculture initiatives is relatively uncommon

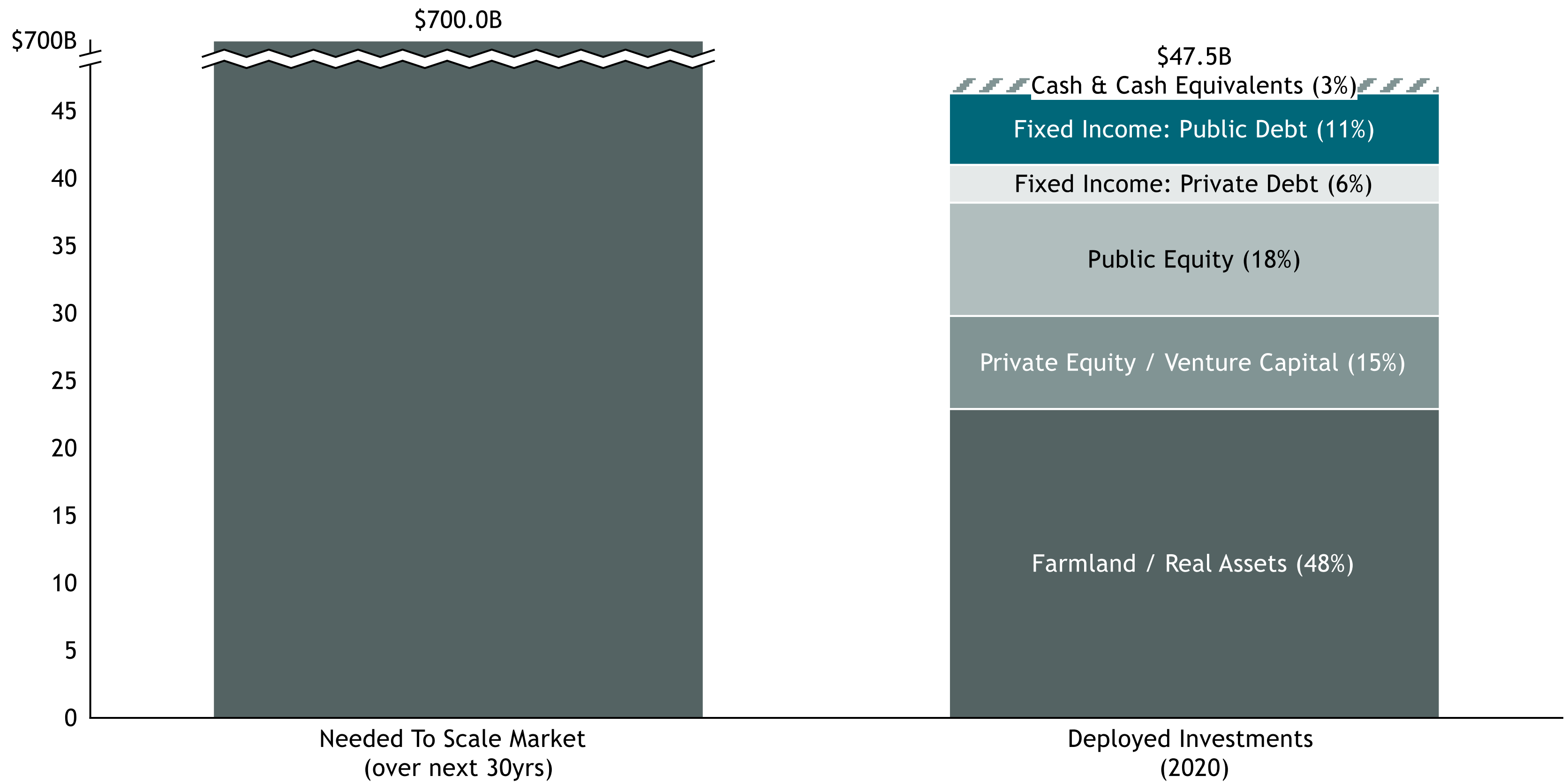


Note: *Global 2022 survey of 167 financial institutions, include 76 from the U.S.
Source: The EDF

As of 2020, only ~$47.5B had been funneled into regenerative agriculture investments in the US; ~$700B+ is required to scale adoption

Spotlight: US

Estimated investment needed and deployed in the US regenerative agriculture market ($B)



Notes: The $47.5B deployed investments had one or more criteria related to some facet of regenerative agriculture
Source: 2020 Soil Wealth Report; Croatan Institute

Commentary

- Deployed dollars only represent **~7% of what is needed** to scale regenerative agriculture in the U.S. over the next 30 years
- Anticipated net financial return is expected to be **nearly $10T** (~13x return) if all investments are made
- Farmland, cash, and fixed income were viewed as the best positioned for rapid development
  - This is because bank financing remains the leading form of financing farms and businesses in rural communities

"Every time investors talk to leadership about short-term results, they disincentivize investments needed for more sustainable practices"

The business case may be hard to prove (even when it is attractive)

- **Lack of adequate soil health data** makes it difficult to build a business case (U.S. actors lag non-U.S. peers in collecting relevant data*)
  - Some examples of necessary data includes:
    - Adoption indicators for a comprehensive list of practices
    - Regenerative outcomes (e.g., soil, carbon, water) using standardized metrics
    - Operational and economic outcomes for farmers (yield, costs)
    - Financial outcomes for lenders (probability of default, loss given default) and insurers (size and frequency of claims)
- **Insufficient coordination between food system participants** weakens economics for financial actors (e.g., demand from agri-food value chain players, government, farmers)
- Most U.S.-based agricultural financial actors have **no ag climate goals**; around half do not consider climate change in decision-making*

Government policy may limit the opportunities financial actors can pursue

- For example, in the U.S., the USDA dictates the terms of primary crop insurance policies and the premiums at which they can be offered

Actors may **fail to notice** opportunities, or **lack the necessary capabilities** to implement them

- Some financial actors may **lack expertise** in agriculture or sustainability **or resources** to pursue opportunities
- **Pre-existing beliefs** that investments in regenerative agriculture will be unattractive may deter exploration

Note: Title quote is from Director of Sustainable Business, Agri-food provider #1; *Global 2022 survey of 167 financial institutions, including 76 from the U.S.: Globally, 59% have not set ag climate goals (U.S., 89%); 23% do not consider climate change in decision-making (U.S., 46%); 66% of ag finance institutions report that they collect climate or weather data (U.S., 34%); 66% collect client production data (U.S., 41%)
Source: The EDF, Corporate interviews

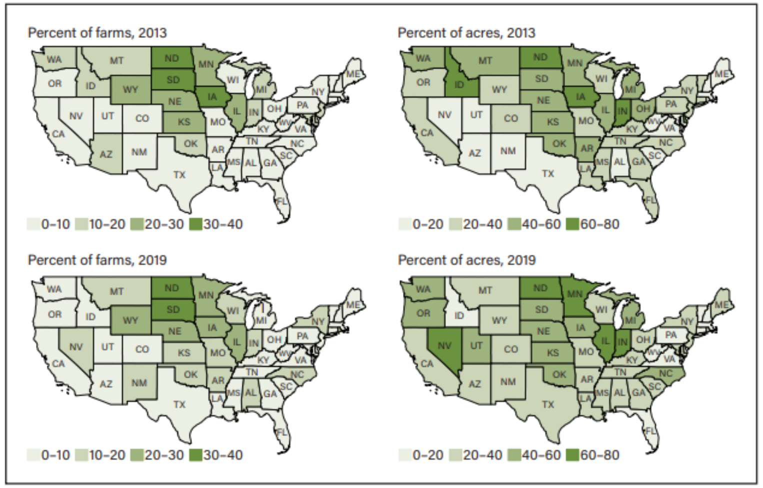
However, most monitoring and measuring technologies to improve data availability are cost prohibitive, resulting in varied adoption

One yield monitor and drone can contribute ~6-9% of an average US farm's total expenditure

Expenditure	Cost Type	Cost
Yield Monitor (per harvester)	Equipment	$8,051 - $13,775
	Annual fee	$1,041 - $1,772
Drones	Equipment	*$2,610
2021 avg total farm expenditure	Total	$196,087

Adoption is also varied due to farm size, crop type, and technological savviness of the farmer

Percent of total farms and total farm/ranch acres using GPS for on-farm production activities, 2013 and 2019



Note: The top panels depict the percent of each State's total farms and total farm/ranchland, respectively, in 2013, with operators who indicated they used GPS for on-farm production activities. Similarly, the bottom panel depicts these percentages for year 2019. Data are not available for Alaska and Hawaii.

While digital agriculture is correlated with larger farm sizes and higher crop yields, farmers are still hesitant to adopt; farmers need support in overcoming the technical, structural, and financial barriers of adoption

Notes: Cost data for technology was for corn and soybean farms only; *drone cost was provided in 2018 and has gone down since the data was collected
Source: USDA and Economic Research Service, *Precision Agriculture in the Digital Era;* National Agricultural Statistics Service

Carbon credits can help drive additional investment in regenerative agriculture practices

carbon by indigo **Spotlight: Indigo**

Company overview

- **Description:** Indigo is one of the leading soil carbon developers in the US. They develop projects for a variety of crops across 30 states and have strong relationships with large corporate buyers, such as Microsoft
- **Founded:** 2013
- **Footprint:** 8M global acres
- **Carbon Credits:** 133k issued

Strategy: Maximize Acreage

- **Objective:** Maximize acreage to build a robust dataset to improve their carbon modeling and reduce error
  - Indigo acquired Soilmetrix, a biochemical modeling company to process the data and model carbon projects
- Indigo started with key crops / geographies (e.g., the corn belt) because those regions had better data and where they could build acreage quickly
- **Contract Terms:**
  - Duration: Typically, renewable 5-yr contracts
  - Flat rate pricing: ~$20-40/cc up to 2cc/acre

Process

Farmers make practice changes

- By adding new or intensifying practices, farmers improve their soil health. **Agronomists support farmers** through the transition (e.g., assisting in identifying the right solution, execution, etc.)
- Practices such as cover crops, reducing tillage, and rotating crops **enable resilient soil and additional profitability**

Carbon credit generation

- Soil samples and on-farm data are collected and anonymized, with results securely shared for verification and credit issuance
  - Indigo uses proprietary software platforms, remote sensing, and farm management systems
  - Soil sampling and testing is done through the Soil Enrichment Protocol, co-authored and approved by Verra
- 3rd party verifiers conduct limited site visits and in-depth reviews of documentation, reporting, and quantification

Corps purchase credits

- Indigo facilitates the payout process, delivering **at least 75% of the average credit price directly to the farmer**
  - Indigo calculates size of credits, organizes verification, and sells credits to corporate buyers

Source: Lit. search; Indigo

However, carbon markets are limited to monetizing carbon, while many outcomes from regenerative agriculture go beyond that

01 02 03 **04 ON-FARM CROP EMISSIONS**

Benefits	Description
Carbon sequestering	• Regenerative agriculture practices **increase sequestering carbon at greater depths**, reducing the levels of atmospheric CO_2
Profit realization	• Adopting regenerative agriculture practices **generates profits for growers** without: – Adoption of organic farming practices and certifications – Requiring growers to command premium pricing
Organic matter increase	• Regenerative agriculture practices **increase soil microbiome health,** leading to: – Reduced fertilizer input costs (microbes can help fix nitrogen to crop roots) – Protection against pest infestations and fungal infections
Drought preservation	• Regenerative agriculture practices **enhance soil moisture, preserving yields** during drought years and **reducing water inputs**
Erosion prevention	• Adopting reduced till and no-till practices **reduces soil erosion from wind and water**

Carbon markets only incentivize a small portion of benefits regenerative agriculture provides

Source: Lit. search

“The challenge is that there are long value chains; it’s difficult to have real clarity on the sources of our supply chain”

01 02 03 **04 ON-FARM CROP EMISSIONS**

CPGs can play key roles

- Downstream buyers can help **mitigate farmer income risk by providing upfront financing** via scale purchase & upfront payment commitments, as well as providing access to favorable loans

Companies that have piloted supporting roles

Unilever, Nestlé, DANONE

…however, there are challenges

- **Time: Setting up a repeatable model can take 8-10 years** – initial onboarding and alignment of partners can take 1-2 years, with another 2-5 years required for stabilization
- **Data: Robust traceability solution and reporting** of different KPIs by company are crucial to onboard CP offtakers; this can be done by tracing sustainability at village/farm/farmer/product levels (e.g., by JDE, Danone)
  - **Satellite monitoring, sampling by agronomist**, field sensors and digital tools (e.g., Cool Farm) can be explored

...and limited returns on investment

- **Large CPGs have funded end-to-end projects for supply chain resilience;** however, market premiums were not sufficient to pay for regenerative agriculture practices (e.g., farmer incentives, additional input costs, etc.)
- Alternative funding models are likely needed, including carbon credits and loans

To setup the value chain requires engagement with **FMCGs** (e.g., approvals for resource mobilization), **partnering with aggregators** (for payments, logistics etc.), and deep **in-roads into farmer communities for effective traceability**

Note: Title quote is from Director of Sustainable Business, Agri-food provider #1
Source: Lit. search

Addressing upfront cost and income risk barriers of farmers can encourage behavior change

Spotlight: Unilever

Context

- Kenya faces **high (25%) malnutrition** due to droughts, mono-crop diets, and food insecurity
  - **Finger millet** was identified as a **nutritious and drought resistant** crop to tackle food insecurity
- **An end-to-end value chain** was set up for finger millets
  - **10+ partners** across the value chain
  - Farm to Market Alliance (FtMA) facilitated **on-ground GAP trainings and 1:1 interactions** with **800+ farmers**
- Enabled **self sustaining value chain** by prioritizing premium price organic products

Success factors for behavior change / Key Learnings

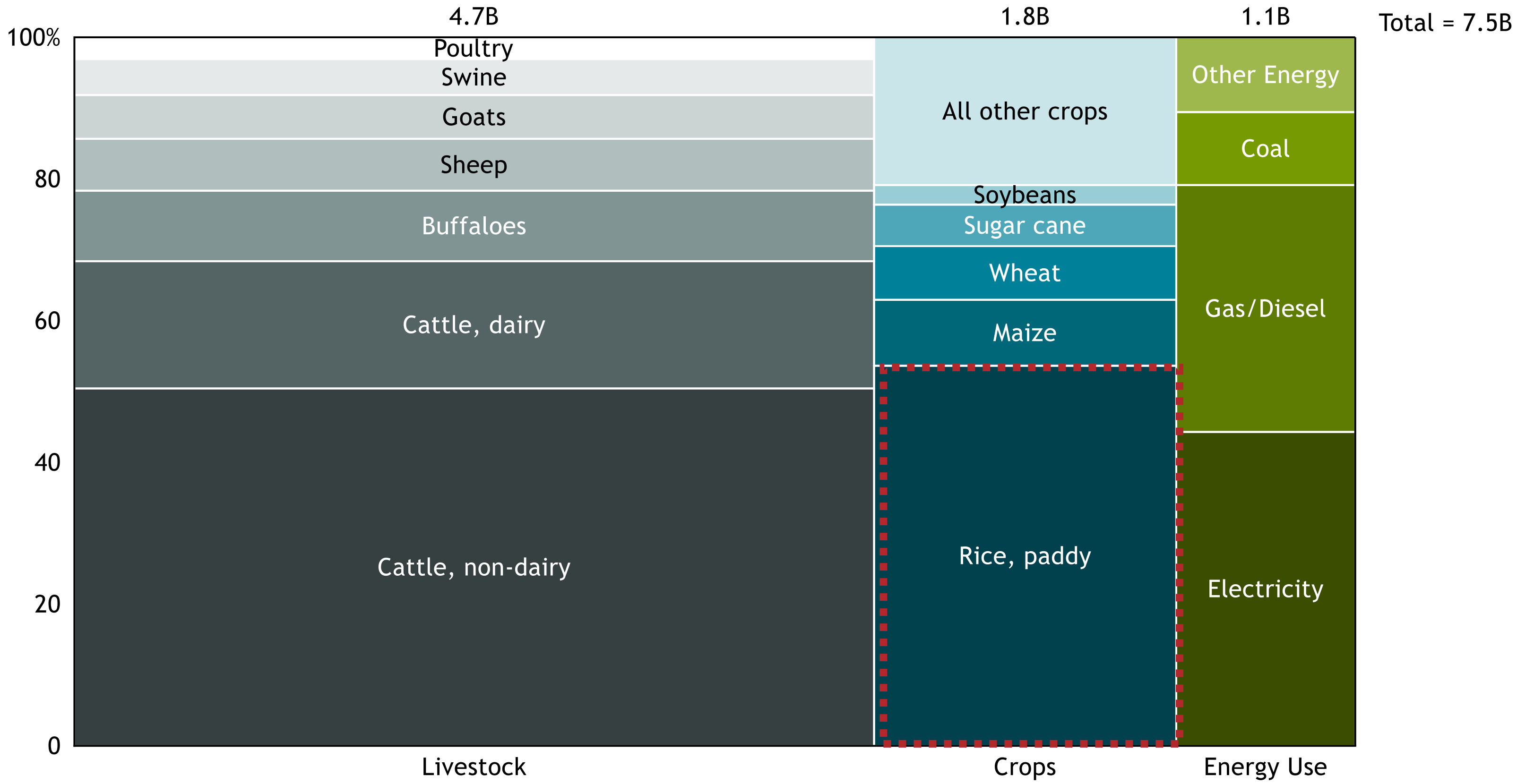
Success factors for behavior change		Key Learnings
Income risk mitigation	**Farmer-specific mobilization** and trust building	**Communicate pick-up and payment details** as early as possible (e.g., before seeds planting) to signal trust
	Price and volume guarantee	**Ensure early payment (based on estimated yield), volume guarantees at farmer level,** by involving CPG functions (e.g., procurement, finance) at start of operations
	Attractive revenues for farmers	**Fix farmer prices** in advance basis production **cost plus added margins** to ensure higher incomes
Accessibility and upfront costs	Collaboration partners providing **inputs at scale**	**Make offtaker commitments early to contact potential partners** (e.g., input providers) and organize enough input supply
	Input **credit financing**	**Ensure affordability** of necessary inputs (e.g., certified seeds, fertilizers) by establishing a robust financing mechanism **(e.g., asset-based loans, loans from local banks)**

To maintain farmer trust, important to manage product and financial flows from the get-go (by onboarding and aligning reliable aggregation partners)

Source: Unilever; Lit. search

Rice production constitutes >50% of on-farm crop emissions; methane is emitted from bacteria resulting from flood conditions required to produce rice

Global GHG emissions from the on-farm emissions (T, CO2-equivalent)



Source: FAO Stat, World Resources Institute (WRI)

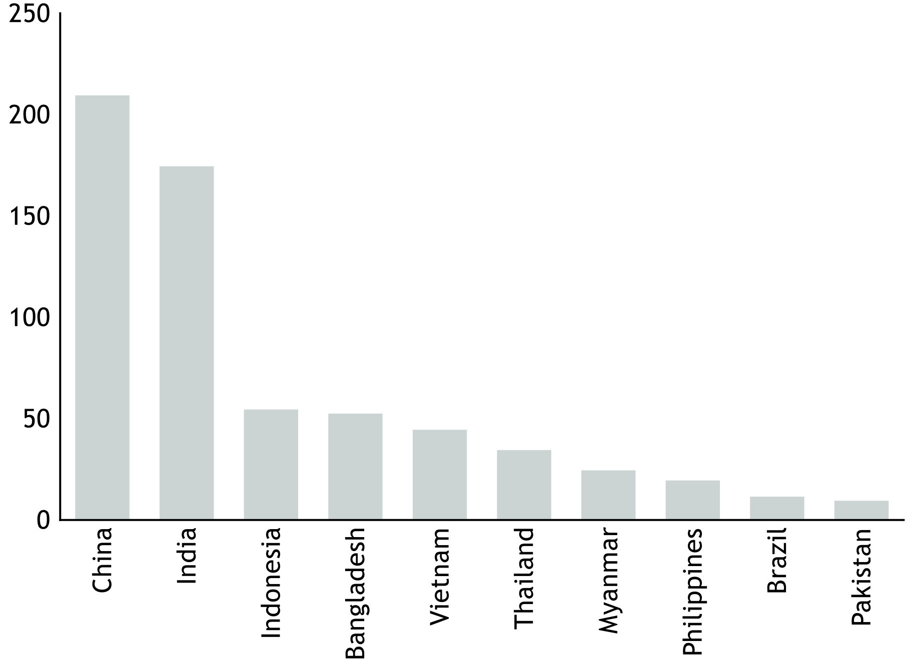
Commentary

- As a natural wetland, **flooding a rice field cuts off the oxygen supply** from the atmosphere to the soil; the result is anaerobic fermentation of soil organic matter
- **Methane is a major end product** of anaerobic fermentation
  - Methane is released from submerged soils to the atmosphere by diffusion and ebullition and through roots and stems of rice plants
- By contrast, **other staple crops like maize, wheat, sugar cane, and soybeans do not require flooding to grow,** so their relative emissions footprint is much smaller

Water management could reduce rice emissions by 90% with no effects on yield, but farmers lack irrigation infrastructure and incentives to change

Emissions intensity from rice production varies by geography

Rice production (in millions of metric tons)



	China	India	Indonesia	Bangladesh	Vietnam	Thailand	Myanmar	Philippines	Brazil	Pakistan
Emissions intensity (ton CO2e / ton of rice)	0.7	0.7	1.1	0.6	0.8	1.5	1.1	2.4	0.3	1.0

Source: World Resources Institute; World Bank

While water management techniques could address these emissions, there remain barriers to adoption

Water management techniques

- Single drawdown of water during mid-season
- Alternate wetting and drying (AWD)
  - Repeatedly interrupting irrigation, so water levels modestly decline below the soil level before reflooding
- Dry seeding
  - Practiced in rainfed and deep-water ecosystems
  - Farmers sow seeds onto dry soil surfaces
- Aerobic rice systems
  - Aerobic rice varieties are grown in well-drained, non-puddled, and non-saturated soils

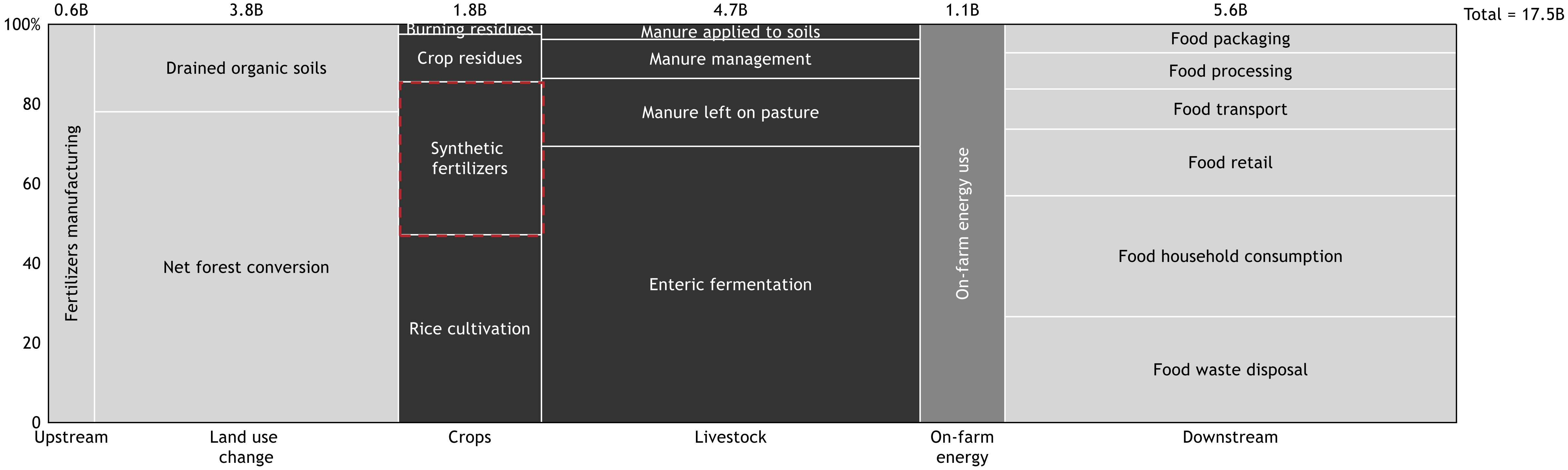
Barriers to adoption

- Water management techniques such as AWD requires **irrigation infrastructure to control water levels**
- **Limited information** regarding the relative cost-effectiveness of implementation in major rice-growing areas
- **Limited economic incentives** to improve water management, especially true in areas with water shortages where farmers have increased reluctance to drain their fields

Use of synthetic fertilizers contributes ~4% of total emissions in the agri-food system

Legend *(from farmer perspective)* *Scope 1* *Scope 2* *Scope 3*

Global GHG emissions from the agri-food system (T, CO2-equivalent)



Share	Upstream	Land use change	Crops	Livestock	On-farm energy	Downstream
Share	3%	25%	10%	26%	6%	31%

Note: Land use change and Farm gate emissions measured using FAO Stat emissions totals data; Pre- and post-production emissions measured using FAO Stat emissions shares data
Source: FAO Stat

Fertilizers are essential for global food security; increasing nitrogen use efficiency (NUE) is critical to address fertilizer-related emissions

Increasing NUE through best management practices is key to addressing GHG emissions from fertilizer use

- Fertilizer applications should synchronize nutrient supply with crop requirements and so **maximize the share of nutrients taken up by the plant, thereby reducing nutrient losses to the environment**
- However, **NUE varies significantly across the globe**
  - E.g., In France and the United States, NUE is >70%, while in China and India NUE is <50%
- A realistic ambition would be to improve average global NUE in crop production from around 50% currently to 70% by 2040, which **could save 190–370 Mt CO_2e in nitrous oxide emissions and 30–50 Mt of carbon dioxide in 2050**
- The changes in **practice required to improve NUE depend on local circumstances**
  - The fertilizer sector's 4R Nutrient Stewardship program sets out how to improve NUE by applying the right nutrient source, at the right rate, at the right time and in the right place to best meet plant needs
  - Farmers and nutrition advisers can use the 4R toolbox to select those practices that are most suitable to their site- and crop-specific conditions
- **Improving NUE does not only mean optimizing nitrogen management, but also other inputs**
  - Plants need access to the right mix of other nutrients, including phosphorus, potassium, sulfur, calcium, magnesium and micronutrients, as well as sufficient water, healthy soil and appropriate labor inputs
  - For example, phosphorus can improve plants' nitrogen uptake and biological nitrogen fixation, thus increasing NUE

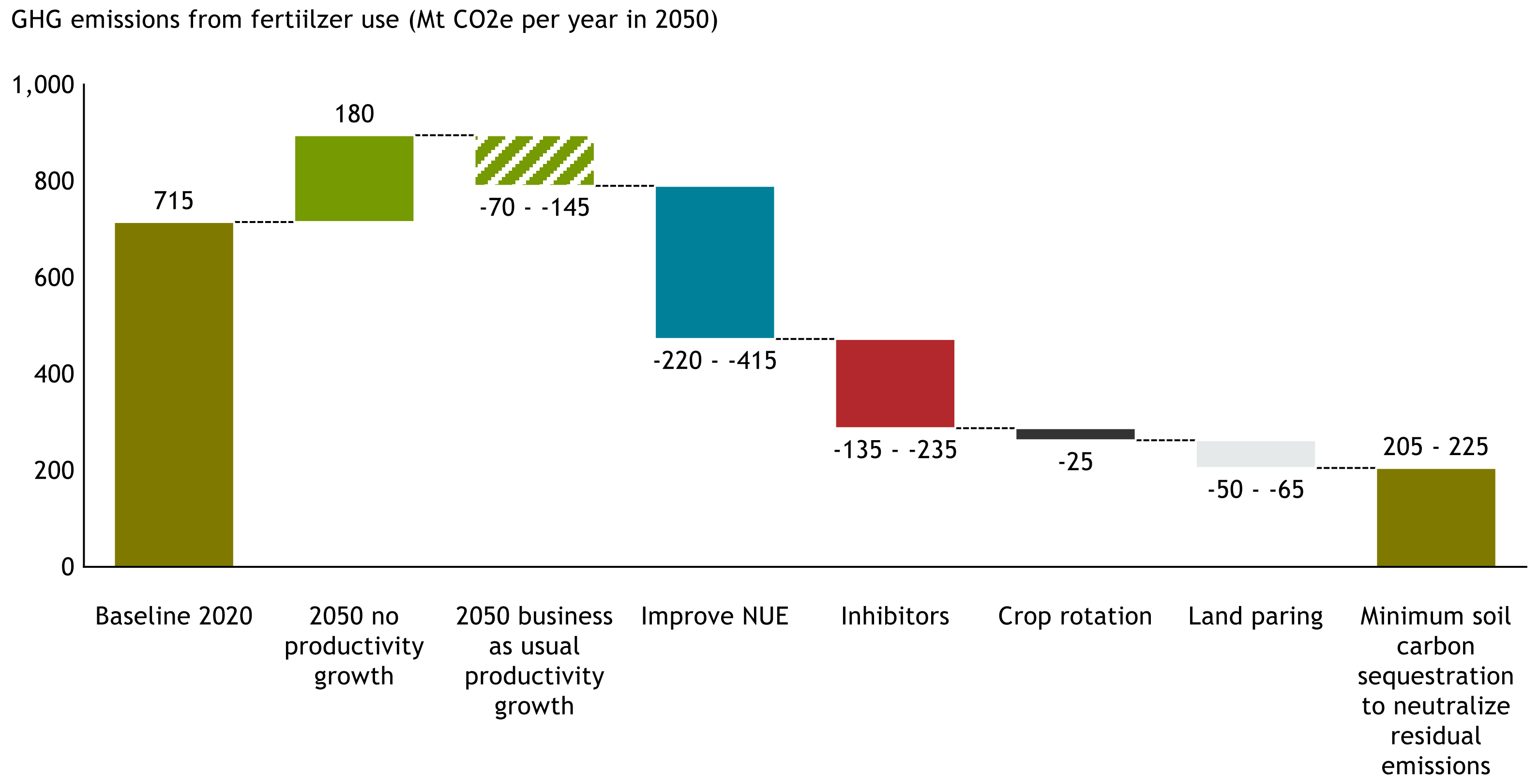
Inhibitors and controlled-release fertilizers can further reduce emissions

- **Urease and nitrification inhibitors slow the conversion of nitrogen fertilizer** to other nitrogen compounds in the soil
- **Controlled-release fertilizers help match nutrient release** with crop requirements
- **Further research and product development is needed** to make these technologies more affordable, to better understand the synergies between them, and to improve understanding of wider environmental impacts
- If these technologies were implemented with half of all fertilizer applied, it **could cut GHG emissions by a further 100-200 Mt CO_2e in 2050**

Source: September 2022 IFA / Systemiq report on "Reducing Emissions from Fertilizer Use"

Up to ~70% of emissions from fertilizer use can be addressed with a combination of these practices

Most fertilizer emissions could be addressed without soil carbon sequestration...



Source: September 2022 IFA / Systemiq report on "Reducing Emissions from Fertilizer Use"

...but crop rotation is also still needed

- Further reductions **will depend on a wider transformation of the food system**
- **Changing crop rotations to allow more biological nitrogen fixation could further reduce fertilizer use,** though it also requires a rebalancing of human dietary preferences and industrial processes towards increased consumption of such crops
  - Together, these actions could save a further 65–75 Mt CO2e in nitrous oxide and 10–15 Mt of carbon dioxide in 2050
- Measures to improve yield and reduce food loss and waste **would also reduce emissions from fertilizer in the future**

Solutions are available to enable a reduction in fertilizer use, but implementation ultimately depends on behavior change by farmers

"Many new technologies that are being introduced today fall outside standard definitions of conservation practices. USDA, their partners, and peer organizations globally will ***need to work in conjunction with growers to develop the right guidance and incentives to de-risk practice change on the farm and reduce emissions."***

Pivot Bio

Source: Corporate interviews

Economic, technical, and social barriers for growers, as well as improving fertilizer use will determine the rate of adoption for regenerative agriculture globally

Economic barriers for growers

- **Regenerative agriculture can remove carbon from the atmosphere while benefitting farmers** by increasing soil fertility and quality, controlling weeds and pests, improving yield resilience, and more, but adoption amongst farmers has been low
- While regenerative agriculture can increase yields, resilience, and cash flows, bearing the **economic risk for upfront financing, near-term losses, higher variable costs, and less-certain long-term upside** presents a substantial barrier for adoption

Technical & social barriers for growers

- **Many farmers would need to learn new skills to implement these practices,** and lack both the willingness to change behaviors, and the access to comprehensive technical assistance programs to support adoption
- Farmers, especially those in developing markets, **don't have access to quality inputs and equipment necessary to scale regenerative practices,** with accessing these farmers made even more difficult by lower rates of digital literacy, minimal internet connectivity, and the use of legacy analog systems

Improving fertilizer use

- The production and use of synthetic fertilizers generates nitrous oxide and carbon dioxide emissions, but **studies suggest that agricultural yields will not be sufficient to meet global food demand** without the use of synthetic fertilizer
- **Fertilizer use and resulting nitrous oxide emissions can be optimized,** given overuse, but the impacts of new technologies, such as controlled-release fertilizers, that could reduce these risks are not well understood and will require significant behavior change from farmers

Government can make a series of economic, technical, and social interventions to accelerate regenerative ag adoption

Improving economics for farmers

- **Farmers and producers need more financial support to help hedge against** the economic risk for upfront financing, near-term losses, higher variable costs, and less-certain long-term upside that today present substantial barriers to adoption of regenerative agriculture practices

Dismantling technical and social barriers

- **Governments can provide training and technical assistance programs to help upskill farmers and producers** who may be able to implement regenerative agriculture programs, helping to encourage technical know-how and subsequent behavioral change
- **Governments can also provide direct funding for quality inputs and equipment necessary to scale regenerative practices,** including better access to internet to bolster digital literacy and complement use of legacy analog systems in place in many farms, especially in developing markets, today

Optimizing fertilizer deployment

- **Governments can provide direct funding for R&D into the use of synthetic fertilizers** to help determine the risks associated with new fertilizer technologies, such as controlled-release fertilizers, and identify necessary behavioral changes for adoption

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