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ORBITAS
Navigating climate transition risks

Agriculture in the Age of Climate Transitions

Stranded Assets. Less Land. New Costs. New Opportunities.

AN INITIATIVE OF
CLIMATE ADVISERS TRUST

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Orbitas
DECEMBER 2020

Foreword

When economies change, **those that are most willing and able to adapt to new realities always come out on top.** In this respect, the transition to the zero-carbon economy that the scientific evidence so clearly tells us we need will be no different: the businesses, investors and financiers who prove themselves most able to devise and implement strategies that allow them to take advantage of the growing demand for climate-friendly goods and services will thrive in the economy of the future, while those that do not will struggle to survive.

We can already see this happening in the fossil fuel sector; yet in other sectors, many are still unaware of the changes that are coming down the line. This is particularly true of tropical agriculture. We established Orbitas to help the producers of internationally traded agricultural commodities and their capital providers to anticipate and adapt to the new government policies, corporate commitments and changing consumer preferences that the imperative to protect the world's forests will undoubtedly bring.

This report represents the first step in that process. By outlining the risks – and substantial opportunities – associated with the coming climate transition, we hope to initiate a conversation that will lead business and investors in the tropical agriculture sector to begin the process of adapting to a new reality in which the ability to expand agricultural land is likely to be severely constrained, standing forests have financial value and emissions costs need to be factored into business models.

Although we believe the evidence presented here is striking enough to command the attention of all actors in the tropical commodity sector, we also recognise that this is only a start. In the coming weeks we will publish deep dives on cattle-ranching in Colombia, palm oil in Indonesia and palm oil in Peru. And, in 2021, we plan to expand our analysis to cover more countries and commodities, put our methodology in the public domain and develop tools that enable direct assessment of individual companies and investment portfolios. We will also publish a disclosure framework compatible with the Task Force on Climate-Related Financial Disclosures (TCFD).

We would like to express our sincere appreciation and gratitude to all those who have made this work possible. The Norwegian Agency for Development Cooperation (NORAD) provided the core funding for Orbitas, and we received additional financial support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The core modelling and analytical work was carried out by Michael Obersteiner, Nikolai Khabarov and Sylvain Leduc from the International Institute for Applied Systems Analysis (IIASA), Jason Eis, Bryan Vadheim, Mateo Salazar, Madison Cole and Alessa Widmaier of Vivid Economics and the Concordian Global team of Markus Walther, Emily McGlynn and Kandice Harper. Without their intellectual curiosity, rigour and commitment, none of this would have been possible. We are particularly grateful to Shally Venugopal for her outstanding leadership in coordinating collaboration and analysis across all the project partners. Finally, we would like to thank our Climate Advisers Trust colleagues for their creativity, intellect and collegiality, in particular Anthony Mansell and Ameer Azim, the core members of the Orbitas team.

Nigel Purvis
CEO, Climate Advisers Trust

Mark Kenber
Managing Director, Orbitas

Executive Summary

This report breaks new ground by illuminating how inevitable responses to today's climate crisis will impact global agriculture sectors. The first-of-its-kind economic and financial analysis presented here demonstrates that those associated with the $1.5 trillion global market for agricultural commodities must proactively manage so-called "climate transitions"—rapidly evolving policy, corporate, consumer, and civil society responses to the climate crisis.

A. INTRODUCTION

It is widely recognized that a meaningful climate transition will require systemic transformations in the global energy and transportation sectors, resulting in new sources of risk. For example, investors are increasingly aware that oil, coal and gas reserves are likely to become "stranded assets," i.e., assets whose values deplete or become unusable under climate transitions.

But climate transitions and their impacts are not limited to the energy and transportation sectors. Global agricultural sectors, which contribute to 23 percent of anthropogenic greenhouse gas (GHG) emissions globally, are similarly exposed.[2] Agricultural activity is also a key driver of forest loss, especially in the case of palm, beef and soy, which jointly account for 36 percent of global deforestation.[3] Yet, these sectors are largely overlooked by investors assessing climate transitions owing to a lack of awareness, inadequate measurement tools, the sector's complexity, and the absence of reliable data, among other factors. Of 24 capital providers recently surveyed by Orbitas--all of whom had tropical commodity exposure--not even one had screened their loan books and/or investments for agricultural transition risks.

The report's findings demonstrate that climate transition risks – and opportunities – are as material in agriculture as they are in the energy and transportation sectors. Our analysis shows that under climate transitions:

1. **Growth strategies premised on converting forests into farmland have no future.** In a world that adequately limits global temperature rises, up to 600 million hectares of agricultural land – or over 10% of agricultural land globally - would revert to forests.
2. **Companies relying on expansion into forested lands face significant asset stranding.** In Indonesia, up to 76% of unplanted forest concessions and 15% of existing palm oil assets could be written-down or off under a meaningful national climate transition.
3. **Greenhouse gas pricing and/or regulations will disrupt agricultural business models.** Global palm, beef, and soy producers alone face $19 billion in additional costs.

As countries strengthen their actions to reduce GHG emissions and growing populations demand more food, these transition risks (Box 1) will become increasingly evident. It is essential – both for the planet and investment returns - that commodity producers and their financiers are aware of these risks and factor them into their investment decisions.

Despite these material risks, agricultural companies and investors can also derive significant opportunities (Box 2) from climate transitions. By investing in sustainable intensification, regenerative agriculture, and diversifying revenue streams, forward-looking agricultural companies will see their net value and profitability rise under transitions. For example, our analyses show that in Indonesia climate transitions could boost the palm oil industry's value by US$9 billion. In Colombia, potential carbon sequestration revenues of up to US$485/hectare could dwarf current cattle ranching profits.

Policymakers have an essential role to play in ensuring that incentives for agricultural growth are aligned with the need for climate mitigation. The livelihoods and wellbeing of subsistence and family farmers, so-called "smallholders," will need particular attention. Smallholders produce around 40 percent of the world's palm oil and one-third of the world's food supply.[4,5] Indeed, our findings underscore that policies that disregard smallholders won't halt deforestation and will also fail these communities by not helping them finance the agricultural improvements necessary for them to thrive.

Box 1:
CLIMATE TRANSITION RISKS IN AGRICULTURE

Climate Transitions Risks

Stranded Assets

76%

of Indonesia's unplanted concessions at risk of becoming stranded assets.

15%

of current Indonesian plantations are on peatlands and are also at risk of stranding.

78%

less land available in Peru for palm expansion compared to business as usual.

Growth Constraints

286-604 million

hectares of global agricultural land will be converted to forest by **2050** compared to BAU.

This means cropland prices are higher by

50%

Carbon pricing plus NDPE restrictions lead to

7.5m ha

of extra forest cover and

13% less

land available for cattle ranching in Colombia in **2040.**

Emissions Costs

$19 billion

annual emissions costs for tropical agriculture companies.

15%

of total operational costs for palm oil companies in Peru and Indonesia by **2040.**

By **2040**, Colombian cattle breeders face emissions costs almost

6 times

higher than current production costs.

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B. ORBITAS APPROACH

Assessing climate transition risk impacts in agriculture requires addressing the complex relationships within and between commodities, value chains, and the broader economy. Existing scenario analysis frameworks tend to focus on the energy and transportation sectors, discounting the major role of agriculture, forest, and land use change activities in anthropogenic GHG emissions.

To address this gap, Orbitas collaborated with Concordian, Vivid Economics, and the International Institute for Applied Systems Analysis (IIASA) to create transition risk analysis tailored for agricultural commodities. The result is a pioneering analytical framework that draws together a number of economic and financial models alongside land use and industry datasets to quantify the financial impacts of a range of possible climate transitions on tropical soft commodity production. This framework and its results offer a first-of-its-kind tool for investors to examine how agricultural portfolios and investees fare in various climate transition scenarios.

Our framework, which is outlined in Figure 1 and detailed in this report's accompanying Technical Guidance, consists of four steps:

a) **Climate Transition Scenario Planning:** We start by defining five global and three corresponding national climate transition scenarios--Historical (Baseline), Modest, and Aggressive--which represent increasing levels of climate ambition. These scenarios vary by climate mitigation policies, forest area protections, bioenergy pathways, and consumer diets.[6]

b) **Sectoral Projections:** We use Step 1's scenarios as inputs into macroeconomic and land use modelling tools that project how, and to what extent, climate transitions would impact global and regional agricultural commodity prices, production, and land use over the next 30 years.

c) **Industry Impact Evaluation (National):** Using Step 1's scenarios and Step 2's projections, we use land use, financial, and economic models to evaluate transition impacts on three case study industries: Indonesian palm oil, Peruvian palm oil, and Colombian beef. These three industries were chosen due to their high emissions-intensity and historical association with tropical deforestation, but also to represent regional variation and different industry maturities.

d) **Company-Level Vulnerability Analysis:** Finally, we use a mix of risk benchmarking, company-level profitability projections, and market power analysis to stress-test the vulnerability of companies to the industry impacts identified in Step 3.

C. KEY RESULTS

Our analysis finds that across all scenarios, agricultural demand and prices rise over the next fifty years to feed a growing and increasingly wealthy global population. By 2050, our model projects agricultural commodity prices that are 10 to 40 percent higher, and production volumes around 50 percent higher than today across all scenarios. These results are primarily driven by higher demand for food and bioenergy, which overcomes the competing force of rising production costs.

Climate transitions' favorable pricing conditions benefit many agricultural commodity markets if companies manage these changes effectively-- e.g., in Indonesia, an Aggressive climate transition could boost the palm oil industry's baseline value by at least $9 billion if companies invest in sustainable yield improvements, avoid high carbon stock and conservation value lands, and invest in new revenue streams like intercropping and biogas capture and cogeneration. But in some emissions-intensive sectors like beef, market value deteriorates due to higher input and production costs and because consumers shift toward more sustainable alternatives.

Under climate transitions, most agricultural producers face three material risks: stranded assets, growth constraints, and emissions costs. These are detailed below.

1. Stranded Assets
Effective climate transitions will require society to protect and restore high carbon stock and high conservation value lands, including forests and peatlands. Already, corporate purchasers have put in place No Deforestation, No Peat, No Exploitation (NDPE) requirements for their suppliers. Under climate transitions, government-mandated land use restrictions will further threaten to render assets stranded, particularly in palm:

- In Indonesia, up to 76%–almost 10 million hectares–of the country's unplanted concessions and up to 15% of existing smallholder and industrial palm plantations on peat are at risk of asset stranding and/or losing value under an ambitious climate transition.[7]
- In Peru, 97% of palm-suitable land is located on forest and/or peat soils; to avoid stranded asset risks, producers must focus on expanding into already degraded lands. Grupo Palmas–the industry's largest cultivator–has already had to forgo clearing forests within their owned land banks in response to civil society outcry.

Orbitas' framework offers a first-of-its-kind tool to examine agriculture across various climate transition scenarios.

Box 2:
CLIMATE TRANSITION OPPORTUNITIES IN AGRICULTURE

Climate Transitions Opportunities

By acting optimally, Indonesia's palm oil industry could realize $9 billion in additional value.

Higher demand for food and bioenergy drives commodity prices 10–40% higher. Production also increases by **50%**, but only sustainable companies will capitalize.

Installing biogas generation facilities at Indonesia palm oil mills increases enterprise value by 400%

Carbon sequestration payments for Colombian forests reach as much as **$485/ha**, far higher than revenues obtained from dairy and beef sales from cattle ranchers.

Upgrading practices improves pro itability, but will require capital investments 30% higher than under a business as usual pathway.

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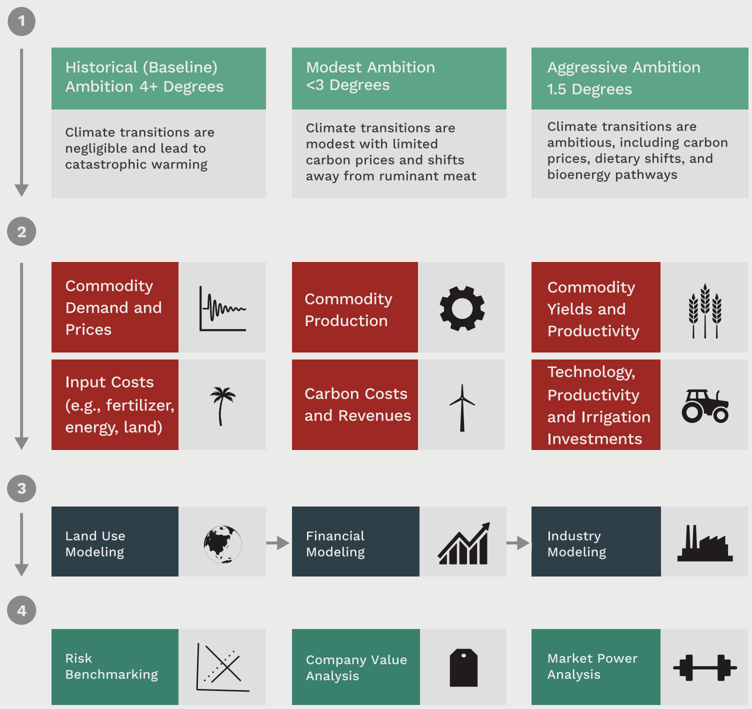
Figure 1:
TRANSITION RISK FRAMEWORK FOR AGRICULTURE



Source: Authors

Beyond legal stranding, companies face "economic stranding" under climate transitions as some assets are no longer able to generate the output and revenues required to offset expected increases in production costs.

- In Indonesia, we expect significant economic stranding where palm plantation and mill expansion is NDPE-restricted; for example, our analysis finds that Kalimantan Barat's palm industry could see its value decline by $512 million under an Aggressive climate transition relative to the baseline pathway.
- In Colombia, as beef demand and production ramp down, breeders, slaughterhouses, processing plants and warehousing facilities are likely to see significant write-downs.
- Economic stranding in many industries is highly associated with sustainability strategies and transparency: for example, in Indonesian palm oil, the company with the greatest expected losses under transitions–BEST group–also has among the lowest industry SPOTT[8] scores (1.3%)–a measure of its environmental, social, and governance (ESG) practices.[9]

2. Geographic Growth Constraints
Under climate transitions, the combination of land use restrictions and carbon sequestration payments incentivizes net forest gains at the expense of agriculture. We project total global net agricultural land losses ranging from 4 to 15% of current area--286 to 604 million hectares--by 2050 under our transition scenarios, relative to the baseline scenario. Tropical agricultural commodity-producing regions like South America, Southeast Asia, Africa, and China see the largest drops in agricultural land. These trends are also apparent in our industry analyses:

- In Indonesia, within 20 years, an Aggressive climate transition would lead to 15 million hectares more forest cover compared to the baseline scenario, thereby reducing the maximum future footprint of industrial oil palm plantations by 31%.
- In Peru, within 20 years, NDPE restrictions under an Aggressive climate transition would reduce land available for industrial palm[10] by 78% relative to the baseline scenario.
- In Colombia, within 20 years, even a Modest transition with zero-deforestation restriction results in forest expansion of 2.6 million hectares, reducing total available land for commercial ranching (i.e., contiguous tracts of over 200 hectares on land suitable for cattle[11]) from 13.7 million hectares to 11.9 million hectares of land (-13%).

3. Emissions Costs
Within just ten years, we project that an Aggressive transition's carbon pricing would mean emissions costs of up to $19+ billion annually in beef, palm, and soy. The beef supply chain is particularly emissions-intensive; annual emissions costs would reach more than $11 billion by 2030. That is equivalent to 1% of revenue in the global beef sector, which is material for an industry that operates on tight margins. And while total emissions costs in 2030 are lower in palm and soy than in beef, the cost as a percentage of sector revenue is notably higher, at roughly 8% for palm oil and 3% for soy (Figure 2, next page). In our industry case studies, emissions costs are also material:

- In Indonesia and Peru, direct operational emissions costs (including from fertilizer application, diesel fuel use, and mill processing) for an archetypical mill-plantation would comprise up to 15% of annual operational costs within 20 years.

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- Emissions costs for Colombia's commercial beef producers would be devastating; large breeders (over 250 head) in particular would see operational emissions costs rise to a level equal to total projected production costs within 10 years. Within 20 years, these emissions costs rise to almost 5 times the projected production costs.[12]

The beef supply chain is particularly emissions-intensive; annual emissions costs would reach more than $11 billion by 2030.

D. RISK EXPOSURE AND VULNERABILITY ANALYSIS

To manage these three risks, agricultural producers will need to undergo radical transformations in their operational and growth strategies – namely, by increasing productivity. Under an Aggressive transition, the average cost of cropland by 2050 is nearly 50% higher than in the baseline scenario; in our industry-specific analyses, shadow agricultural land values almost double by 2040. Traditional growth strategies relying on land clearing and limitless geographic expansion are clearly no longer tenable under climate transitions. Instead, producers will have to find low carbon means to increase yields on existing land.

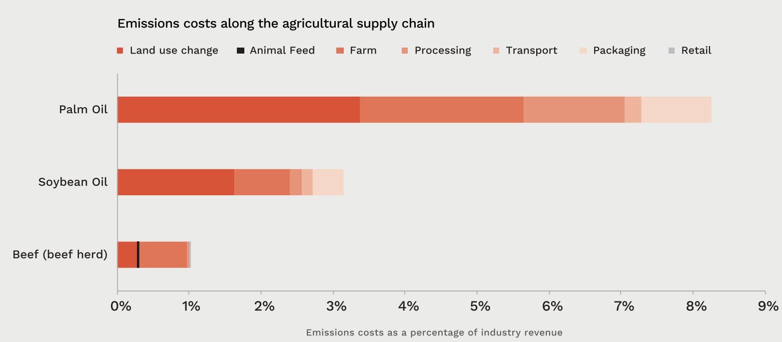
While sustainable productivity investments are essential under transitions, they will not come cheaply: firms must raise funds today to adequately cover necessary increases in operational and capital expenditures, particularly to boost productivity. Public investments are also required, especially to support smallholders. By 2050, cumulative required investments in technological change under climate transitions are between 6 and 30 percent higher than in the baseline scenario.

Where productivity increases are costly or inadequate to combat rising production costs, we expect land conversion to more profitable crops like palm or, in some areas, back to forest. In Colombia, where 63% of the country's existing pasture overlaps with palm-suitable land,[13] beef producers may find it more profitable to sell their land, convert to palm--which provides 15 times higher profit margins[14]-- or even reforest for carbon sequestration payments.

Smallholders will play a pivotal role in both increasing industry productivity and meeting climate goals. Smallholders require substantial technical and financial assistance to close current yield gaps, but nevertheless represent low hanging fruit to increase industry productivity cheaply. Notably, overlooking the need for smallholder support from both the public and private sectors will jeopardize valuable forest and peatlands, especially since local land use restrictions are likely to be more lenient for smallholders. In Indonesia, for example, our models project that without enforcement of zero deforestation, smallholders could expand into up to 5 million hectares of forest and peatlands by 2040 under a Modest climate transition.

Low carbon, efficient producers with capital access are best positioned to manage transition risks and also stand to gain under our Aggressive climate transition scenario. Producers who proactively pursue deforestation-free growth strategies, increase yields sustainably, and find smart ways to capture GHG emissions can considerably benefit from the rising commodity and/or GHG emissions prices associated with ambitious climate transitions; for example:

FIGURE 2:
2030 SUPPLY CHAIN EMISSIONS COSTS AS A PERCENTAGE OF INDUSTRY REVENUE FOR A 1.5 DEGREE WORLD



Source: Vivid Economics
Notes: 1.5C Strong Ambition LP Scenario; Emissions intensities from Poore & Nemecek (2018) are multiplied with model-led 2030 production results by commodity to yield emissions by each commodity by supply chain position in 2030. The emissions share of each commodity and supply chain position is then multiplied by the total emissions cost to obtain an estimate of emissions costs along the supply chain for each commodity. Emissions costs are then normalized by total industry revenue. Note that while beef represents the lowest emissions costs as a percentage of industry revenue, beef production is the most expensive in absolute terms, with more than $11billion in annual emissions costs. Emissions costs are GHG certificate prices – these do not include search, information, or trade costs.

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- Installing biogas generation facilities in mills in 2030 (when carbon prices start to become material) could boost an Indonesian palm oil company's enterprise value[15] by four times or more due to reduced emissions, diesel fuel needs and electricity sales.
- In Colombia, converting an average-sized dual-purpose (dairy and beef) ranch to an intensive silvopastoral system (ISPS) that includes high-density fodder shrubs and timber trees would result in the following benefits under transitions:
  - Emissions and their associated costs are up to 44% lower, while potential certified-sustainable price premiums boost sales revenues by up to 23%.
  - Storing carbon provides potential revenues as high as $485 per hectare–which is much higher than current per-hectare revenues from dairy and beef sales.

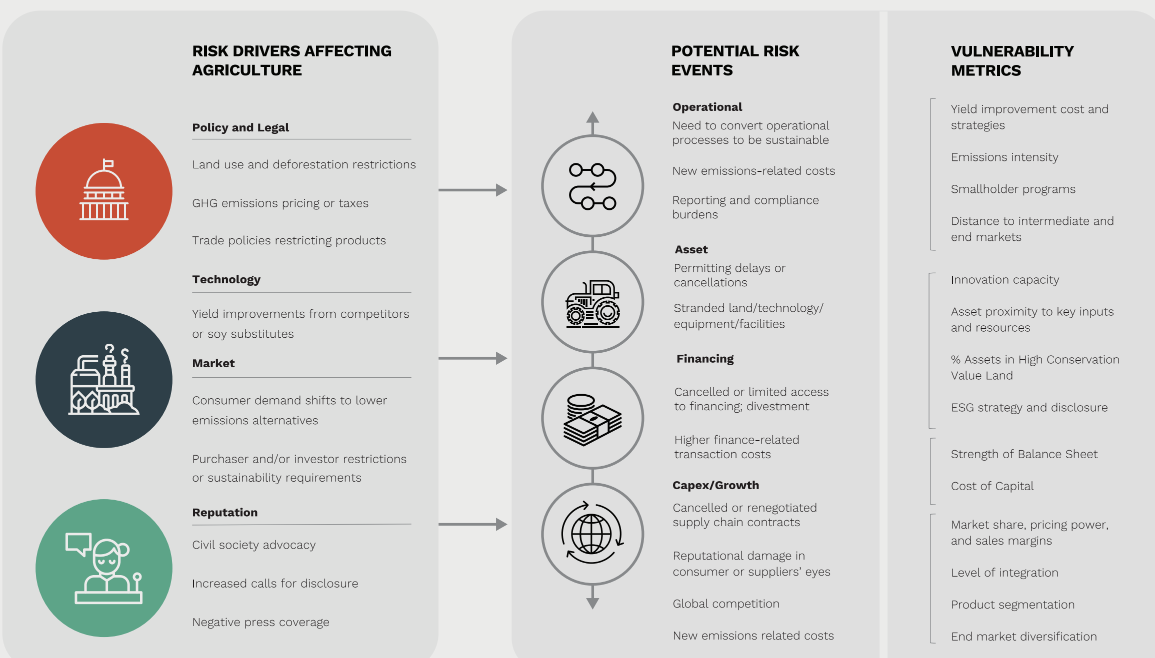
E. CONCLUSIONS AND RECOMMENDATIONS

Our analysis makes it clear that climate transitions pose material risks to companies and investors who are unwilling or unable to adapt to their associated shifts. But these same transitions create significant opportunities for those who can and do proactively embrace sustainable practices. This report and our methodological framework provide important guidance to companies, investors, and policymakers. Our findings clearly underscore that these actors must examine climate transitions more closely and take the following actions:

Agricultural producers should embrace the opportunities afforded by climate transitions, but also adopt the following risk mitigation strategies:

- Institute and enforce NDPE policies, including by progressing toward 100% supply chain traceability and meaningful technical and credit support to smallholders.
- Invest in increasing yields sustainably, including by closing smallholder yield gaps within agricultural supply chains.

FIGURE 3:
CLIMATE TRANSITIONS AND VULNERABILITY METRICS



Source: Concordian

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- Shift to emissions-mitigating agroforestry techniques like intercropping and technologies like biogas capture and cogeneration which will lower costs, increase productivity, and diversify income as a hedge against likely commodity and energy price volatility.

Climate transitions pose material risks to companies and investors who are unwilling or unable to adapt to its associated shifts.

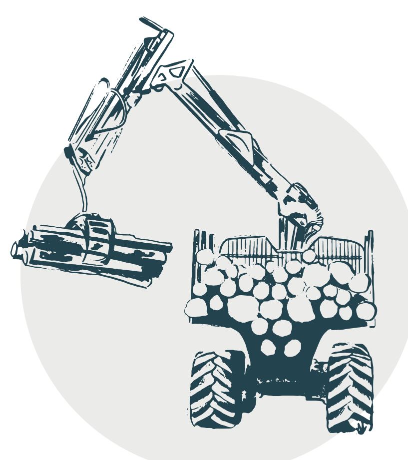
Investors and financiers should shift capital toward sustainable companies, technologies, and practices. Climate transitions will magnify the divide between sustainable and unsustainable business practices and render emissions-reducing technologies more appealing. To preserve capital returns and repayment security, investors with agricultural exposure should:

- Require investees to assess and disclose climate transition risks and associated vulnerability indicators (see Figure 3) using the methods detailed herein alongside other guidance from existing disclosure frameworks (e.g., such as the Sustainability Accounting Standards Board (SASB), CDP, TCFD, and World Business Council for Sustainable Development (WBCSD)).
- Arrange results-based financing to incentivize company investments in emissions-reducing growth strategies that are well-positioned under climate transitions.
- Encourage investees to consider climate transitions across all business lines and supplier relationships, and as an essential input into business growth strategies.
- Shift capital away from companies that are vulnerable to stranded asset risks, i.e., companies whose growth relies on expansion into high carbon stock and conservation value lands.

Policymakers can simultaneously support economic growth, climate goals, food security, poverty alleviation, and energy independence by:

- Investing heavily in improving agricultural productivity, particularly by scaling up technical assistance, grants, and favorable credit to smallholders.
- Implementing and enforcing forest and peatland protections, which protect industries from reputational risks, preserve valuable ecosystems, and inspire consumer confidence.
- Providing agricultural actors, their financiers, civil society, and consumers with robust, and where possible, spatially specific, industry and land use data.

Climate transitions will magnify the divide between sustainable and unsustainable business practices and render emissions-reducing technologies more appealing.



Introduction
Assessing Climate Transition Risks in Agriculture

SECTION HIGHLIGHTS

Agricultural sectors contribute to 23% of anthropogenic emissions, exposing its producers and financiers to emerging policy, reputational, market, and technology-related climate transition risks.

Agricultural transition risk assessment is essential to managing financial and corporate risk. It is challenging, however, due to the uncertain timing and nature of climate transitions as well as the complexity of agricultural value chains.

Orbitas uses the following four-step framework to address some of these challenges and help agricultural producers and investors assess their exposure and vulnerability to climate transition risks:

- **Step 1:** Transition Scenario Planning: Construct plausible global and national climate transition scenarios.
- **Step 2:** Sectoral Projections: Model how scenarios impact global and regional commodity prices and production; input costs; and land use.
- **Step 3:** Industry Impact Evaluation: Assess how, and to what extent, case study industries and their assets face both risks and opportunities.
- **Step 4:** Company-Level Vulnerability Analysis: Analyze company-level vulnerability and positioning vis-a-vis climate transitions.

To understand the relevance of Orbitas' analytical framework, it is helpful to demonstrate the materiality of climate transition risks to tropical commodities. We then present the challenges of assessing climate transition risks in agriculture, and how the Orbitas framework breaks new ground by enabling climate transition to be assessed at various levels of specificity.

A. MATERIALITY OF CLIMATE TRANSITIONS IN AGRICULTURE

Agricultural value chains face material climate transition risk exposure due to their emissions intensity and reliance on land. Agricultural activity currently accounts for 23% of anthropogenic GHG emissions, including 44% of global methane emissions–largely from ruminant livestock–and 81% of nitrous oxide emissions related to fertilizer use.[16] Beyond these direct emissions, agriculture is a key driver of deforestation–particularly palm, beef, and soy, which jointly account for 36 percent of global deforestation.[17] The current trajectory of growing emissions, as agriculture continues to expand to feed a larger, wealthier global population is incompatible with a world that adequately limits global warming to 1.5°C. At the same time, agricultural actors are acutely exposed to potentially devastating physical impacts (see Box 3) associated with warming temperatures.

Climate transitions are already starting to impact agricultural actors through public policies, consumer demand shifts, and private sector actions, as shown in Figure 4 (next page).

B. CHALLENGES TO TRANSITION RISK ASSESSMENT

Financial regulators and actors are increasingly aware of the materiality of climate transitions risks. Over the past few years,

**BOX 3:
PHYSICAL IMPACTS OF RISING TEMPERATURES ON AGRICULTURE**

A warming and volatile climate will have far-ranging physical impacts on the global agricultural and forestry sectors, causing volatility in the availability of inputs, changes in crop and production/processing yields, and new transportation and distribution challenges. Climate disruptions to agricultural production have already increased over the past several decades[18] and are projected to further increase in coming decades.[19] Many of these physical impacts will have uneven, complex, and compounding interactions within agricultural systems. For example, in tropical regions, warming temperatures can both hurt animal health and lower the yields and/or quality of a key feedstock like corn, soy, or grain. In some regions, warming temperatures may create favorable growing conditions but these gains may be outweighed by the greater frequency of extreme weather events and pests, including flooding, hurricanes, droughts, and fires.

Sources: FAO, Science, PNAS

Agriculture is responsible for 23% of global GHG emissions. Palm, beef and soy jointly account for over one-third of deforestation.

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initiatives like CDP, Sustainability Accounting Standards Board (SASB), and the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD), organizations like the World Business Council for Sustainable Development (WBCSD), and regulators like the U.S. Commodity Futures Trading Commission (CFTC) have increasingly made the case that assessing the impact of climate transitions is essential to safeguarding investments and preserving financial stability. In addition, the European Commission has established a taxonomy to distinguish between investments that support the transition to a low-carbon future and those that do not in an effort to enable capital to flow to the former.

FIGURE 4: CLIMATE TRANSITIONS IMPACTING AGRICULTURE

Category	Event	Example or Potential Source in Palm Oil and/or Beef
Policy & Legal	Government restrictions on deforestation and peatland conversion for agricultural uses.	Indonesian government moratorium on new concessions that clear primary forest or peatland within a 66 million hectare area.
	Introduction of GHG taxes or pricing systems that cover agricultural producers.	Peru, Colombia, and Indonesia have all committed to significant GHG emissions reductions.
	Importing countries restrict or ban non-certified products, or those associated with deforestation	The E.U. plans to phase out palm-oil derived biodiesel.
Technology	New planting technologies enable higher yields.	Emerging agroforestry techniques open opportunities to boost yields, diversify income, and reduce emissions in both palm oil and beef.
Market	Shifts in consumer demand away from emissions-intensive products.	Transition scenarios project rises in global and regional palm oil demand but shifts away from emissions-intensive ruminant meats.
	Purchasers require new environmental standards from their suppliers.	At least 16 major Indonesian palm oil producers and refiners have committed to "No Peat, No Deforestation, No Exploitation" (NDPE) policies.
	Corporate and consumer demand increases for sustainable products and/or substitutes.	Preliminary studies show that Colombians are willing to pay significant premiums for sustainable beef even while overall beef demand is slowing.
Reputation	Shareholders or capital providers divest or express concerns about environmental commitments.	Norges Bank Investment Management (NBIM)–the Norwegian Sovereign Wealth Fund–divested from Alicorp over civil society concerns.
	Increased non-governmental organization (NGO) and stakeholder concern about issues such as deforestation or climate change increases scrutiny of tropical commodity supply chains.	NGOs play a highly active role in monitoring palm driven deforestation, including initiatives like MAAP and through the Roundtable on Sustainable Palm Oil.

Source: Concordian

But agricultural actors have yet to robustly assess, disclose, and act on climate transition risks, partly because assessing these risks remains difficult for multiple reasons:

1. Using traditional risk assessment methods that rely on historical data to make forward-looking projections ignores the uncertain nature, timing, interrelation, and non-linear nature of climate transition impacts.[20]

2. Agricultural commodities touch multiple complex global value chains, are exposed to dynamic trade policies, and are produced by a wide range of heterogeneous actors, from smallholders to vertically integrated conglomerates.

3. Industry, land use, and financial data are both not readily available, nor of required quality and detail necessary to inform investment decisions in many of the geographies in which agricultural commodities are produced.

C. TRANSITION RISK ASSESSMENT FRAMEWORK

To overcome key challenges to risk assessment, Orbitas uses a four-step framework and a pioneering set of land use, economic, and financial models. We conducted investor surveys, drew upon existing CDP, SASB, TCFD and WBCSD guidance, and evaluated dozens of financial and economic models and approaches to create the following scenario-analysis based framework and set of modeling tools. This framework is summarized below and in Figure 5, and also detailed in this report's accompanying Technical Guidance.

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Assessing Climate Transition Risks in Agriculture

Where can I see this framework applied?

This report provides topline results from applying our framework to specific palm oil and beef cattle industries. Orbitas will soon release more detailed industry analyst briefs that apply our framework to the following sectors:

Indonesian Palm Oil

Peruvian Palm Oil

Colombian Beef Cattle

Figure 5:
AGRICULTURAL TRANSITION RISK ASSESSMENT FRAMEWORK AND MODELS

Source: Authors

Our framework consists of four steps:

1. **Climate Transition Scenario Planning:** We start by defining and evaluating five plausible global climate transition scenarios with increasing levels of global climate ambition. These scenarios vary by climate mitigation policies, forest area protections, bioenergy pathways, and consumer diets[21] as detailed in the following section. We then created three corresponding global-national transition scenarios for use in our industry case studies: Historical (Baseline), Modest, and Aggressive.

2. **Sectoral Projections:** Using Step One's climate transition scenarios, we use macroeconomic and land use modeling tools--namely, the Potsdam Institute's Model of Agricultural Production and its Impact on the Environment ("MAgPIE") to project global and regional shifts in agricultural commodity production; input and commodity prices; and land use over the next 30 years.

3. **Industry Impact Evaluation:** Drawing from Step 2's projections, we use the following financial, economic and land use models alongside industry data to assess how three industries–Indonesian palm oil, Peruvian palm oil, and Colombian beef –are exposed to climate transitions:
   a. *Land Use Modeling:* Concordian's spatially-explicit land use and forest cover modeling show where, and to what extent, producers face stranded assets and geographic growth constraints, and/or expansion opportunities.
   b. *Financial Modeling:* IIASA and Concordian's pro forma asset and company-level discounted cash flow models project profitability and capital needs.

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Assessing Climate Transition Risks in Agriculture

c. *Industry Modeling:* Financial and economic spatial modeling (using IIASA's BeWhere technoeconomic model and Concordian's industry value analysis) uncover effective growth, contraction, and capital allocation strategies under climate transitions.

4. **Company-Level Vulnerability Assessment:** Finally, we use the following three methods to stress test the vulnerability of companies to the impacts identified by Step 3. These methods consider key aspects of company vulnerability to climate transitions including operational footprint, productivity, emissions intensity, market power, cost of capital, and balance sheet strength.
   a. *Risk Benchmarking:* This simple, risk-focused approach provides a qualitative evaluation of company vulnerability by using sustainability and financial metrics that are easily procured from public databases and annual reports.
   b. *Company Value Analysis:* This sophisticated Concordian analysis quantifies, in dollar terms, the discounted value of a company's optimized profits/losses under climate transitions based on its current operational footprint. To undertake this analysis, we combine our industry NPV analysis with asset ownership data.
   c. *Market Power Analysis:* This detailed economic modeling approach, which uses Vivid Economics' Reduced Industrial Market Model (RIMM) model, gives investors and companies insights into future industry dynamics and examines which types of business models are well-positioned under climate transitions.

Our preliminary results underscore that both supporting and preparing for inevitable climate transitions makes good business sense. The subsequent sections of this report detail our approach and summarize the key results that our framework yields. While this report emphasizes "downside" risks, companies that navigate climate transitions have opportunities for growth. Indeed, in all three industries Orbitas analyzed, we find that companies switching to more sustainable practices like intercropping, smart land use intensification, and zero deforestation growth strategies will hold a competitive advantage under climate transitions.

On the other hand, companies whose growth strategies depend on aggressive geographic expansion and deforestation will see write-offs, shareholder value erosion, and credit deterioration. Critically, without these climate transition responses, companies, industries, and indeed, the global economy as a whole will suffer significantly from the adverse impacts of a warming world.

In all three industries Orbitas analyzes, we find that companies switching to more sustainable practices like intercropping, smart land use intensification, and zero deforestation growth strategies will hold a competitive advantage under climate transitions.

Section I
Climate Transition Scenario Planning

STEP 1:
Scenario Planning

SECTION HIGHLIGHTS

We created five global climate transition scenarios and three global-national climate transition scenarios to form the basis of our climate transition impact analyses.

This set of scenarios represents a range of climate ambition, from a baseline pathway that does little to mitigate emissions to an Aggressive scenario that limits global temperature rise to almost 1.5°C by 2100.

Each scenario varies by carbon pricing policies, bioenergy pathways, technical progress, global and national area protections, and diets, among other factors.

Given the uncertain nature and timing of climate transitions, our scenario analysis began by constructing five global climate transition scenarios. For this report, we drew on scenarios that were already familiar to the international climate community. We ensured that the scenarios met two criteria. First, to represent a range of outcomes relevant to investors. Second, to align with parallel modeling exercises like those of TCFD, the WBCSD, and the Food and Land Use Coalition's 2019 Growing Better Report. These global scenarios served as the basis for three corresponding global-national climate transition scenarios used in our industry analyses.

A. GLOBAL CLIMATE TRANSITION SCENARIOS

Each of the five scenarios, outlined below and in Figure 6, next page, vary by GHG pricing policies; bioenergy pathways; technical progress; area protections; and diets, among other factors:

- **4C Business As Usual ("Baseline"):** Representative of recent trajectories and policy measures, this scenario represents a world in which little is done to address rising emissions, and acts as a baseline to which climate transition projections are compared. Warming in this scenario is likely to near or even exceed a catastrophic 4°C.
- **3C Already Committed Action:** A future in which some action is taken to stabilize, but not reduce emissions. The land sector is subject to half the carbon price of industrial sectors (referred to as "partial participation"). This results in limited forest protection and expansion, and limited uptake of bioenergy and biofuels. Warming is kept to below 3°C.
- **2C Moderate Ambition:** The world takes action to limit warming below 2°C, but lack of international coordination and partial land sector participation increases the overall costs of this scenario. Consumers reduce emissions-intensive meats in their diets.
- **1.5C Strong Ambition LI (LI = Land Intensification pathway):** Robust international cooperation and investment in bioenergy plus carbon capture and storage (BECCS) technology keeps warming below 1.5°C. Full land sector participation further lowers costs and drives agricultural yields to increase rapidly.
- **1.5C Strong Ambition LP (LP = Land Protection pathway):** Ambitious warming targets are met through coordinated international action and complete land sector participation. Bioenergy is limited due to concerns about its negative environmental and social impacts, but a market remains for sustainable bio-based feedstocks. Area protections allow forest cover to regenerate and expand substantially while consumers substantially shift away from emissions-intensive products like ruminant meats.

B. GLOBAL-NATIONAL CLIMATE TRANSITION SCENARIOS

For the three industries --Indonesian palm oil, Peruvian palm oil, and Colombian beef cattle--that are analyzed in Sections III to V, we augmented three of our global scenarios with national transitions to form three "global-national" scenarios as summarized in Figure 7 and below. Using "global-national" scenarios alongside industry-specific data was essential to ensuring that our subsequent industry analyses reflected realities on the ground.

1. **Historical Ambition ("Historical" or "Baseline")** combines the global 4C Business as Usual assumptions with limited to no land use restrictions in all three countries, reflecting a status quo in which deforestation restrictions are not meaningfully enforced.
2. **Modest Ambition ("Modest")** combines the 3C Already Committed Action global scenario with sensitivities to national policy with and without deforestation restrictions for industrial producers and/or smallholders.
3. **Aggressive Ambition ("Aggressive")** combines the 1.5C Strong Ambition LP scenario with strong national-level restrictions on deforestation and peatland disturbance.

The subsequent sections of this report present projections and analysis at the sector level (Section II), industry level (Sections III-V), and company level (Section VI), drawing from these five "global" and three "global-national" transition scenarios.

Continued
Climate Transition Scenario Planning

Figure 6: GLOBAL CLIMATE TRANSITION SCENARIOS

		Climate Transitions			
	4C **Business as usual**	**3C** **Already Committed Action**	**2C** **Moderate Ambition**	**1.5C** **Strong Ambition LI**	**1.5C** **Strong Ambition LP**
Warming Target (Degrees Celsius)	4C+	3C	2C	1.5C	1.5C
Population and GDP Growth	SSP2	SSP2	SSP2	SSP2	SSP2
Climate Mitigation Policies*	Currently implemented	Carbon Pricing • Partial participation of land use sector	Carbon Pricing • Partial participation of land use sector • Land use NDCs	Carbon Pricing • Complete participation of land use sector • Land use NDCs	Carbon Pricing • Complete participation of land use sector • Land use NDCs
Global Carbon Price: Land Sector (2019 USD per ton CO2)**	None	$3 in 2030 $7 in 2040	$5 in 2030 $18 in 2040	$14 in 2030 $69 in 2040	$14 in 2030 $69 in 2040
Global Protected Natural Areas *(Mha)**	352	352	352	352	2,707
Bioenergy Pathways (EJ by 2100)	27	70	70	157 (Optimistic)	70
Ruminant Meat Consumption****	No reduction	No reduction	25% reduction by 2050	25% reduction by 2050	50% reduction by 2050

Source: Vivid Economics based on MAgPIE assumptions and REMIND carbon price modeling results from the report "Transition Scenarios for Tropical Agriculture."
Notes: * Land use NDCs (Nationally Determined Contributions) assume full implementation of currently committed NDCs within land use and agriculture. For some countries (e.g. Brazil) current NDCs are relatively ambitious and not necessarily on track to be met. **Carbon prices presented are averages in 2019 USD; this report's financial analysis uses regional GHG prices. GHG emissions prices reflect land sector GHG prices, rather than energy or economy-wide GHG prices which may be higher. ***Global Protected Natural Areas are defined by the International Union for the Conservation of Nature (IUCN). All scenarios protect IUCN Categories I and II while the 1.5C Strong Ambition LP Scenario protects IUCN Categories I to VI, both designated and proposed. ****Ruminant meat fadeout – this is a gradual decrease in the role of ruminant meats (beef, lamb, mutton and goat) as a protein source. Fadeout scenarios replace ruminant meat with less carbon intensive protein sources, including poultry, fish, eggs, and alternative meats.

Figure 7: GLOBAL-LOCAL CLIMATE TRANSITION SCENARIOS

	Historical Ambition (Baseline)	**Modest Ambition**	**Aggressive Ambition**
Corresponding Global Climate Transition Scenario	4C Business As Usual	3C Already Committed Action	1.5 Strong Ambition LP
Global Carbon Price (2019 USD per ton CO2)	None	$3 in 2030 $7 in 2040	$14 in 2030 $69 in 2040
Peruvian Development Restrictions	Deforestation allowed	For both industrial and smallholders: • A. Deforestation allowed • B. No peat, no forest disturbance	For both industrial and smallholders: • A. Deforestation allowed • B. No peat, no forest disturbance
Indonesian Land Use Restrictions	No new palm permits are allowed on primary natural forest, peat forest, or peat within the government's current moratorium map for both industrial and small-holder actors.	A. "Historical" restrictions + No conversion of primary or secondary forests or peat-lands, even where already permitted for both industrial actors and smallholders. B. All restrictions from A hold except smallholders are exempted.*	"Modest" restrictions + all existing plantations on peat soil must relocate or abandon without compen-sation for both industrial and smallholder actors.
Colombian Development Restrictions	Deforestation allowed	Deforestation not permitted	Deforestation not permitted

Source: Authors and Vivid Economics, based on MAgPIE assumptions and REMIND carbon prices from the report "Transition Scenarios for Tropical Agriculture."
Notes: * In the Historical scenario smallholders are restricted to historical rates of deforestation and the Indonesian moratorium map, but in the Modest B scenario there are no restrictions on smallholder deforestation rates.

Section II
Sectoral Projections – Global and Regional

STEP 2:
Sectoral Projections

SECTION HIGHLIGHTS

Under plausible climate transitions, our models project that by 2050:
- Global agricultural commodity prices rise by 10-40% relative to a baseline pathway.
- Global agricultural land shrinks by up to 604 million hectares relative to a baseline pathway as forest losses are slowed or reversed.
- Global annual productivity gains of 1.6% relative to today will require up to $1.2 trillion in annual technology-related investments.

Agricultural producers can benefit from expanding markets but face greater risks of stranded assets, geographic growth constraints, and rising production costs in the face of new emissions costs, land use restrictions, and necessary productivity improvements.
- Global emissions costs for the global beef sector alone will rise to be $11 billion (annual) by 2030, reaching 25% of projected revenue for the average producer.

To evaluate the impacts of climate transitions on a basket of global agricultural commodities, including those most associated with deforestation (palm, beef and soy), we ran the five global scanerios presented in Section I through the Potsdam Institute's MAgPIE model (Box 4). This section describes global and regional results derived from MagPIE, which also inform our subsequent industry and company-level analyses.

A. GLOBAL SECTORAL PROJECTIONS

With rising climate ambition, our modeling projects agricultural commodity demand, land prices, and input and production costs all rise, leading to higher agricultural prices. Each of these supply- and demand-side shifts are detailed below. Impacts vary at the region, industry, and company levels based on their vulnerability to risk events.

Population and income growth mean that demand for agricultural commodities will rise over the next three decades.

i. Rising Agricultural Demand

Across all scenarios, agricultural markets expand to both feed and supply bioenergy to a growing and increasingly wealthy global population. Total caloric budgets expand by about 50% by 2050 due to population growth and an increase in per capita income as developing countries become wealthier, especially in Africa and South Asia. This demand growth is a primary driver (alongside rises in land and production costs, as described below) of increasing food prices, which increase between 10% to 40% depending on the scenario (Figure 8). Notably, however, rising incomes mean that food as a share of household expenditure falls, on average, from 4% to 3% by 2050. Market growth varies by commodity, but in general, rising prices and production levels combine to increase total revenue of most agricultural goods.

BOX 4:
GLOBAL ECONOMIC AND LAND USE MODELING

Our global and sector-wide climate transition modeling relies on the Potsdam Institute's Model of Agricultural Production and its Impact on the Environment–MAgPIE, a spatially explicit partial equilibrium land use allocation model. First, food demand is estimated using population, GDP, dietary assumptions, and demand elasticities from the GTAP (Global Trade Analysis Project) database. Then, the model determines the least cost way to meet that food demand, while accounting for biophysical constraints including those on land and water, as well as potential crop yields. Additional information about this model is available in this report's Technical Guidance.

The model relies on seven categories of scenario assumptions in order to model agricultural production and its corresponding prices and distribution under different climate transition scenarios:

1. Socioeconomic Characteristics: All scenarios described in this report use the Shared Socioeconomic Pathway (SSP) 2 utilized by the IPCC, which provides assumptions for population and GDP growth to estimate agricultural commodity demand.
2. Climate Policy: the model uses assumptions about the trajectory of global carbon prices facing the agricultural sector, generated by a separate model called REMIND.
3. The model uses each scenario's assumptions about land protection policy and incentives for restoring biodiversity to constrain possible agricultural expansion.

Continued
Sectoral Projections – Global and Regional

BOX 4: CONTINUED

4. Diet Change: Assumptions on global diets inform global demand projections for agricultural commodities. Meat consumption, for example, is generally expected to increase with population and GDP, but declines in wealthy countries in some scenarios.

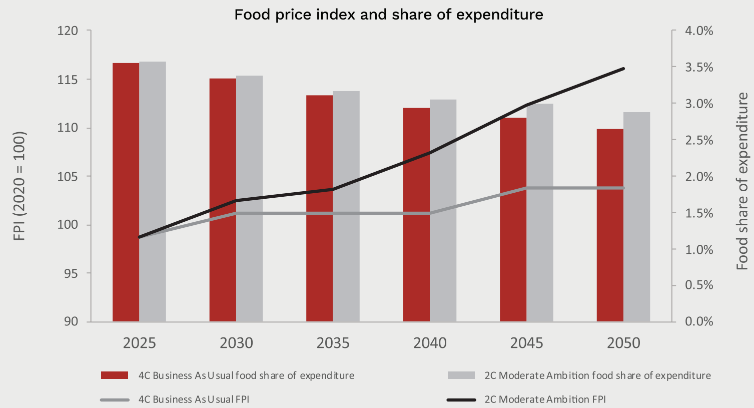
5. Bioenergy Demand: We provide assumptions about the amount of biomass required by the energy sector for each scenario, with a significant determinant being the availability of bioenergy crops with carbon capture and storage (BECCS) technology.

6. Trade: The future of trade in agricultural goods has huge implications for global and regional land use, but is assumed to be largely unchanged across scenarios in this report since each region, country, and industry will face a very different set of trade policies. Trade policies can instead be considered in industry-specific analysis.

7. Investment cost: The future of agricultural productivity is determined in part by the expected returns to agricultural productivity investments. These returns are higher in scenarios that rely on ambitious technological development in agriculture.

Source: Vivid Economics

FIGURE 8:
FOOD PRICE INDEX AND SHARE OF EXPENDITURE



Note: Carbon price takes effect in 2025
Source: Vivid Economics

ii. Stranded Assets and Geographic Growth Constraints

The expansion of land protection policies and carbon payments made to preserve and expand forests reduce land available for agriculture. By 2050, agricultural land decreases by 286 to 604 million hectares relative to the baseline scenario as forest losses are slowed or reversed. The areas with the biggest shifts are all tropical agricultural commodity powerhouses – South America, Southeast Asia, Africa and China. Competition from energy, food, feed, and carbon sequestration results in higher agricultural land prices relative to the baseline, except for the 1.5C Strong Ambition LI where high growth in agricultural yields reduces price premiums resulting from land competition (Figure 9).

By 2050, agricultural land decreases by up to 10% relative to the baseline scenario as forest losses stop or reverse.

iii. Higher Production Costs: Yield Investments and Emissions Costs

The combination of land competition and emissions costs also raises production costs as producers pay for 1) productivity increases via technology, seed, fertilizer, and irrigation investments, and 2) emissions either directly or through higher input, energy, and land costs.

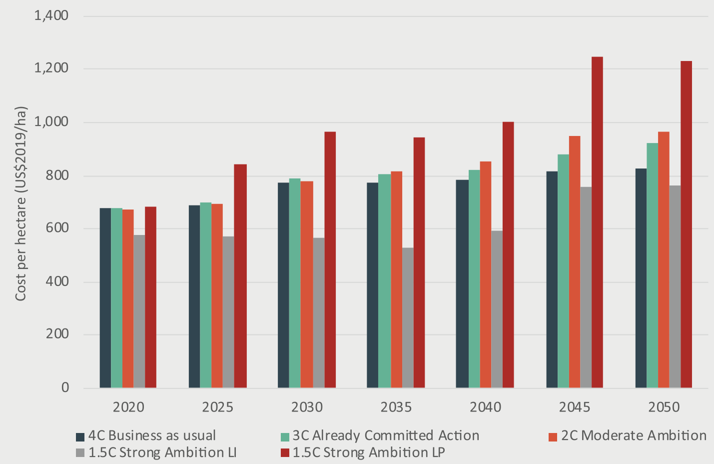
Productivity: Under the 1.5C Strong Ambition LP, crop yields grow 1.6% (0.4% higher than the baseline) annually from 2020 to 2050, a pace that requires annual technology investments[22] of up to $1.2 trillion (versus baseline investments of $900 billion) annually by 2050 (Figure 10). These investments could support traditional crop variety breeding, developments in frontier technologies, such as CRISPR editing of crop varietals, or precision nutrient application.

Achieving these productivity gains requires a collective investment from public and private sector actors. Firms will be required to fund at least some implementation costs, with the potential for additional capital expenditure to invest in research and development (R&D) and technology deployment necessary for long-term productivity growth. Some countries may choose to increase export taxes to recover expenses for productivity enhancement from importing

Continued

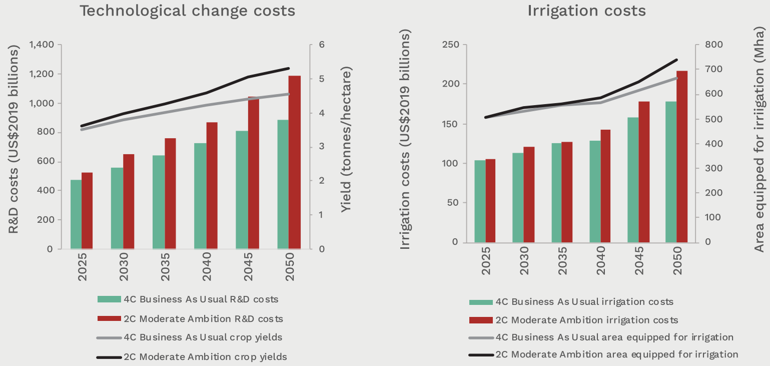
Sectoral Projections – Global and Regional

FIGURE 9:
AGRICULTURAL LAND VALUE UNDER CLIMATE TRANSITIONS



Note: Reported land costs are long run global averages, and not representative of local real estate prices. Land prices are strongly impacted by local characteristics and policies, but the values reported here are indicative of underlying dynamics. Source: Vivid Economics

FIGURE 10:
PROJECTED TECHNOLOGICAL AND IRRIGATION COSTS



Note: Carbon price phases in in 2025.
Source: Vivid Economics

countries. In either scenario, the costs of productivity gains will be reflected downstream.

Emissions Costs: Under our global climate transitions, agricultural producers pay for emissions from deforestation, fertilizer-related emissions, fossil fuel-related emissions, and any other process emissions, resulting in new and material production costs. Landowners are rewarded for negative emissions to varying degrees in global climate transitions, encouraging carbon-negative management techniques. Emissions intensities are particularly high in the beef supply chain, driven
by the release of nitrous oxide from the application of fertilizers for feed crops, methane emissions resulting from enteric fermentation, and in some regions, carbon emissions released when converting forest to pasture.

Annual technology investments required to increase yields reach up to $1.2 trillion annually by 2050 versus $900 billion under business as usual.

Total annual emissions costs from palm, soy, and beef alone reach more than $19 billion by 2030 in the 1.5C Strong Ambition LP scenario. In the global beef sector, emission costs are equivalent to 1% of revenue–significant in a sector already operating on tight margins. For palm and soybean oil, total emissions costs are lower than for beef in 2030 in the 1.5C Strong Ambition LP scenario but are higher as a percentage of sector revenue, representing 8% of revenues for palm oil and 3% for soy.

B. REGIONAL SECTORAL PROJECTIONS

To demonstrate how to evaluate climate transition risks in a manner that reflects on the ground realities, we examine three industries: Indonesian palm oil, Peruvian palm oil, and Colombian beef cattle. Each case study provides a unique perspective on assessing climate transition risks given their varying size, maturity, and emissions contributions. Future Orbitas reports will examine other agricultural sectors and industries.

MAgPIE's regional projections provide baseline inputs into each of our three industry analyses. In addition to providing global results, MAgPIE provides downscaled regional commodity market and land use results. These regional projections--which include prices, production, land use, land sector carbon prices, input and factor cost increases, and food price indices--are critical inputs into our industry analysis. In the following

Continued
Sectoral Projections – Global and Regional

subsections, we briefly present the most relevant regional projections used to inform our results. Additional inputs are described in detail in this report's Technical Guidance.

In both Indonesia and Peru, we project rising regional palm oil prices and productivity with greater climate ambition. Over the next 10 to 15 years, the Modest and Aggressive climate transition scenarios drive up global and regional palm oil prices compared to the Historical scenario (Figure 11). In the longer run, Modest and Historical prices follow similar trends. In contrast, Aggressive prices increase rapidly between 2035-2045, even with significant increases in agricultural productivity in both regions (Figure 12).

We see similarly rising beef prices in Central and South America, but unlike in the case of palm oil, production and demand growth slow with greater climate ambition (Figure 13). Over the next 15 years, the Historical and Modest scenarios result in relatively unchanged beef prices and production, while the Aggressive scenario's significant emissions costs constrain global and regional beef supply, resulting in rapidly rising beef prices, especially after 2035.

In both regions, carbon prices introduce new production costs in our modelling, particularly for beef producers. Industrial palm oil producers pay direct GHG emissions costs or higher input costs, primarily stemming from diesel fuel use, fertilizer application, and mill processing and waste-related emissions. Cattle ranchers face significant costs primarily from direct methane emissions and inputs like fertilizer. Agricultural GHG prices in both regions are minor in early years, but in the Aggressive scenario, they rise substantially to $28 per ton CO2e in Other Developing Asia (including Indonesia) and $40 CO2e in Central and South America (including Peru and Colombia) by 2040 (Figure 14).

FIGURE 11:
REGIONAL PALM OIL PRICES (PERCENTAGE RELATIVE TO 2020)

A. Central South America | B. Other Developing Asia

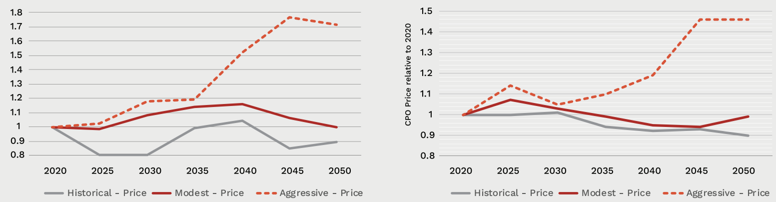
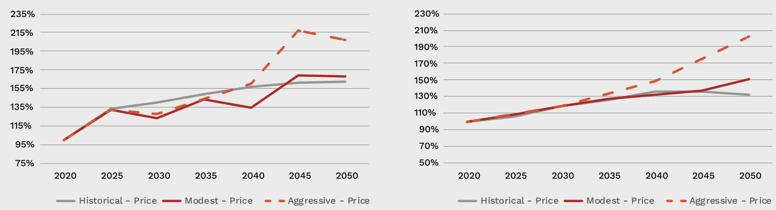


FIGURE 12:
REGIONAL OIL PALM PRODUCTIVITY (YIELD PER HECTARE RELATIVE TO 2020)

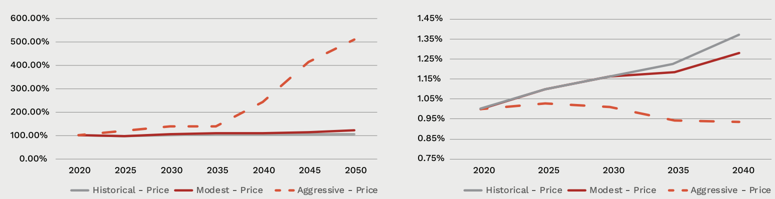
A. Central South America | B. Other Developing Asia



Source: Authors, based on modeling results from the report "Transition Scenarios for Tropical Agriculture."

FIGURE 13:
REGIONAL BEEF PRICES

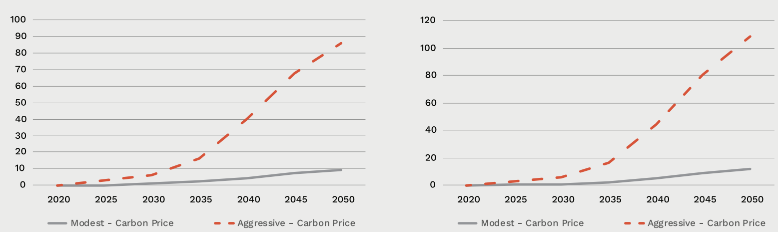
A. Central South America | B. Other Developing Asia



Source: Concordian, based on results from Vivid Economics and the report "Transition Scenarios for Tropical Agriculture"

FIGURE 14:
REGIONAL CARBON PRICES (LAND SECTOR)

A. Central South America | B. Other Developing Asia



Source: Concordian, based on results from Vivid Economics and the report "Measuring the Materiality of Climate Transitions" Notes: These prices reflect land sector GHG prices, rather than energy or economy-wide GHG prices.

Section III
Industry Impact Evaluation- Land Use Modeling

In this section we evaluate how climate transitions create stranded asset risks and geographic growth constraints for agricultural producers in the Indonesian palm oil, Peruvian palm oil, and Colombian beef cattle industries.

STEP 3:
Industry Impact Evaluation
- Land Use Modeling

SECTION HIGHLIGHTS

We downscaled our global and regional results alongside national climate responses to evaluate impacts on Indonesian and Peruvian palm oil as well as Colombian beef cattle. Our analysis finds:

- In Indonesia and Peru, rising palm oil prices under more ambitious transitions help to counteract rising input and production costs, though geographic expansion is substantially limited by zero deforestation restrictions and rising land values.
- In Colombia, regional beef prices rise but due to dramatic rises in production costs, the industry's producers will struggle to compete against lower carbon beef imports, more sustainable protein substitutes, and higher margin agriculture.

Section II's global and regional results provide essential guidance on broader, global, sector-level market shifts, but evaluating industry impacts requires a more nuanced approach that considers national climate transitions (see Section I) as well as industry characteristics. This section uses land use modeling to highlight two important risks that are unique to land use dependent sectors: regulatory-driven stranded assets and geographic growth constraints.

A. PALM OIL - INDONESIA AND PERU

The Indonesian and Peruvian palm oil sectors differ in size by orders of magnitude. In Peru, only two operators–Grupo Palmas and Alicorp, both affiliated with Grupo Romero–control its small, but growing palm oil industry that relies on less than 100,000 hectares of plantations. In contrast, Indonesia is the world's largest palm oil producer, with over 16 million hectares of oil palm plantations. The industry comprises hundreds of companies–including several large, vertically-integrated, publicly listed companies–and millions of smallholders.

Nevertheless, palm oil producers in both regions are exposed to both asset stranding and reputational risks under climate transitions. Already, in Peru, civil society advocacy around deforestation and intrusion into indigenous lands has stymied Grupo Palmas' expansion plans and spurred divestment from Alicorp. Similarly, in Indonesia, palm oil product purchasers like PepsiCo and Nestle, and financiers like Citigroup, severed ties with Indofood over environmental, social and governance (ESG) concerns. Under climate transitions, palm oil companies will face increasing pressures even as demand grows from domestic biofuel mandates. Additionally, more stringent corporate zero deforestation policies and government land use moratoria expose producers to potential write-offs. Our analysis finds that:

- **76% (9.2 million hectares) of Indonesia's unplanted concessions–i.e., land permitted for palm development–are at risk of stranding under climate transitions.**[23] Provinces most impacted include Kalimantan Barat (2.4 million hectares), Papua (2.1 million hectares), Kalimantan Tengah (1.7 million hectares), and Kalimantan Timur (1.1 million hectares).
- **A further 2.2 million hectares of currently planted oil palm on peatlands–15% of total industrial and smallholder palm plantation area in 2015–would also face write-offs** under an Aggressive transition that supports peatland restoration.[24]
- **In Peru, our spatial analysis found that 97% of biophysically suitable land for palm cultivation in Peru is unusable under NDPE restrictions** to which many global agricultural conglomerates have recently subscribed.

Palm oil producers in both regions also face significant geographic growth constraints as NDPE restrictions and carbon pricing together incentivize forest gains at the expense of agricultural land. Using the OSIRIS model (see Technical Guidance, Annex 1 for more details), we projected how forest cover would change in both Indonesia and Peru under different climate transitions. As shown in Figure 15, deforestation restrictions alongside a carbon price incentivize significant net forest expansion, thereby limiting the land available for palm oil and other agricultural expansion:

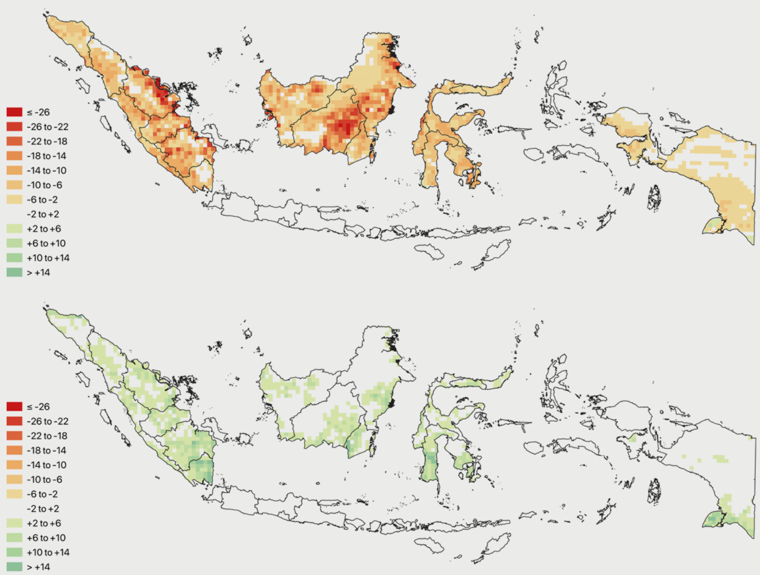
- **In Indonesia, palm expansion potential[25] is 33% lower under the Aggressive scenario relative to the Historical ambition pathway by 2040,** as forest area expands by 3.8 million hectares (3.6%) between 2020 and 2040 under the Aggressive scenario. In 2040, forest cover is expected to be 15 million hectares higher under the Aggressive scenario relative to Historical ambition.

Continued

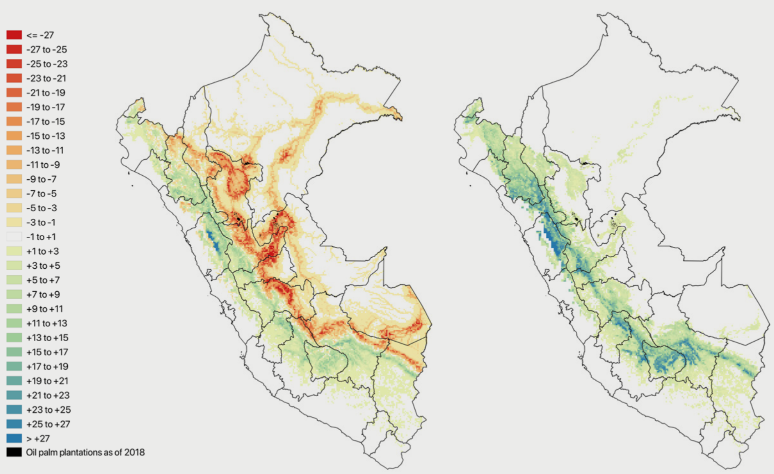
Industry Impact Evaluation- Land Use Modeling

FIGURE 15:
20-YEAR FOREST COVER PROJECTIONS IN INDONESIA AND PERU: HISTORICAL AND AGGRESSIVE SCENARIOS

A. Indonesia



B. Peru



Notes: Forest cover projections are based on the OSIRIS model (Busch et al., 2019).[26] Spatial resolution is 5.5 km x 5.5 km for Peru (panel B) and 25 km x 25 km for Indonesia (panel A; OSIRIS output were re-gridded to the resolution of the BeW-here model). For Indonesia, forest projections are shown only for the analysis region covering the mainland of Sumatra, Kalimantan, Sulawesi, and Papua. Plotted values indicate the percentage of the grid cell area that has experienced a net decrease (red) or net increase (green) in forest cover over 2020–2040. For Peru (panel B), grid-cell-level net forest cover changes range from -30.5% to +35.9% for the Historical scenario and 0% to +46.4% for the Aggressive scenario with zero deforestation restrictions enforced. For Indonesia (panel A), grid-cell-level net forest cover changes range from -34.0% to +7.3% for the Historical scenario and 0% to +18.8% for the Aggressive scenario. Administrative boundaries are from GADM.[27] Oil palm plantation data for Peru are from Finer et al. (2018).[28]

- **In Peru, commercial palm expansion is limited to 257,000 ha by 2040 (78% lower than the Historical scenario)** due to NDPE restrictions and a 4% increase in forest cover between 2020 and 2040 under the Aggressive scenario. In contrast, smallholders face fewer expansion constraints, underscoring how important their production will be under climate transitions (Box 5).

B. BEEF CATTLE- COLOMBIA

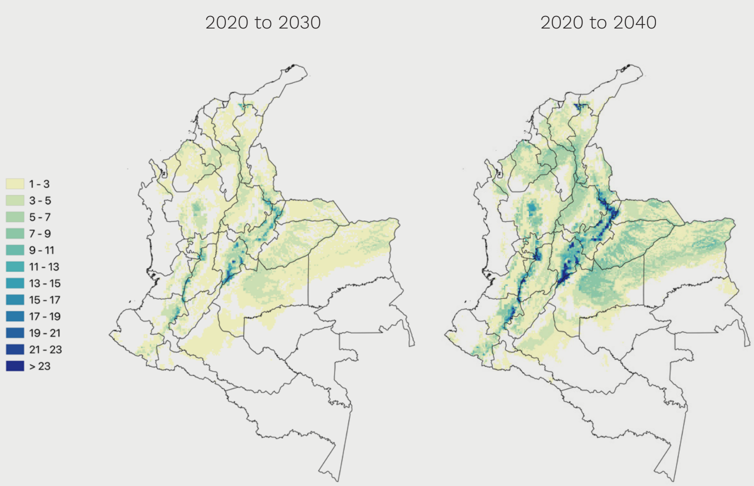
Colombia is the world's 17th largest beef producer but the 2nd most emissions-intensive.[29] Almost all of its production is consumed domestically, though both import and export markets are starting to grow. Colombia has 34 million hectares of pastureland but only 15 million hectares of total land cover are identified as suitable for cattle ranching.[30] Most production occurs within extensive systems with low stocking rates, low productivity, and unimproved grass grazing. Around 43% of Colombia's greenhouse gas emissions are related to agriculture, forestry and land use change; nearly 30% of these emissions are from cattle-driven methane, and around 35% are related to deforestation.[31,32,33,34]

As with our palm oil analyses, land use restrictions alongside GHG pricing drive forest expansion, reducing the potential for legal and economically feasible cattle expansion. If the Colombian government restricts deforestation in combination with setting a carbon price consistent with the Modest scenario, we project forest cover gains of 1.3 million hectares by 2030 and 2.6 million hectares by 2040 (Figure 16). By 2040, the zero-deforestation restriction, together with a Modest carbon price, reduces total available commercial[35] cattle-suitable land[36] by 1.8 million ha (13%) from the Historical scenario.

Continued

Industry Impact Evaluation- Land Use Modeling

FIGURE 16:
FOREST COVER EXPANSION IN COLOMBIA: MODEST SCENARIO



Source: Authors. Forest cover projections at 5.5 km x 5.5 km spatial resolution are based on the OSIRIS model.[37] Plotted values indicate the percentage of the grid cell area that has experienced an increase in forest cover over the 10- or 20-year time period; changes <1% appear white. Nationally, grid-cell-level forest cover expansion ranges from 0% to +22.0% for 2020–2030 and 0% to +41.9% for 2020–2040 for the Modest scenario with zero-deforestation restrictions enforced; the equivalent ranges for the Aggressive scenario with zero-deforestation restrictions enforced are 0% to +23.4% for 2020–2030 and 0% to +56.7% for 2020–2040. Administrative boundaries are from GADM (version 3.6, https://gadm.org). See technical annex for more information on data sources and methods. Notes: This scenario assumes no deforestation is permitted and that a modest carbon price incentivizes larger net forest areas.

BOX 5:
SMALLHOLDER GEOGRAPHIC GROWTH CONSTRAINTS

Smallholders face less severe expansion constraints under climate transitions–even assuming they face the same land use restrictions as industrial actors–as they require smaller contiguous parcels of land. In Peru, for example, the 2030 land available for smallholder palm expansion within 100km of existing mills is 549,000 hectares under the Modest and Aggressive scenarios, 35% lower than in the Historical scenario. Within 20 years, this figure further shrinks to 521,000 hectares, 54% lower than the 1,135,000 hectares in the Historical scenario but still 51% higher than the corresponding land available for industrial palm expansion.

By 2040, a modest carbon price and zero deforestation restrictions would spur forest cover gains at the expense of 1.8 million hectares of cattle-suitable lands in Colombia.

Larger, commercial breeders, finishers, and dual-purpose farms will likely face significant operational emissions costs. Traders and wholesalers will also are subject to higher transportation costs, as diesel and other fossil fuels face carbon taxes or pricing. While cattle breeders, in particular, achieve comparatively high margins among beef producers today, they are also some of the most emissions-intensive within the beef value chain, and thus most exposed under climate transitions as discussed in the following section.

These commodity market and land use projections underscore how climate transitions can create material risk exposure in agricultural industries. Importantly, while growth is achievable due to rising food demand under climate transitions, rising land prices and restrictions mean that producers must start focusing on sustainably increasing productivity both in their own assets as well as those of smallholders in their supply chains, as further discussed in Section IV.

Section IV
Industry Impact Evaluation - Financial Modeling

In this section we demonstrate how country-specific transitions and regional commodity market projections will influence asset and company profitability and growth strategies.

STEP 3:
Industry Impact Evaluation
- Financial Modeling

SECTION HIGHLIGHTS

In Indonesia and Peru, existing palm assets prosper under climate transitions, but future growth is hampered by stranded concessions and land prices doubling by 2040.

In Colombia, emissions costs create significant challenges for producers, particularly commercial cattle breeders, who by 2040 could see emission costs up to six times larger than their production costs.

In all three industries, sustainable growth strategies, high productivity, favorable capital access, and high borrowing capacity drive profitability under climate transitions.

- Producers have significant opportunities to both reduce operational emissions and diversify income in the face of price volatility, through emerging agroforestry techniques and emissions capture technologies.
- The relative profitability of sustainable approaches is even higher under climate transitions, bolstered by emissions cost savings, potential sequestration payments and, in some markets, price premiums.

The climate transition projections outlined in Sections II and III can affect agricultural producers and their supply chains in multiple ways, including:

- Revenues grow due to rising global demand and commodity prices.
- More write-offs and geographic growth constraints due to greater land use restrictions and prices.
- Rising production costs due to higher input costs, direct GHG emissions costs, as well as investments to improve yields.

To evaluate asset- and company-level vulnerability to these projections, Orbitas modeled how the profitability of industry assets and the Enterprise Value (EV)[38] of companies are impacted by climate transitions. These financial modeling techniques–which include pro forma cash flow projections, real options analysis, and discounted cash flow (DCF) models–also uncover how companies can optimize their operational performance and better allocate capital to prepare for climate transitions.

A. FINANCIAL RESULTS: PALM OIL - INDONESIA AND PERU

We employed pro forma cash flow and DCF models to calculate how the EV of both new and existing mill-plantations[39] would change under climate transitions. We used cost structure data for plantations, mills, kernel crushers and biogas capture to create illustrative companies to model financial impacts. The scenarios discussed in Section III provided the changes in business conditions, such as commodity prices, capital investment and emissions costs. To view the changes in financial terms, we integrated the results into a DCF model, which projects the impact of climate transitions on income statement, balance sheet and cash flows. We used EV, a measure of a company's value that accounts for both its equity and its debt, to compare how companies fare under climate transitions.

Rising palm oil prices drive up profitability under transitions, so long as companies can increase yields and access capital cheaply.

Our analysis finds that climate transitions' rising palm oil prices increases the relative profitability of plantations, but the benefits of asset expansion are highly sensitive to capital needs and productivity. Existing assets generate positive EV under all climate transition scenarios, whereas new assets generally do not see positive EV except for the most efficient ones and only under the "Aggressive" scenario. Across both existing and new assets in Indonesia and Peru, we find that EV rises materially (i.e. becomes more positive or less negative) with greater climate ambition, driven by higher prices under the Aggressive and Modest scenarios. These results are highly sensitive to a company's weighted average cost of capital (WACC) and its oil palm productivity as shown in Figure 17. Importantly, this sensitivity and the overall results suggest that companies can prosper under climate transitions so long as they have a strong balance sheet and maintain high levels of productivity.

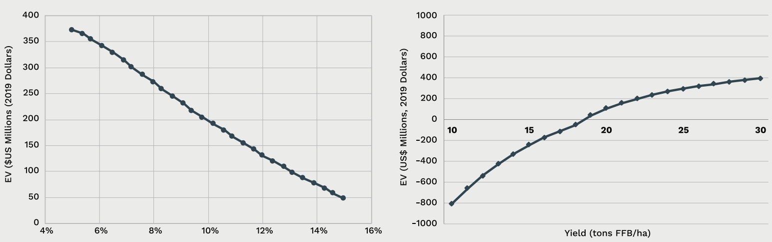
Continued

Industry Impact Evaluation - Financial Modeling

FIGURE 17:
PALM OIL ENTERPRISE VALUE: NEW ASSETS

A. EV of New Company by WACC (Industry Ranges):

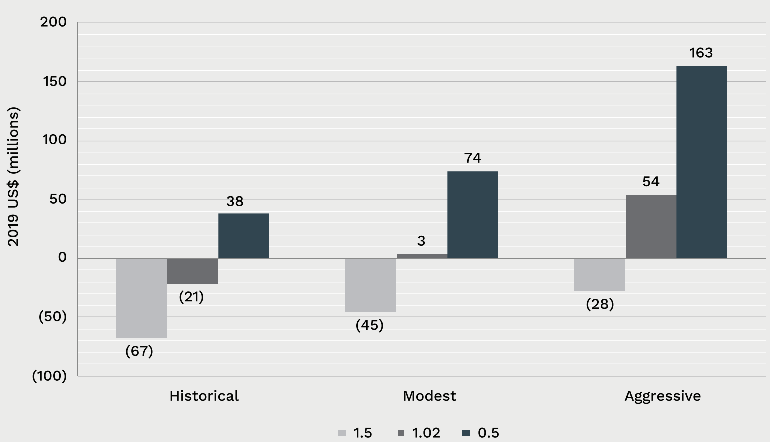
B. EV of New Company by Oil Palm Productivity (Industry Ranges):



Source: Authors, based on financial modeling using the results from the report "Transition Scenarios for Tropical Agriculture" Notes: This figure is based on an illustrative company operating 60,000 hectares of newly planted land and three mills with a capacity of 80 tons FFB per hour. Key assumptions include i) a base crude palm oil price of $656 (15-year average); ii) a cost-to-yield multiplier of 1, i.e., every 1% increase in yields requires a 1% increase in USD costs, and iii) a 2% growth rate in future cash flows after 30 years to calculate the assets' terminal value. The annual average yield for mature trees in Figure 17A is 20.7 tons FFB/ha, and the WACC in Figure 17B is 11.7%. FFB production is modeled with a yield curve reflecting tree productivity by age.

Readers should note that although we present results in dollar terms for visual ease, this analysis is meant to compare the overall magnitude and direction of impacts between scenarios rather than provide absolute results.

FIGURE 18:
HIGH YIELDING NEW ASSETS IN INDONESIA: SENSITIVITY OF ENTERPRISE VALUE TO COST-TO-YIELD MULTIPLIER



Source: Authors, based on pro forma modeling using the results from the report "Transition Scenarios for Tropical Agriculture" Notes: See Technical Annex for detailed calculations. This Figure is based on three illustrative companies with the same asset profiles–240 FFB tons per hour of milling capacity alongside 60,000 hectares of plantations–but that vary by yield management strategies and their cost of capital. Key assumptions include i) a base crude palm oil price of $656 (15-year average); ii) weighted average costs of capital (WACC) of 11.7% (Best); iii) a cost-to-yield multiplier of 1, i.e., every 1% increase in yields requires a 1% increase in USD costs, and iv) a 2% growth rate in future cash flows after 30 years to calculate the assets' terminal value. For existing assets, we assume a constant replanting rate to achieve steady state yields; for new plantations we include upfront capital expenditures, land acquisition costs, and an FFB production yield curve reflecting tree productivity by age.

Readers should note that although we present results in dollar terms for visual ease, this analysis is meant to compare the overall magnitude and direction of impacts between scenarios rather than provide absolute results.

BOX 6:
REAL OPTIONS UNDER CLIMATE TRANSITIONS

Under climate transitions, asset owners are exposed to potentially volatile price and input cost conditions as countries undertake their transitions in a piecemeal fashion. These dynamics create different yield investment trade-offs, which are especially important in the case of palm oil: as a perennial crop, palm oil production is hard to ramp up and down, and is thus less resilient to price shocks relative to its annual oil crop counterparts.

Real options analysis (ROA) can help inform how asset owners consider price volatility and other changes in operating conditions in their decision making. Real options commonly considered include:

- Increasing or decreasing the output of the asset
- Investing capital to upgrade the technology of the asset
- Mothballing the asset or putting a mothballed asset back into operation
- Acquiring additional assets
- Relocating, selling or abandoning the asset, or
- Continuing operations without changes.

A future Orbitas report will delve more deeply into two of these options for oil palm plantation owners: 1) the choice of the fertilizer application rate and 2) decisions on replanting of aged plots (those where palm trees have reached the end of economic life). As in our other analyses, we use MAgPIE results to project future cash flows. However, our ROA will additionally consider local policy and price assumptions, reflecting the likely volatility associated with climate transitions at a finer temporal resolution: the analysis covers 25 years at annual simulation intervals i.e. market conditions and company reactions are modeled once per year.

Continued
Industry Impact Evaluation - Financial Modeling

BOX 6: CONTINUED

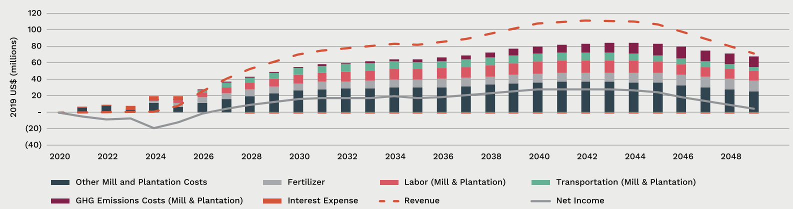
The preliminary results of our analysis underscore the long-term favorability of investing in both replanting and fertilizer application. However, in the short term, when the prices for the oil palm derivative products fluctuate, a company's operational costs may exceed operational revenues over the low-price periods. In this situation, companies[41,42] typically reduce costs either by reducing replanting or decreasing fertilizer application.

Our preliminary ROA indicates that asset owners in Indonesian companies should prefer a temporary reduction of fertilizer even at the expense of incurring short-term yield losses. Otherwise, this company could lose land to a competitor by not replanting it in a timely manner and, consequently, lose all future returns that this land can generate.[43] Under all transition scenarios, less efficient companies will stop re-planting and gradually exit the market, while higher efficiency companies facing the same level of the discount rate/WACC would continue to profitably operate and potentially expand plantations.

Source: IIASA and Concordian

Within 20 years, emissions costs could rise to be six times production costs for emissions-intensive beef producers.

FIGURE 19:
INDICATIVE REVENUES AND COSTS FOR A PERUVIAN MILL-PLANTATION: AGGRESSIVE SCENARIO:



Source: Authors, based on proprietary pro forma modeling using the results from the report "Transition Scenarios for Tropical Agriculture" Notes: Based on a case study of a Peruvian mill-plantation with 10,000 hectares of owned plantation and 6% sourcing from third parties; this is not representative of all industry assets. This modeling contains many assumptions that may not reflect reality for a new or existing project. Key assumptions include a base crude palm oil price of $656 (15-year average); discount rate of 12%; corporate tax rate of 30% on profits; a cost-to-yield multiplier of 1, i.e., every 1% increase in yields requires a 1% increase in USD costs. Assumes a 2% growth rate in future cash flows after 30 years to calculate the assets' terminal value.

Since EV is sensitive to yields, the cost of yield increases is a particularly important predictor of how well-positioned a company is to sustain climate transition risks. Profitability and enterprise value can vary substantially across transition scenarios, depending on the level and cost of the yield improvements necessary to counteract higher production costs. For example, in Indonesia, under the Aggressive scenario, EV decreases substantially–by 117% in absolute terms–even for a "best-in-class" efficiency company whose cost-to-yield multiplier[40] is 1.5 rather than 0.5 (Figure 18, previous page).

Under climate transitions, companies will also see different trade-offs when spending to increase yields. Real options analysis can help uncover how agricultural actors should evaluate these trade-offs under the context of climate transitions, as described in Box 6.

In both Peru and Indonesia, operational GHG emissions costs are material under transitions, but only in later years, giving companies adequate time to prepare. For example, for an illustrative mill-plantation in Peru, GHG emissions costs from non-deforestation activities–like mill processing, fertilizer use, and diesel fuel–comprise 1% (Modest) and 3% (Aggressive) of total operational costs by 2030. By 2040, these percentages rise to 3% (Modest) and 15% (Aggressive) (see Figure 19). As a reference, a significant cost item like fertilizer typically comprises 20 to 30% of operating costs.

B. FINANCIAL RESULTS: BEEF CATTLE - COLOMBIA

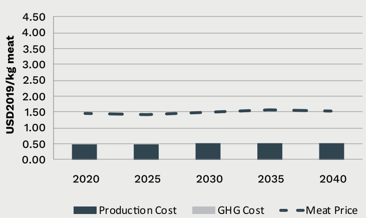
Commercial Colombian beef producers are far more vulnerable to climate transitions than palm oil companies. Climate transitions are highly likely to incentivize emissions-intensive and inefficient producers to leave the market and/or convert to higher-margin commodities, particularly in the absence of trade protections. This result is driven both by the low-profit margins that characterize the local beef industry, but also because emissions costs rise to be unmanageable for ranchers.

Continued

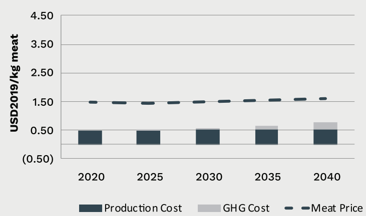
Industry Impact Evaluation - Financial Modeling

Figure 20:
ANNUALIZED PRODUCTION AND EMISSIONS COSTS FOR LARGE BREEDERS

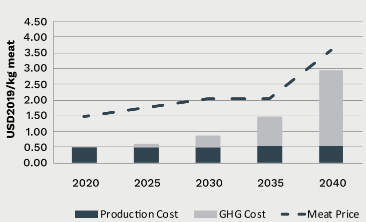
A. Historical Ambition



B. Modest Ambition



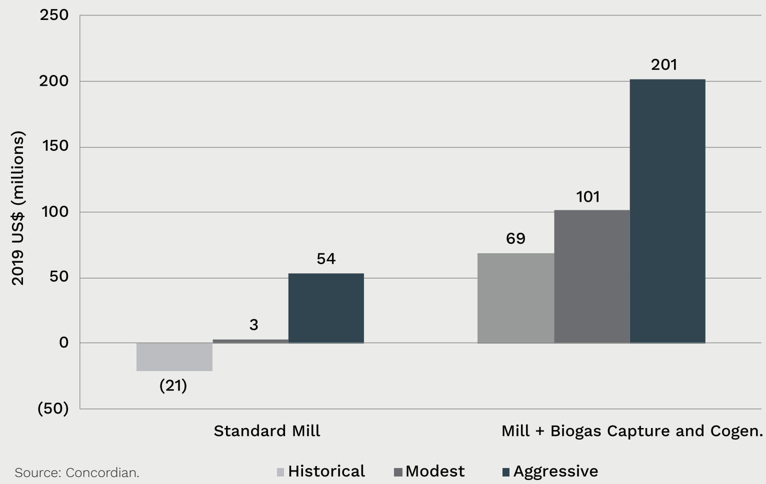
B. Aggressive Ambition



Source: Authors using data from Gonzalez et. al 2019.[44,45]
Notes: See accompanying Technical Guidance for methods, data sources, and caveats related to these projections. These projections reflect a "steady state," i.e., they do not reflect projected cash flows or income over time; rather they provide a snapshot in each year of relative production and emissions-related costs based on the prevailing GHG prices in that time step. Emissions costs are based on an estimated emissions intensity for larger breeders (251-500 head) of 37.3 kg CO2eq per kg of live weight gain (LWG).

- Projected production costs also assume increases in factor costs including labor, energy, and equipment; they do not consider increases in fertilizer nor land costs; we assume fertilizer-related cost increases are driven by emissions costs within the farm gate rather than fertilizer prices.
- Emissions from transportation are not included in this chart, but are likely to also be material throughout the value chain, further impacting profits for the industry as a whole. Emissions from land clearing are also not considered.

FIGURE 21:
ENTERPRISE VALUE: 2030 STANDARD MILL VERSUS MILL WITH BIOGAS METHANE CAPTURE



Source: Concordian.

Among beef producers, large cattle breeders will be particularly hard hit due to their high emissions intensity. Cattle breeders achieve comparatively high margins among beef producers but are also some of the most emissions-intensive within the beef value chain. Under an Aggressive climate transition, large breeders (over 250 head) could see emissions costs rise to the same level as total production costs within 10 years (Figure 20). Within 20 years, emissions costs rise to over six times the projected production costs. We assume that smaller breeders are unlikely to be subject to GHG pricing policies given the high administrative burdens of collecting emissions payments from small ranchers.

Beef producers and processors cannot easily pass these costs downstream and still compete with higher margin crops and cheaper international substitutes. Given both cattle ranching's currently thin profit margins and suboptimal land use, we expect climate transitions to incentivize the conversion of inefficient, emissions-intensive pasture lands either back into forests, and/or into palm oil, sugar cane, or coffee – crops that achieve 3 to 15 times higher margins[46].

Climate transitions will incentivize conversion from pasture to forest and/or into palm oil, sugar cane, or coffee, crops that achieve 3 to 15 times higher margins in Colombia.

While inefficient, emissions-intensive producers in Colombian beef, Indonesian palm and Peruvian palm all face significant risks in the face of climate transitions, those who are able to pursue more sustainable strategies can take advantage of rising prices and new transition opportunities as described below.

Continued
Industry Impact Evaluation - Financial Modeling

C. CLIMATE TRANSITION OPPORTUNITIES

Our research finds two particular examples of profitable and income-diversifying investments for palm and beef producers: biogas methane capture and cogeneration, and intensive silvopastoral systems[47] ("ISPS"). **Importantly, both of these investments are profitable even in the absence of climate transitions, underscoring that companies can confidently prepare for climate transitions today without worrying about opportunity costs.** While not analyzed herein, agricultural producers may also be able to generate revenues from storing carbon on their land and/or from providing other biodiversity conservation and ecosystem services.

Sustainable investments like ISPS and biogas capture are profitable even in the absence of climate transitions, so companies can confidently prepare for climate transitions today.

Biogas Methane Capture and Cogeneration:

In the case of palm oil, the midstream use of palm oil effluent ("POME") for biogas capture and electricity cogeneration is an easy financial and environmental win for companies with access to capital. This technology has a clear social benefit as well, making it appealing to policymakers attempting to increase and diversify energy access: If less than a tenth of Indonesia's palm oil mills had biogas facilities, together they could support the electricity needs of 240,000 households and reduce direct emissions by 2.5 million metric tons of CO_2-equivalent annually, with potential additional emissions reductions from displacing coal-generated electricity.

Installing biogas capture and cogeneration facilities can boost a company's value by more than 4 times under an ambitious climate transition.

In Indonesia, our model estimates more than 400% higher EV for a large producer that installs biogas facilities in its mills in 2030 (Figure 21). This result is driven both by the profitability of these facilities and because these facilities counteract mill emissions at a time when GHG prices start to become material under the Aggressive scenario. Importantly, EV also rises significantly under both the Historical and Modest scenarios, implying that companies cannot go wrong in investing in these profitable assets regardless of the transition scenario.

Intensive Silvopastoral Systems (ISPS)

ISPS boost cattle ranching profitability and diversifies income sources, counteracting the significant rises in production costs and price volatility likely under climate transitions. Sustainable farming techniques range from simple investments in fences and dispersed trees to highly productive ISPS, which carefully combine trees, pasture, and livestock. Profit gains are driven by greater productivity, lower input costs, and new sources of revenue from timber or fruit sales. ISPS also allows producers to capture potential sustainable price premiums thereby counteracting slowing demand. One study found that Colombian consumers may be willing to pay a 23% price premium for eco-friendly beef and 10% for beef labels that addressed environmental impacts.[49]

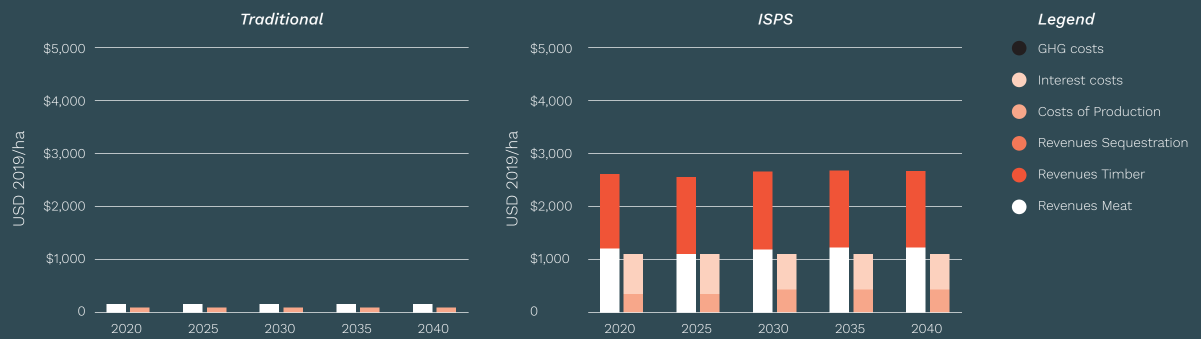
Figure 22 illustrates the relative cost, productivity, and price premium benefits achievable under each transition scenario for an illustrative dual-purpose farm that is subject to GHG emissions pricing. In the Aggressive scenario, ISPS profits per hectare are up to 8 times and 13 times higher than conventional systems by 2030 and 2040, respectively. It is worth noting that, these results may be less applicable to large scale operations that have higher carrying capacities and productivity; for these types of operators, alternative sustainable farming techniques like industrial-scale intercropping may make better sense. Additionally, not all ranches are ideal candidates for conversion to ISPS.

ISPS profits per hectare are up to 8 times and 13 times higher than conventional systems by 2030 and 2040 under an ambitious climate transition.

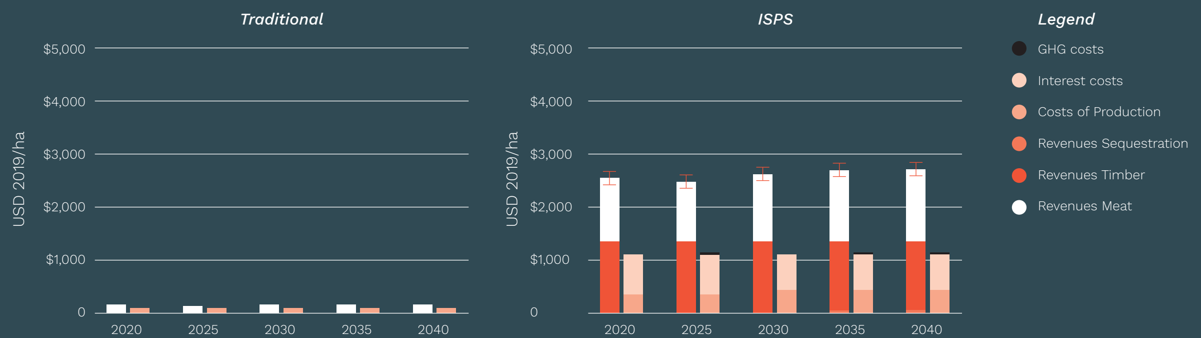
Continued
Industry Impact Evaluation - Financial Modeling

Figure 16:
ANNUAL REVENUES AND COSTS: DUAL PURPOSE ISPS VERSUS TRADITIONAL SYSTEMS

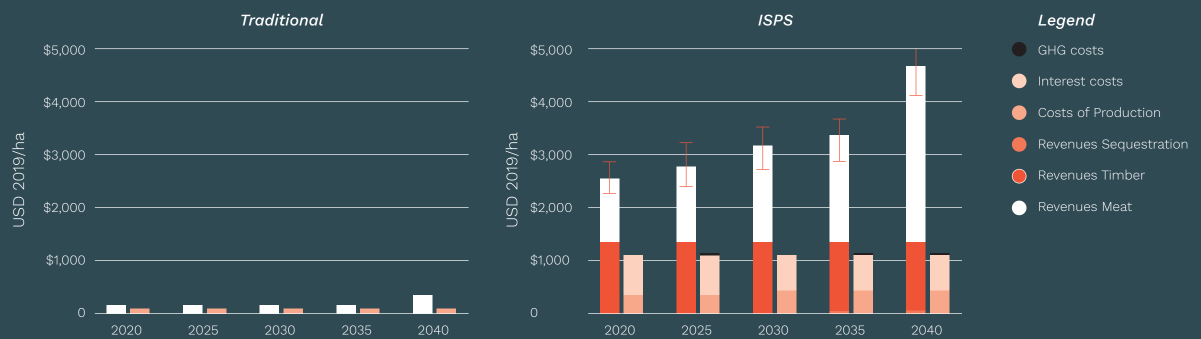
A. Historical Ambition Scenario: No ISPS Price Premium



B. Modest Ambition Scenario: Up to 10% ISPS Price Premium



C. Aggressive Ambition Scenario: Up to 23% Price Premium



Source: Concordian, based on data from FEDEGAN, Broom et al 2013, Nelson and Durschinger 2015, Charry et al 2019, and Cardona et al. 2012. See technical annex for additional details regarding calculations and data sources.
Notes:

- Due to data constraints, this chart only includes methane emissions that are largely related to enteric fermentation.
- This chart's intention is to give an indication of the cost differences for ISPS versus traditional systems. Not all producers will face these costs. The calculation makes several simplistic assumptions as outlined in the Technical Annex.
- This figure's underlying data assumes an average-sized dual purpose farm that is subject to emissions pricing, using land sector GHG prices.

Section V
Industry Impact Evaluation- Industry Modeling

This section describes and presents preliminary results from specialized economic models that optimize industry expansion and contraction under climate transitions.

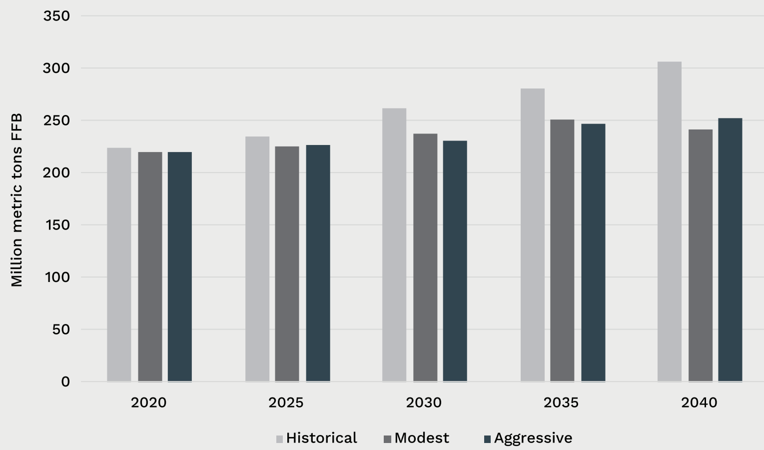
STEP 3:
Industry Impact Evaluation
- Industry Modeling

SECTION HIGHLIGHTS

Climate transitions could boost the Indonesian palm oil industry's total value by $9 billion or more relative to a baseline pathway

But capital needs will be significant: future gains will be largely derived from capital-intensive assets that diversify revenue streams like kernel crushers and biogas capture and cogeneration facilities.

FIGURE 23:
PROJECTED OPTIMAL FFB MILLING CAPACITY UNDER CLIMATE TRANSITIONS (INDONESIA)



Source: Concordian
Note: Predictions for total FFB processed closely tracks installed capacity over time in model results, so we show only installed capacity. See Appendix for calculation methods.

As climate transitions come into effect, agricultural producers will need to adjust their growth strategies and production levels. In this section, we used highly specialized and spatially-explicit economic and financial analysis tools to model how and where it makes economic sense for Indonesian palm producers to increase or decrease palm oil production under each climate transition scenario. We also project how the industry's overall value would be impacted by climate transitions relative to a baseline pathway.

While we only focus on Indonesian palm oil, our models and approaches (which are described in this report's Technical Guidance) can be replicated across other industries, particularly those comparable in size and maturity to Indonesian palm.

A. OPTIMAL INDUSTRY EXPANSION AND CONTRACTION

Our Indonesian palm oil models project[51] how and where palm oil production assets, including fresh fruit bunch (FFB) production, mill processing, kernel crushing, and biogas capture and cogeneration facilities, would optimally expand and contract under climate transitions. Notably, these projections assume that producers are able to access the capital necessary to optimize their production and expansion in light of climate transitions.

Our modeling finds that optimal, industry-wide FFB milling capacity increases across all scenarios, but less so under an Aggressive climate transition (Figure 23).

The largest projected losses occur where forests are most likely to expand and in NDPE restricted areas, indicating that companies should avoid land or concession acquisition in these areas.

Continued
Sectoral Projections – Global and Regional

Within 20 years:
- Nationwide optimal milling capacity is 37% higher in the Historical scenario relative to only 10 and 15% increases in the Modest and Aggressive scenarios, respectively.
- Interestingly, these production trends are not consistent across islands:
  - In Kalimantan, optimal milling capacity is 73 million metric tons lower in the Aggressive scenario relative to the Historical one.
  - In contrast, Sumatran milling capacity is 20 million metric tons higher in the Aggressive scenario relative to the Historical one.
- Provincial differences will be driven by a number of factors including each region's achievable yields, carbon storage potential, and distance to transportation routes and end markets, among other factors.

B. INDUSTRY VALUE UNDER TRANSITIONS

Although optimal milling capacity declines under climate transitions, investors will see overall industry value rise under an Aggressive climate transition. To quantify these differences by region we conducted a spatially explicit Net Present Value (NPV) analysis, which finds:[52]
- Industry-wide NPV increases by 5% between the Historical and Aggressive scenarios-- **i.e., the industry's value is boosted by over $9 billion by ambitious climate action.**
- To benefit from these predicted gains under climate transitions, palm producers must diversify the products they produce and upgrade their mill technology--particularly through biogas capture and cogeneration facilities and kernel crushers.
- NPV impacts vary significantly at the grid cell level, with some areas benefiting strongly from climate transitions and other areas suffering large losses as shown in Figure 24.
- The largest NPV losses occur where forests are most likely to expand and where palm plantation and mill expansion would be limited by NDPE restrictions, underscoring the importance of companies avoiding high carbon stock and conservation value lands.
- Independent smallholders will play a key role in the industry's future development. For example, if independent smallholders are allowed to deforest under the Modest scenario, the industry's NPV increases substantially but this occurs at the expense of up to 5 million hectares of valuable forests and peatland (Box 7).

Based on these findings, we conclude that it is possible for the Indonesian palm oil industry to both create shareholder value[53] and preserve valuable forest and peatland, so long as governments institute robust and meaningful deforestation and peat development restrictions on both small and large holders.

Although optimal milling capacity declines under climate transitions, investors will see overall industry value rise under an Aggressive climate transition.

BOX 7:
THE ROLE OF INDEPENDENT SMALLHOLDERS IN CLIMATE TRANSITIONS

Independent smallholders can play an important role in increasing industry productivity while reducing future deforestation but will need the right support from both the public and private sectors to increase production sustainably. Local land use restrictions and moratoria could bypass smallholders, resulting in additional net losses in forest cover across Indonesia. Figure 24 illustrates the impact of enforcing NDPE restrictions on smallholders (Panel B vs. Panel A). Excluding smallholders from NDPE restrictions and deforestation-related carbon costs allows for 27% higher industry-wide NPV than when smallholders are restricted, but this comes at the expense of up to 5 million hectares of deforestation and/or peatland destruction relative to the Modest A scenario (equivalent to nearly 20% of total Indonesian deforestation since 2001). NDPE restrictions on smallholders, therefore, play a large role in determining palm oil expansion potential as well as industry-wide valuation.

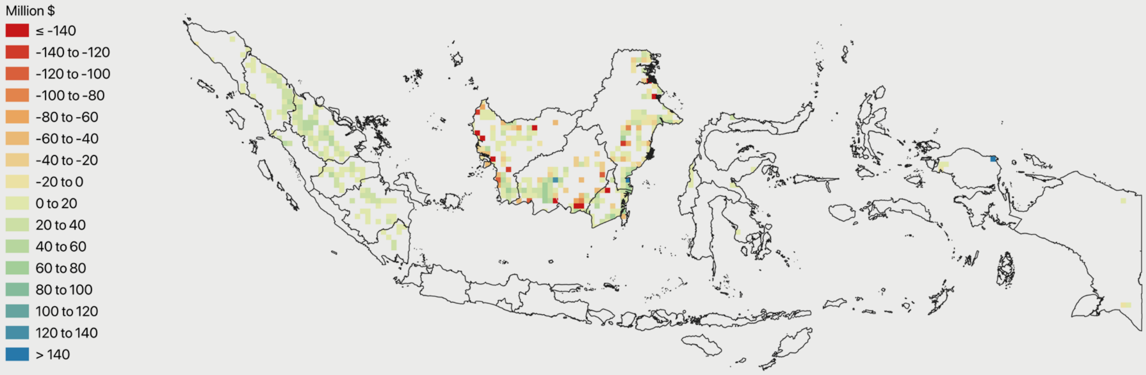
To manage climate transition risks, large companies must improve supply chain traceability and transparency, and also provide smallholders with the education and support they need to embrace forthcoming RSPO standards and sustainable NDPE practices, including by implementing the High Carbon Stock Approach (HCSA). Ramping up this process now will not only ease auditing burdens but will also make a significant difference in reducing reputational risks.

Access to credit is a significant barrier to smallholder intensification. Smallholders are both capital-constrained and have limited access to credit, making it difficult for them to replant and use quality seeds once their land is past its prime--an exercise that can cost more than $2,000 per hectare, roughly 2 years of full-time minimum wage work. While the government does provide replanting subsidies to farmers, not all farmers are able to access these programs or can wait for the four years it takes for palm oil to mature. The resulting "yield gap" can be significant, with many farmers losing the opportunity to double their revenues and yields.

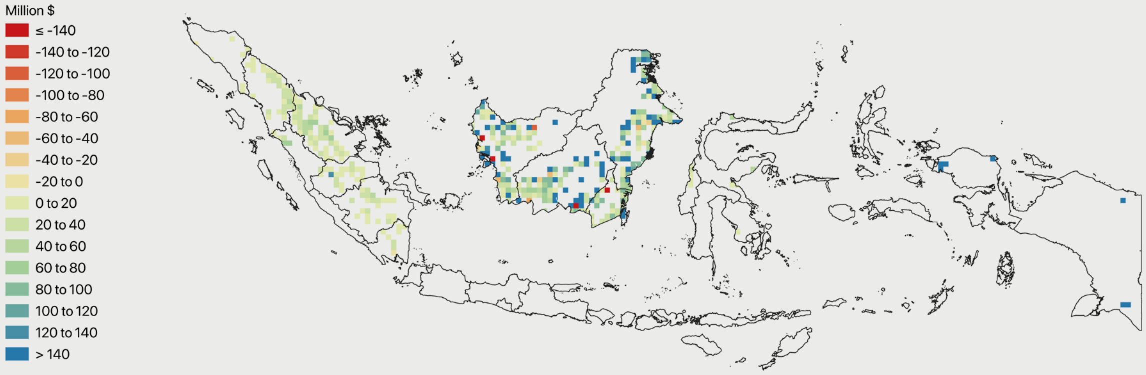
Source: Authors

FIGURE 24:
INDUSTRY NET PRESENT VALUE UNDER CLIMATE TRANSITIONS

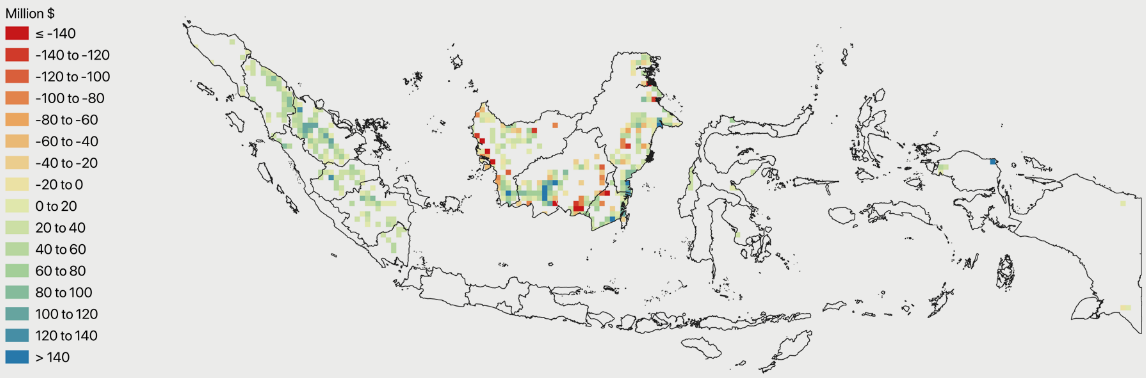
A. Modest: Gain of $1.8 billion of NPV Relative to Historical



B. Modest (Smallholders Exempt from NDPE Restrictions): Gain of $42.0 billion in NPV Relative to Historical



C. Aggressive: Gain of $9.4 billion of NPV Relative to Historical



Source: Concordian
Notes: Grid cell-level results show the difference in 30-year net present value (NPV) compared to the Historical scenario (red cells indicate NPV loss, blue cells indicate NPV gain). All profits for each mill and affiliated plantations are assigned to the grid cell in which the mill is located. In panel B, only smallholders can convert forests and peatland to palm plantation without incurring deforestation-related carbon costs. White cells indicate no NPV difference between the indicated scenario NPV and Historical NPV, typically because of an absence of mills in the grid cell (that is, NPV = $0).

Section VI
Company-Level Vulnerability Analysis

This section describes and presents preliminary results from specialized financial and economic models that test how vulnerable specific companies and business models are to climate transitions.

STEP 4:
Company-Level Vulnerability
- Risk Benchmarking
- Company Value Analysis
- Market Power Analysis

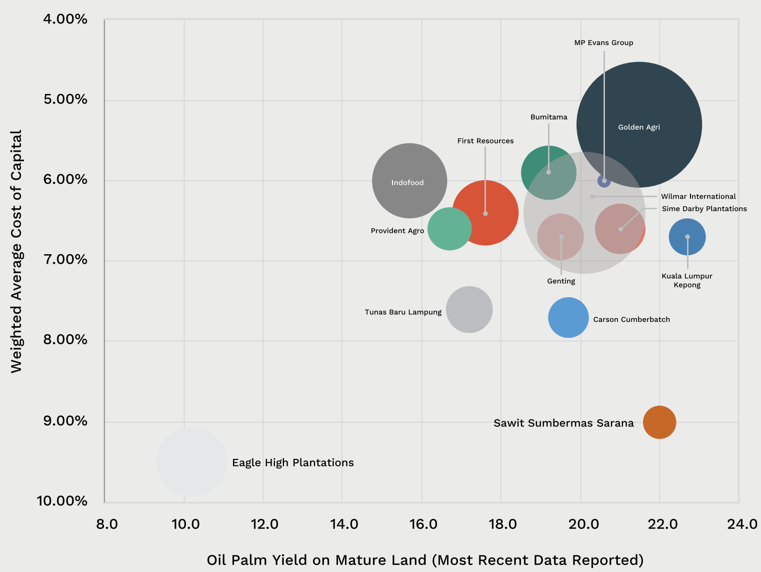
SECTION HIGHLIGHTS

Palm producers are likely to see a wide variation in potential growth and losses depending on their financial and sustainability profile, and level of integration:

- Companies facing the greatest risks under climate transitions tend to be midstream integrated companies--i.e., millers and cultivators--who have weaker pricing power and higher capital costs.
- Vertically integrated actors could face fewer risks under climate transitions given their pricing power and access to capital, but may also be less flexible to convert favorable price increases into profits.

FIGURE 25:
COMPANY VULNERABILITY TO CLIMATE TRANSITION RISK

Bubble size represents total concessions at risk, bubble color represents the percentage of concession at risk



Source: Concordian, based on data from: Damodaran; Bloomberg; Company Annual Reports; Greenpeace 2015 concessions map; 2015 forest cover derived from Hansen et al. 2013; 2012 peat map from Indonesian Ministry of Agriculture, obtained from Global Forest Watch; planted palm maps from Kemen Austin, Austin et al. 2017, and Danylo et al. 2020; and report analysis. Notes: This chart relies on dated maps of concessions, forest cover, and planted palm; and some incomplete or unavailable information on concession ownership for 5.2 million hectares of 2015 industrial palm area that occurs outside of the boundaries of the concession map. Since 2015, some of these concessions may have been planted with oil palm and thus no longer face stranded asset risks under climate transition scenarios unless these concessions are on peatlands and/or violate a company's existing NDPE policies. Yields are not adjusted to reflect the age of the plantation and use the most recent reported yields from company sources.

Climate transitions will have varying impacts on different actors depending on their operational footprint, productivity, and ability to access capital cheaply, among other factors. This variation is especially apparent in the case of Indonesia's palm oil industry which includes actors ranging from independent smallholders to vertically-integrated conglomerates who control downstream refining and trading.[54] In this section, we use the Indonesian palm oil industry as a test case to highlight three methods that uncover company vulnerabilities to climate transition risks:

1. **Risk Benchmarking:** This simple, risk-focused qualitative approach uses sustainability and financial metrics to identify how vulnerable a company is to climate transition risks.

2. **Company Value Analysis:** This sophisticated approach quantifies, in dollar terms, the discounted value of a company's projected profits/losses under climate transitions based on its current operational footprint.

3. **Market Power Analysis:** This detailed economic modeling approach gives investors and companies insights into future industry dynamics and examines which types of business models are well-positioned under climate transitions.

With a few exceptions, these three approaches reach similar conclusions: Larger, vertically-integrated palm oil companies with a strong sustainability profile are well-positioned under climate transitions due to their access to capital and pricing power.

Continued
Company-Level Vulnerability Analysis

A. RISK BENCHMARKING

Figure 25, previous page, charts the following vulnerability metrics to benchmark major palm oil companies against each other:

1. Weighted average cost of capital--an indicator of how cheaply and easily a company can finance productivity and technology upgrades.
2. Current oil palm yields on mature plantations (a proxy[55] for a company's management strategy and replanting discipline).
3. Concessions at risk--i.e., how much of their unplanted concessions are on forest or peatlands (a proxy for their sustainability profile)

This approach highlights that larger, vertically-integrated companies like Sime Darby, Wilmar International, and Golden Agri are well-positioned for climate transition risks relative to their peers. This approach provides a useful indication of a company's vulnerability to climate transition risks. However, it does not fully capture how a company can benefit from opportunities associated with climate transitions whether through rising prices and productivity, new revenue streams like electricity sales from biogas capture and cogeneration, and ability to set prices based on its market power within the palm oil value chain. These factors are considered in the second and third approaches detailed below.

B. COMPANY VALUE ANALYSIS

To undertake our company value analysis we followed the same methods employed in our industry-wide NPV analysis (see Section V) but then allocate NPV results to individual companies by finding each company's mill capacity in each grid cell as a proportion of total grid cell mill capacity, and summing this proportion of cell-level NPV across all grid cells where each company owns mills.[56]

> Most companies stand to gain from an ambitious climate transition, with some companies like Golden Agri gaining over $1 billion in value based on their current asset footprint.

This analysis finds that most companies are able to gain value from climate transitions, though a few companies--particularly BEST Industry Group--are significantly and negatively impacted by forest area expansion, which results in mill and plantation retirements.[57] **In line with the vulnerability benchmarking approach, our company value analysis also identifies Golden Agri, Sime Darby, and Wilmar as beneficiaries under climate transitions (Figure 26, next page).**

C. MARKET POWER ANALYSIS

To predict how industry dynamics could shift due to climate transitions, we use Vivid Economics' Reduced Industrial Market Model (RIMM), an economic model that determines how the market power influences optimal palm oil production and profits under each climate transition scenario. It specifically estimates the degree to which different business models, that vary by levels of integration and operational scale, can pass on costs and secure profits that arise from climate transitions.

RIMM's approach allows for each company archetype to exercise some degree of price-setting power through its production choices. This is particularly important in the Indonesian palm oil industry where a company's market power and revenue-cost structure are largely determined by its level of vertical integration. FFB producers (smallholder farmers and large plantations) face FFB production costs that are almost as high as their revenues, leaving the average producer with thin profit margins. Crude palm oil (CPO) producers have larger margins, in part because they have pricing power, which allows them to sell their products at prices above their marginal costs. Finally, downstream refined palm oil (RPO) producers show narrow margins because they sell their product in the international market, which limits their ability to influence prices. Fully integrated companies face international competition but are able to produce at slightly lower costs by eliminating CPO margins.

To reflect these differences in market power and level of integration, RIMM analyzes four archetypal business models that are representative of the industry:

1. Upstream Separate
2. Upstream Integrated
3. Fully Integrated
4. Downstream Separate

Our modeling results confirm that climate transition impacts will vary by business model, with larger fully integrated companies most protected from downside risks. Key findings include:

- Under all scenarios, fully integrated companies do the best and downstream separate companies do the worst, though the magnitude of difference is greatest under the Aggressive scenario.
- Vertically integrated companies are better positioned because of their ability to capture demand increases and pass-through costs onto final consumers through higher prices.
- Fully integrated companies also gain RPO market share relative to downstream separate companies under the Historical (+0.5 percentage points), Modest A (+0.4 percentage point) and Aggressive (+1.6 percentage points) scenarios.

Continued
Company-Level Vulnerability Analysis

Preliminary modeling results indicate that vertically-integrated companies are less vulnerable to cost increases but less able to benefit from favorable pricing conditions.

Our market power analysis finds that more integrated companies are less vulnerable to climate transition risks. However, it also finds that less integrated companies are better equipped to maximize the benefits from any price increases and/or cost declines. This is an important finding considering that while palm oil prices are likely to rise in the long run under climate transitions, short-term price volatility is likely.

FIGURE 26:
NPV GAINS AND LOSSES RELATIVE UNDER CLIMATE TRANSITIONS BY COMPANY

Company	NPV difference for Modest vs. Historical (million $)	NPV difference for Aggressive vs. Historical (million $)	SPOTT Score (%)	% of Unplanted Concessions at Risk
10 Worst Positioned for Climate Transitions				
BEST Industry Group	-117.2	-59.2	1.3%	40
Teladan Prima Group	114.2	4.5	NA	40
PT Multi Agro Gemilang Plantation Tbk	-0.1	11.2	NA	86
PT Provident Agro Tbk	19.7	13.6	NA	74
PT Andira Agro Tbk	7.2	18.3	NA	NA
M.P. Evans Group Plc	12.3	21.6	63	54
SOCFIN Group	10.9	30.5	NA	60
PT Duta Marga Lestarindo	12.2	33.6	NA	NA
Genting Berhad	41.6	37.2	50.9	70
Anglo Eastern Plantations Plc	20.4	38.4	39.3	55
10 Best Positioned for Climate Transitions				
Musim Mas	111.3	224	69.9	86
First Resources Ltd.	203.8	269.2	64.1	71
PT Triputra Agro Persada	452.8	283.5	25.9	62
Royal Golden Eagle	157.8	297.2	NA	55
Bumitama Agri Ltd.	219.3	331.1	63.3	65
Indofood Agri Resources Ltd.	294.5	340.8	51.1	62
Sime Darby Plantations	395.6	577.6	72.1	62
Wilmar International Ltd.	334.6	583.8	81	69
PT Perkebunan Nusantara XII	485.4	708.4	NA	66
Golden Agri-Resources Ltd.	1,123.4	1,575.8	77.7	65

Source: Concordian, using mill location and ownership data from the Universal Mill List 2019 (available on Global Forest Watch) and mill capacity data compiled by Harahap et al 2020. See Appendix for a description of data limitations for this figure and for further detail on additional datasets used as input to the BeWhere model. Data sources and limitations related to unplanted concession areas at risk are detailed in our Indonesia analyst report available at http://orbitas.org

Section VI
Next Steps for Agricultural Actors and Financiers

SECTION HIGHLIGHTS

Our climate transition risk analysis uncovers the following:

- Land use restrictions and greenhouse gas (GHG) pricing create stranded asset risks for operators–especially those who own or operate on high conservation value and/or high carbon stock lands.
- Business as usual growth strategies on forest and peatlands will no longer be tenable, forcing producers to better use existing land rather than expanding geographically.
- Smallholders represent low hanging fruit to increase industry yields and prevent further deforestation, underscoring the need for both public and private actors to provide technical and financial assistance to smallholders.
- Emerging agroforestry and carbon sequestration approaches like intercropping, silvopastoral farming, and biogas cogeneration all create significant opportunities for companies to both survive and thrive under climate transitions.
- Company-level vulnerability to climate transition risks will depend on several factors including operational footprint, emissions intensity, productivity practices and investments, sustainability strategies, market power, cost of capital, and access to capital.

Orbitas' analysis underscores that climate transition risks will create both major opportunities and major challenges for food and land use systems. To assess and mitigate these risks and take advantage of future opportunities, the public and private sectors must take significant steps toward assessing, disclosing, and preparing for climate transition risks in agricultural sectors. Crucially, without these transitions, agricultural producers, investors, food systems, and our global populations at large, will suffer under the debilitating impacts of extreme temperatures and weather events.

Mitigating climate transition risks will require significant actions from both the public and private sectors.

Based on our analysis, we suggest the following concrete next steps for agricultural stakeholders, including industry actors, financiers, and policymakers. It is in both the public and private sectors' interests to proactively prepare for inevitable climate transitions not just to preserve our fragile food systems and global ecosystems, but also to preserve the profitability and longevity of agricultural activity.

A. INDUSTRY ACTORS

Objective:

Industry actors must both support climate transitions and prepare for them. As evidenced by this report, climate transitions create opportunities for many agricultural producers to benefit from higher prices while also minimizing industry exposure to the physical impacts of warming temperatures. To adequately prepare for transitions companies must:

Actions:

1. **Create in-house capacity or outsource climate risk assessment functions.** Practitioners can use the framework described in this report and its accompanying Technical Guidance to inform climate transition risk preparation and to take advantage of corollary opportunities.
2. **Disclose climate transition risks.** Proactive disclosure using existing guidance from the SASB, CDP, WBCSD, and/or TCFD and methods employed in this report signals to the investment community and other stakeholders that a firm's risk management functions are robust and forward-looking.
3. **Prepare a climate transition risk mitigation strategy that includes the following actions:**

    a. **Implementing and enforcing NDPE policies,** including through the High Carbon Stock Approach (HCSA)-- a method that distingu-ishes forest areas for protection from degraded lands with low carbon and biodiversity values.

    b. **Increasing transparency and traceability within supply chains** to minimize indirect exposure to climate transition risks through suppliers.

    c. **Investing in sustainable strategies, such as** yield improvements emissions reduction technologies, and more sustainable farming, breeding, and raising techniques.

    d. **Focusing on producing and marketing sustainable products** like plant-based proteins and deforestation free consumer goods to avoid reputational risks in the eyes of increasingly climate-aware consumers.

Continued
Next Steps for Agricultural Actors and Financiers

e. **Improving smallholder capacity** through technical assistance programs, credit facilities, and direct financial assistance. Importantly, increasing income stability for smallholders, for example, through long-term supply contracts, will ensure consistent, higher-yielding, better quality supply for Firms.

f. **Sharing high-quality land use, operational, and cost structure data** to ensure that the industry, its trade associations, and governments can make more informed decisions about how to support the industry, its firms, and smallholders.

Orbitas' analysis underscores that climate transition risks will create both major opportunities and major challenges: for food and land use systems.

B. FINANCIERS

Objective:

Agricultural financiers must avoid unsustainable investments, while ramping up investment in sustainable technologies, practices, and companies. Not only do unsustainable companies face future stranded asset risks, they also face immediate reputational risks as downstream purchasers increasingly adopt and enforce NDPE policies. Meanwhile, as our analysis shows, sustainable companies can benefit substantially from climate transitions. To better inform their investment decisions, financiers must:

Actions:

1. **Assess in-house and client exposure to climate transition risks** using the guidance from this report and TCFD guidelines.

2. **Predicate lending to, and investment in, producers on adopting sustainable practices and sourcing from sustainable suppliers.** Sustainable investees protect investors from immediate reputational risks while also acting as a hedge against future climate transition risks.

3. **Request investees assess and disclose climate transition risk and vulnerability** per TCFD guidelines. Some global agricultural companies like Olam have already hired in-house practitioners or outsourced consultants to assess climate transition risks; investors should encourage and/or require all investees to do the same, drawing from the results and methods presented in this report. Relevant vulnerability indicators include:
   - Percentage of operations, concessions, and/or landbank in areas with high conservation, carbon stock, biodiversity, ecosystem and/or social and indigenous community value.
   - Emissions intensity, including emissions from peat drainage, fires, diesel fuel use, fertilizer application, and methane emissions per unit of palm oil.
   - Asset portfolio mix and sustainable growth strategy.
   - Operational efficiency.
   - Access to and cost of capital (as indicated by a company's WACC).

4. **Provide favorable financing for profitable emissions mitigation measures, sustainable yield enhancements, and technology innovation such as:**

   - Agroforestry techniques like intercropping which provide opportunities for carbon sequestration payments, increased productivity, and lower costs.
   - Using information technologies like satellites, drones, and artificial intelligence to optimize productivity under unpredictable weather conditions.[58]
   - On-lending and dedicated credit facilities that provide subsidized lending, favorable financing, and technical assistance to small- and medium-sized producers adopting sustainable methods.
   - Biogas capture and cogeneration, which reduces onsite fuel costs and emissions while also improving rural electrification and diversifying income sources.
   - Better utilizing intermediate and waste products such as palm kernel shells and empty fruit bunches in the case of palm oil.

5. **Engage with policymakers to support financial stability regulations** and to normalize climate risk disclosure throughout the financial sector.

C. POLICYMAKERS

Objective:

Implement economy-wide emissions mitigations policies that include essential support provisions for affected industries. Proactively pricing emissions will avoid a "disorderly repricing of assets" that would hurt investment portfolios and balance sheets, and consequently destabilize agricultural commodity markets. Concrete next steps to

Continued
Next Steps for Agricultural Actors and Financiers

ensure a smooth transition for industry actors include:

1. **Empower financial regulators to require climate transition risks assessment and disclosure** by both companies and financial institutions. This risk assessment and disclosure, which should include disclosure of a company's operational and/or portfolio emissions inventory and intensity-is an important and critical first step to ensuring the future stability of financial--including insurance--and agricultural systems.

2. **Invest heavily in and encourage productivity improvements.** Governments have historically been some of the largest investors in agricultural productivity–including by scaling up assistance and credit to smallholders. Policymakers will need to recommit to and scale-up playing this role as yield improvements become critical to achieving climate goals. Specific actions include:
   i. Supporting large scale research and development into sustainable yield-enhancing technologies and emerging agroforestry techniques.
   ii. Providing dedicated financing and grant facilities to smallholders to encourage crop yield improvements and more sustainable livestock breeding and raising practices.
   iii. Mandating and financially supporting the use of emissions-reducing and yield-enhancing technologies.
   iv. Ramping up forest crime monitoring and enforcement to ensure a level playing field across agricultural industries.

3. **Improve industry and land use data availability and transparency,** which are both essential to tracking progress toward climate mitigation commitments, rural planning, and to providing industries with necessary support during transitions. Governments should specifically release data on land use and agricultural production to all stakeholders to ensure that civil society is able to keep the public and private sectors accountable.

Future Orbitas reports will more deeply examine how transition risks and opportunities can impact agricultural sectors and industries, as well as their companies and investors. Orbitas also believes that expanding data access and transparency within agricultural supply chains, including financial flows is necessary for stakeholders to identify pathways to more sustainable business practices and investments.

Annex 1
Forest Cover Projections Methods

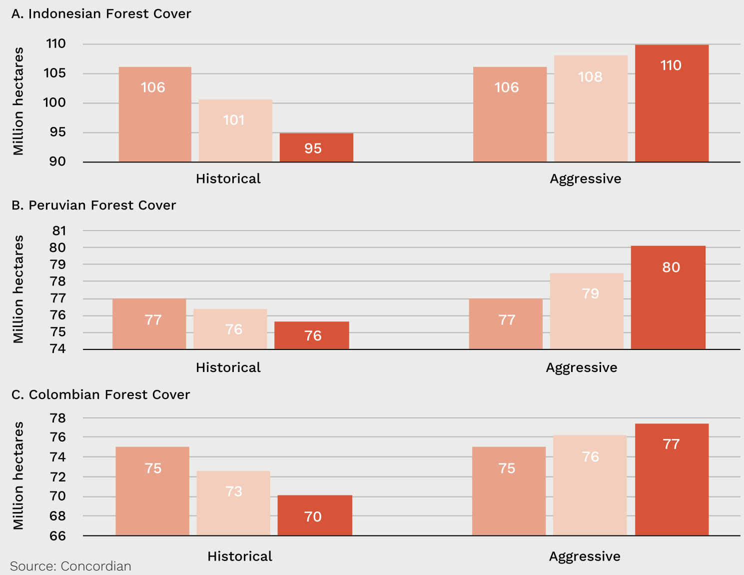
To implement the national-level land use restrictions in each of our industry analyses, and to develop high spatial resolution predictions for forest area changes under each climate transition scenario, we utilize a model called OSIRIS.

OSIRIS is an econometric model used to predict reforestation and deforestation in countries located in the tropics.

OSIRIS is an econometric model used to predict reforestation and deforestation in countries located in the tropics. It achieves much higher spatial resolution (0.05° latitude x 0.05° longitude, or approximately 5.5 km x 5.5 km at the Equator) than MAgPIE because it relies on high-spatial-resolution historical observations of agricultural prices, yields, and forest area in each 0.05° x 0.05° grid cell across tropical countries, finding the most likely relationship between agricultural value and forest area for a given grid cell. Under climate policies, OSIRIS can accommodate the effect of GHG prices on forest area by subtracting potential forest carbon value from agricultural value in each grid cell and, along with the estimated historical relationship between agricultural value and forest area, separately predict both deforestation and reforestation in each grid cell for all future time steps.

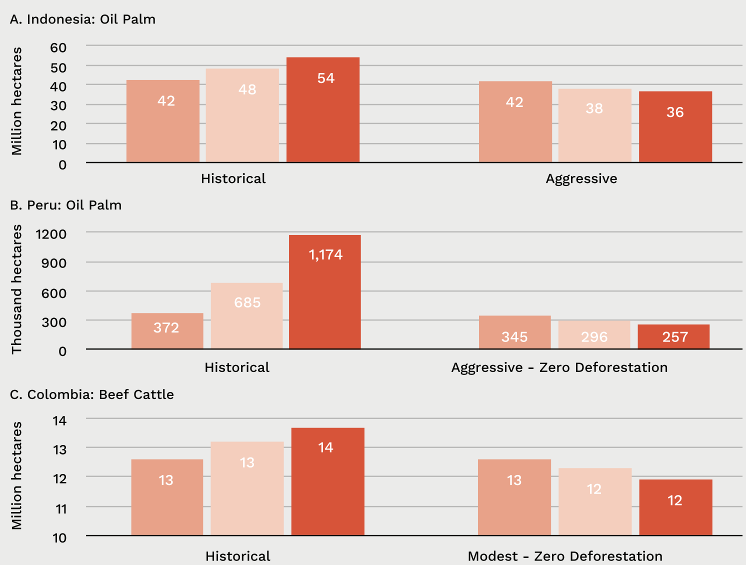
We run OSIRIS for each global-local climate transition scenario. For each scenario, OSIRIS uses the same GHG prices used in MAgPIE. We also multiply the agricultural commodity price observations used in OSIRIS (which uses 2000-2010 production-weighted average national farmgate prices for the top five producer countries of each crop (Busch et al. 2019)) by

FIGURE A: FOREST COVER BY COUNTRY



Source: Concordian
Notes: Forest cover projections are based on the OSIRIS model (Busch et al., 2019).[60] Indonesian forest cover estimates only account for forest on the mainland of Sumatra, Kalimantan, Sulawesi, and Papua.

FIGURE B: AGRICULTURAL LAND EXPANSION POTENTIAL BY COUNTRY



Source: Concordian
Notes: See Technical Guidance for calculation details. For Indonesia, values indicate the maximum footprint (millions of hectares) of the oil palm industry –including both industrial and smallholder plantations– for the mainland of Sumatra, Kalimantan, Sulawesi, and Papua. The estimates include all palm-suitable land (Pirker and Mosnier 2018)[61] that meets the indicated scenario's land-use constraints. Not all of this land is found to be economically feasible for development using the BeWhere model. For Peru, values indicate the palm-suitable land (Pirker et al. 2016)[62] available for industrial palm development, using a minimum plantation size of 1,000 hectares; NDPE restrictions are applied in the Aggressive scenario. For Colombia, values indicate the cattle-suitable land (Colombia's Rural Agriculture Planning Unit)[63] available for industrial beef cattle production, using a minimum farm size of 200 hectares. For all countries and scenarios, the estimates account for the forest projections from the OSIRIS model (Busch et al. 2019).

MAgPIE food price index (FPI) values to generate grid-cell level agricultural value projections to 2050 by scenario. For scenarios where deforestation is not allowed, FPI values are increased by 10% from MAgPIE estimates to account for increasing agricultural prices if commodity supply is further constrained. Using these inputs, OSIRIS provides area reforested and deforested (if applicable) for each grid cell and for each 10-year time step between 2020 and 2050. The grid cell-level forest area projections are calculated for Peru, Colombia, and Indonesia, with OSIRIS trained on historical data specific to each country. The results (Figure A) are used in several ways:

- In Indonesia, OSIRIS results are used to create a land use constraint map for an additional palm oil industry optimization model, BeWhere.
- In Peru and Colombia, OSIRIS results are overlaid with palm oil and cattle grazing suitability maps respectively to estimate constraints to future agricultural growth.

Annex 2
BeWhere Assumptions

Combining global models like MAgPIE with regional, spatially-explicit models like BeWhere and OSIRIS allows for making powerful predictions about how global climate policies and market shifts can impact individual assets over time and space. However, these predictions are heavily dependent on model assumptions. Some of the strongest assumptions required for applying the BeWhere model in this context include:

- The industry-wide Indonesian expansion or contraction predicted by BeWhere is sufficiently aligned with global market trends such that MAgPIE results remain valid. Since we do not run the BeWhere model for all palm oil production globally, we cannot verify this assumption, but both BeWhere and MAgPIE suggest similar trends in Indonesian and global palm oil production, respectively.
- Forest cover expansion predicted by OSIRIS is binding for Indonesian palm oil producers, assuming that OSIRIS accurately predicts where forest cover will become more economically attractive than palm oil plantation. We assume producers are not eligible to receive carbon payments for planting forests.
- We assume producers are able to significantly increase FFB yields on existing and new plantations, by up to 200% between 2020 and 2050 in the Aggressive scenario. This allows producers to both increase plantation profitability and avoid deforestation GHG costs. Producers' ability to achieve yield improvements may depend on government support or additional company investments beyond what we account for in our models.
- Another important opportunity that increases revenues in climate transition scenarios is the ability of mills to invest in technologies that diversify revenue streams, including kernel crushing and biogas capture. Thus, we assume producers have uninhibited access to capital needed for making optimal investments, avoiding the complication of capital constraints.
- Additional discussion on our assumptions and BeWhere model structure can be found in this report's accompanying Technical Guidance document.

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(6) For each global scenario, we assess risk exposure for a basket of agricultural commodities using MAgPIE, an open source land use allocation model that projects commodity prices, production, productivity, and land use, among other variables. MAgPIE is the Potsdam Institute's Model of Agricultural Production and its Impact on the Environment, See this report's accompanying Technical Guidance for additional details on MAgPIE. **(7)** Due to spatial and temporal misalignments between concession data sets and planted palm data sets, our calculations may over or understate the amount of unplanted palm in forest and/or peat. Nevertheless, these calculations are based on the most reputable and recent publicly available data and provide a useful indication of the extent of asset stranding risks under climate transitions. **(8)** Sustainability Policy Transparency Toolkit, available at: http://spott.org **(9)** Percentage of concession area that is unplanted peat land or forest (2%) plus percentage of concession area that is palm on peat (25%). Estimate is based on Greenpeace 2015 concessions map; 2015 forest cover derived from Hansen et al. 2013; 2012 peat map from Indonesian Ministry of Agriculture (obtained from Global Forest Watch); planted palm maps from Kemen Austin, Austin et al. 2017, and Danylo et al. 2020. **(10)** Tracts of non-forest, non-peat, palm-suitable land with minimum size of 1,000 hectares. **(11)** As defined by the Colombian rural agricultural planning agency, UPRA. **(12)** This assumes that the Colombian government does not provide any kind of subsidies to the industry to cope with emissions costs increases.
(13) Concordian, combining a land use map from IDEAM 2012 and an oil palm biophysical suitability map from Pirker et al. 2016. Administrative boundaries are from GADM. See Technical Guidance for more details.
(14) FEDEGAN, "Beef Production and Silvopastoral Systems,"Agri Benchmark Beef and Sheef Conference, 2015, http://www.agribenchmark.org/beef-and-sheep/conferences/2015-colombia.html.
(15) Enterprise value (EV) represents the takeover value, i.e, the amount of money an investor should have to pay to get complete ownership of the company. It is calculated by taking a company's projected free cash flows and discounting them at an industry-appropriate weighted average cost of capital.
(16) Shukla, Priyadarshi, Jim Skea, Eduardo Calvo Buendia, Valérie Masson-Delmotte, Hans-Otto Pörtner, Panmao Zhai, Raphael Slade, Sarah Connors, Renée van Diemen, Marion Ferrat, Eamon Haughey, S. Luz, Suvadip Neogi, Minal Pathak, Jan Petzold, & Joana Portugal Pereira, "Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems," IPCC, 2019, https://www.ipcc.ch/srccl/ **(17)** 36 percent of global tropical forest loss between 2000 and 2011 was driven by the production of beef, palm oil, and soy. Tropical Forest Alliance, "Commodities and Forests Agenda 2020: Ten priorities to remove tropical deforestation from commodity supply chains," World Economic Forum, September 2017, https://climatefocus.com/sites/default/files/TFA2020_CommoditiesandForestsAgenda2020_Sept2017_0.pdf. **(18)** Lobell, David, Wolfram Schlenker, and Justin Costa-Roberts, " Climate trends and global crop production since 1980," Science, Vol. 333, 6042, July 2011, https://science.sciencemag.org/content/333/6042/616. **(19)** Rosenzweig, Cynthia, Joshua Elliott, Delphine Deryng, Alex C. Ruane, Christoph Müller, Almut Arneth, Kenneth J. Boote, Christian Folberth, Michael Glotter, Nikolay Khabarov, Kathleen Neumann, Franziska Piontek, Thomas A. M. Pugh, Erwin Schmid, Elke Stehfest, Hong Yang, and James W. Jones, "Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison," PNAS, 111 (9), March 2014, https://doi.org/10.1073/pnas.1222463110. **(20)** Battiston, Stefano and Irene Monasterolo, "The Climate Spread of Corporate and Sovereign Bonds," SSRN, July 1, 2020, http://dx.doi.org/10.2139/ssrn.3376218.
(21) For each global scenario, we assess risk exposure for a basket of agricultural commodities using MAgPIE, an open source land use allocation model that projects commodity prices, production, productivity, and land use, among other variables. MAgPIE is the Potsdam Institute's Model of Agricultural Production and its Impact on the Environment, See this report's accompanying Technical Guidance for additional details on MAgPIE. **(22)** This includes efficient replacement of less productive crops/livestock **(23)** The Indonesian government does not provide current data on oil palm concessions. To calculate stranded asset risks we used oil palm concession data roughly representative of 2015 compiled by Greenpeace from multiple data sources; peat map from the Indonesian Ministry of Agriculture (2012, obtained from Global Forest Watch); 2015 satellite-based tree cover derived from Hansen et al. 2013; and satellite-derived industrial planted palm area for 2015 from Austin et al. 2017, with more recent updates from Kemen Austin for Papua and Sulawesi, and additional planted palm data from approximately 2017 from Danylo et al. 2020. We apply a 50% canopy cover threshold to delineate between forest and non-forest areas, meaning that even non-forest areas can contain up to 50% tree

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cover, yet such areas are not considered stranded in this analysis. Due to a lack of more recent available data, our calculations do not account for changes in the concession map, forest cover, or plantation map since 2015. We use all concessions in the Greenpeace dataset regardless of permit level issued. Due to a lack of publicly available data on concession ownership, we have not updated the ownership information from this 2015 dataset, although we have performed additional subsidiary–parent matching to better assign parent companies to the original ownership data. Combining the concession dataset with the satellite-derived planted palm maps, we find that 45% (5.2 million hectares) of 2015 industrial palm plantation area occurs outside of the concession boundaries. This area is excluded from the analysis in this table because we have no information regarding ownership of plantations outside of the available concession map. We estimate that in 2015, 66% (12.2 million hectares) of the concession area was unplanted; however, very young plantations present in 2015 may not have been observed from space, resulting in an underestimate of unplanted concession area in 2015. **(24)** We assume that plantation developers would not receive compensation under peatland restoration policies; it is possible that producers would not face the full extent of these write-offs if governments provided compensation to the private sector for vacating peatlands. Approximately 53% of 2015 planted palm area on peat occurs outside of the boundaries of the Greenpeace 2015 concession map, with about three quarters of this area associated with industrial plantations and one quarter associated with smallholder plantations. **(25)** This statistic considers economically feasible expansion into biophysically suitable areas by both industrial and smallholder plantations. **(26)** Busch, Jonah, Jens Engelmann, Susan C. Cook-Patton, Bronson W. Griscom, Timm Kroeger, Hugh P. Possingham, and Priya Shyamsundar, “Potential for Low-Cost Carbon Dioxide Removal through Tropical Reforestation,” Nature Climate Change, 9(6), June 2019, doi:10.1038/s41558-019-0485-x. **(27)** Version 3.6. https://gadm.org. **(28)** Finer, M., Vijay, V., and Mamani, N. (2018). Oil Palm Baseline for the Peruvian Amazon. 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González-Quintero, Ricardo, Maria Solange Sánchez-Pinzón, Diana María Bolívar-Vergara Ngonidzashe Chirinda, Jacobo Arango, Heiber Alexander Pantévez, Guillermo Correa-Londoño, Rolando Barahona Rosales, “Technical and environmental characterization of Colombian beef cattle-fattening farms, with a focus on farm size and ways of improving production,” Outlook on Agriculture, October 2019, https://doi.org/10.1177/0030727019884336. **(36)** As defined by UPRA: Colombia’s rural planning department. See https://sipra.upra.gov.co/ for technical definitions of suitability; For our calculations we consider UPRA-defined “Medium” and “High” suitable land areas as suitable for cattle ranching. This suitability definition considers several factors including biophysical suitability as well as social, economic, and ecological factors. **(37)** Busch, Jonah, Jens Engelmann, Susan C. Cook-Patton, Bronson W. Griscom, Timm Kroeger, Hugh P. Possingham, and Priya Shyamsundar, “Potential for Low-Cost Carbon Dioxide Removal through Tropical Reforestation,” Nature Climate Change, 9(6), June 2019, doi:10.1038/s41558-019-0485-x. **(38)** Enterprise Value (EV) is the measure of an asset's total value, comprising equity market capitalization and short-term and long-term debt. Enterprise value is calculated by taking a company’s projected free cash flows and discounting them at an industry-appropriate weighted average cost of capital to estimate the sum of the company’s equity value and debt. **(39)** For existing assets we assume a constant replanting rate to achieve steady state yields; for new plantations we include upfront capital expenditures, land acquisition costs, and a FFB production yield curve reflecting tree productivity by age. **(40)** The “Cost-to-Yield Multiplier” the relationship between yield increases and operational expenses, e.g. due to more intensive application of fertilizer and harvesting practices. A multiplier of 1 implies that a 1% increase in yield requires a 1% increase in certain operational costs (like fertilizer and labor, but not transportation and overhead). A multiplier of 0.5 means a 1% increase in yield only requires a 0.5% increase in operational costs. **(41)** Chu, Mei Mei, and Krishna N. Das, “Small oil palm farmers face survival crisis in risk to future output” Reuters Business News, May 20, 2020, https://www.reuters.com/article/us-health-coronavirus-malaysia-palmoil-idUSKBN22W0MN **(42)** Goh K.J., Ng P.H.C. and Lee C.T., “Fertilizer Management and Productivity of Oil Palm in Malaysia,” accessed on Aug 3, 2020, www.aarsb.com.my/wp-content/AgroMgmt/OilPalm/FertMgmt/Research/FertMgmt&Product.pdf

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(43) In the indicative modeled case, a CPO/FFB price drops from a "normal" 118 $/tFFB level to 85 $/tFFB for just one year and fully recovers the year after. The high efficiency plantation that temporarily stops fertilizer use in the year of low price (and resumes it to the full extent starting from the year after) is experiencing the yield losses of 7% and 5% in the two following years. These yield losses are well compensated by the zero fertilizer cost in the low price year which creates a positive impact on the NPV. Alternatively, losing a hectare of productive land (that has a positive NPV) negatively impacts the total company's NPV. **(44)** González-Quintero, Ricardo, Maria Solange Sánchez-Pinzón, Diana María Bolívar-Vergara Ngonidzashe Chirinda, Jacobo Arango, Heiber Alexander Pantévez, Guillermo Correa-Londoño, Rolando Barahona Rosales, "Technical and environmental characterization of Colombian beef cattle-fattening farms, with a focus on farm size and ways of improving production," Outlook on Agriculture, October 2019, https://doi.org/10.1177/0030727019884336.
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(46) FEDEGAN 2019. **(47)** Simply put, forms of cattle production where ranchers graze their cattle in areas where they also planted trees and fodder shrubs for a more sustainable land use. **(48)** Forgotson, Joshua, "Generating Electricity from Biogas from Palm Oil Mill Effluent," Climate Links, April 2019, https://www.climatelinks.org/blog/generating-electricity-biogas-palm-oil-mill-effluent
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(56) This approach requires assuming that companies will maintain equal proportional mill and plantation capacity over time within each grid cell and that companies cannot relocate across grid cells over time. However, it does allow individual companies to expand and contract in accordance with trends predicted for each grid cell. **(57)** Even so, in reality, with adequate knowledge of coming transitions, these companies would have the option to relocate to more favorable areas and benefit from the gains predicted for other companies-- an option our NPV analysis is unable to consider at the company level. **(58)** Global Oils and Fats, "Digitisation of agriculture: Transforming production agriculture," Issue 3, September 2019, http://gofbonline.com/digitisation-of-agriculture/ **(59)** CFTC, Managing Climate Risk in the US Financial System, 2020, Available at: https://www.cftc.gov/sites/default/files/2020-09/9-9-20%20Report%20of%20the%20Subcommittee%20on%20Climate-Related%20Market%20Risk%20-%20Managing%20Climate%20Risk%20in%20the%20U.S.%20Financial%20System%20for%20posting.pdf **(60)** Busch, Jonah, Jens Engelmann, Susan C. Cook-Patton, Bronson W. Griscom, Timm Kroeger, Hugh P. Possingham, and Priya Shyamsundar, "Potential for Low-Cost Carbon Dioxide Removal through Tropical Reforestation," Nature Climate Change, 9(6), June 2019, doi:10.1038/s41558-019-0485-x. **(61)** Pirker J and Mosnier A (2018). Suitability map for industrial-scale oil palm cultivation for Indonesia. Accessed through IIASA on 3 May 2020: http://pure.iiasa.ac.at/id/eprint/15148/
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Navigating climate transition risks

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