Research Paper

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Environment, Energy and Resources Department | July 2016

Managing the Risk of Stranded Assets in Agriculture and Forestry

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Summary

- To date, much of the research into stranded assets – broadly defined as assets incurring significant unanticipated or premature write-downs or devaluations – has focused on the fossil fuel sector. However, not least in the context of the 2015 Paris Agreement, and with growing understanding that climate change may become a major factor in the creation of stranded assets, it has become clear that it is not just the energy sector that will be affected. Assets in agriculture and forestry may also be at risk of stranding, because of physical impacts such as drought and desertification as well as through regulatory and technological change.

- The risk of stranding is particularly high in production regions where natural forests are being cleared for agricultural use. Other regions at high risk are those where climate change is predicted to have impacts that will severely disrupt production cycles or shift production patterns. In addition, strong low-carbon development plans can affect the regulatory frameworks that govern the agriculture and forestry sectors, bringing further risks of stranding.

- Stranding risks have a potential impact on the various actors positioned along the supply chain for agriculture and forest commodities. They include the land- or rights-owners, the owners of infrastructure related to the transport and processing of commodities, consumer companies and investors.

- The faster the pace of decarbonization, or the more pronounced the impacts of climate change, the greater the chance of asset stranding and the higher the likelihood of economic, social and political impacts. The prospect of asset stranding could be sufficient to cause potentially affected groups to impede efforts towards low-carbon development, but this possibility has not been sufficiently accounted for in the national low-carbon development plans of either developed or developing economies. As a result, there is a potential risk to the implementation of such plans.

- This paper includes case studies of stranding risk in Brazil, Malaysia and Liberia. In these countries, there are potentially significant risks of stranding, both from regulation and climate change impacts. However, there has been very little consideration of these risks by policy-makers, and there are significant information gaps.

- Further research is necessary in the following areas: analysing the outlook for biofuels to assess the risk of stranding and the possible impacts of new technology; assessing the physical impacts of extreme weather events on investments, taking into account the role of the insurance industry and price fluctuations; and determining whether growing consumer preferences for 'sustainable' products contribute to the risk of stranding in agriculture and forestry.

- Such research could be used to initiate discussions within producer countries about the risk of stranded assets given their national strategies and policies, and in light of the available evidence of the physical impacts of climate change, in order to identify the options for both mitigating and managing that risk.

Introduction: Definition and time frames of stranding

'Stranded assets' are defined as assets that have suffered 'unanticipated or premature write-downs, devaluations, or conversion to liabilities'.[1] While stranding may occur for many different reasons, this paper focuses on potential risks arising from climate change in relation to the agriculture and forestry sectors, with specific case studies on Brazil, Malaysia and Liberia. In this context, the risks of stranded assets can be divided into two broad categories:

- Physical risks – such as land degradation and climate variability, which have various consequences for production and trade; and
- Regulatory and economic risks affecting supply chains – such as new legislation to mitigate environmental impacts, changes in policies and the interpretation of laws, as well as evolving business practices.

Following the landmark Paris Agreement, adopted in December 2015 by the 21st Conference of the Parties (COP 21) under the auspices of the UN Framework Convention on Climate Change, it is clear that the question of how efforts to reduce greenhouse gas emissions will affect investments is a crucial one. The agreement contains a long-term goal to limit the global temperature increase to 'well below 2°C above pre-industrial levels', and to 'pursue efforts' to limit that increase to 1.5°C; and achieve a balance between anthropogenic greenhouse gas emissions by sources and removals by sinks in the second half of the 21st century.

Scientific assessments suggest that the global carbon budget (the amount of carbon dioxide that can be emitted while limiting global average temperature increases below 2°C) is approximately 1,000 gigatonnes, and significantly less for 1.5°C.[2] This has implications for large emitting sectors such as energy, transport, forests and agriculture. For example, it is estimated that in order to stay within the 2°C carbon budget, only around one-third of existing fossil fuel reserves can be burned.[3] This means that, depending on the extent to which governments pursue policies consistent with a below 2°C objective, there is a risk for the remaining two-thirds of the world's reserves that they become stranded assets. Moreover, even if efforts to decarbonize the energy sector are successful, it will not be possible to stay below 2°C without addressing emissions associated with agriculture and forestry.[4] As countries seek to reduce emissions in these other sectors, this brings the risk of creating stranded assets.[5]

To date, much of the stranded assets debate in relation to climate change has focused on fossil fuels. As implementation of the Paris Agreement moves forward, however, it will be important to consider stranding risks across the full range of sectors that will potentially be affected. The speed at which

[1] Caldecott, B., Dericks, G. and Mitchell, J. (2015), *Stranded Assets and Subcritical Coal: The Risk to Companies and Investors*, Oxford: Smith School of Enterprise and the Environment.
[2] International Energy Agency (2014), *World Energy Outlook 2014*, Paris: IEA Publications.
[3] Leaton, J., Ranger, N., Ward, B., Sussams, L., and Brown, M. (2013), Unburnable Carbon 2013: Wasted capital and stranded assets, London: Carbon Tracker and The Grantham Research Institute, LSE.
[4] Wellesley, L., Froggatt, A. and Happer, C. (2015), *Changing Climate, Changing Diets: Pathways to Lower Meat Consumption*, Chatham House Report, London: Royal Institute of International Affairs.
[5] This paper focuses in particular on applying the concept of stranded assets to forest-related agriculture and associated products. In some instances, however, the authors use the short-form AFOLU, encompassing the wider agriculture, forest and other land use sector.

the various physical and regulatory risks can result in stranded assets varies, but the time horizon required for investors to take note of potential stranding is estimated at between five and 15 years.[6] Mark Carney, the governor of the Bank of England, has referred to the 'tragedy of the horizon', whereby impacts beyond a time frame of 15 or so years are often beyond the focus of the financial community.[7] None the less, as countries establish plans for decarbonization and adaptation to climate change to meet their commitments under the Paris Agreement, these are likely to have impacts on forest and agricultural assets within the 15-year horizon that is critical for investors. Similarly, the physical impacts of climate change are already being seen, bringing risks of stranding within this horizon.

There are important differences between the fossil fuel industry and the agriculture, forest and other land use (AFOLU) sector that affect how the concept of stranded assets can be applied. Whereas in the case of fossil fuels it has been predicted that stranding will occur across the sector as a whole, this is unlikely to happen in agriculture and forestry. Rather, the stranding risks for agriculture and forestry investments are likely to be differentiated according to sub-sector, practice or geography. It is not surprising therefore that the concept of stranded assets has more quickly found acceptance in relation to the extraction of fossil fuels. All the same, a comparison can be drawn with the energy sector as a whole, which encompasses both sustainable (e.g. renewable) and unsustainable (e.g. fossil fuel) options, and will thus also have different impacts in different sectors. The closest equivalent to the unsustainable option in the AFOLU sector is the logging of natural primary forests, which are, like fossil fuels, a resource that cannot be replaced. Indeed, reducing deforestation has been identified as the climate change-mitigation action with the largest carbon-stock impact in the short term; this is in itself significant as it means that regulatory risks are likely to increase and thus increase the probability of stranding in the forest sector.[8]

The paper provides an assessment of how the concept of stranded assets can be applied to the AFOLU sector, draws together initial lessons from a set of case study countries – Brazil, Liberia and Malaysia – and makes recommendations for further work.

The risks of stranding in AFOLU

It is critical to recognize that the various factors underlying the risks of stranding do not operate in isolation; rather, they have an influence over one another. Changes in regulatory frameworks, for example, may be in response to current or predicted climate-change impacts; but they may also be the result of changes in consumer demand, or in response to campaigns by various pressure groups. Similarly, new legislation can have strong impacts on supply chains and production patterns and in this way affect investment patterns.

[6] Caldecott, B., Tilbury, J. and Carey, C. (2014), *Stranded Assets and Scenarios*, Discussion Paper, January 2014, Oxford: Smith School of Enterprise and the Environment.
[7] Bank of England (2015), 'Breaking the Tragedy of the Horizon – climate change and financial stability', speech given by Mark Carney, Governor of the Bank of England, Chairman of the Financial Stability Board, delivered at Lloyd's of London, 29 September 2015, http://www.bankofengland.co.uk/publications/Pages/speeches/2015/844.aspx.
[8] Nabuurs, G. J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., Ford-Robertson, J., Frumhoff, P., Karjalainen, T., Krankina, O., Kurz, W. A., Matsumoto, M., Oyhantcabal, W., Ravindranath, N. H., Sanz Sanchez, M. J., and Zhang, X. (2007),' Forestry', in Metz, B., Davidson, O. R., Bosch, P. R., Dave, R. and Meyer, L. A. (eds) (2007), Climate Change 2007: Mitigation of Climate Change, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge and New York: Cambridge University Press.

Moreover, the forecast increase in the global human population to more than 9 billion by 2050 means that the production of food, feed and fuel from agricultural products is set to rise too, and this will create challenges for low-carbon development and climate change mitigation strategies, as well as for related investments.

In order to minimize stranding risk, investors will increasingly have to consider both changes to regulatory frameworks to promote low-carbon development and the risks of stranding arising from climate and/or environmental change. A focus on sustainable agriculture and forestry may provide one means to manage regulatory risks, while adaptation strategies may be able to manage some, but by no means all, physical risks.

AFOLU commodities and regions that pose a risk of stranding

With governments and businesses alike seeking to reduce deforestation in supply chains, agricultural commodities and production regions that are associated with the conversion of natural forests may pose a particularly high risk of stranding. Such commodities include most notably palm oil, cocoa, beef and soy, all of which have been strong drivers of deforestation over the past few decades in tropical forest regions – resulting in significant carbon emissions and also impacting on global carbon storage.

Other regions where the risk of stranding may be especially high are those where the impacts of climate change are predicted to severely disrupt production cycles or to shift production patterns significantly, not least owing to changes in rainfall. At the same time, low-carbon development plans can affect the regulatory frameworks governing agriculture and forestry activities: for example, they may necessitate the introduction of requirements for certified sustainably produced commodities; changes to land use management (including conservation or sustainable management); the introduction of carbon taxes; and the establishment of mandatory emission reduction regimes.

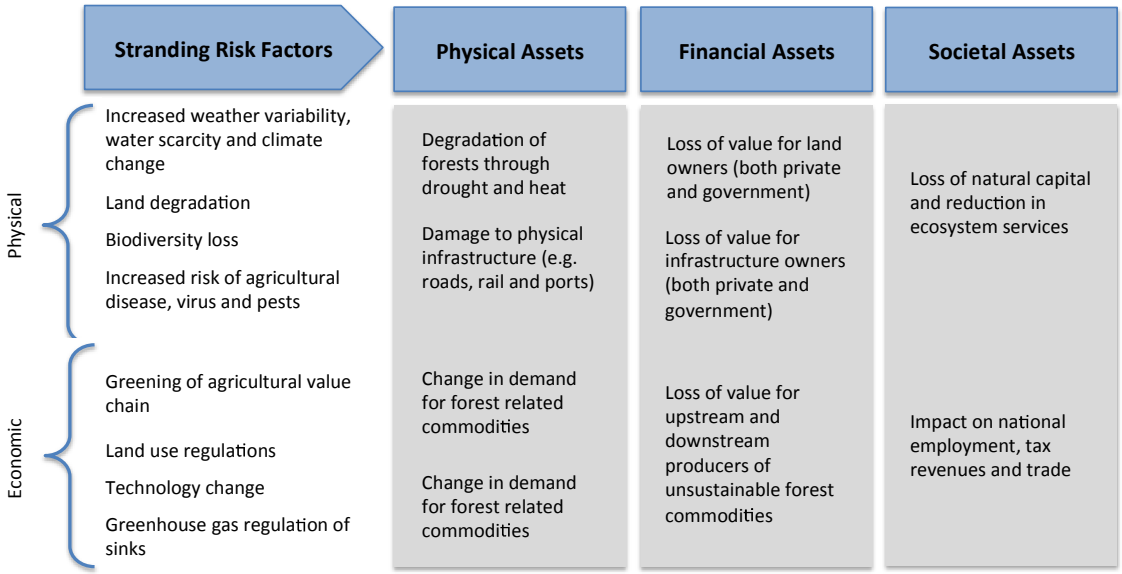
However, many of the areas that are most at risk from economic or regulatory stranding are in developing countries with weak governance and capacity-building challenges, which may hinder the formulation and adoption of policy responses.

Which actors are affected by stranding?

The physical and economic factors that may lead to stranding create physical, financial and societal risks across a range of different actors, as shown in Figure 1. If stranding does occur, it is, of course, not only investors who are impacted. The various actors positioned along the whole length of the soft-commodities supply chain may be affected. They include landowners (private and public), who benefit directly from production, and concession- and lease-holders – for example, those who have long-term rights to timber harvests. In the case of the latter, the impact of the risk of stranding will depend on the structure of the individual concession. To the extent that lease-holders have options to exit concessions early, the risk may, ultimately, be faced by the government or the private owner of the land. For small landowners, who are likely to have few alternative livelihood options, or those locked into long leases, the cost of stranding will be borne directly by the concession-holders. Small

landowners may be particularly at risk as they lack the resources to invest in adaptation measures to manage physical risks, or to diversify into alternative investments/business models in the face of regulatory risks.

Figure 1: Impact of stranding risk factors on different actors



Source: Adapted by the authors from Caldecott et al. (2013).

Larger-scale stranding can impact actors involved in the supply chains of the agricultural and forest sectors, such as the owners – whether private or state – of infrastructure (dedicated roads, railways or port terminals, etc.) to transport or process agricultural and/or forest commodities that have become obsolete. Traders of such commodities may also be exposed to risks, especially if there are major changes in production patterns over a longer period. While the global commodities trade is dominated by a small number of very large corporations, which may well be able to absorb the impact of individual risks and, by adopting a diversified portfolio, maintain market dominance, there may none the less be impacts on company value if production and consumption patterns shift as a result of climate change. Given that the supply chain progresses from the producer via the trader, processor and manufacturer to the retailer, the risk of a significant impact from stranding is likely to diminish the closer the player is positioned to the consumer; this applies not only to private companies but also to the shareholders and investors in publicly traded companies. The scale of risks to the financial and insurance sectors may be determined by the same factor.

Ultimately, stranding may also have societal impacts. This may include risks to natural capital and a loss of ecosystem service provision (see Box 1). It may also affect employment if forest commodity production is significantly impacted, as well as associated tax revenues and the balance of trade. All of these factors could result in increased stress on governance systems in developing countries with significant forest assets.

Box 1: Natural capital

Stranded assets in agriculture and forestry could be influenced by the debate on natural capital (the world's stock of natural assets) from which a wide range of ecosystem services are derived. Even though the concept of natural capital is not globally accepted, it can allow for the quantification of financial impacts from stranded assets and therefore influence the decision-making of investors and other stakeholders exposed to the risk of stranding. It has been suggested that the framework for natural capital accounting, which is being supported by more than 70 countries as well as by a large number of companies and NGOs,[9] could be used to measure progress towards achieving the targets of the Sustainable Development Goals (SDGs).[10]

Since natural capital is not currently included in investor and corporate balance sheets, the role that natural assets play in underwriting financial value and the risks associated with those assets is often insufficiently recognized. A 2013 study concluded that there is 0.5 per cent chance of an annual natural capital loss of, respectively, $6.3 trillion, $8.7 trillion and $11.2 trillion in the current, moderate and extreme scenarios (0.5 per cent being a value commonly used in the insurance industry for solvency calculations).[11] Regulatory efforts aimed at giving more weight to natural capital considerations in determining financial value could therefore increase the awareness of stranding risks.

Physical risks of stranding

It is predicted that forests around the globe will be significantly affected by climate change: *inter alia*, the frequency of forest fires will increase, pests and diseases will be more widespread, and thousands of species may become extinct. Ecosystem services such as water regulation and purification, carbon storage and soil protection will also be affected. It has been estimated that 'the global economic cost of the climate change impacts of deforestation will rise to around $1 trillion a year by 2100 if unabated'.[12]

The Intergovernmental Panel on Climate Change (IPCC) expects all aspects of food security to be potentially affected by climate change, including food access and utilization as well as price stability. The IPCC assesses that there is a medium to high risk that by 2030 reduced crop productivity due to droughts will have an adverse effect on regional, national and household incomes and food security. In particular, damage to forests and agricultural land may be caused by pests and disease, and by the impact of more flooding on the food system infrastructure. A number of climate change-related impacts can already be observed, including changes to the hydrological system that influence both the quality and the quantity of available water resources resulting in negative impacts on crop yields – particularly, according to the IPCC, those for wheat and corn.[13]

[9] Waves Partnership (2014), 'Natural Capital Accounting – List of Supporters', https://www.wavespartnership.org/sites/waves/files/documents/NCA%20supporters%20060314.pdf.
[10] Hickey, V. (2014), 'Natural Capital Accounting for sustainable development', presentation by Valerie Hickey (World Bank) at the second meeting of the High-level Political Forum on Sustainable Development, 2 July 2014, http://m.webtv.un.org/watch/valerie-hickey-world-bank-on-natural-capital-accounting-for-sustainable-development-2nd-meeting-of-the-high-level-political-forum-on-sustainable-development/3655217881001?page=3.
[11] Caldecott, H., Howarth, N. and McSharry, P. (2013), Stranded Assets in Agriculture: Protecting Value from Environment-Related Risks, Oxford: Smith School of Enterprise and the Environment.
[12] Eliasch, J. (2008), Climate Change: Financing Global Forests – The Eliasch Review, Office of Climate Change, London, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228833/9780108507632.pdf.
[13] IPCC (2014), 'Summary for Policymakers', in Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R. and

Crops such as soy will also be affected. For example, it has been estimated that by 2030 Brazil could lose as much as 10 million hectares of cropland because of climate change: in the optimistic scenario, key growing areas for soy could decrease by around 15 per cent; and in the pessimistic scenario by 28 per cent.[14] In the United States, another key soy producer, yields are forecast to decrease by up to 80 per cent by the end of the 21st century;[15] climate-related losses for the industry there have already reached $11 billion.[16] Other stranded assets could include oil palm plantations. According to models based on IPPC forecasts, in some low-lying production regions in Malaysia nearly all peatland is expected to be lost for production – much of it within decades: it is projected that some 42 per cent of current industrial plantations in the Rajang Delta will experience problems associated with reduced drainage by 2034.[17] Taking a natural capital approach, the Smith School at Oxford University has estimated the total value of investments at risk of stranding in the agriculture sector at between $6.3 trillion and $11.2 trillion across a range of different scenarios.[18]

Climate variability is another factor that can turn investments into stranded assets – particularly the increased danger of extreme weather events and related disasters, which affect agriculture more than other sectors. Of the total damage and loss arising from the drought in Brazil in 2013, estimated at some $10 billion, agriculture accounted for 43 per cent. In Pakistan the floods in 2010 caused damage and losses estimated at $10.1 billion (equivalent to almost 6 per cent of gross domestic product – GDP), half of which in the agriculture sector.[19] To the extent that repeated extreme weather events undermine the future viability of forest commodity production in a region, such incidents can create stranded assets. These can arise both through impacts on the land itself, whereby yields are consistently undermined with the effect that production operations have to be abandoned and relocated; and through impacts on related infrastructure such as roads, ports and railways, as a result of which it is no longer possible to transport goods to markets.

Adaptation and new technologies may be able to reduce some of the physical risks of stranding. Investment in resilient infrastructure, water management and drainage systems, as well as improved crop varieties, could all reduce such risks. However, there are limitations to these: as climate change gathers pace, in some parts of the world – particularly those that are most vulnerable to climate impacts – adaptation strategies may no longer be viable.[20]

In summary, the stranding of assets from physical risks is likely to occur, or is already occurring, within the relevant, 15-year time frame for decision-making among investors. Inertia in the climate

White, L. L. (eds) (2014), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. *Contribution of* Working Group II to the Fifth Assessment Report of the International Panel on Climate Change, Cambridge and New York: Cambridge University Press.

[14] World Bank (2010), *Impacts of Climate Change on Brazilian Agriculture: Refocusing Impact Assessments to 2050*, Washington, DC: World Bank, https://openknowledge.worldbank.org/handle/10986/12475 License: CC BY 3.0 Unported.

[15] Schlenker, W. and Roberts, M. (2009), 'Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change', Proceedings of the National Academy of Sciences, 106(37): pp. 15594–98, doi: 10.1073/pnas 0906865106.

[16] Mourtzinis, S., Specht, J. E., Lindsey, L. E., Wiebold, W. J., Ross, J., Nafziger, E. D, Kandel, H. J., Mueller, N., Devillez, P. L., Arriaga, F. J. and Conley, S. P. (2015), 'Climate-induced reduction in US-wide soybean yields underpinned by region- and in-season-specific responses', Nature Plants 1, Article No. 14026 (2015), doi: 10.1038/nplants.2014.26.

[17] Hooijer, A., Vernimmen, R., Visser, M. and Mawdsley, N. (2015), Flooding projections from elevation and subsidence models for oil palm plantations in the Rajang Delta peatlands, Sarawak, Malaysia, Deltares report 1207384.

[18] Caldecott, Howarth and McSharry (2013), Stranded Assets in Agriculture: Protecting Value from Environment-Related Risks.

[19] United Nations (2014), 'Agriculture and disaster risk: a contribution by the United Nations to the consultation leading to the Third UN World Conference on Disaster Risk Reduction', New York: United Nations, http://www.preventionweb.net/publications/view/38775.

[20] World Economic Forum (2016), 'Part 3.2: Climate Change and Risks to Food Security', in The Global Risks Report 2016, 11th Edition, Geneva: World Economic Forum, http://reports.weforum.org/global-risks-2016/.

system – i.e. the inherent delay in the system in responding to changes in the composition of the atmosphere – means that this trend would continue to accelerate for the next 40 years even if all emissions were to cease with immediate effect. However, the public debate has not yet made the connection between climate change-induced impacts and the stranding of assets. The impact of potential physical risks is considered in Box 2.

Box 2: Summary of physical stranding risks from case study countries

Brazil

Several studies have forecast that climate change will have a severe impact on agriculture and forestry in Brazil within the next 15 years. It is thought that much of that impact will be due to changes in rainfall patterns and soil moisture, although there is still no consensus on the most likely impact scenarios. According to one study, Brazil could lose more than 11 million hectares of cropland by 2030 – although impacts are predicted to vary from crop to crop.[21] The consequent decline in production and the associated increase in commodity prices could make stranded assets a possibility in some regions; but, equally, those developments could mean increased returns on certain investments.

The effects of extreme weather events are illustrated not only by the drought in 2013 (referred to above), but also by the drought in late 2014 and early 2015 – the worst in 80 years: an estimated 4 million people were affected by factors including power cuts, protests and business closures. Arabica coffee production fell 15 per cent in 2014, due to the low rainfall that year, pushing the global price of that commodity up by almost half. (Brazil is the world's largest Arabica producer.)[22]

Malaysia

More frequent extreme weather events are already having a significant impact on the Malaysian agricultural sector. For example, severe droughts followed by flooding in 2014 caused a sharp decline in palm oil production.[23]

From an investment perspective, such declines are not necessarily problematic in the medium term. In mid-2015, for example, major palm oil producer Sime Derby predicted a 6 per cent decrease in production in the event of a moderate El Niño (which in the case of Southeast Asia creates unusually dry climatic conditions), and a 15–20 per cent drop if the occurrence was extreme. However, while the initial impact can be a downturn in business, price increases usually follow: El Niño events in 1997–98, 2006 and 2009–10 contributed to price increases of 75 per cent, 40 per cent and 22 per cent, respectively, according to analyst reports.[24] Sime Derby's stated intention prior to the 2015–16 El Niño was to manage the impact on yields, 'in order to ride on the opportunities of an increase in [crude palm oil] prices'.[25] This would suggest that there is awareness of risks from climate variability in the business community – although any variability

[21] World Bank (2010), Impacts of Climate Change on Brazilian Agriculture: Refocusing Impact Assessments to 2050, Washington, DC: World Bank.
[22] Watts, J. (2015), 'Brazil's worst drought in history prompts protests and blackouts', Guardian, 23 January 2015, http://www.theguardian.com/world/2015/jan/23/brazil-worst-drought-history.
[23] Malay Mail (2015), 'Palm oil output in Malaysia, Indonesia to increase if climate remains normal', 3 March 2015, http://www.themalaymailonline.com/money/article/palm-oil-output-in-malaysia-indonesia-to-increase-if-climate-remains-normal.
[24] Yanzi, D. (2015), 'Uncertain prospects for palm oil', China Daily, 17 July 2015, http://www.chinadailyasia.com/asiaweekly/2015-07/17/content_15291719.html.
[25] Ibid.

resulting from climate change could be less predictable than El Niño effects, and this may reduce the ability of businesses to manage such impacts.

Of greater concern to investors are assets on which climate change has a more lasting physical impact, for example, increases in sea level and higher temperatures at which crops can no longer grow. According to one study, some 1,000 km² of cropland in Malaysia could be destroyed by 2100 if the sea level were to rise by 90 cm;[26] while another study suggests that various low-lying palm oil production areas could be severely affected over the next 20 years.[27]

Liberia

Climate change is predicted to have significant impacts on weather variability, temperatures and sea levels in Liberia. Simulations suggest that, on average, temperatures in Liberia will rise by 1.6°C, 2.5°C and 3.4°C by the 2020s, 2050s and 2080s, respectively, while national rainfall levels will increase by 3.4 per cent, 3.7 per cent and 10 per cent, respectively, and become increasingly variable.[28] This could have far-reaching consequences for the hundreds of thousands of smallholders in Liberia. Indeed, according to one study, no less than 96 per cent of smallholders report that climate change has already affected productivity.[29] There are no available data on the potential impact of the physical risks of climate change on investments in Liberia; but since such investments focus on perennial crops such as oil palm and rubber as well as forest concessions, it is likely that they could be affected in the same way as described in the Malaysian case study.

Regulatory and economic risks of stranding

The large volume of emissions in the AFOLU sector provide huge abatement and mitigation opportunities, as a result of which a number of mitigation strategies are being discussed or are already being applied in agriculture and forestry. A lack of detailed data and modelling hitherto mean that it is not possible to state in detail the potential financial losses, but it is none the less evident that, depending on the time frame in which they are implemented, regulatory initiatives are likely to impact investments, shares and physical assets.

Until recently, mitigation efforts were directed at forestry rather than agriculture. Forestry has therefore been one of the main focuses at international climate change negotiations, while debate on agriculture has been marginal. The situation has begun to change in the past several years, however, with the recognition first that the main driver of deforestation globally is agriculture, and also that there may be significant opportunities for emissions reductions in agriculture. There are now numerous voluntary initiatives by the private and public sectors towards achieving the goal of zero or net zero deforestation in both agriculture and forestry. Prominent such initiatives are the New York Declaration on Forests, endorsed by more than 150 governments, companies and

[26] Sujahangir, K. S., Begum, R. A., Pereira, J. J., Jaafar, A. H. and Saari, M. Y. (2014), 'Impacts of and Adaptations to Sea Level Rise in Malaysia', Asian Journal of Water, Environment and Pollution, 11(2), pp. 29–36.
[27] Hooijer et al. (2015), Flooding projections from elevation and subsidence models for oil palm plantations.
[28] Environmental Protection Agency of Liberia (2013), Liberia: Initial National Communication, Monrovia: Environmental Protection Agency of Liberia, http://unfccc.int/resource/docs/natc/lbrnc1.pdf.
[29] Tarway-Twalla, A. K. (2013), 'Agricultural Productivity, Climate Change and Smallholder Farmer's [sic] Entrepreneurship: A Case Study of the Central and Western Regions of Liberia', a report published by Trust Africa and International Development Research Centre.

indigenous peoples' and civil society organizations at the UN Climate Summit in 2014,[30] and the Tropical Forest Alliance 2020.[31]

The timing of this shift can be linked to the publication of several significant studies that have concluded that radical changes to the world's food system are needed in order to ensure its long-term sustainability. Climate change mitigation measures include the increased use of agroforestry and agroecology as production systems; removing deforestation from global supply chains; boosting soil carbon sequestration through improved tillage systems and crop rotations; phasing out energy-intensive chemical fertilizers; ensuring better management of livestock, pasture and water; reducing global meat consumption; and eliminating food waste.[32] The extent to which mitigation activities can cause stranding depends on the speed at which the relevant legislation or changes in business practice (e.g. zero deforestation commitments) are implemented. That speed is likely to be faster in countries that have ambitious emission reduction targets coupled with significant mitigation potential from agriculture – although this will also be dependent on a country's ability to implement such targets (a consequence of its resources and level of governance).

Following the Paris Agreement, the establishment of the long-term goal to include a reference to both 1.5°C and achieving a balance between anthropogenic emissions and removals by sinks has important implications for forest assets. Given current emission trajectories, it is increasingly likely that negative emission technologies will be required in order to stabilize global average temperature increases to below 2°C.[33] This implies the need for large-scale development and deployment of bioenergy with carbon capture and storage (BECCS) technology – whereby the carbon used in a plant's development is captured and stored as it is converted into energy, thus leading to a net reduction in CO_2 in the atmosphere. This may shift policy objectives from reducing emissions from land use change to utilizing land as a source for bioenergy crops. A recent study suggested that under a 2°C-compatible scenario, between 7 and 25 per cent of agricultural land would be required for bioenergy production in relation to BECCS.[34]

In some sectors, particularly the palm oil industry, there is growing awareness of the impacts that climate change mitigation activities may have on business operations. Malaysia's Bousted Plantations Berhad, for example, noted in its initial public offering (IPO) prospectus that there was likely to be continued pressure to demonstrate sustainable practices in the palm oil sector, and that the industry could increasingly be constrained by both government legislation and the policies of consumer companies.[35]

[30] See Forest Declaration, http://forestdeclaration.org/.
[31] See Tropical Forest Alliance 2020, https://www.tfa2020.org/.
[32] See for example Government Office for Science (2011), Foresight: The Future of Food and Farming – Final Project Report, London: Government Office for Science; and Paillard, S., Tréyer, S. and Dorin B. (eds) (2011), Agrimonde: Scenarios and Challenges for Feeding the World in 2050, Versailles: Editions Quae.
[33] Caldecott,B., Lomax, G. and Workman, M. (2015) *Stranded Carbon Assets and Negative Emissions Technologies,* Working Paper, February 2015, Oxford: Smith School of Enterprise and the Environment.
[34] Smith, P., Davis, S. J., Creutzig, F, Fuss, S., Minx, J., Gabrielle, B., Kato, E., Jackson, R. B., Cowie, A., Kriegler, E., van Vuuren, D. P., Rogelj, J., Ciais, P., Milne, J., Canadell, J. G., McCollum, D., Peters, G., Andrew, R., Krey, V., Shrestha, G., Friedlingstein, P., Gasser, T., Grübler, A., Heidug, W. K., Jonas, M., Jones, C. D., Kraxner, F., Littleton, E., Lowe, J., Moreira, J. R., Nakicenovic, N., Obersteiner, M., Patwardhan, A., Rogner, M., Rubin, E., Sharifi, A., Torvanger, A., Yamagata, Y., Edmonds, J. and Yongsung, C. (2015), 'Biophysical and economic limits to negative CO2 emissions', *Nature Climate Change*, 6 (January 2016), doi: 10.1038/nclimate2870.
[35] See Bousted Plantations Berhad IPO prospectus, http://www.sc.com.my/boustead/boustead_eng.pdf.

One area in which the concept of stranded assets can most readily be applied to agriculture is biofuels. According to one estimate, the use of biofuels – particularly ethanol and biodiesel – is expected to provide 9 per cent of global demand for transport fuel in 2030,[36] and a number of countries already mandate the use of biofuels (to reduce both emissions and reliance on imported fossil fuels). However, the context of a relatively fast-changing regulatory framework, along with the potential social and environmental impacts, puts investments in the industry (particularly downstream investments such as refineries) at risk of becoming stranded assets. In particular, investments in first-generation biofuels that compete with food crops on arable land will be endangered. The European Union (EU) has acted to cap the use of food crops that can be used to meet its 2020 renewable transport fuel target, and is already working on legislation to ensure a speedy transition to second-generation biofuels, which cause fewer emissions and reduce indirect land use change (whereby biofuels displace food crops to previously non-cultivated land such as grasslands or forests). The combination of the cap on first-generation fuels and the collapse in the oil price has fundamentally undermined the economics of some biofuel production and may lead to stranding for the enterprises and associated infrastructure.

The major international goals and agreements reached in 2015 represent another source of change that may affect investments in natural resources. The SDGs, adopted at the end of 2015 to supersede and build on the Millennium Development Goals, comprise 17 goals (within which 169 targets) that will influence international development priorities within the period 2016–30 (i.e. within a time frame that is currently relevant to stranding).[37] Most relevant to the stranding of assets in agriculture and forestry are:

- **SDG 2.4:** By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

- **SDG 15.2:** By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

In addition to the SDGs, the ratchet mechanism in the Paris Agreement, whereby pledges will be revisited every five years in an effort to close the gap with a below 2°C trajectory, should result in increasingly ambitious mitigation targets. This is likely to be a driver of increased action on deforestation (among other measures), and so bring an increased risk of regulatory-driven stranding in the future. If resources are adequate and indicators sufficiently well designed to help ensure implementation, both the Paris Agreement and the SDGs could have a significant impact not only on agricultural production systems that do not support sustainable development targets but also on investments into those systems.

[36] Forecasts from World Energy Outlook 2009, cited in Eisentraut, A. (2010), Sustainable Production of Second-generation Biofuels: Potential and perspectives in major economies and developing countries, Paris: International Energy Agency.
[37] The full set of SDGs is available at https://sustainabledevelopment.un.org/sdgs.

It is difficult to assess the extent to which investment mechanisms as part of the Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme have the potential to cause stranding, or – more likely – help mitigate the risk by providing compensation for not carrying out activities that result in deforestation and related impacts on agriculture. Much depends on whether an active market for such instruments is created. REDD+ aims to create financial value for the carbon stored in forests through forest protection, sustainable forest management and the enhancement of carbon stocks. Although the REDD+ rules are now largely complete, the market has not yet developed to the extent that had been expected. In particular, the number of private-sector investments has been insufficient. It has been suggested that REDD+ projects could be used as a hedging strategy against stranded assets in the fossil fuel sector,[38] but it appears that the voluntary nature of the market does not provide the necessary clarity for investors. Moreover, it is not currently planned to introduce a regulatory market.

In the absence of such a market, some current investments – the vast majority of which were financed from public funds – could fall significantly in value. Another concern is the time lag between the signing of the Paris Agreement in 2015 and its scheduled entry into force in 2020. This means that the necessary incentives for REDD+ to function may not be in place for some time to come.[39]

The impacts of regulatory risks on AFOLU stranding in case study countries is considered in Box 3.

Box 3: Summary of regulatory stranding risks from case study countries

Brazil

In its National Policy on Climate Change, enacted in 2009, Brazil pledged to achieve a 39 per cent reduction in emissions by 2020. In preparation for the 2015 Paris Climate Conference, Brazil submitted its Intended Nationally Determined Contribution (INDC), which will serve as a national action plan for the post-2020 period, in which it has committed to a 37 per cent reduction in emissions by 2025, compared with 2005 levels, and a 43 per cent reduction by 2030.[40] There is also a focus on increasing the role of biofuels in the energy sector, as well as on reducing illegal deforestation and restoring and reforesting 12 million hectares of forest for multiple use.[41] Attainment of these goals could create stranding risks for a range of investments.

Other domestic mitigation policies could enhance the risk of stranding. For example, the government aims to promote the increased use of electric and hybrid vehicles through tax exemptions (although these have

[38] Laing, T., Taschini, L., Palmer, C., Wehkamp, J., Fuss, S. and Reuter, W. H. (2015), *Understanding the demand for REDD+ credits*, Centre for Climate Change Economics and Policy Working Paper No. 218 and Grantham Research Institute on Climate Change and the Environment Working Paper No. 193.
[39] Global Canopy Programme (GCP), Amazon Environmental Research Institute (IPAM), Fauna and Flora International (FFI), UNEP Finance Initiative (UNEP FI), (2014), Stimulating Interim Demand for REDD+ Emission Reductions: The Need for a Strategic Intervention from 2015 to 2020, Oxford: GCP, Brasília: IPAM, Cambridge: FFI, and Geneva: UNEP FI.
[40] Romeiro, V. and Biderman, R. (2015), 'A Closer Look at Brazil's New Climate Plan (INDC)', World Resources Institute blog, 30 September 2015, http://www.wri.org/blog/2015/09/closer-look-brazils-new-climate-plan-indc.
[41] The full text of Brazil's INDC is available at http://www4.unfccc.int/submissions/INDC/Published%20Documents/Brazil/1/BRAZIL%20iNDC%20english%20FINAL.pdf.

yet to be approved);[42] if this strategy does prove successful, domestic use of biofuels could be affected in the longer term by reduced demand. Moreover, since Brazil is a leading exporter of ethanol, policies and regulations on biofuels in other markets could affect both production and investments in Brazil. The EU, for example, is committed to ending its contribution to natural forest loss, not least by changing its own consumption and trading patterns; and since it is a major importer of Brazilian agricultural commodities – in particular soy for animal feed – policy initiatives such as an EU action plan on deforestation, the mandatory labelling of the forest footprints of products, or imposing sustainability criteria for imported commodities may affect exports of and, ultimately, investments in Brazilian agricultural products that are linked to deforestation.[43]

Having once numbered among the countries most criticized for not tackling deforestation, Brazil is now acknowledged for its extraordinary success in reducing the rate of deforestation by some 70 per cent, achieved through a range of measures including improved law enforcement, expanding protected areas and policies to restrict agricultural expansion.[44] However, stranded assets are not currently discussed in government policy papers; nor has the NGO community, which has played an important role in securing moratoriums on deforestation in the soy and beef industry, been communicating the investment risks of such actions. This may be because much of the deforestation that has been halted was illegal, and so there were no 'legal assets' at risk of stranding. The close engagement with the private sector in many of the measures adopted is also likely to have been a factor in reducing any risks of stranding.

Malaysia

Malaysia is the world's second largest producer of palm oil (after Indonesia), which generates some 5–6 per cent of annual GDP.[45] The AFOLU sector overall accounts for more than 30 per cent of national emissions. Malaysia's INDC pledges a 45 per cent reduction in greenhouse gas emissions intensity of GDP by 2030, compared with the 2005 level (35 per cent unconditional, and 10 per cent conditional on sufficient financing, technology transfer and capacity-building assistance from developed countries).[46]

Under Malaysia's National Transformation Programme, there are a number of entry point projects (EPPs) specific to the oil palm sector that may be vulnerable to regulatory stranding risks. For example, the first EPP is focused on replanting oil palm plantations and establishing new plantations by providing support to independent smallholders.[47] Another goal is to secure investments in order to increase downstream palm oil activities, especially in segments that generate high-value products such as palm oil derivatives.[48]

[42] Details of the proposed legislation are available (in Portuguese) at http://www25.senado.leg.br/web/atividade/materias/-/materia/117572.
[43] CDP in conjunction with Schroders (2015), Soybean overlooked? The investor case for deforestation-free soy – A white paper exploring regulatory risks from soy associated with deforestation, London: CDP, https://www.cdp.net/Documents/forests/Forests-investor-white-paper-Soybean-overlooked.PDF.
[44] Nepstad, D., McGrath, D., Stickler, C., Alencar, A., Azevedo, A., Swette, B., Bezerra, T., DiGiano, M., Shimada, J., Seroa da Motta, R., Armijo, E., Castello, L., Brando, P., Hansen, M. C., McGrath-Horn, M., Carvalho, O. and Hess, L. (2014), 'Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains', Science, 344 (6188), pp.1118–23.
[45] See http://www.palmoilworld.org/about_palmoil.html.
[46] The full text of Malaysia's INDC is available at http://www4.unfccc.int/submissions/INDC/Published%20Documents/Malaysia/1/INDC%20Malaysia%20Final%2027%20November%202015%20Revised%20Final%20UNFCCC.pdf.
[47] Performance Management & Delivery Unit (PEMANDU) (2016), 'Economic Transformation Programme: Accelerating replanting of oil palm', http://etp.pemandu.gov.my/8_March_2011-@-Accelerating_Replanting_of_Oil_Palm.aspx.
[48] Performance Management & Delivery Unit (PEMANDU) (2016), 'EPP 9.1: Ensuring sustainability of the upstream rubber industry', http://etp.pemandu.gov.my/Palm_Oil-@-Palm_Oil_-%E2%97%98-_Rubber_-_EPP_9@1-;_Ensuring_Sustainability_of_the_Upstream_Rubber_Industry.aspx.

Regulation that affects future palm oil production either through domestic policy aimed at reducing emissions, or through action to limit unsustainable palm oil consumption in importer countries, could result in stranding risks along the palm oil supply chain. However, the issue of stranded assets is not mentioned – either directly or indirectly – in any of the strategies or focus areas included in the programme.

Liberia

Liberia's INDC contains an emissions reduction target of 15 per cent below the business-as-usual scenario by 2030, and a longer term ambition of carbon neutrality by 2050.[49] Attainment depends on financial resources, capacity-building and the transfer of technologies. Both the agriculture and forest sectors are considered to be under the 'adaptation' category in the INDC. There are plans to invest in new adaptive and resilient technologies, new farming techniques and production systems, the cultivation of more resilient species, and the sharing of knowledge on best practice, as well as in increasing awareness about, and the participation of local people in, forest conservation, protection of forest zones and reforestation of degraded lands.

In a 2014 letter of intent between the governments of Norway and Liberia, it was set out that the Norwegian government would provide Liberia with $150 million in support of efforts to reduce emissions from deforestation through the greening of supply chains, the protection of forests and the promotion of sustainable agriculture.[50] A number of activities that are covered by the agreement have the potential to affect planned or existing investments, among them the imposition of moratoriums on new industrial logging concessions, the suspension of companies suspected of involvement in illegal logging, and examination of the legality of existing concessions. Furthermore, the agreement envisages that some 30 per cent of Liberia's forest estate will be given protected area status. As regards the agriculture sector, it is envisaged that only multinational companies that have drawn up and adhere to zero deforestation policies will be permitted to do business in Liberia.

Given that large areas of as yet undeveloped land have already been purchased or are under concession agreements in Liberia, the letter of intent could put a significant number of investments at risk of stranding. This seems already to have been recognized by industry. Shortly after the letter of intent was released, the Liberia Timber Association (LTA) announced that it was considering legal action to prevent ratification of the agreement by the Liberian parliament. According to the LTA, the planned measures would be detrimental to the development of forest communities as well as to the interests of investors, businessmen and thousands of Liberians who are currently employed in the forest industry.[51]

[49] The full text of Liberia's INDC is available at http://www4.unfccc.int/submissions/INDC/Published%20Documents/Liberia/1/INDC%20Final%20Submission%20Sept%2030%202015.002.pdf. See also http://www.carbonbrief.org/paris-2015-tracking-country-climate-pledges.
[50] Government of Norway (2014), 'Liberia and Norway launch climate forest partnership', Press Release No. 91/2014, 23 September 2014, https://www.regjeringen.no/en/aktuelt/Liberia-and-Norway-launch-climate-and-forest-partnership/id2001145/.
[51] Fayia III, Edwin. M. (2014) 'Timber Assn. Threatens Anti-Forest GOL Letter of Intent', *Liberian Observer*, 14 October 2014, http://liberianobserver.com/news/timber-assn-threatens-anti-forest-gol-letter-intent.

Conclusions and recommendations for further research

There are credible reasons why stranded assets in agriculture and forestry may result from climate change. This will be driven both by the physical impacts of climate change, and by the economic and regulatory responses to mitigate those impacts. Both of these factors may accelerate as the existing carbon budget is used up, and as post-Paris Agreement policy responses are developed and implemented.

It is at present difficult to analyse stranding risks precisely. The likelihood of stranding is subject to a range of uncertainties, among them how climate change affects geographies; how different actors respond; and how companies and farmers adapt. Notwithstanding, further study of the risks of stranding is greatly needed, as are strategies for how these can be managed by investors and companies. Key areas for research include:

- Analysing by region the outlook for biofuels to assess the risk of stranding and the possible impacts on investment of new technologies, such as electric vehicles or hydrogen fuel cells, both of which will affect future demand for this form of energy;
- Assessing the physical impacts on investments of extreme weather events such as droughts and floods, taking into account the role of the insurance industry as well as price fluctuations generated by production decline and the resulting impact on assets and their performance; and
- Exploring the risks of stranding in the agricultural and forestry sector arising from growing consumer preferences for 'sustainable', 'deforestation-free' or 'low-carbon' products.

Research in these areas could, furthermore, be used to initiate discussions within key producer countries about the risks of stranding that may result from their national strategies and policies. It could also be used to highlight the available evidence of the physical impacts of climate change. The aim of any such in-country discussions should be to identify effective ways of mitigating and managing these risks.

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Acknowledgments

Chatham House would like to thank Ben Caldecott (University of Oxford) and Roberta Iley (formerly of CDP) for reviewing this paper.

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ISBN 978 1 78413 155 5

All Chatham House publications are printed on recycled paper.

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