STRANDED ASSETS

PROGRAMME

Smith School of Enterprise and the Environment

UNIVERSITY OF OXFORD

Stranded Assets in Agriculture: Protecting Value from Environment-Related Risks

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About the Stranded Asset Programme

There are a wide range of current and emerging risks that could result in ‘stranded assets’, where environmentally unsustainable assets suffer from unanticipated or premature write-offs, downward revaluations or are converted to liabilities. These risks are poorly understood and are regularly mispriced, which has resulted in a significant over-exposure to environmentally unsustainable assets throughout our financial and economic systems.

Some of these risk factors include:

- Environmental challenges (e.g. climate change, water constraints)
- Changing resource landscapes (e.g. shale gas, phosphate availability)
- New government regulations (e.g. carbon pricing, air pollution regulation)
- Falling clean technology costs (e.g. solar PV, onshore wind)
- Evolving social norms (e.g. fossil fuel divestment) and consumer behaviour (e.g. certification schemes)
- Litigation and changing statutory interpretations (e.g. changes in the application of existing laws and legislation)

The Stranded Assets Programme at the University of Oxford’s Smith School of Enterprise and the Environment was established in 2012 to understand these risks in different sectors and systemically. We analyse the materiality of stranded asset risks over different time horizons and research the potential impacts of stranded assets on investors, businesses, regulators and policy makers. We also work with partners to develop strategies to manage the consequences of stranded assets.

The Programme is currently being supported through donations provided generously from The Ashden Trust, Aviva Investors, Bunge Ltd, HSBC Holdings plc, The Rothschild Foundation and WWF-UK. Our non-financial partners currently include Standard & Poor’s, Trucost, Carbon Tracker Initiative, and the Asset Owners Disclosure Project.

The Programme is led by Ben Caldecott and its work is guided by a high-level Consultative Panel chaired by Professor Gordon Clark, Director of the Smith School.

Members of the Consultative Panel currently include:

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Acknowledgements

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Executive Summary

'Stranded assets', where environmentally unsustainable assets suffer from unanticipated or premature write-offs, downward revaluations or are converted to liabilities, can be caused by a range of environment-related risks. This report maps out these risks in agriculture and shows how they might affect agricultural assets over time.

We have systematised the different risk factors that could affect assets across the agricultural supply chain and have completed a high-level assessment of where and how risks might affect these assets. A high-level Value at Risk (VaR) assessment has also been completed to give an indication of the magnitudes of capital exposed and to stimulate further work in this area.

The report is meant to provide an introduction to these issues so as to help inform investors and businesses working in the agricultural supply chain, as well as policy makers and governments who are concerned with the stability and environmental sustainability of the agricultural sector and its contribution to the wider economy. Our aim is to investigate the issue of stranded assets and the environmental risks involved with agriculture, and set a framework for further in-depth studies in specific sectors and geographies.

Environment-related risks and stranded assets

If and when environment-related risks materialise they can result in stranded assets in the agricultural supply chain. This could be at a sector or asset-specific level, such as with respect to processing facilities, or be felt across an entire commodity or region.

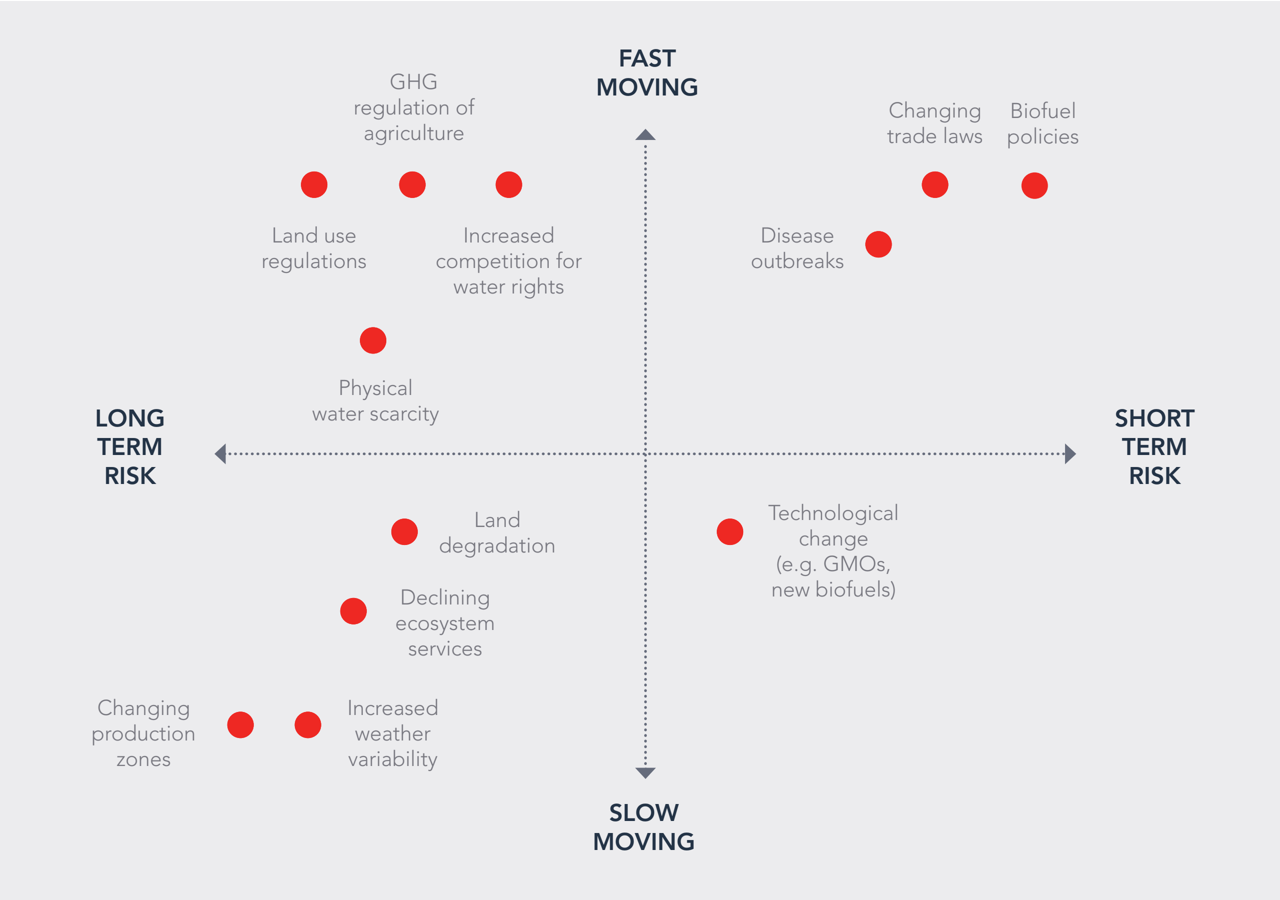
The speed at which these risks materialise is important to understand, with fast-moving risks being harder to manage than slow-moving ones. For example, regulatory change is often fast-moving. At the other end of the spectrum, physical risks such as climate change tend to manifest themselves much more slowly.

As well as the speed of change, understanding when risks are likely to materialise is also critically important. Risks can be classified along a continuum from the short-term to the very long-term. For example, biofuel regulation is part of current problem agendas facing many governments. At the other end of the spectrum, classic problems of the commons such as declining ecosystem services, water quality and land degradation are long-term risks. Such problems often take a long time to manifest themselves, and are difficult to remedy once they have occurred.

The report is meant to provide an introduction to these issues so as to help inform investors and businesses working in the agricultural supply chain

Figure 1 (page 8) maps out the environment-related risks explored in this report based on the speed at which we think given risks could materialise and over what time-horizons they might emerge.

Figure 1: Time horizons for environment-related risks in agriculture



In addition to investigating the timing aspects of environment-related risks in agriculture, we have evaluated how asset stranding might affect different agricultural assets using a traffic light system to indicate sensitivity to each risk factor – ranging from red (high vulnerability) to green (lower vulnerability). We have applied this evaluation to natural assets (e.g. farmland water), physical assets (e.g. animals, crops, on-farm infrastructure), financial assets (e.g. farm loans, derivatives), human assets (e.g. know-how, management practices) and social assets (e.g. community networks).

Table 1 (page 9) shows how these different agricultural assets could be affected by the environment-related risks we explore in this report.

Table 1: Environment-related risks affecting different agricultural assets

	RISK-FACTORS	Physical assets	Natural assets	Human assets	Social assets	Financial assets
Physical	Increased weather variability, physical water scarcity and climate change	red	red	yellow	orange	green
	Land degradation	orange	red	yellow	orange	green
	Biodiversity loss and collapse of ecosystem services	orange	red	yellow	orange	yellow
	Overfishing and impacts on marine ecosytems	red	red	orange	red	yellow
	Increased risk of of agricultural diseases, viruses and pests	red	orange	yellow	orange	yellow
	Phosphate availability	yellow	orange	yellow	yellow	green
Economic	Economic water scarcity	orange	red	yellow	orange	green
	The greening of the agricultural value chain	orange	orange	yellow	red	yellow
	Land use regulations	orange	red	yellow	yellow	yellow
	Changing biofuel regulations	red	green	orange	orange	yellow
	Regulation and diffusion of biotechnology	orange	red	red	orange	yellow
	Greenhouse gas regulation of agriculture	orange	yellow	yellow	yellow	yellow

For each environment-related risk above we have systematically investigated whether it is material or not, identified who might be affected by such risks and highlighted what further work stakeholders should undertake in order to understand and manage such risks.

Value at Risk

We have also set out three scenarios to test to what extent declining natural capital could place the stock of invested capital in agriculture at risk globally: the first scenario represents current levels of natural capital, the next a medium level of loss of natural capital and thirdly a situation of extreme loss of natural capital. Each of these scenarios represents escalating levels of risk.

Under the extreme loss of natural capital scenario, we found that the loss measured by the 0.5 percent VaR could almost double from USD 6.3 trillion to USD 11.2 trillion. In other words, there is a 0.5 percent chance of the annual loss being more than USD 11.2 trillion. This would clearly represent significant stranding of assets. The 0.5 percent VaR is of interest to the insurance sector as this corresponds to the Solvency II regulation, which requires insurers to determine their solvency capital requirements at this level of risk.

> *Under the extreme loss of natural capital scenario, we found that the loss measured by the 0.5 percent VaR could almost double from USD 6.3 trillion to USD 11.2 trillion.*

Conclusions

There are three main conclusions that are emphasised throughout this report.

First, environment-related risk factors are material and can strand assets throughout the agricultural supply chain. The amount of value potentially at risk globally is significant.

Second, the potential challenge of stranded assets in agriculture is currently being exacerbated by an ongoing agricultural boom, which is feeding off high commodity prices and poor investment returns elsewhere in the economy to push farmland values to record highs in many markets.

Third, understanding environment-related risks that can induce asset stranding can help investors, businesses and policy makers to develop effective risk-management strategies, which can improve resilience and minimise value at risk.

Introduction

Why worry about the risk of stranded assets in agriculture?

The recent boom in agricultural commodity prices has sparked interest in agriculture as an asset class. It has contributed to an increase in the value of underlying assets such as farmland and seen capital flow into much needed productivity enhancing investments.

As new resources have flowed into the sector, investment has risen in several emerging market countries such as Brazil, Nigeria, China, India, and parts of Europe. After suffering declining terms of trade for much of the 1980s and 1990s, all of a sudden even the more established agricultural powerhouses of North America, Russia and Australia are experiencing resurgent conditions.

This shift raises two closely interrelated questions which this report will seek to answer:

- Will capital flow to assets exposed to environment-related risks that could ultimately result in them becoming stranded assets, or
- Will capital flow into assets which can support an environmentally sustainable, long-term expansion of output?

'Stranded assets', where environmentally unsustainable assets suffer from unanticipated or premature write-offs, downward revaluations or are converted to liabilities, can be caused by a range of environment-related risks. This report looks at these risks and how they might affect assets in agriculture over time. We have systematised the different risk factors that could affect assets across the agricultural supply chain and have completed a high-level assessment of where and how risks might affect these assets. A high-level Value at Risk (VaR) assessment is provided to give an indication of the magnitudes of capital exposed and to stimulate further work in this area.

The report is meant to provide an introduction to these issues so as to help inform investors and businesses working in the agricultural supply chain, as well as policy makers and governments who are concerned with the stability and environmental sustainability of the agricultural sector and its contribution to the wider economy. Our aim is to investigate the issue of stranded assets and the environmental risks involved with agriculture, and set a framework for further in-depth studies for certain sectors and geographies.

Since 2008, the ongoing financial and economic crisis centred in the developed world has resulted in a prolonged period of poor economic performance and political instability.[1] During this time of increasing unemployment, weak economic growth and volatile commodity prices, there has also been an intensification of damage on assets and livelihoods from extreme weather-related events.[2]

While it may be impossible to prevent or accurately forecast such events, much of recent history has reminded us that humans do not make reasonable preparations for risks which have been foreseeable.

Much of recent history has reminded us that humans do not make reasonable preparations for risks which have been foreseeable.

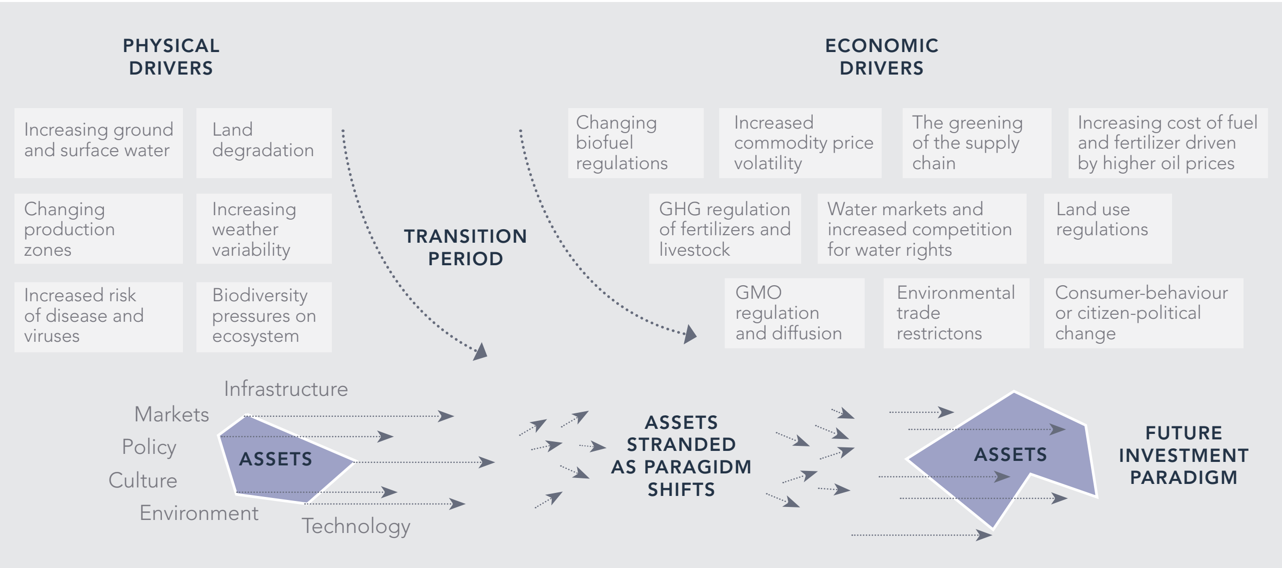
Footnotes:

[1] World Economic Forum (2013), *Global Risks* 2013: http://www.weforum.org/reports/global-risks-2013-eighth-edition
[2] For example, see the natural catastrophe database of the Swiss Reinsurance Company: http://www.swissre.com/sigma/

In *Figure 2* below, we view an agricultural asset as existing within an investment context including demand and supply conditions, the available technologies, social norms, local agro-economic and overseas conditions, and the policy frameworks of different governments. Using concepts borrowed from transitions theory, we then outline a number of risks that could lead to the investment context changing. Our premise is that agricultural investors could find themselves with stranded assets if they do not correctly anticipate or build resilience to this new investment context.

We have placed environment-related risk drivers into two groups: physical and economic. These risks have the potential to affect assets along the supply chain from the production enterprises themselves through to the processing, transport and sale of agricultural goods.

Figure 2: Environment-related drivers of asset stranding in agriculture[3]



Exposure to stranded assets will be highest where the value of assets is high and the vulnerability to drivers is high. It is important to keep in mind, however, that a significant component of the value of agricultural assets will not be priced by markets. This can be more readily understood by considering the following typology of assets:

- **Natural assets:** such as farmland (e.g. land improvements and accompanying ecosystem services. Water can also be considered a natural asset – part of which may be recognised in markets (such as allocation/access rights) and others not recognised (such as poorly defined water rights and water quality);
- **Physical assets:** such as animals, plantation crops, farm buildings, on-farm infrastructure (e.g. irrigation networks), off-farm and community infrastructure (e.g. processing facilities, dams, roads, towns);
- **Financial assets:** financial products that are tied to agricultural production (e.g. farm loans, derivatives);

Footnotes:

[3] It is important to bear in mind that this figure presents a simplified view of the physical and social drivers of asset stranding. In the real world, decisions are taken in a complex adaptive system, where the relationship between drivers and any responses from managers and governments are constantly co-evolving. Thus, while some broad lessons can be drawn from this analysis, it is important to remember that in practice context matters a great deal, and risk management will need to be tailored to local conditions.

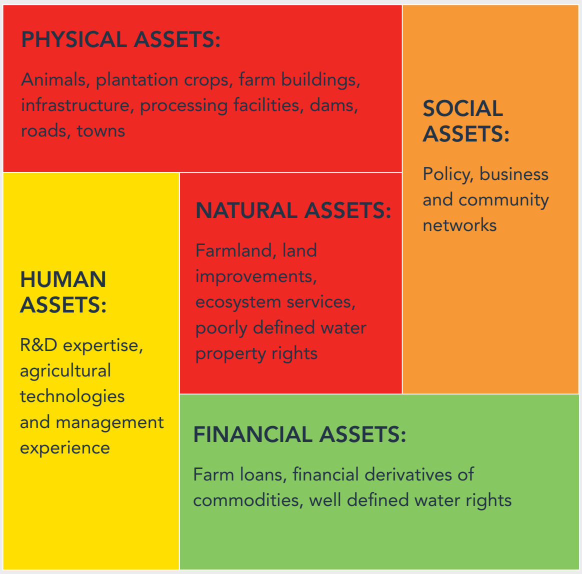
- **Human assets:** human know-how which has been built up through education and experience; research and development expertise; agricultural technologies (e.g. genetically modified organisms, fertilisers and pesticides) and management practices; and
- **Social assets:** policy and community networks such as producer organisations can build trust and support access to markets and finance which increase resilience and reduce risk.

Some types of assets are more easily measured by the market than others and thus some have more obvious and immediate financial implications. For example, the component of natural assets which makes up the price of farmland that may be bought or sold on the market is unlikely to include the full environmental and social value of land. These could include ecosystem services, or cultural values attached to the land.

For each of the drivers to be considered in this report, this typology has been used to evaluate how asset stranding might affect agricultural assets using a traffic light system to indicate sensitivity to each environmental risk – ranging from red (high vulnerability) to green (lower vulnerability).

> *Some types of assets are more easily measured by the market than others and thus some have more obvious and immediate financial implications*

Figure 3: Asset stranding risk framework by asset category



From a business perspective, stranded assets are a problem as they are generally low-liquidity investments, highly vulnerable to potentially abrupt and material devaluation. In *Figure 3* (page 13), this might include farmland and physical infrastructure. Such assets are usually 'tied to the land' so can be characterised as being the fixed or sunk costs of doing business. Social assets are vulnerable, but less so as they often relate to a wider range of activities, or can be put to a wider range of uses, such as the marketing cooperatives or political lobby groups and less physically tied to the land. Human assets are less vulnerable still, owing primarily to the possibility of migration, or the applicability of education and training elsewhere in the economy. Financial assets such as farm loans, stocks related to agricultural enterprise, or derivatives of commodities are the least vulnerable as a general rule as they are generally characterised by often highly liquid markets which can enable risks to be moved around.

Asset stranding may be driven by a range of risks across the economic, environmental, geopolitical and societal domains which can alter the operating paradigm for business. Risk and exposure to stranded assets is often compounded because of the problems of *path dependency* and *short term decision-making biases*. These forces describe the tendency of firms and decision-makers to invest in reinforcing and protecting their existing asset base and business models, rather than adapting to a new forward looking strategic environment.

From a government perspective, stranded assets are a problem because they often arise from *market failures* and the materialisation of long-overlooked external costs and the associated poor regulation of the economy.[4] Stranded assets can often carry with them implicit government insurance to ease 'transition' costs when things go wrong. This may take the form of the 'temporary' nationalisation of firms (as in the case of the recent bank bailouts), or the imposition of trade restrictions, subsidies or other direct support, for example 'exceptional circumstances' drought payments in the case of agriculture. Government support is also indirect through broader social programmes such as unemployment and health benefits and the re-skilling of the labour force through education and training. Many of the costs of stranded assets are therefore ultimately born by the state.

Risk and exposure to stranded assets is often compounded because of the problems of path dependency and short term decision-making biases

From a macroeconomic perspective, stranded assets are a problem because if otherwise unsustainable assets are kept in production for too long they become a drag on productivity, economic growth, social welfare and the public purse. However, if the gales of creative destruction are allowed to blow too fiercely, asset stranding can exacerbate the swings of the business cycle, with potentially costly and unpredictable political consequences. The risks of stranded assets are therefore of interest to finance ministries and central banks concerned about system-wide stability and economic performance.[5]

Footnotes:

[4] For example, five decades ago the US tobacco industry would not have suspected that in 1997 it would agree to pay USD 368 billion in health related damages: Gruber, J (2002), 'The Economics of Tobacco Regulation', *Health Affairs*, 21(2): 146-62.

[5] For correspondence with the Bank of England see: http://www.climatechangecapital.com/news-and-events/press-releases/bank-of-england-urged-to-review-uk-exposure-to-high-carbon-investments.aspx

The financial risk of stranded assets can be described by the following identity:

Financial risk of of asset stranding	=	Intensity of hazard (Stranding driver)	x	Exposure to Risk	x	vulnerability sensitivity adaptability

Thus financial risk exposure to stranded assets will depend on a range of context specific factors as well as the physical nature of the phenomenon. Because the sources of risk in agriculture are diverse and rarely independent from one another, it is also more meaningful to consider stranded asset risk as part of a holistic, rather than linear approach connecting one risk to financial impact. For illustrative purposes, in this report we provide a classification of risks according to different sources and review the literature around them to provide some indication of their potential financial and economic impacts.

In addition we do not suggest that all risks can be perfectly assessed in a systematic way, either linear or holistic. Many risks are non-systematic, that is, their occurrence and associated damage are unknown to a great extent.[6] This makes them very difficult to manage by either individuals or markets. Some weather-related risks such as drought and floods have a systemic component in that they affect most farmers within a region or country. This type of risk is difficult to pool with private insurance within the sector. Others, like hail damage, are more idiosyncratic and thus easier to pool. Some input and output prices (for example, fuel and fertiliser and crop prices) may be positively correlated, so accounting for these relationships is crucial in management strategies. Some risks are catastrophic because although they are very infrequent they cause a large amount of damage, and they are often systemic and non-systematic at the same time.

The agricultural sector is also characterised by a high level of investment synergies between different types of assets. For example, physical assets such as roads, electrification and storage facilities are intimately linked with the value of investments in on-farm production. Such synergies along the agricultural supply chain help open up new markets, create opportunities for agricultural value-added goods and services, increase the efficiency of production and help enhance the broader economic benefits from agriculture to the economy. But they also mean that stranded asset risk in one part of the supply chain will have implications for others.

An understanding of stranded asset risk will also assist with boosting sustainable agricultural investment in developing countries, where it is needed most. Agricultural investment has been identified as one of the most effective ways to boost the earnings of the nearly three quarters of the population in developing countries who live in rural areas.[7] However, this will not happen if governments have not put in place policy frameworks that establish and protect property rights, invested in good public rural infrastructure, and created the conditions for well functioning markets. Putting in place a risk management approach that accounts for stranded asset risk is likely to help build confidence in emerging markets and promote greater investment.

Footnotes:

[6] OECD (2009:7), Managing Risk in Agriculture: a holistic approach, OECD Publishing Paris.

[7] FAO (2011), *Looking Ahead in World Food and Agriculture: perspectives to 2050*, FAO Publishing, Rome.

Managing stranded asset risk boosts resilience and assists with adaptation at two levels. At the firm-level improved management around the risk of stranded assets can help companies and investments bounce back faster after an economic or environmental shock, and can help insulate them from the effects of that shock. At the system level, managing stranded assets better would help reduce volatility in stock indices and commodity markets. It would also promote the ability of agents in the economy to withstand, recover from and reorganise in response to a shock.

Changes in the wider economy also have an important effect on agricultural investments. For example, higher growth rates lift incomes and are thus likely to increase demand for some commodities (like meat and dairy), and lower it for others (such as staples like potatoes or maize). Interest rates and inflation will also have an important bearing on capital investments, land values and commodity storage options, and exchange rates will have a major impact on competitiveness and trade flows.

It is not the purpose of this report to investigate the effects of these broader economic drivers on stranded assets in agriculture. Neither is it the purpose of this report to address the political risks of high agricultural commodity prices such as witnessed by the Arab Spring.[8] Such issues are covered elsewhere.[9]

Of course, asset stranding has and will occur for reasons other than from environmental drivers. For asset managers and investors it is necessary to consider the possible interrelationships between environmental, political and economic risks. These are often linked in non-linear ways, and as the interconnected nature of global supply chains intensifies, this will only mean an understanding of these risks in different geographies becoming even more important.

With critical infrastructure and trillions of dollars across the agricultural sector at risk, managing stranded asset risk from environmental drivers should be an important part of the risk management strategies adopted by investors, business and public policy makers. As a way to consider the impacts of environmental pressures on the economy it also can inform discussions on global risk, resilience and adaptation.[10]

Footnotes:

[8] In this case, high food prices stemming from drought conditions in key growing regions, combined with weak economic performance following the financial crisis, helped fuel supply concerns. This contributed to the imposition of export controls in key countries such as Russia, further exacerbating supply shortages and higher food prices in North Africa. As a result of system collapse from political unrest, assets were left unused or destroyed, and suffered substantial loss in value.

[9] Chatham House, (2012:123) *Resources Futures*, Chatham House, London.

[10] For examples, see 'Shaping climate resilient development: a framework for decision-making', Economics of Climate Adaptation Working Group; 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation', Special Report of the IPCC; and 'Private Sector Initiative of the Nairobi work programme', UNFCC.

Agricultural commodity market context and outlook

The world's cultivated area has grown by 12 percent over the last 50 years, driven by a doubling of global irrigated area over the same period. Over this time, agricultural production has grown between 2.5 and 3 times, due to yield-enhancing technological change and management techniques. Agriculture uses around 11 percent of the land surface for crop production and makes use of 70 percent of all water withdrawn from aquifers, streams and lakes.[11]

However, these achievements of production in many regions have been associated with the degradation of land and water resources, and the deterioration of related ecosystem services. Such pressures, to be discussed in the second part of this report, can be characterised as environmental flows from an otherwise under-priced natural asset (the land). These natural assets form the foundation of much of the agricultural sector, however if not held in good stewardship, then productivity can fall – potentially in a non-linear and irreversible way.

After declining in real terms throughout the 1980s and 1990s, international food prices began rising in 2002 in an apparent reversal of this long-term trend. This signalled the beginning of a commodity boom which has been the longest and broadest (in terms of the commodities involved) of the post-Second World War period.[12] This boom has been fuelled by a range of factors, both macro and long term, as well as sector-specific and short term.

By 2011, the FAO Food Price Index *(Figure 5)* had reached more than double its level during 2000 – 02. This represents the longest sustained cyclical rise in real agricultural commodity prices experienced over the last 50 years. This has been driven by a range of factors including: three droughts in Australia between 2001 and 2007; a heat wave in central Asia during the summer of 2010; declining global stocks to historical lows of several agricultural commodities (especially rice and wheat), and government policies, such as export bans and prohibitive export taxes.

A further significant recent occurrence has been the diversification of some food commodities to the production of biofuels, particularly maize in the United States and edible oils in Europe. This has strengthened the connection between agriculture and energy markets.

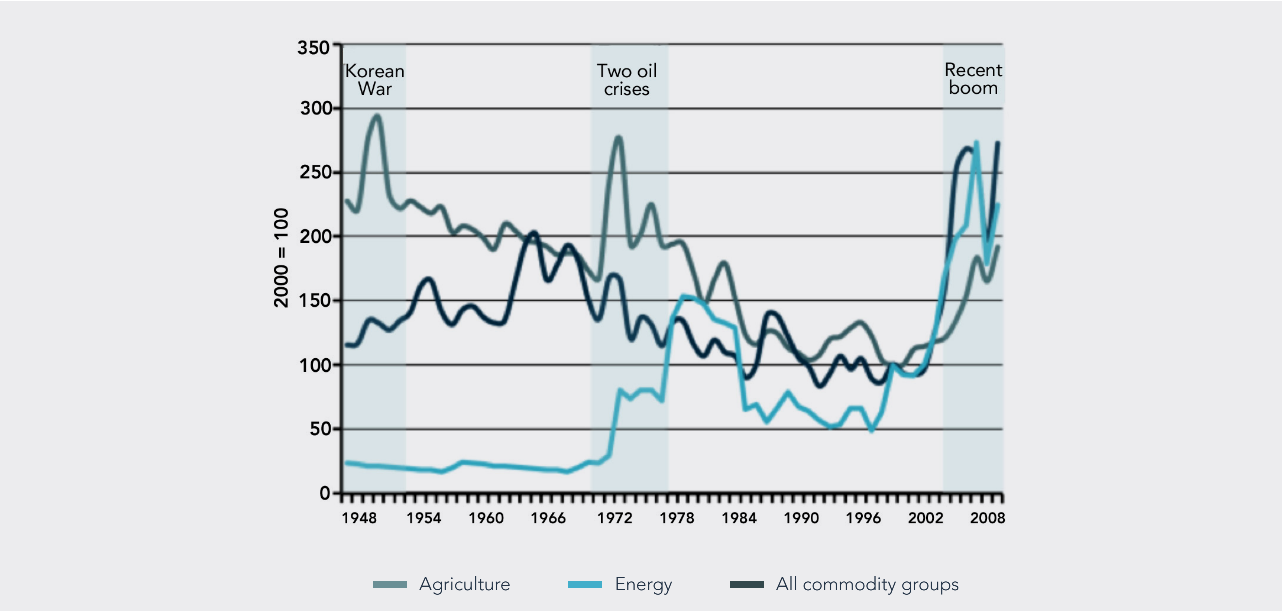
For example, a major contributor to the general rise in agricultural commodity prices was a strong rise in the price of sugar, which has tripled over the last ten years. Part of this can be explained because sugar crop products are important feedstocks for the biofuel sector. This means that high oil prices combined with strengthening biofuel mandates have both put upwards pressure on sugar prices at the same time as a general rise in demand for agricultural food production. Such effects will be discussed in more detail later in the report.

Footnotes:

[11] FAO (2013), *The State of the World's Land and Water Resources for Food and Agriculture: managing systems at risk*, FAO Publishing, Rome: http://www.fao.org/nr/solaw/en/

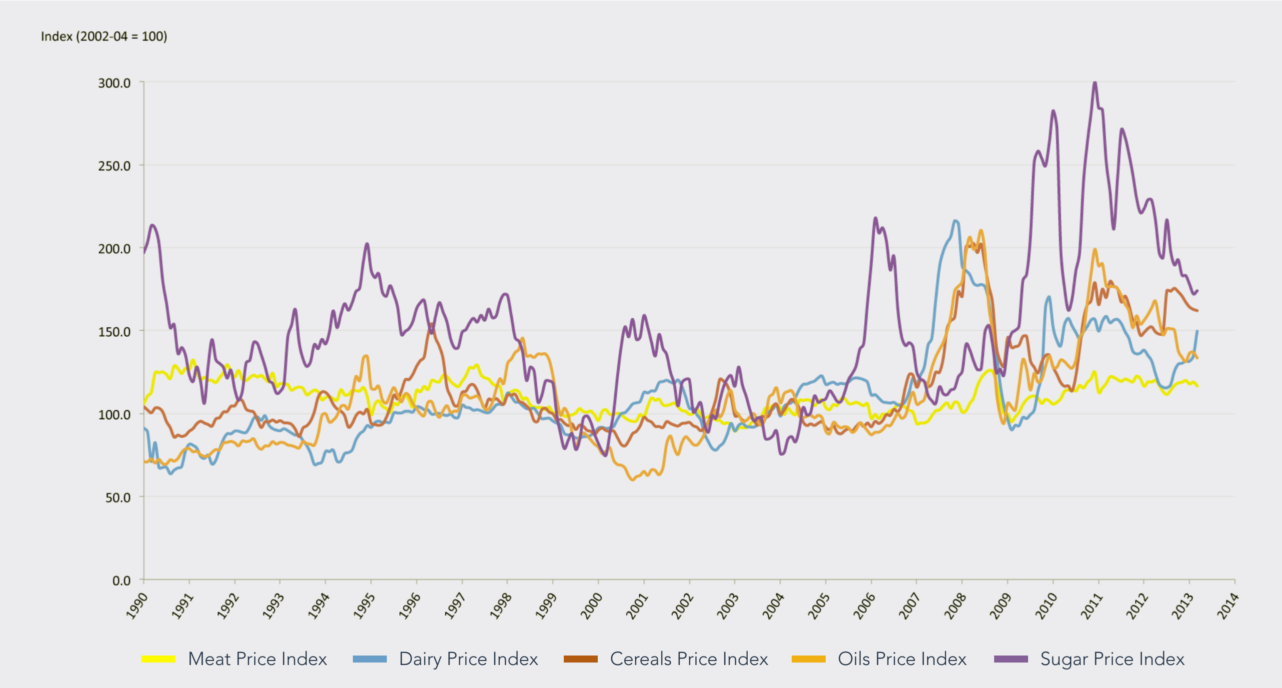
[12] World Bank (2009), *Global Economic Prospects: commodities at the crossroads*, Washington, DC.

Figure 4: The current commodity boom in context: a 'new normal of high volatile prices' or short-term spike in long-term trend of declining prices? (real prices, Manufacturing Unit Value index – deflated)



Source: World Bank

Figure 5: Key agricultural commodity price indices



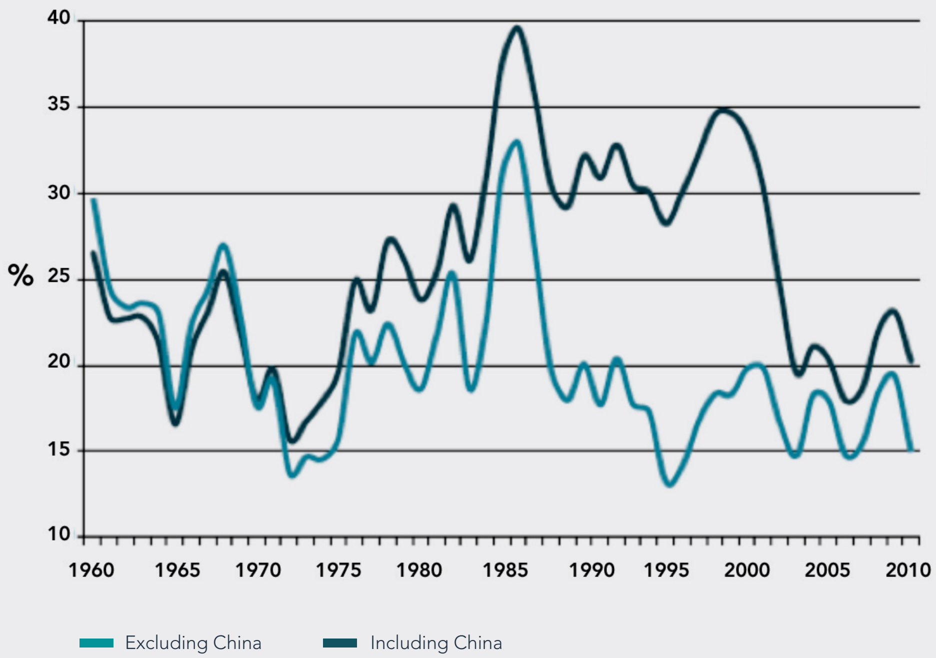
Source: FAOSTAT. Note: The price indices are monthly observations plotted from January 1990 to March 2013 and adjusted for inflation

All else being equal, when commodity prices rise, the profitability of farming increases and the attractiveness of the sector for new investment is enhanced. Thus the current burst of strong agricultural commodity prices should, in theory, lead to greater resources flowing into the agricultural sector.

At the same time, food availability and food security concerns have generated calls for coordinated policy actions at the national and international levels, reminiscent of actions taken in earlier booms.[13] High agricultural commodity prices exacerbate poverty and malnutrition[14], and have contributed to political instability in some regions, particularly northern Africa.

When commodity prices rise, the profitability of farming increases and the attractiveness of the sector for new investment is enhanced

Figure 6: Global stock to use rations, 1960 to 2010



Source: World Bank calculation based on USDA data

Footnotes:

[13] FAO (2011), *Looking Ahead in World Food and Agriculture: perspectives to 2050*, Chapter 5, FAO Publishing Rome.

[14] Beddington J et al (2012), *Achieving Food Security in the Face of Climate Change*, Final Report from the Commission on Sustainable Agriculture and Climate Change. Copenhagen: http://ccafs.cgiar.org/commission/reports; Carter, M and Barrett C (2006), 'The Economics of Poverty Traps and Persistent Poverty: An asset-based approach', *Journal of Development Studies* 42, (2):178-199.

Spurred on by low returns in equities and bonds since the financial crisis, another factor contributing to the recent boom in commodities has been increased interest from various investment, pension and sovereign wealth funds to place part of their holdings in commodities. Agriculture as an asset class is relatively new for institutional investors and so there have likely been more inflows than outflows from investors, placing temporary upwards pressure on price levels, this may be a particular issue given the size of the funds is large and disproportionate to the size of the available investment vehicles in markets.[15]

While these macro and sector-specific issues have been investigated in some detail, in the rush to take advantage of the booming investment climate, less attention has been given to the question of whether capital will flow to assets exposed to environment-related risks that could result in asset stranding or flow into assets which can support an environmentally sustainable, long-term expansion of output.

Footnotes:

[15] Soros, G (2008), Testimony before the US Senate Commerce Committee Oversight: Hearing on FTC Advanced Rulemaking on Oil Market Manipulation, 3 June, 2008, Washington, DC: www.georgesoros.com/files/sorosfinaltestimony.pdf; Eckaus, R (2008), 'The Oil Price is a Speculative Bubarrele', Center for Energy and Environmental Policy Research, Working Paper 08-007 Washington, DC; Wray, R (2008), 'The Commodities Market Bubble: Money manager capitalism and the financialization of commodities', Public Policy Brief No 96, Levy Economics Institute, Bard College, Annandale, New York.

Mapping capital investment in agriculture

Investment is vital to promoting long-run economic growth and development. Capital formation, such as expenditure on new machinery, infrastructure and technology, enables an economy to produce more, and more efficiently. This is particularly true in the agricultural sector, where countries that perform best in reducing poverty and hunger are also those that achieve higher net investment per agricultural worker. Agricultural investment, such as land improvements, is also essential for reducing the environmental impact of farming on natural ecosystems and expanding the natural capital base.

Most investment in agriculture[16] is conducted by farmers and agribusiness on approximately 525 million farms worldwide.[17] Despite strong world demand driven by rising incomes and population in the developing world, the FAO has pointed to a general slowdown in agricultural investment. For instance, over the period 1975-90 the rate of capital formation in primary agriculture grew annually at 1.1 percent, while over the period 1991-2007 it grew only at 0.5 percent. Declining investment and the gross value of agricultural capital stock has been most prominent in countries of the former Union of Soviet Socialist Republics. Global investment would have collapsed further if not supported by investment in the emerging markets of Brazil, China, India and parts of Africa, particularly Nigeria. Indeed, recent analysis by McKinsey suggests 83 and 84 percent of the opportunity to boost resource productivity in water and land respectively is to be found in developing countries suggesting there is much room for profitable investment in this part of the world.[18]

Globally, the total accumulated investment, as measured by the value of agricultural capital stock, has increased about 20 percent since 1975 and now exceeds USD 5 trillion.[19] The bulk of this is concentrated in North America and in Europe followed by China, India and Japan, with the Russian Federation, Brazil and Australia also having high levels of investment. These investment patterns have been influenced by major political and economic developments, such as rising prosperity in China and India, the collapse of the former Soviet Union and a pro-investment economic climate in Brazil. Long-term movements in economic variables such as commodity prices, interest rates and exchange rates also have played an important role.

Agricultural investment, such as land improvements, is also essential for reducing the environmental impact of farming

Farmers and other private investors will invest in agriculture only if the expected returns compensate for the perceived risk and exceed returns from other types of investment. Agriculture is usually highly seasonal or cyclical in nature, and vulnerable to natural phenomena such as drought, pests and diseases. Producers are often dispersed and most agricultural products bulky and perishable. These factors make agricultural investment relatively risky and highly dependent on public goods, such as good rural infrastructure, robust input supply and output processing industries, stable property rights and exposure to transparent market signals.

Footnotes:

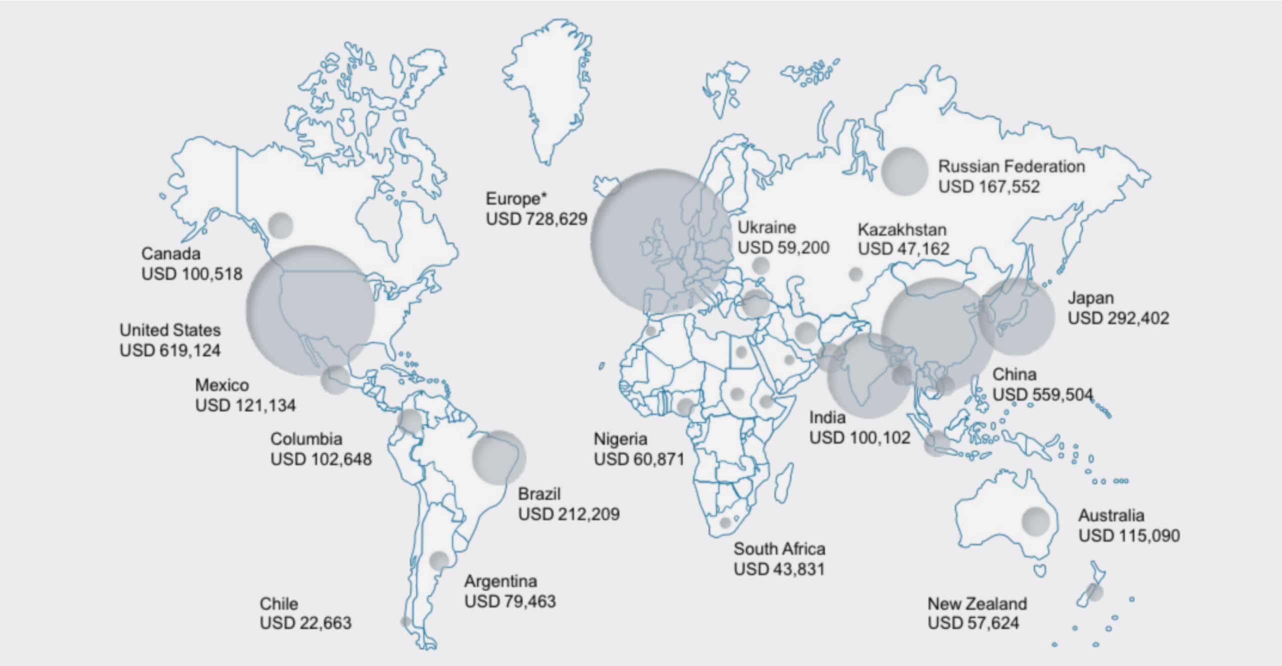
[16] Following FAO (2012) "agriculture" refers to crops, livestock, aquaculture and agroforestry.

[17] Nagayets, O (2005), 'Small Farms: current status and key trends', Information Brief, International Food Policy Research Institute, Washington, DC.

[18] McKinsey (2011), 'Resource Revolution: meeting the world's energy, material, food, and water needs', McKinsey Global Institute.

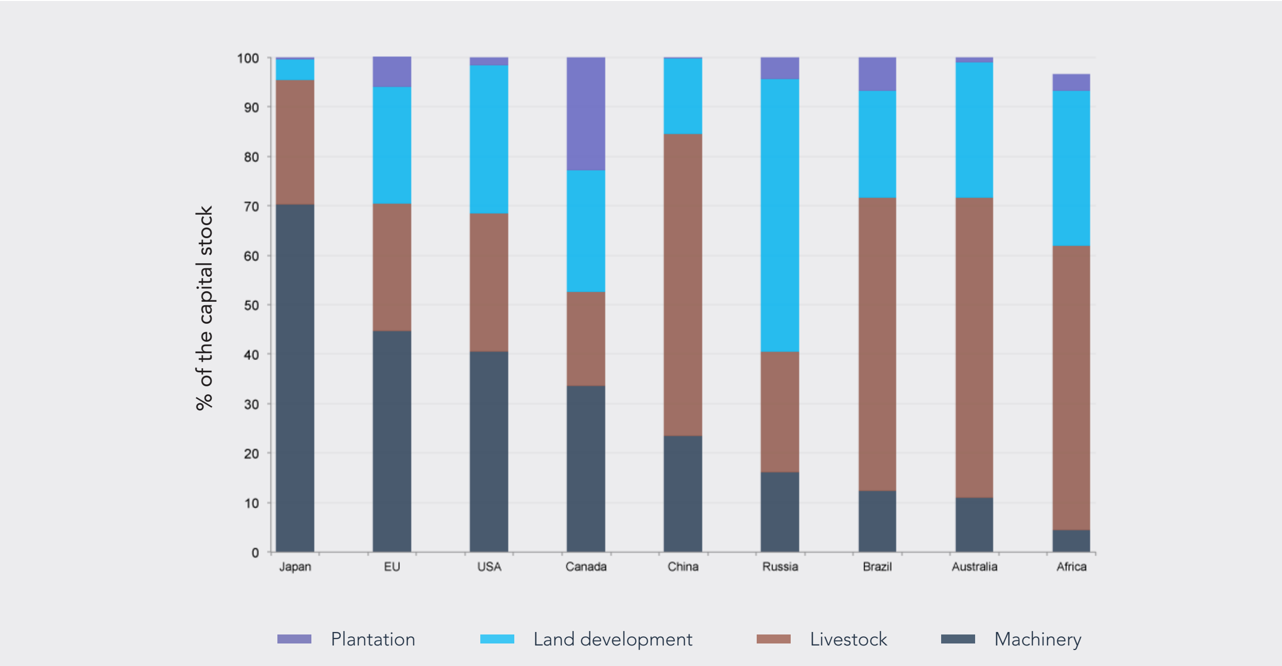
[19] FAO (2013), *The State of the World's Land and Water Resources for Food and Agriculture*: *managing systems at risk*, FAO Publishing, Rome: http://www.fao.org/nr/solaw/en/

Figure 7: *USD 5 trillion gross value of capital investment in agriculture (2007, USD millions)*



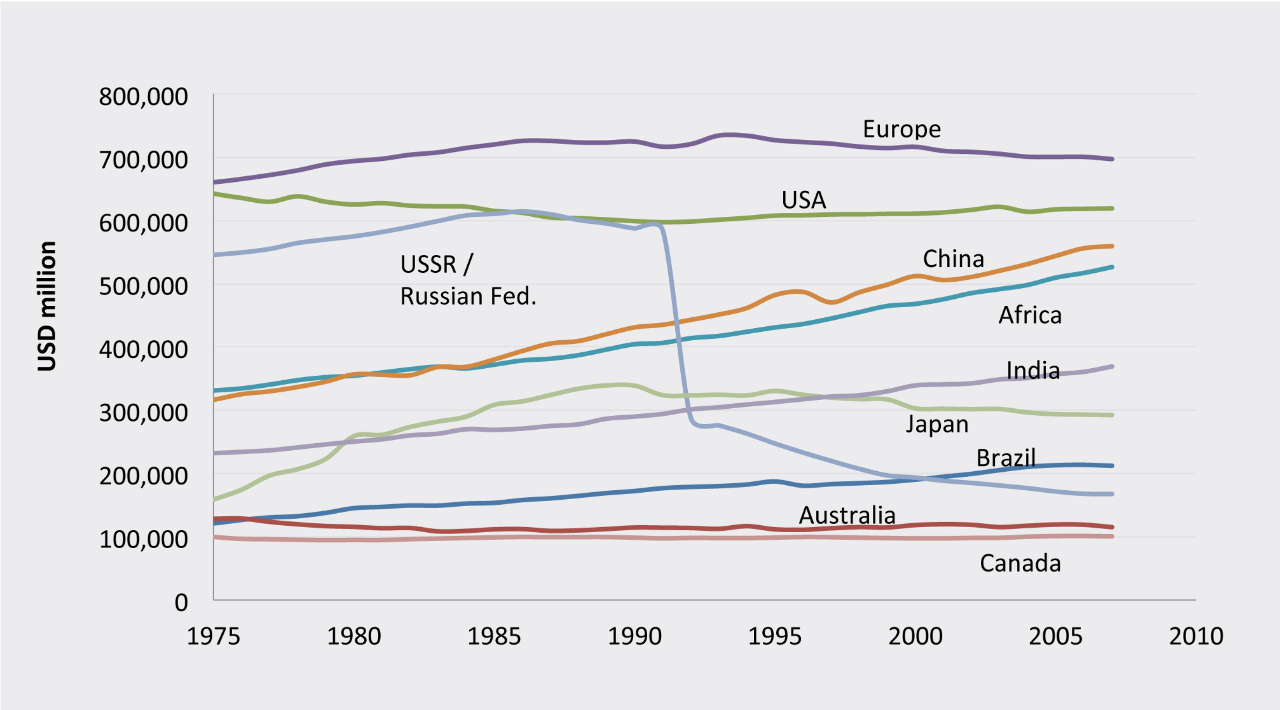
*Source: FAOSTAT (extracted May 2013). *Europe includes: France, Spain, Italy, Germany, Poland, United Kingdom, Romania, Greece, Ireland, Austria, Sweden, Portugal, Finland, Denmark, Netherlands, Czech Republic, Hungary, Norway, Lithuania, Switzerland, Serbia, Belgium, Slovakia, Bulgaria, Albania, Latvia, Slovenia, Estonia, Croatia, Luxembourg, Malta, Liechtenstein*

Figure 8: Measured components of the capital stock in gross capital investment



Source: FAO Year Book (2012b)

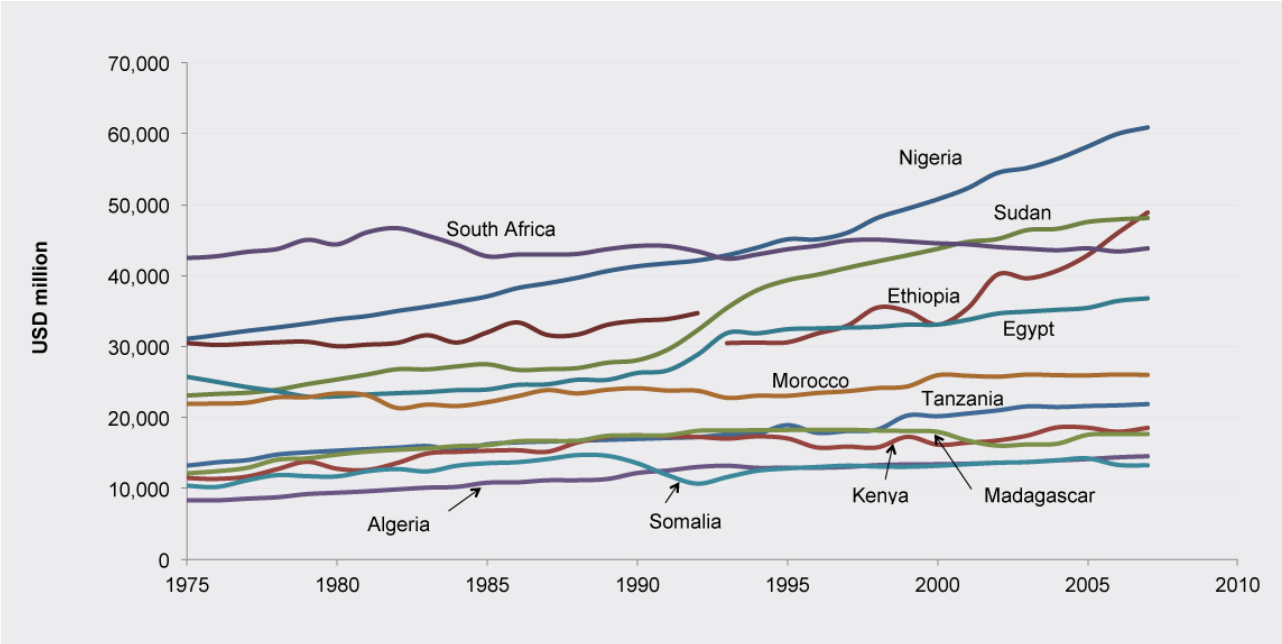
*Figure 9: Gross value of agricultural capital investment in agriculture (1975-2007)**



*Source: FAOSTAT. *Selected countries. Includes investment in land development, livestock (fixed assets), livestock (inventory), structures for livestock, machinery and equipment, and plantation crops*

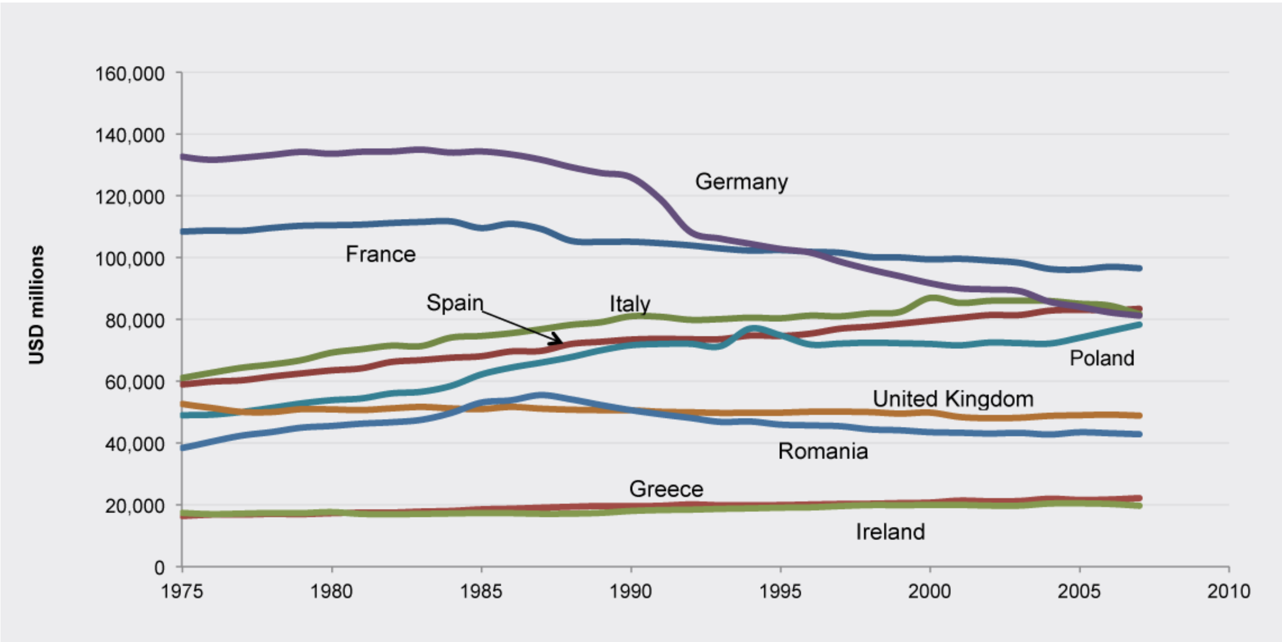
In *Figure 9*, the regional breakdown of gross agricultural investment in Africa is shown. This highlights the strong growth in agricultural investment in many countries, although in absolute terms, this investment is low by international standards, especially given the potential of the region. The standout country is Nigeria, where agricultural investment has steadily risen from USD 30,000 million in 1975 to around double that number by 2007. Sudan and Ethiopia have also experienced strong growth in investment in recent decades rising from around USD 30,000 million each in the early 1990s to just under USD 50,000 million today – an increase of around 66 percent. Egypt has also seen significant growth in the value of gross agricultural investment rising from around USD 25,000 million in the early 1990s to around USD 38,000 million in 2007, or around 50 percent.

Figure 10: Value of gross agricultural capital investment in Africa (1975-2007) in leading countries



FAOSTAT (extracted May 2013)

Figure 11: Value of gross agricultural capital investment in Europe (1975-2007) in leading countries



FAOSTAT (extracted May 2013)

In Europe, while a relatively steady value of gross agricultural capital investment is evident at the aggregate level, significant changes have occurred at the country level. The most dramatic has been the decline in the value of German agricultural investment, from around USD 135 billion in 1985 to around USD 80 billion according to the latest data. This can be explained in part by the broad collapse in economic activity and investment across Eastern Europe and the republics of the former Soviet Union, following the collapse of communism. The value of gross capital investment has also fallen in France, declining from around USD 115 million to just under USD 100 million in 2007 or by around 13 percent.

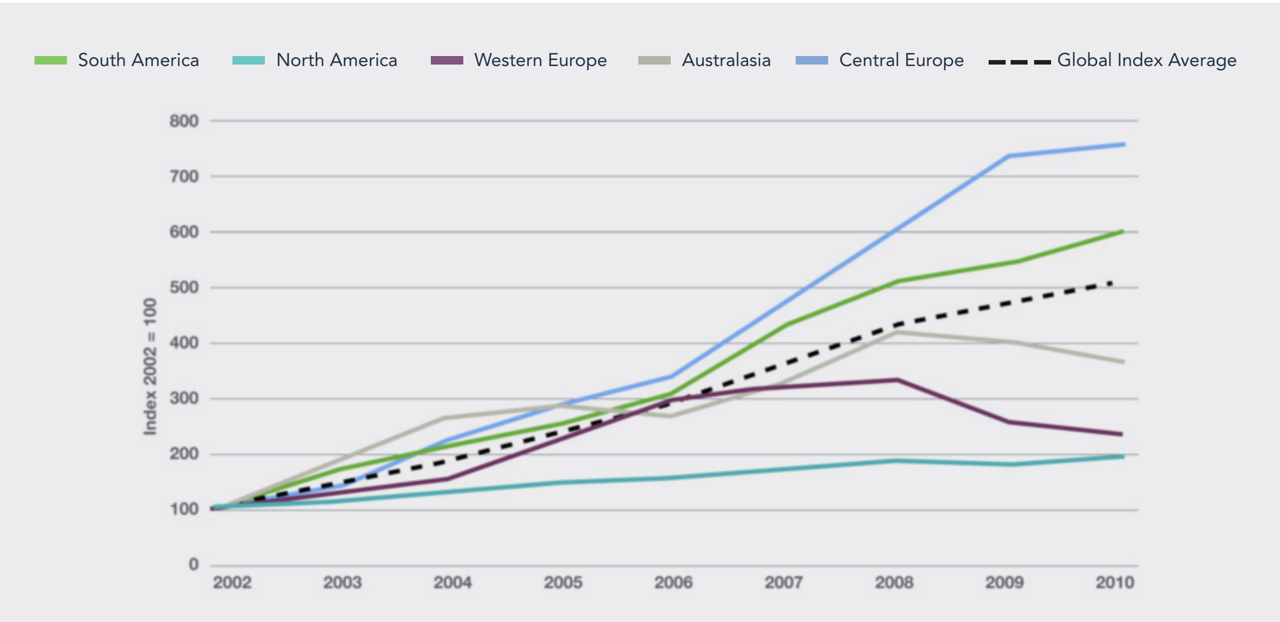
Counter to this trend of stable or declining investment in northern Europe, the value of gross agricultural capital stock has been rising in several countries in the Mediterranean region, particularly Spain, Italy and Portugal – all countries that are expected to be strongly impacted by the intersection of increasing water scarcity and increasing droughts and weather variability as a result of climate change.

Mapping investment in agricultural land

While there is some overlap with agricultural investments considered in the last sector, it is important to consider farmland itself as an important asset class in its own right.

Driven by turbulence in other parts of the economy many investors have looked to tangible assets as safe havens – such as gold, prime urban real estate and agricultural commodities. Agricultural land has been one of the asset classes most affected by this trend, rising over 400 percent in value between 2002 and 2010, according to the main global farmland price index.[20]

Figure 12: Global farmland values



Source: USDA, Eurostat and Savills

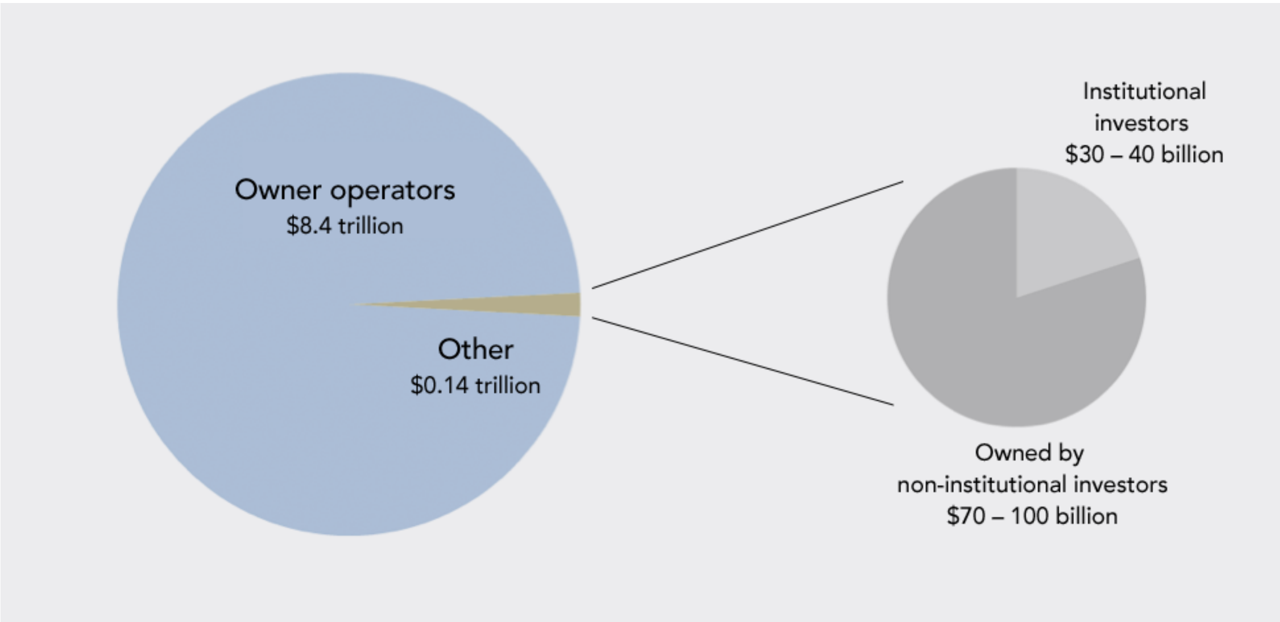
Footnote:

[20] Savills Rural Research (2012), *International Farmland in Focus 2012*: www.savills.co.uk/research. Although converting to USD per hectare can have an effect on annual growth rates in terms of domestic currency, it does allow potential investors a good starting point for comparable analysis.

Investment in farmland by itself will not necessarily boost productivity if it simply involves a transfer of title. Nor will it necessarily add to the capital stock of a country. It can, however, be associated with new knowledge or improved management expertise, and can also be accompanied with increased investment in capital stock, if such investments are a feature of land purchases. Such investments, which can enhance productivity and improve yield, would be associated with increasing capital stock in a country.[21] Thus farmland investment may or may not be associated with increasing the value of the agricultural capital stock.

Obtaining robust farmland value data, especially in emerging markets, is a challenging task and there are many gaps – even in developed markets. In this report, we synthesize some of the main sources of this data; however, the picture that emerges is still far from comprehensive.

Figure 13: Global agricultural land ownership

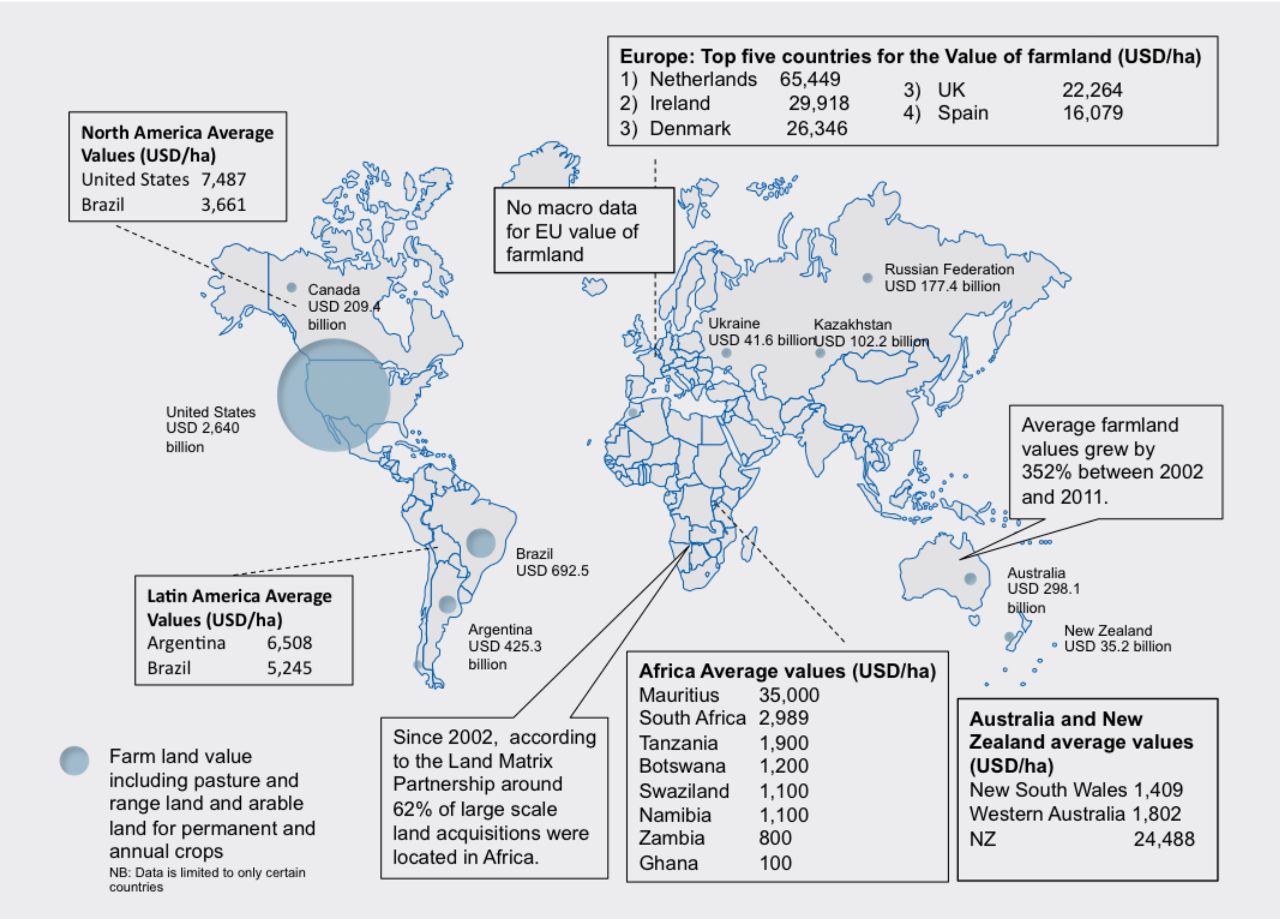


Source: FAO (2011); Macquarie Agricultural Funds Management (2012)

Footnote:

[21] FAO (2013), *The State of the World's Land and Water Resources for Food and Agriculture: managing systems at risk*, FAO Publishing, Rome: http://www.fao.org/nr/solaw/en/

Figure 14: A snapshot of available global land value statistics



Sources: Savills (2012) International Farmland, Land Matrix Database

According to the FAO, agribusiness and industry account for the largest share of investors in farmland. Foreign governments and sovereign wealth funds[22] are also increasingly involved in buying or leasing large tracts of land in developing countries and, with yields on government bonds at record low levels, some private equity groups and pension funds have been active in this area.[23]

Footnotes:

[22] The sovereign wealth funds of China and the Republic of Korea along with the Gulf States of Qatar, Saudi Arabia and the United Arab Emirates appear to be emerging as key investors in these land purchases.

[23] See McNellis, P (2009), 'Foreign Direct Investments in Developing Country Agriculture: the emerging role of private sector finance', FAO Commodity and Trade Policy Research Working Paper No 28, Rome; Anseeuw, W, Ducastel, A and Gabas, J (2011), 'The End of the African Peasant? From investment funds and finance value chains to peasant related questions', paper presented at the International Conference on Global Land Grabbing, 6-8 April, 2011, Brighton UK; *Wall Street Journal* (2010), 'Private sector interest grows in African farming'; FAO (2011), Report on expert meeting on international investment in the agricultural sector of developing countries, 22-23 November, Rome; FAO, IFAD, UNCTAD and World Bank (2012), *Principles for Responsible Agricultural Investment that Respects Rights, Livelihoods and Resources.*

Due to often extreme price differentials for agronomically equivalent land between countries, many jurisdictions, including Brazil and South America, have implemented regulatory controls to slow the pace of foreign investment. The Organisation for Economic Cooperation and Development (OECD) monitors such restrictions for all sectors including primary industries across four main measures: equity restrictions, screening and approval requirements, restrictions on foreign key personnel, and other operational restrictions such as limits on the purchase of land and repatriation of profits and capital.[24]

For instance, the Savills Global Farmland Index shows that the more immature markets of Romania, Hungary, Brazil, Argentina and Poland recorded the highest increases in farmland value between 2002 and 2012. The primary reason for accelerated growth in central European countries was their entry into the European Union in 2004 and Bulgaria and Romania in 2007. Romania has experienced growth in farmland value by 1,817 percent since accession to the EU in 2007. In 2002 a hectare of land in Brazil would cost around USD 800 compared with over USD 5,200 in 2010.

Land values in mature agricultural land markets still grew strongly albeit at less exuberant levels. Between 2002 and 2007 farmland values rose by 300 percent in Australia and 262 percent in New Zealand, outpacing the United States where the value of farmland grew by a relatively slow 75 percent over the same period.

This booming investment climate, combined with concerns around poor transparency and governance of land purchases, particularly in developing markets, recently led a group of pension funds to launch the Principles for Responsible Investment in Farmland.[25] The World Bank has also called for increased monitoring, citing that many land-deals have suffered from limited screening, lack of due diligence, weak contracts and an air of secrecy.[26]

The FAO caution that 'land grabbing' hypotheses must be treated carefully as what is often reported as a foreign acquisition is often majority owned by domestic investors with only a minority foreign share.[27]

While it contains major risks, especially for the rights of existing landholders where property rights are uncertain, such investment can also fill investment gaps in countries with large natural resources, but limited financial capital. It can also assist with the transfer of new technologies, building human capital, the diversification of crops, and the generation of additional jobs and adoption of higher standards where the investment targets specific export markets with strong sustainability requirements.

Footnotes:

[24] http://www.oecd.org/investment/fdiindex.htm

[25] http://www.unpri.org/areas-of-work/implementation-support/the-principles-for-responsible-investment-in-farmland/

[26] web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:22694767~pagePK:64257043~piPK:437376~theSitePK:4607,00.html

[27] FAO (2012) In one extreme case, more than half of all agricultural land in Liberia was involved in large scale land acquisitions between 2004 and 2009, but only about 30 percent involved foreign purchasers.

Box 1: The Land Matrix Partnership and Database[28]

Since 2000, the Land Matrix Project has been collecting information on the transnational transfer of land rights through the sale, lease or concession for transactions of more than 200 hectares. Such investments have increased significantly over recent years, focused on Africa and Latin America, driven by investments from the Gulf States, China and the Republic of Korea.

The data, which found 924 documented deals between 2000 and 2011 covering 46.9 million hectares, was gathered through media reports and from NGOs, which may lead to a certain bias and over-representation of areas attracting public attention. A World Bank study which looked in detail at a number of countries found that only 21 percent of announced deals had been completed.[29]

Many deals are stimulated by food security concerns, especially from wealthier countries with land and water constraints. High food prices and policy-induced supply shocks have evidently created fears of over-dependence on world markets to satisfy domestic demand.

More positively, new inclusive models of investment are allowing the combination of the assets of local farmers, such as land, labour and local knowledge, with corporate investors providing financial capital, facilitating access to markets, and technology transfer. For example, recent years have seen the growth of investment funds for agriculture, with an emphasis on value creation through processing, logistical services and wholesaling.[30] Other inclusive business models in agriculture could include: contract farming, lease and management contracts, tenant farming and share cropping, farmers' organisations and cooperatives, and building upstream and downstream business links.

Clearly, the ultimate impact of land acquisitions on the environment and people affected will depend on the motives of the purchaser, as well as the policy, legal and institutional framework in the host country. In terms of stranded asset risk, as farmland comprises a significant proportion of the capital investment in a farming operation, we have particularly focused on it within our analysis.

Value at risk

Over recent years, increasing attention has been given to attempts at linking the functioning of ecosystems and the atmosphere with human wellbeing.[31] Two central elements of this 'link' are the entwined notions of natural capital 'stocks' and the ecosystem services that 'flow' like interest or dividends from them.

The Millennium Ecosystem Assessment recognised four categories of services: supporting (e.g. nutrient cycling, soil formation and primary production); regulating (e.g. climate regulation, flood and disease regulation and water purification); provisioning (e.g. food, fresh water, wood, fibre and fuel); and cultural (e.g. aesthetic, spiritual, education and recreational).[32]

Footnotes:

[28] http://www.landmatrix.org/

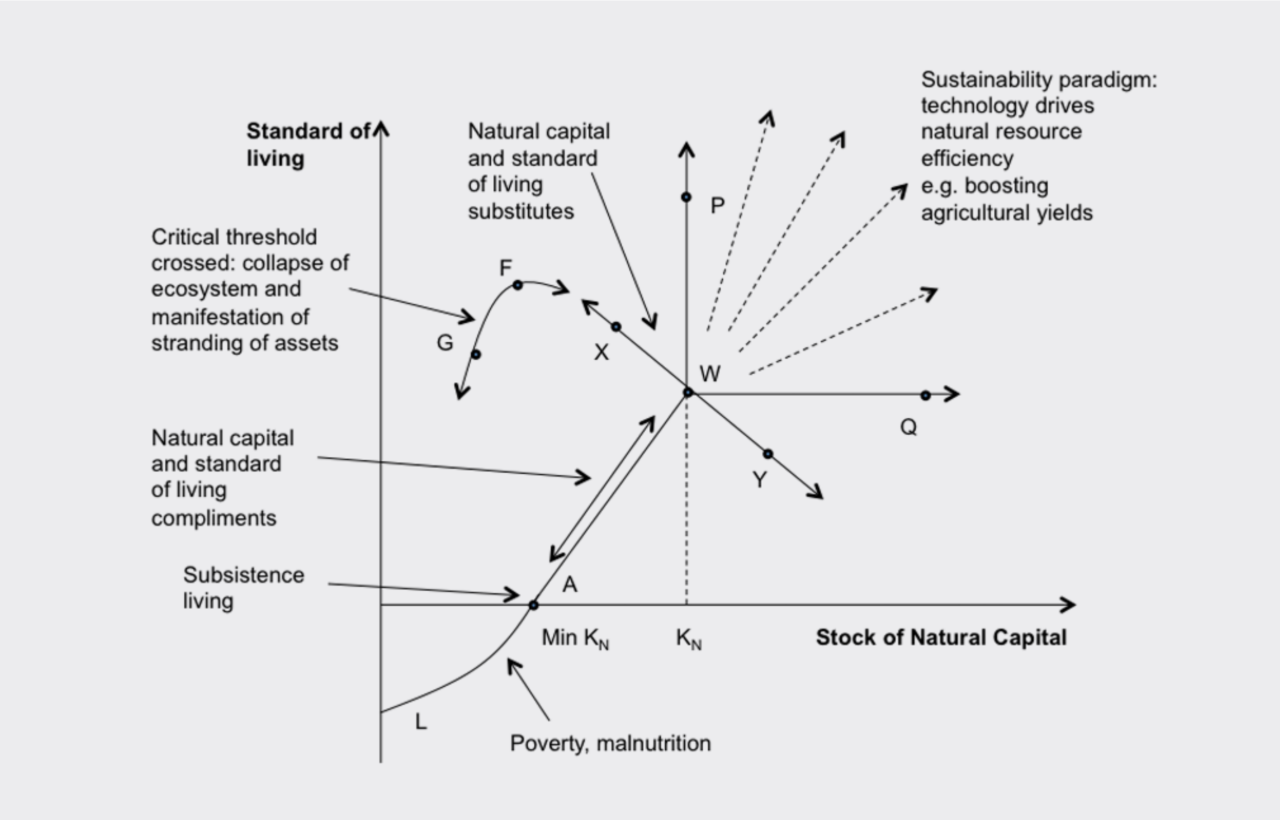
[29] Deininger, K and Byerlee, D (2011), 'Rising Global Interest in Farmland: can it yield sustainable and equitable benefits?' World Bank Publishing, Washington, DC.

[30] Miller, C, Richter, S, McNellis, P and Mhlanga, N (2010), 'Agricultural Investment Funds for Developing Countries', FAO, Rome.

[31] For example, Stern Review (2006) *The Economics of Climate Change*, Cambridge University Press; TEEB, The Economics of Ecosystems and Biodiversity: http://www.teebweb.org/ ; Fisher, B, Turner R and Morling, P (2009), 'Defining and Classifying Ecosystem Services for Decision Making', *Ecological Economics* 68: 643-653.

[32] Millennium Ecosystem Assessment (2005), 'Ecosystems and Human Well-being: Synthesis', Island Press, Washington, DC.

Figure 15: Stock of natural capital and standard of living and stranded assets



Source: based on Pearce, D and Turner, R (1990:46)

Figure 15 above is useful in highlighting how the relationship between standards of living and natural capital can be thought of at different stages of development and levels of natural capital.

If we represent standard of living as a vector beginning at point *L* there is some minimum level of natural capital *Min* K_N which is required to support a subsistence lifestyle. Beyond this point, we can think of economic development being able to proceed while both natural capital and standards of living increase up to the point K_N, that is – they are complementary. Natural capital could expand, for instance, through the discovery of previously inaccessible natural resources such as new mineral reserves or potential areas of land development. It could also expand due to technologies and infrastructure opening up new resource possibilities (e.g. dams and irrigation may increase the agricultural potential of a region). For example, in Saudi Arabia, it is difficult to imagine increased development without natural resource augmentation such as desalination infrastructure.

At point *W* three paradigms of thinking about resource relationships are illustrated. Along the ray *XY* natural capital and living standards are thought of as substitutes, that is – it is not possible to increase living standards without either depleting natural resources (*WX*) or alternatively it is impossible to expand natural capital without lowering living standards (*WY*). A sustainability paradigm is illustrated in the range of rays between *WP* and *WQ*. Here improvements in technology, continue to open up new resource possibilities, through efficiency and substitution of new materials and behaviours. A third and final paradigm illustrates the situation of over-extraction of natural capital that leads to ecosystem collapse and the stranding of assets (*FG*).

Figure 15 (page 30) is meant to be illustrative only. But it helps show how natural capital stocks can change over time and the important role of technology and investment in augmenting it. In reality whether technology and infrastructure enhance the natural capital stock or help undermine it is an empirical question that will depend on the nature of economic and political institutions which govern such investment, population pressures and other physical and economic drivers.

This discussion on natural capital has raised the question of the capacity of the economic system to substitute losses of natural capital with human-made capital, which also has an important bearing on issues of short-termism in markets and intergenerational equity.[33]

In the context of agriculture, this substitutability of natural for human-made capital could take the form of increased investment in on-farm machinery, fertilisers and insecticides boosting yield, while simultaneously, land degradation and loss of biodiversity from land clearing leads to reduced natural pollination from insects and soil erosion. Thus, using the typology of assets from the earlier section, the physical capital stock has increased, the natural capital stock has decreased and yield may have gone up or down. At the extreme, we may see food and fibre being grown independently of conventional farming systems in highly-capital intensive laboratory-like conditions.

While the degree of substitution is ultimately an empirical question (for example, the cost of a hamburger grown in the lab would be around £200,000 using current technology),[34] it is generally recognised that the degree of substitution has practical and economic limits.[35] Closely related to this are the notions that a critical amount of natural capital must be maintained for ecosystems to function, and that thresholds exist whereupon non-linear changes to the functioning of ecosystems may occur.

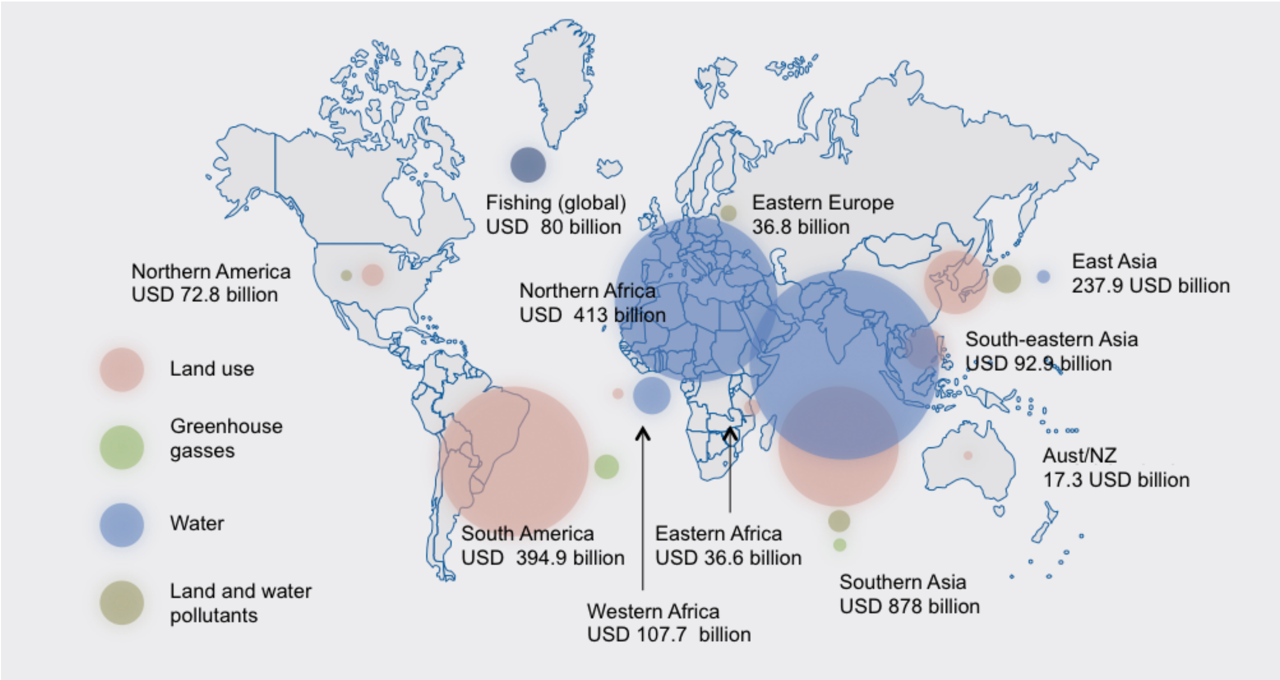
Footnotes:

[33] TEEB (2010:6), 'The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations', Earthscan, London and Washington.

[34] http://www.bbc.co.uk/news/science-environment-16972761

[35] Barbier, E (1994), 'Natural Capital and the Economics of Environment and Development', in Jansson, A-M, Hammer, M, Folke, C and Costanza, R (Eds), *Investing in Natural Capital*, Island Press, Washington, DC; Daly, H (1996), Introduction to Essays toward a Steady-State Economy. In: Daly, H and Townsend, K (Eds), *Valuing the Earth: Economics, ecology, ethics*, The MIT Press, Cambridge, Massachusetts, 11–47 ; Prugh, T et al (1999), *Natural Capital and Human Economic Survival*, Lewis Publishers, Boca Raton, FL.

Figure 16: Agriculture-related environmental key performance indicators: 'total natural capital cost' USD 2,369 billion per year



Source: Trucost/TEEB (2013) Natural Capital at Risk

In *Figure 16* above, data is presented from the Trucost/TEEB *Natural Capital at Risk Study*. This work seeks to identify the world's biggest natural capital risks for business, investors and governments and place a high-level monetary valuation on them.[36] The data presented here relates to the top 58 'natural capital risks' that affect agriculture. These range from unsustainable fishing, rice farming in East Asia, wheat and corn farming in northern Africa, cattle ranching in South America, palm oil in Southeast Asia and wheat farming in southern Asia.

Taken together, the total natural capital cost from agriculture is USD 2.369 trillion per annum in terms of the 'environmental and social costs of lost ecosystem services'. This can be thought of as a negative flow each year, which pulls the economy back towards the vector *XY* in *Figure 15* (page 30) and away from the sustainable production possibilities bound by the area *PWQ*.

Although this data only provides a partial picture of the potential environmental costs associated with unsustainable agriculture, it makes a vital contribution towards raising awareness of the magnitude of the value that is being extracted from the natural world and treated as a 'free resource'.

This notion of declining natural capital is what we use to inform the following Value at Risk (VaR) calculation. We set out three scenarios: the first representing current levels of natural capital, the next a medium level of loss of natural capital and thirdly a situation of extreme loss of natural capital. Each of these scenarios represents escalating levels of risk.

Footnote:

[36] http://www.trucost.com/news-2013/175/teeb-for-business-coalition-study-shows-multi-trillion-dollar-natural-capital-risk-underlying-urgency-of-green-economy-transition

Box 2: Some characteristics of risk[37]

The distinction has been made between *systematic* and *non-systematic risks*.[38] Systematic risks are related to events that repeat over time with a pattern of probabilities that can be analysed in order to have a good estimate of the actuarial odds. In contrast, non-systematic risks are characterised by very short or imperfect records of their occurrence and, therefore, difficulties in estimating an objective pattern of probabilities or distribution of outcomes. This distinction is similar to the distinction between risk and uncertainty and no clear-cut line can be drawn between these two types of risk. The concept of *cognitive failure* follows the same line of distinction: it occurs when individuals do not know the probability or potential magnitude of a given event.[39] Decision-makers often forget bad loss events and do not use this information in their decision-making. Most other characteristics normally used to qualify risks are based on some knowledge of the right distribution of the risky events.

It is often argued that it is *downside risk* that matters most. Downside risk is more likely to occur when the risky outcome depends on non-linear interactions among several variables, and it can be particularly relevant in agriculture.[40] For instance, yields depend on several factors such as rainfall and temperature, but large deviations from central values of these variables in either direction have adverse effects. A 'normal' season could be defined as a season with all variables having their expected values. This would be very unlikely to occur, and the probability of yields being below a 'normal' season is likely to be large. In this case, the distribution of outcomes will be skewed towards the lower values of yields and downside risk becomes particularly relevant. But downside risk is part of the whole distribution of outcomes in a way that there is no downside risk without some associated upside risk. The point of reference will determine how much 'risk' is considered in each side of the distribution.[41]

This focus on downside risk has led to measures of risk that are based on downside outcomes such as the *value at risk*, which is a percentile of outcomes (e.g. there is 1 percent probability of losing a given amount of money) that is often used in portfolio analysis and decision-making, particularly in the context of insurance and financial risk management.[42]

Risks are often characterised by their frequency, in terms of probability of occurring, and intensity, in terms of the magnitude of the loss. This is often a simplification of a more complex reality in which the whole distribution of probabilities and outcomes needs to be considered. Furthermore, the links among the distributions of different risks are very important for any risk evaluation. An individual risk that is independent or uncorrelated with any other risk is called idiosyncratic risk. But typically a risk has some degree of correlation with other risks. If there is a high degree of correlation among individual risks in the same region or country, the risk is called *systemic risk*. But correlation can also occur over time (repetition of risk) or with other risks, and there can be positive and negative correlations.

It is common to find the term *catastrophic risk* both in the technical literature and, particularly, in the more policy oriented or general debates. A technical definition of a catastrophic risk is associated with the idea of a risk with low frequency but high losses. It relates to the extreme of the negative tail of the distribution of outcomes. However, the concept is sometimes linked also to high overall losses for a region or a country. In that case the risk is simultaneously catastrophic and systemic. Even if some authors prefer to define catastrophes as systemic events, the distinction between an event that is a catastrophe for an individual or a local community from an event that is catastrophic for a whole region or a country is a useful one.

Footnotes:

[37] OECD (2009:18) *Managing Risk in Agriculture: a holistic approach*, OECD Publishing, Paris.

[38] Newbery, D and Stiglitz, J (1981), *The Theory of Commodity Price Stabilization*, Oxford: Clarendon Press.

[39] Skees, J and Barnett, B (1999), 'Conceptual and Practical Considerations for Sharing Catastrophic/Systemic Risks', *Review of Agricultural Economics*, 21 (2): 424-441.

[40] Hardaker, J, Huirne R, Anderson, J and Lien, G (2004), *Coping with Risk in Agriculture*, CABI Publishing.

[41] Menezes, C, Geiss, C and Tressler, T (1980), 'Increasing Downside Risk'. *The American Economic Review*, 70: 921-932.

[42] Jorion, P (2001), *Value at Risk: The new benchmark for managing financial risk*, McGraw Hill, New York.

To perform our VaR analysis we consider a distribution of profit and loss for global agriculture based on the calculations performed by the OECD.[43] This suggests that, under present conditions, the expected profit is around 7 percent but with a range of -50 to 50 percent. A Gumbel distribution provides a convenient means of describing the variability of the profit and loss and is often used for predicting the chance that an extreme event will occur. Along with specifying an average value, we can consider the implications of increasing the standard deviation of the distribution. This analysis allows us to explore the impact of greater variability resulting from loss of natural capital, uncertain future conditions and the potential for asset stranding, on the VaR.

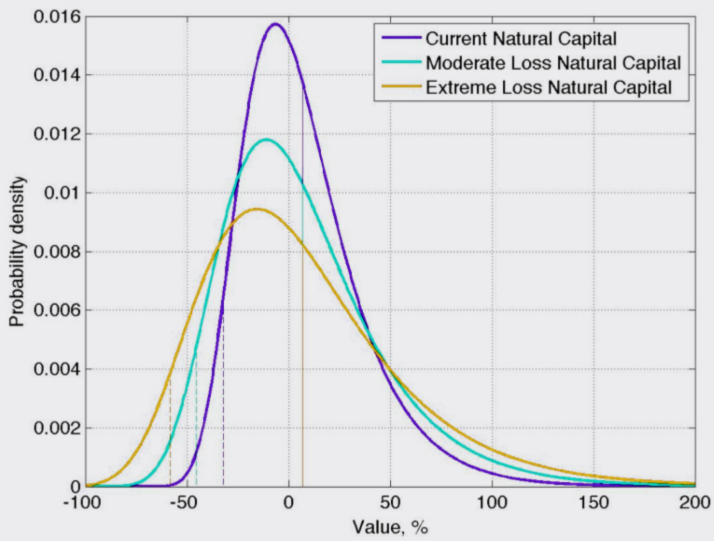
The specific assumptions about the scenarios are given in *Table 2* below.

Table 2: Assumptions about the distribution of profit and loss for each scenario

SCENARIO/METRIC	AVERAGE	STANDARD DEVIATION
Current Conditions	7%	30%
Moderate Stranding	7%	40%
Extreme Stranding	7%	50%

The three distributions corresponding to these assumptions are shown in *Figure 17*. Note that the average is fixed at 7 percent and by varying the standard deviation from 30 to 40 to 50 percent, we investigate the impact of this increasing variability on the VaR.

Figure 17: Probability densities for the three scenarios, showing the average at 7 percent and the 5 percent Value at Risk (dashed lines)



Footnote:

[43] OECD (2009:30) *Managing Risk in Agriculture: a holistic approach*, OECD Publishing, Paris.

In the previous sections of this report, we gathered the most recent data on gross value of the agricultural capital stock (USD 5,356 billion) and the value of farmland assets (USD 8,500 billion). We believe that the sum of these two global figures (USD 13,856 billion) constitutes an informed basis for our initial capital stock. While several caveats are attached to this figure,[44] we consider it a reasonable starting point to use for what is a synthetic thought experiment looking into what sort of value is at risk from escalating environmental risks associated with the decline of natural capital.

Using this figure, we are able to estimate the VaR and provide monetary values for each of the three scenarios. We quantify three different VaR levels, 5 percent, 1 percent and 0.5 percent. The 0.5 percent VaR is of interest to the insurance sector as this corresponds to the Solvency II regulation, which requires insurers to determine their solvency capital requirements at this level of risk.

Table 3: Value at Risk calculations for the three scenarios

METRIC (USD TRILLIONS) / SCENARIO	CURRENT	MODERATE	EXTREME
Average	0.970	0.970	0.970
Standard Deviation	4.157	5.542	6.928
Median	0.287	0.059	-0.168
Mode	-0.901	-1.524	-2.148
5 percent VaR	-4.452	-6.283	-8.072
1 percent VaR	-5.867	-8.114	-10.402
0.5 percent VaR	-6.325	-8.738	-11.151

In summary, this analysis shows that under the extreme loss of natural capital scenario the loss measured by the 0.5 percent VaR could almost double from USD 6.3 trillion to USD 11.2 trillion. In other words, there is a 0.5 percent chance of the annual loss being more than USD 11.2 trillion. This would clearly represent significant stranding of assets.

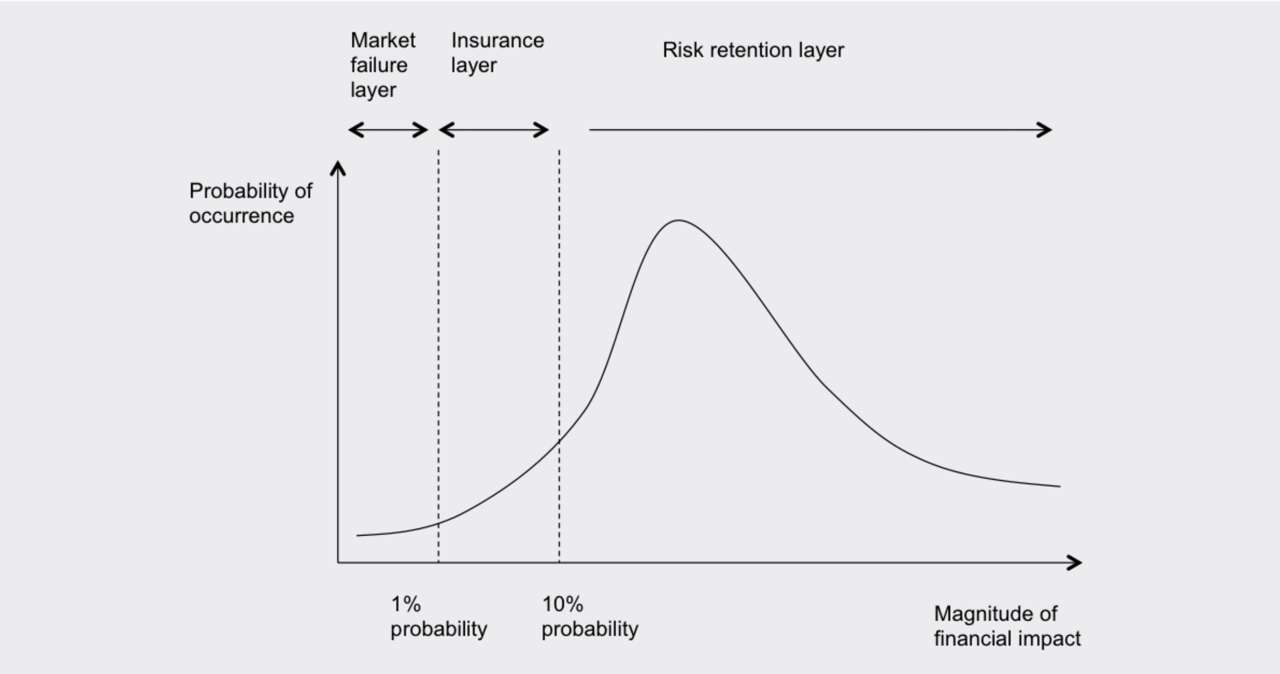
Footnote:

[44] In using this figure it is obviously necessary to make several caveats. First, the value of farmland estimates are not comprehensive across countries, and several important farmland markets are unlikely to be included, resulting in an underestimation of their value. There is also likely to be overlap between the value of farmland, and improvements to farmland (e.g. livestock structures, irrigation etc.) which is included in gross capital investment, so there may be some double counting.

Managing value at risk

Risk management strategies start with decisions made on the farm and the household regarding the set of outputs to be produced, the allocation of land, the use of alternative inputs and production techniques, investment in physical capital such as irrigation and machinery and the diversification of activities and investments on and off-farm.

Figure 18: Probability densities function and risk layers



Source: based on OECD (2009:30), Managing Risk in Agriculture

Risk can also be managed through insurance and futures markets. However, several forces act against market insurance strategies including: the systemic nature of risks, the lack of information on probabilities, and information asymmetry with respect to those probabilities. The OECD suggests it is therefore useful to segment all risks into three different layers according to the instruments most appropriate or available.[45] Risks that are frequent but do not imply large losses are typically managed on the farm. Risks that are infrequent but generate a large amount of damage to farm income are likely to fall under the catastrophic risk layer, for which market failure is more likely. In between these two layers there are intermediate risks for which some insurance or market solutions can be generated.

The implications of the above analysis for the management of VaR from such events, is that the probability distribution is likely to be changing shape in different regions, and external costs, become increasingly internalised through either physical or economic events. This will have implications for the bounds used for the layering of risks, and the instruments that should be made available to farmers.

Footnote:

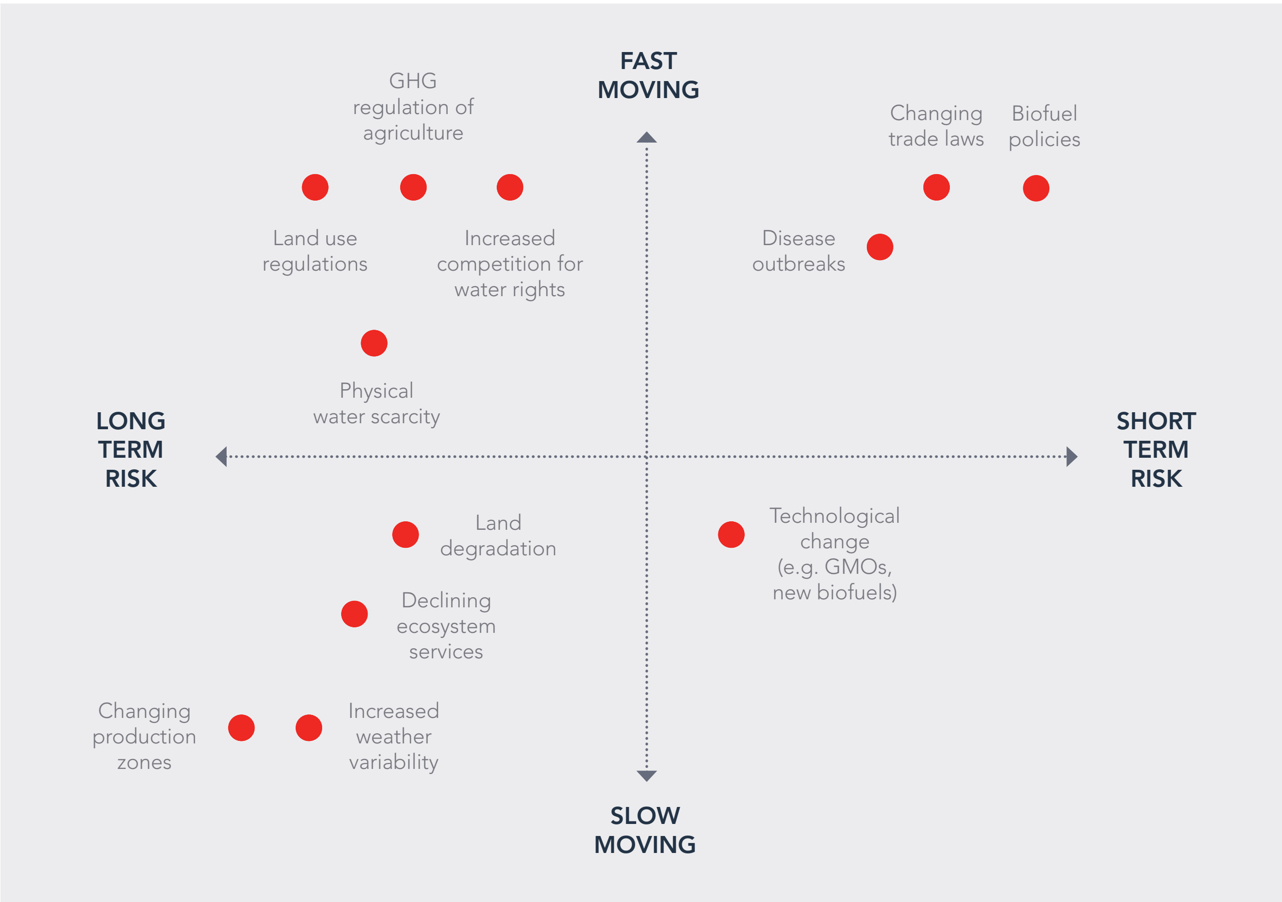
[45] OECD (2009:30) *Managing Risk in Agriculture: a holistic approach*, OECD Publishing, Paris.

Drivers of asset stranding in agriculture

This section of the report sets out some of the main environment-related risks facing agriculture. If and when these risks materialise they can result in stranded assets throughout different parts of the agricultural supply chain. These could be sector-specific, such as with respect to biofuel processing facilities, or be felt across a commodity or a region, if falling productivity and competitiveness as a result of one or more of these drivers leads to wider economic effects such as agricultural 'ghost' towns or regions – the Aral Sea disaster being perhaps the most high profile case.

This section of the report aims to provide an up-to-date synthesis of the literature around these risks. Where this report seeks to make a more original contribution is through the application of the stranded asset concept to these drivers, as a heuristic tool to help investors and others understand how these risks might play out.

Figure 19: Time horizons for environment-related risks in agriculture



In *Figure 19* above, the environment-related risks have been grouped along two axes. The vertical axis reflects the speed at which an environment-related risk manifests itself. Economic drivers, such as regulations, are relatively fast-moving risks which can suddenly be put in place. For example, this could occur through a change in political party, or the adoption of an international agreement, or some new piece of scientific, economic or technological information that gets translated into a legal or other policy instrument.

At the other end of the spectrum, physical risks tend to manifest themselves much more slowly. While weather risks are short-term events that can lead to abrupt change, and indeed trigger non-linear feedbacks in the climate system, the changing frequency of weather-related risks will in general happen over decades. At the macro-level, this will shape average agricultural yields over time and production zones are likely to shift 'stranding' agricultural assets left in unviable areas.

On the horizontal axis, the risks are classed as either short-term or long-term risks. For example, with the pace of technological change and political uncertainty around the industry, biofuel regulations are part of current problem agendas of many governments. They are also likely to have a significant effect on the agricultural industry. Disease risks and changes in oil prices are also drivers that are likely to be faced in the near future, as are the agricultural opportunities that will result from the greening (or otherwise) of the agricultural food chain. At the other end of the spectrum, classic problems of the commons such as declining ecosystem services, water quality and land degradation are long-term risks. Such problems which can be characterised as 'the tyranny of small decisions' or 'tragedy of the commons' are common to agriculture, take a long time to manifest, and are difficult to remedy once they have occurred.

Physical Drivers

Increased weather variability, physical water scarcity and climate change

Why are weather variability and shifting production zones potential drivers of asset stranding?

Weather is the main source of yield risk for crop agriculture and can also have serious consequences for animal agriculture in both confined facilities and in open grazing. Weather risk can be quite idiosyncratic, affecting individual farmers through hail and frost; through to regional effects such as too much or too little rainfall at the wrong time; or pose macro-systemic risks through widespread floods and droughts that trigger political instability.

By 2050, it is very likely that climate change will increase the incidence of extreme drought, especially in the subtropics and low to mid-latitudes (see *Figure 21* on page 45). It is expected that increased water stress will impact land areas twice the size of those areas that will experience decreased water stress. Increased precipitation intensity and variability are projected to increase the risk of flooding. The proportion of land surface experiencing extreme drought at any time is also projected to increase, especially in the subtropics and the low and mid-latitudes.[46]

According to the Intergovernmental Panel on Climate Change (IPCC) there is evidence that over the last century temperatures on the surface of the earth have risen globally, with important regional variations.[47]

The level of precipitation has also changed in most places:

- 'Significantly wetter in eastern North and South America, northern Europe and northern and Central Asia, but drier in the Sahel, southern Africa, the Mediterranean and southern Asia… widespread increases in heavy precipitation events have been observed even in places where total amount has decreased.'
- 'The extent of regions affected by droughts… tropical storms and hurricane frequencies vary considerably from year to year but evidence suggests substantial increases in intensity and duration since the 1970s.'
- 'In a warmer climate, there will be an increased risk of more intense, more frequent and longer lasting heat waves… models project increased summer dryness and winter wetness in most parts of northern middle and high latitudes.'

Footnotes:

[46] Bates, B, Kundzewicz, Z, Wu, S, Palutikof, J (2008), 'Climate Change and Water', Technical paper for the Intergovernmental Panel on Climate Change. Geneva: http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf

[47] IPCC (2007), 'Climate Change 2007: The Physical Science Basis', IPCC Fourth Assessment Report., Cambridge University Press, Cambridge.

According to the IPCC, the global proportion of the land surface in drought is predicted to increase by a factor of 10 to 30, from around 1-3 percent of total land surface today, to around 30 percent by the 2090s.[48] The number of extreme drought events per 100 years and mean drought duration are likely to increase by factors of two and six, by the 2090s respectively.[49]

For example, decreasing summer precipitation in southern Europe, accompanied by rising temperatures which enhance evaporative demand, is likely to lead to reduced summer soil moisture and more frequent and intense droughts.[50] Another important effect of rising temperatures will be to increase the likelihood of precipitation falling as rain, rather than snow in areas with temperatures near to 0°C in autumn and spring. Snow melt is expected to be earlier and less abundant in the melt period, and this may lead to an increased risk of droughts in snowmelt-fed basins in summer and autumn, when demand is highest.[51]

Water supplies from inland glaciers and snow cover are projected to decline in the 21st century, continuing a 20th-century trend. This will reduce water availability during warm and dry periods – when irrigation is most needed – in regions supplied by melt water from major mountain ranges.[52]

Historical studies strongly suggest that climate change has already had negative impacts on crop yields. Yields of maize and wheat are sensitive to temperatures above 30 degrees Celsius. For example, each day above 30 degrees Celsius in the growing season reduces the final yield of maize by 1 percent under optimal rain-fed conditions and by 1.7 percent under drought conditions.[53] Another study found that maize, wheat and other major crops have experienced climate-associated yield reductions globally of around 40 megatonnes per annum between 1981 and 2002.[54]

Another significant effect will be on areas of irrigated rice production. Many of these areas are already drought-prone under present climatic conditions and are likely to experience more intense and more frequent drought events in the future. One study suggested that by 2025, 15-20 million hectares of irrigated rice will experience some degree of water scarcity.[55] Drought stress is the largest constraint to rice production in rain-fed systems. In Asia, it affected 10 million hectares of upland rice and over 13 million hectares of rain-fed lowland rice.[56]

Footnotes:

[48] IPCC (2007:187) Chapter 3: Freshwater resources and their management, Cambridge University Press, Cambridge.

[49] Burke, E, Brown, S and Christidis, N (2006), 'Modelling the Recent Evolution of Global Drought and Projections for the 21st Century with the Hadley Centre Climate Model', *Journal of Hydrometeorology*, 7-1113-1125.

[50] Douville, H et al (2002), 'Sensitivity of the Hydrological Cycle to Increasing Amounts of Greenhouse Gases and Aerosols', *Climate Dynamics*, 20:45-68.

[51] Barnett, T, Adam, J, and Lettenmaier, D (2005), 'Potential Impacts of a Warming Climate on Water Availability in Snow Dominated Regions', *Nature*, 438:303-309.

[52] Bates, B, Kundzewicz, Z, Wu, S, and Palutikof, J (2008), Op cit.

[53] Lobell, D, Schlenker, W, and Costa-Roberts, J (2011), 'Climate Trends and Global Crop Production since 1980', *Science* 333(6042):616-620.

[54] Lobell, D and Field, C (2007), 'Global Scale Climate: crop yield relationships and the impacts of recent warming', *Environmental Research Letters* 2:1-7: http://iopscience.iop.org/1748-9326/2/1/014002/pdf/1748-9326_2_1_014002.pdf

[55] Bouman, B, Humphreys, E, Tuong, T and Barker, R (2007). 'Rice and Water', *Advances in Agronomy* 92:187–237.

[56] Pandey, S, Bhandari H and Hardy, B (2007), 'Economic Costs of Drought and Rice Farmers' Coping Mechanisms: a cross-country comparative analysis, International Rice Research Institute, Manila: http://dspace.irri.org:8080/dspace/bitstream/123456789/951/1/9789712202124.pdf

Flooding due to climate variability is a significant problem for rice farming, especially in the lowlands of South and Southeast Asia. Flooding already affects about 10 to 15 million hectares of rice fields in South and Southeast Asia, causing an estimated USD 1 billion in yield losses a year. These losses could increase considerably given sea level rise as well as an increase in the frequency and intensity of flooding caused by extreme weather events.[57]

Of course water scarcity depends not just on physical phenomena, but also technological investment and institutional arrangements, which can help increase efficiency and resilience to physical scarcity. For example, drought resistant crops, infrastructure such as irrigation, improved management techniques, such as crop tilling practices, and government support mechanisms, such as drought assistance, can all lower the risk of water scarcity to the farmer and investor.

Such practices taken in the context of how climate change may affect production zones will become an increasingly important element of agricultural risk management relevant to agricultural investors.

Box 3: Weather risk and the United States Federal Crop Insurance Programme[58]

The United States Federal Crop Insurance Programme reports the cause of loss for each indemnified insurance policy. This data (1980-2001) can be analysed to identify the primary causes of weather risk for major crops. Drought, excess moisture, and hail are the main causes of yield risk for the major field crops such as maize, cotton, soybeans and wheat. Excessive moisture, freeze, hurricanes and excessive heat are important causes of yield risk for sugar beet. Excessive moisture, excessive heat, drought and freeze are the primary yield risks for potatoes. Drought, excess moisture, freeze, hurricanes and excessive heat are important causes of yield risk for tomatoes and other vegetables. Freeze is the primary risk for citrus fruit. For the other tree and vine fruit such as apples, grapes, pears, peaches, nectarines and cherries, the primary sources of yield risk are frost, freeze, hail and excessive moisture.

Footnotes:

[57] Bates, B, Kundzewicz, Z, Wu, S and Palutikof J (2008), Op Cit.

[58] United States Department of Agriculture Risk Management Agency: http://www.rma.usda.gov/

What kind of assets are at risk?

The assets most vulnerable to increasing weather variability and changing production zones will be those characterised by high fixed or sunk costs and those of low liquidity that are closely tied to the value of land.

Natural assets such as farmland, which is economically marginal in times of good weather conditions and high commodity prices, have been assessed as likely to be highly vulnerable (red) to asset stranding from weather variability. This has particular relevance in the context of the current agricultural commodity and investment boom, which has incentivised new investment, some of which is likely to be unsustainable if commodity prices fall towards more long-term trends.

Other natural assets that may be highly vulnerable to asset stranding from this driver are poorly defined water entitlements attached to the land. If weather patterns change resulting in lower access to water such informal allocations may be appropriated by higher value users such as urban users.

Figure 20: Assets at risk from weather variability and changes in production zones

Physical assets such as farm animals may be possible to move or sell, however they will be still be vulnerable.

Box 4: Climate risk and agriculture

Animal operations are subject to different weather-related risks depending on whether they are in confined spaces or are open grazing. Confined dairy, hog, and poultry operations tend not to be subject to many risks such as drought in the same manner as grazing agriculture, but are still exposed to extreme temperature and rainfall.

For example, milk production will decline due to high temperatures, and for meat animals, growth rates decline in extreme hot or cold situations. Confinement facilities typically reduce these extremes, but come at significant costs, such as those required to cool poultry facilities.[59] In less intensive grazing agriculture, weather risks can result in significant reduction in available forage. In particular, drought can cause reduced rate of gain or in extreme cases cause the liquidation of herds.[60]

Physical assets such as multi-year plantation crops, like orchards and vines in wine growing regions, have been designated highly vulnerable (red) to changes in the amount and pattern of annual rainfall. Where climate change and changing weather patterns result in significantly lower summer melt water, irrigated crops and related infrastructure are vulnerable and may become non-viable.

Social assets, including community business networks such as agricultural cooperatives, networks for processing, distribution and marketing produce, finance relationships between farmers, agribusiness and banks are less vulnerable to the effects of increased weather variability on specific regions. These networks can take time and investment to establish and contribute significantly to the competitiveness of an agricultural region. As they are not easily transferable to other areas, they are vulnerable to stranding should weather variability result in changing production zones. However, because these social assets are likely to be more flexible and have a range of uses, they have been designated as moderately vulnerable (orange).

Human assets are vulnerable, but less so as migration away from adversely affected areas will allow some adjustment to take place. Stranded assets are usually associated with assets of a high sunk or fixed-cost nature, and while education and training is a sunk cost, it is likely to have a wide range of potentially applications and can move with the individual (yellow).

Financial assets are less vulnerable to stranding (green), since although the underlying asset they may be associated with can be a fixed or sunk cost of business, such as farmland in the case of a farm loan, financial institutions can manage some of these risks through effective portfolio diversification and hedging. Access to markets, particularly in agricultural and weather derivatives, can aid risk management. But those financial institutions with large exposures to investments in one particular area, for example farm loans in a region vulnerable to water scarcity, will find it harder to adapt.

Footnotes:

[59] OECD (2009), *Managing Risk in Agriculture: a holistic approach*, OECD Publishing, Paris.

[60] Stockton, M and Wilson, R (2007), 'Simulated analysis of drought's impact on different cow-calf production systems', Paper presented at the annual meeting of the Southern Agricultural Economics Association, Mobile.

It is important to distinguish between *well-defined water property rights*, which are transferable and have value separate from the land on which that water may be applied, and ill-defined water property rights which are not well defined, let alone transferable. Well-defined property rights in water may indeed become more valuable as water scarcity increases, appreciating in value. This is in contrast to *ill-defined property rights* where the value of water is usually attached to the land based on prior use patterns. In the event of rising water scarcity or competition for access, such patterns may not be a strong basis for maintaining the farmer's claim to an entitlement.

Any built-in flexibility afforded by a well-defined property right, means that the water right attached to a production zone that has become subject to increased variability is likely to be even more valuable, instead of simply something that will be taken away without compensation.

Where is the risk concentrated?

Figure 21 (page 45) below synthesises work from the European Union Water and Global Change Programme (WATCH)[61], the FAO's 2012 State of the *World's Land and Water Resources* report and the IPCC's (2007) *Third Assessment Report* (based on their A2 scenario).

This indicates which regions will be most vulnerable to the effects of weather variability and changing production zones by highlighting those which are likely to have more available water in 2071-2100 when compared with 1971-2000 and which regions will have less.

Figure 21 can be used to highlight the countries where water scarcity is increasing, and where the risks of asset stranding from climate change induced shifts in production zones may be most intensely focused.

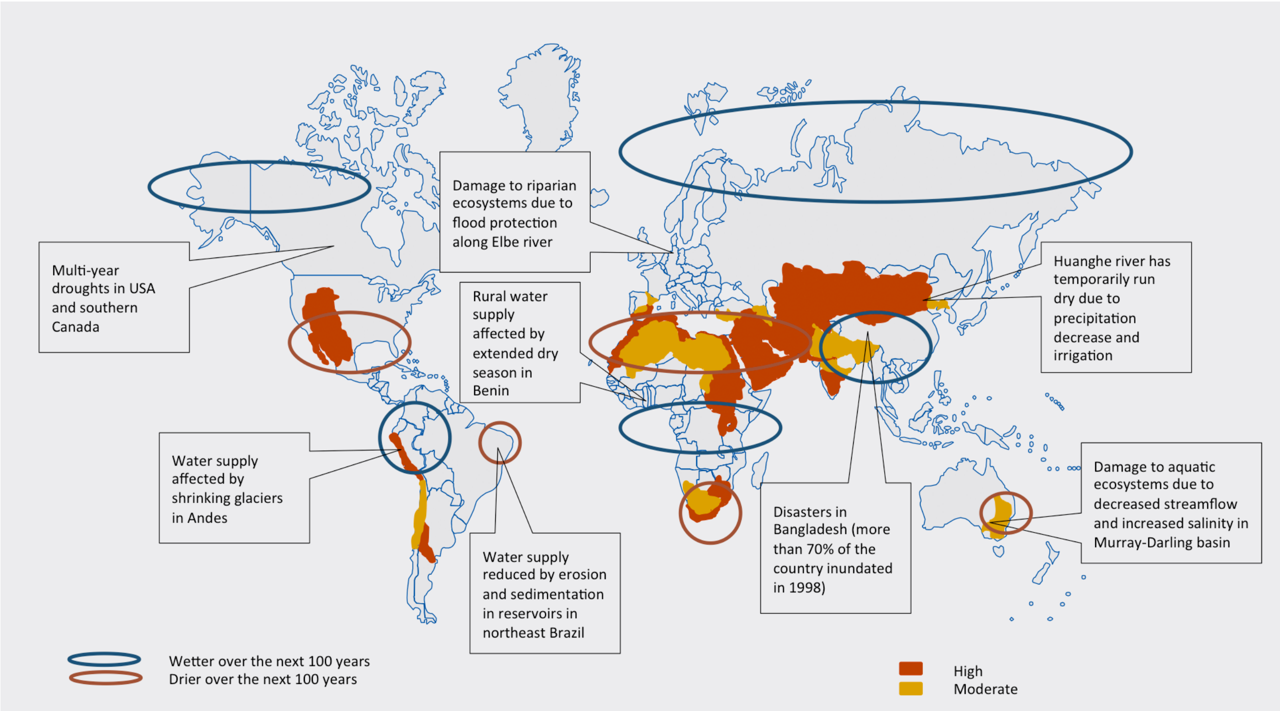
Such integrated assessment models suggest that climate change effects on temperature and rainfall will have positive yield effects in cooler climates, while decreasing cereal yields in low-latitude regions, where most developing countries are located.[62]

Footnotes:

[61] WATCH (2012) *Water and Global Change*: the WATCH project outreach report: www.ceh.ac.uk/collaboration/documents/WATCHOutreachReport.pdf

[62] IPCC (2007:294), Chapter 5, Food, Fibre and Forest Products, Contribution of Working Group II to the IPCC Fourth Assessment Report in Parry, M et al, *Climate Change 2007: Impacts, adaptation and vulnerability*, 273-313, Cambridge University Press, Cambridge.

Figure 21: *Key asset stranding risk areas from physical water scarcity*



Sources: WATCH (2012); FAO (2012); IPCC (2007)

What are the consequences and responses?

Land use activities, primarily the expansion of agricultural land and the extraction of timber, have caused a net loss of approximately 7 to 11 million km^2 of forest in the past 300 years.[63]

Forests cover about 3952 million hectares of the globe – about 30 percent of the world's land area. From 2000 to 2005, gross deforestation continued at a rate of 12.9 million hectares a year. Due to afforestation, landscape restoration and the natural expansion of forests, the most recent estimate of net forest loss is 7.3 million hectares a year.[64]

Footnotes:

[63] Foley, JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N, Snyder PK.2005. Global consequences of land use. *Science* 309:570-574.

[64] FAO (2012:159) *The state of the world's land and water resources for food and agriculture: managing systems at risk*, FAO Publishing, Rome.

In its recent publication, *State of the World's Land and Water Resources for Food and Agriculture*, the FAO outlines several mechanisms for managing water systems at risk from physical water scarcity. Among adaptation strategies, increasing agronomic efficiency will play an important role.

Box 5: Increasing agronomic efficiency[65]

Although some factors such as climate and socio-economic variables are outside their control, much of agronomic efficiency depends on decisions taken at the farm level. Agronomic efficiency can be improved by:

- Water control and soil moisture management to ensure adequate availability of moisture to plant roots for optimal growth. Conservation agriculture, in particular, reduces significantly unproductive water losses.
- Water, soil and nutrient management to ensure timely availability of nutrients to the root zone and efficient uptake by plants. In particular, water, soil and input management to raise nitrogen availability is critical for high yield evapotranspiration.
- Crop husbandry to select the optimal cropping pattern, choose the best varieties, align the cropping calendar with moisture availability, sow at the right time, and manage weeds, arthropod pests and diseases.

It can also be useful to make the distinction between 'blue' water, which is drawn from rivers, lakes, reservoirs and groundwater for use in irrigation schemes, and 'green' water, which is the moisture stored in the soil from rainfall. Around two-thirds of global crop production relies on green water, which constitutes around 90 percent of total agricultural water consumption.

'Virtual' water refers to the water used in the production of goods and services. For example, if the production of one tonne of wheat requires over a million litres of water (most of which evaporates from the crop), then that is the virtual water content of the wheat. If a country then trades that tonne of wheat to another, the virtual water is traded internationally.

For example, a country that imports a crop is saving its own internal blue/green water, and is also saving on land that would otherwise be used to produce the same or an alternative crop. The WATCH Project of the European Union suggests that green water dominates both the virtual water that is imported with goods (external component, 95 percent) and the component of water used from domestic (internal) sources (84 percent). As part of this work it is now possible to quantify the water footprint for all countries.

Footnote:

[65] FAO (2012:159)

Markers for future work

To better understand and mitigate these risks, business, investors and policy makers should ensure that sensitivity to changing climate patterns is factored into environmental risk assessments when looking at agricultural investments.

A maturing market in weather derivatives also exists to equip investors with financial tools to manage the increasing risks associated with weather variability. Working in parallel with insurance companies, governments at a variety of levels should also move to build in the changing nature of the probability density function which transcribes extreme weather events into policy parameters.

Future research in this area could investigate the role of trade in virtual water in facilitating adaptation and resilience strategies. In terms of stranded assets, investment in regions which are inefficient in the water-use footprint of their crops are likely to be higher risk than investments in regions which are efficient in water use.

Agricultural trade will be an increasingly important tool in helping countries which are water poor, obtain food supplies which are more water efficient. This is a matter of great importance if natural resources are to be used efficiently. Multilateral efforts through the World Trade Organisation have proved ineffective at dealing with this issue. Governments must work much harder at the bilateral and multilateral levels to achieve breakthroughs in international trade on agricultural products. This has the potential to be a win both for the environment and the fiscal position of governments, since many agricultural regions – particularly in the United States and Europe – receive unjustified production subsidies. These must be wound back, in concert, as a priority – and should be a key aim for current discussions in the US-EU trade negotiations.

Land degradation

Why is land degradation a potential driver of asset stranding?

The FAO projects that towards 2050, rising population and incomes are expected to call for 70 percent more food production globally, and up to 100 percent in developing countries, relative to 2009 levels. With limited land and water resources, it is expected that the largest contribution to increases in agricultural output will come from the intensification of production on existing agricultural land.

Cropland would have to be nearly doubled if the projected global population of more than 9 billion people in 2050 were to have North America's current diet and agricultural technology. Cropland would have to be expanded 70 percent if the global population had Western Europe's diet and technology.[66]

Between 1980 and 2000, more than 55 percent of new agricultural land replaced intact forests; another 28 percent replaced degraded forests. Even with agricultural yield increases and intensification, net agricultural area expansion will probably be needed to meet future demand.[67]

Footnotes:

[66] Kastner, T, Rivas, M, Koch, W and Nonhebel, S (2012), 'Global Changes in Diets and the Consequences for Land Requirements for Food', *PNAS* 109 (18): 6868–6872: www.pnas.org/cgi/doi/10.1073/pnas.1117054109

[67] Gibbs, H et al (2010), Tropical Forests were the Primary Sources of New Agricultural Land in the 1980s and 1990s, *PNAS* 107(38):16732–16737: www.pnas.org/cgi/doi/10.1073/pnas.0910275107

With a series of important land and water systems facing the breakdown of their productive capacity due to unsustainable agricultural practices, the ability of some regions to continue production in the same way must be called into question. While warming may extend the limits of agriculture in northern latitudes, the FAO anticipates that key agricultural systems in lower latitudes will need to cope with new temperature, humidity and water stress.

Approximately a quarter of the world's agricultural land area is already highly degraded and the magnitude of land degradation is likely to increase, considering the need to produce more crops, meat and dairy products to feed the rising population.[68]

The degradation of agricultural land is a common feature of excessively intense cultivation and inadequate soil management, whereby topsoil is removed, causing soil depletion and reduced crop yields.

Agricultural land degradation is presenting new challenges to business-as-usual assumptions about production, processing and consumption.[69] While agricultural productivity growth has been uneven among countries, positive figures in some areas may conceal depletion of resources and growth in yield that cannot be sustained over time[70]. Areas with lower yields due to water scarcity may resort to cultivating marginal land or to adopting unsustainable cultivation practices, further exacerbating land degradation[71].

What kind of assets are at risk?

As land is one of the basic factors of production in agriculture, natural assets, such as farmland and associated land improvements, are highly vulnerable to land degradation. Such assets may significantly depreciate in value as the land becomes less suitable for agricultural production. If soil erosion is accompanied by pollution, the land may not be even viable for uses other than agriculture and may have to be abandoned, or even become a liability for the owner, in terms of ongoing management and remediation costs.

Physical assets such as animals, the quality and quantity of crops harvested, processing facilities, and infrastructure built specifically for agricultural purposes are likely to be vulnerable to land degradation. For instance, salinity has the potential not only to lower agricultural productivity of the land, but accelerate the depreciation of roads, irrigation infrastructure and plantation crops.

Social assets such as policy, business and community networks will be affected if migration to other production areas occurs due to heavy land degradation. Land degradation, such as results from excessive land clearing, can also detract significantly from the amenity value of the land.

Footnotes:

[68] FAO (2012:65), *The State of Food and Agriculture*, FAO Publishing, Rome.

[69] Chatham House; p. 7

[70] FAO (2012:65), *The State of Food and Agriculture*, FAO Publishing, Rome.

[71] IPCC (2007:275), Chapter 5, Food, Fibre and Forest Products, Cambridge University Press, Cambridge.

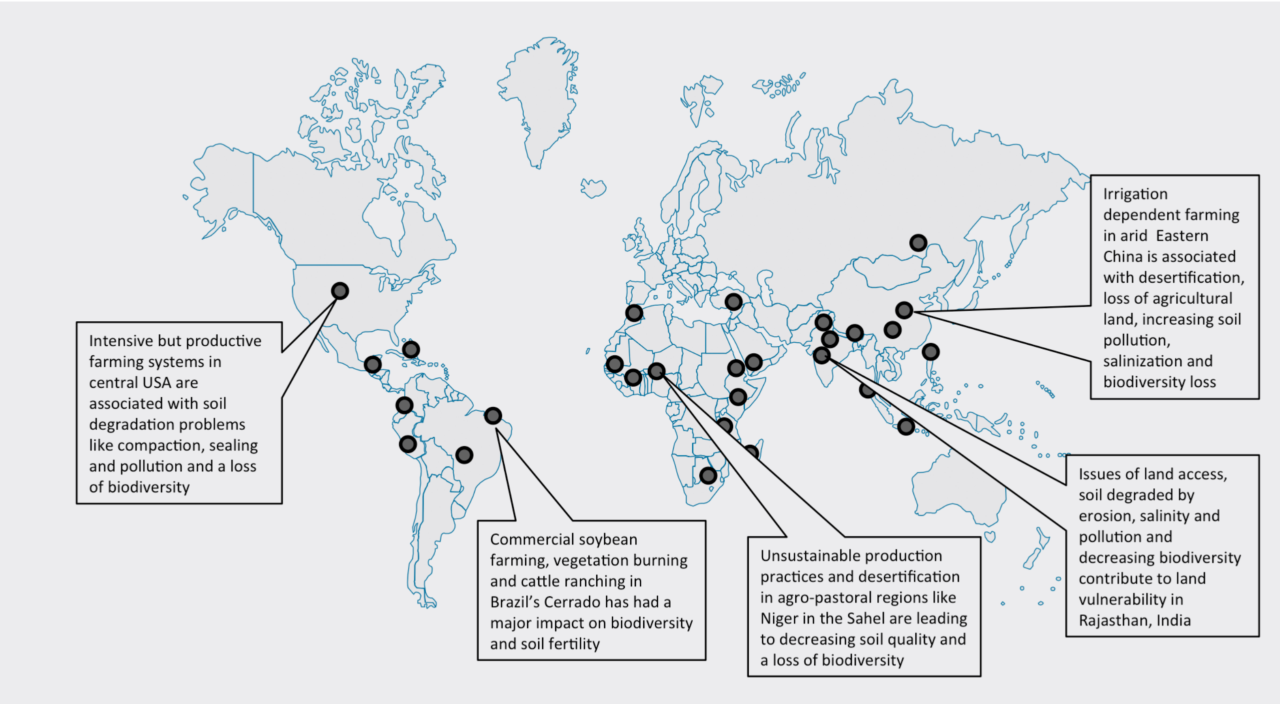
Figure 22: Assets at risk: land degradation

Financial assets such as farm loans and well-defined water rights are moderately vulnerable as land depreciates in value and farm productivity decreases, however, as they are more liquid than other asset classes, investors may be able to divest themselves of at-risk assets before significant devaluations.

Human assets face moderate risk if other agricultural land is available and affordable and farmers are able to switch or complement their production zone.

Where is the risk concentrated?

Figure 23: Map of key areas vulnerable to land degradation



Source: Based on OECD/FAO (2012:53)

OECD and FAO's 2011 reports (see *Figure 23* above) highlight vulnerable land areas with land erosion, land scarcity and problems with soil scarcity. Sub-Saharan Africa and parts of Asia suffer from inherently low soil fertility.[72]

Box 6: Land degradation in China[73]

Over the period 1949-81 China logged some 75 million hectares, 92 percent of which were natural rather than plantation forests, to satisfy demand for timber for construction and other uses. The ensuing rapid deforestation resulted in the loss of ecosystem services, notably watershed protection and soil conservation. In 1997, severe droughts caused the Yellow River to dry up for 267 days, affecting industrial, agricultural and residential water users in northern China. The following year, devastating flash flooding occurred in the Yangtze and other major river basins, resulting in the loss of 4,150 lives, displacement of millions of people, and economic damage estimated at 248 billion yuan (approximately USD 30 billion). China's government determined that deforestation and farming on steep slopes caused these tragic events. In 1998, the government banned logging under the Natural Forest Conservation Program (NFCP). Timber harvests fell from 32 million m^3 in 1997 to 12 million m^3 in 2003, reflected in a 20-30 percent increase in timber prices at the Beijing wood market over the period 1998-2003.

Footnotes:

[72] FAO (2012: 286), Statistical Yearbook, FAO Publishing, Rome.

[73] TEEB (2010:5), *The Economics of Ecosystems and Biodiversity*, TEEB for Business, Executive Summary.

What are the consequences and responses?

According to the Land Degradation Assessment in Drylands (LADA) initiative, land degradation is estimated to cost USD 40 billion annually worldwide.[74] The consequences of land degradation include reduced land productivity and socio-economic problems such as uncertainty in food security, migration, limited economic development and damage to ecosystems.[75]

Some irrigated lands have become heavily salinised, causing a worldwide loss of about 1.5 million hectares of arable land a year and an estimated USD 11 billion in lost production. Soil erosion, reduced fertility or overgrazing impacts almost 40 percent of global croplands.[76]

Smallholder farmers are especially vulnerable to land degradation and other social and environmental stressors as a result of climate trends.[77] In particular, it is expected that an intensification of El Niño and La Niña will affect dry regions. Such changes may also trigger positive feedbacks between soil degradation, reduced vegetation and rainfall, with a corresponding loss of pastoral areas and farmlands.[78]

To increase crop production and avoid further soil degradation, intensive agriculture requires the addition of phosphorous, and farmers in most developing countries have to rely on imports for manufactured water-soluble phosphorous fertilisers.[79] However, large fertiliser applications are not affordable and too risky in regions with low-potential, rain-fed cropping systems such as Sub-Saharan Africa.[80] Reclamation of degraded land is costly and, if severely degraded, impractical.[81]

Markers for future work

According to the FAO, there is potential to expand production efficiently to address food security and poverty while limiting the impact on other ecosystem values through sustainable intensification of production using sustainable land management practices and more efficient use of irrigation water. It would require governments and the private sector, including farmers, to be more proactive in adopting sustainable land and water management practices. Beyond technical options, efforts to remove constraints and build flexibility such as removing environmentally damaging subsidies, improving land tenure and access to resources, strengthening land and water institutions for more collaboration, developing efficient support services such as knowledge exchange, adaptive research, rural finance and securing access to markets.[82]

Footnotes:

[74] The estimated costs do not take into account the hidden costs incurred by increased fertiliser use and loss of biodiversity and unique landscapes.

[75] FAO,(2012: 286), Statistical Yearbook, FAO Publishing, Rome.

[76] Foley, J et al, Op Cit.

[77] IPCC, (2007:294) Chapter 5, Food, Fibre and Forest Products, Cambridge University Press, Cambridge.

[78] IPCC, (2007:287) Chapter 5, Food, Fibre and Forest Products, Cambridge University Press, Cambridge.

[79] FAO (2012:74), *The State of Food and Agriculture*, FAO Publishing, Rome.

[80] FAO, (2012, 288), Statistical Yearbook, FAO Publishing, Rome.

[81] FAO,(2012: 286), Statistical Yearbook, FAO Publishing, Rome.

[82] FAO (2012:69), *The State of Food and Agriculture*, FAO Publishing, Rome.

Biodiversity loss and collapse of ecosystem services

Why are biodiversity loss and the decline of ecosystem services potential drivers of asset stranding?

Biodiversity is a key element of what provides the ecosystem services – or benefits – that humans receive from the environment. As highlighted in the Economics of Ecosystems and Biodiversity Project (TEEB)[83], many of these benefits are particularly important for the agricultural sector. Such services range from the environmental inputs that support the production of food and clean water and raw materials such as fibre for clothing and building, genetic resources used in crop improvement and medicine to regulating services such as supporting air quality, climate regulation, moderation of extreme events, erosion control, maintenance of soil fertility, pollination, seed dispersion and pest control; through to providing cultural and amenity services such as aesthetic appreciation and recreation opportunities.

Biodiversity loss and declining ecosystem services could have profound consequences for the value of agricultural assets. One way to conceptualise these effects is to use the notion of natural capital 'stocks' and the ecosystem services that flow like interest or dividends from those stocks. As the natural capital base is depleted or degraded, the productivity of the land is likely to decline. For example, this could take the form of increasing salinity due to a rising water table as a result of land clearing (such as has occurred in Australia's Murray-Darling Basin); or the need to apply greater quantities of pesticides if bird populations decline due to lack of appropriate habitat. While management techniques can control for the decline in some ecosystem services, it is generally recognised that such substitutability is only possible up to a point after which an ecosystem may collapse.[84]

Box 7: Stranded assets and the link to pollinators

Globally around 70 percent of the crops grown for human consumption around the world are directly dependent on insect pollinators, especially bees.[85] For example, most cereals do not depend on insects for their pollination, whereas many fruits, vegetables and stimulant crops can be highly or totally dependent. The 'importation' or renting out of bee species is also a management tool in areas where farmers seek to supplement the local pollinator fauna. The abundance and diversity of wild and honey bees are now declining and some species are clearly at risk.[86]

In one important study on the issue the world production value for crops used for human food was estimated at €1,618 billion in 2005, and the total value of the insect pollinated crops was estimated at €635 billion, or 39 percent of the world production value. The economic value of insect pollination was estimated at €153 billion, with the most dependent crops being fruits, vegetables and edible oils. The vulnerability of the world's agricultural production used for human food to pollinators is 9.5 percent.[87]

Footnotes:

[83] http://www.teebweb.org/

[84] Barbier, E et al (2008), 'Coastal Ecosystem-based Management with Non-linear Ecological Functions and Values. Science 319: 321–323; Daly, H and Farley, J (2004), *Ecological Economics: Principles and Applications*, Island Press, Washington, DC.

[85] Klein, A et al (2007), 'Importance of Pollinators in Changing Landscapes for World Crops', Proceedings of the Royal Society 274: 303-313.

[86] National Research Council of the National Academies (2007), 'Status of Pollinators in North America', National Academy of Sciences, Washington, DC.

[87] Gallai, N, Salles, J-M, Settele, J and Vaissière, B (2009), 'Economic Valuation of the Vulnerability of World Agriculture Confronted with Pollinator Decline', *Ecological Economics*, 68(3): 810-821.

While the value of agricultural assets may steadily decline as natural capital is 'extracted', at the point of ecosystem collapse there may be a non-linear event from which it is not possible to recover. At this point it may become non-viable to farm, or even to live in such a degraded area, resulting in the abandonment of a region. These complex non-linear dynamics of ecosystems and the difficulty in determining thresholds in advance means that continued biodiversity loss poses significant risks.

What kind of assets are at risk?

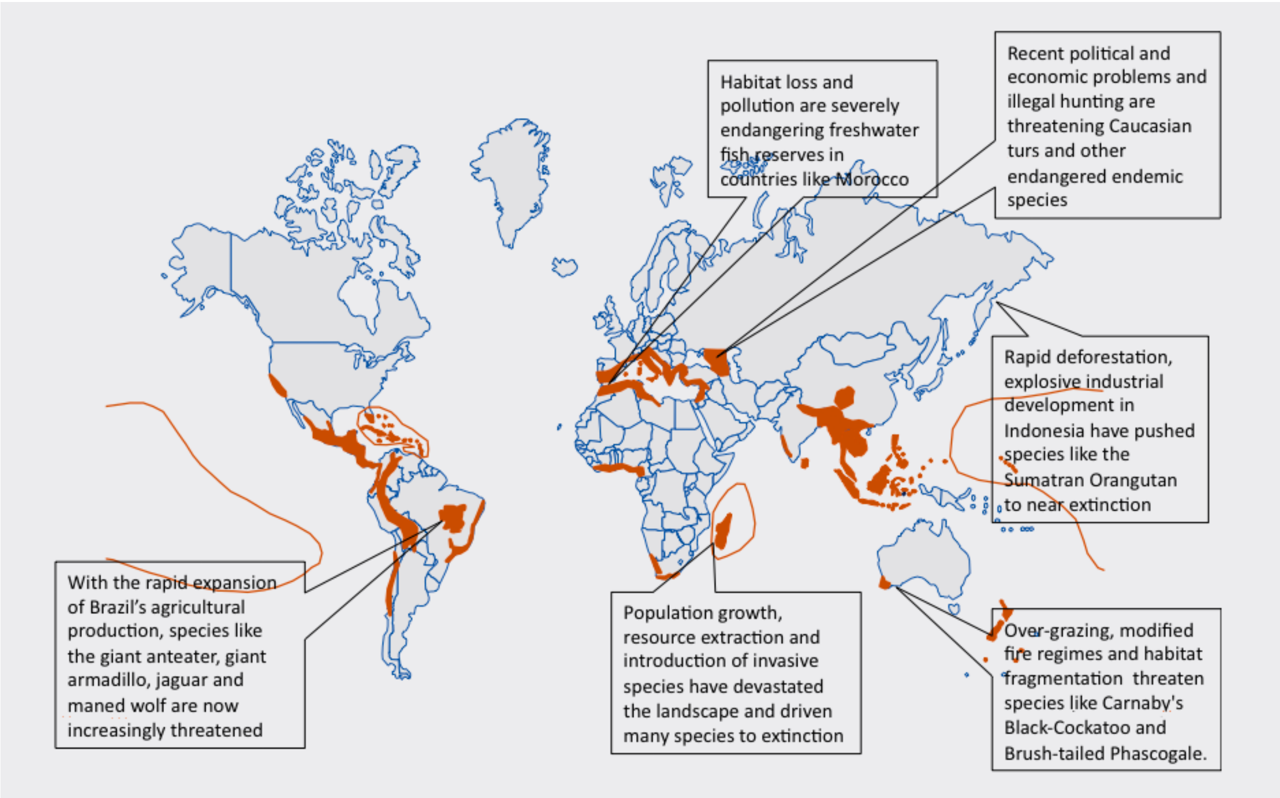
Natural assets, such as farmland and land improvements are the most highly vulnerable agricultural asset class to the risks stemming from the loss of biodiversity and associated ecosystem services. Physical assets, such as plantation crops and animals which depend on the flow of ecosystem services to support healthy yields, are also vulnerable. Once an area of land has been degraded, agricultural activity may well decline in the region, which will gradually undermine social assets built up over many years. Human assets are less at risk of stranding as the option of migration to other areas suggests skills and expertise can be applied elsewhere, and financial assets are usually fungible for with other assets making the less vulnerable to stranding.

Figure 24: Assets at risk from biodiversity loss and the decline of ecosystem services

Where is the risk concentrated?

The biodiversity 'hotspots' approach pioneered by Norman Myers, is a useful tool for assessing areas around the globe which are rich in biodiversity (greater than 0.5 percent or 1,500 of the world's 300,000 plants species), but which also have experienced significant decline (over 70 percent).[88] Such 'hotspots' may therefore be helpful in providing a regional focus for assessing stranded asset risk from biodiversity loss and ecosystem decline *(Figure 25)*.

Figure 25: Biodiversity hotspots and selected environmental pressures



Based on Myers et al (2000). Note: To qualify as a biodiversity hotspot, a region must meet two strict criteria: it must contain at least 1,500 species of endemic vascular plants (> 0.5 percent of the world's total), and have lost at least 70 percent of its original habitat. A major wilderness area is identified as biodiverse if it has 75 percent of the original vegetation remaining in pristine condition and a low human population density (< 5 people/km²)

Footnote:

[88] Myers, N et al (2000), 'Biodiversity Hotspots for Conservation Priorities', Nature, 403:853-858.

In its 2012 Environmental Outlook, the OECD expects biodiversity (measured as terrestrial mean species abundance) to decline by about 10 percent between 2010 and 2050 globally, with especially high losses in parts of Asia, Europe and southern Africa (see *Figure 25* on page 54).[89] In its work, the OECD acknowledges that its approach is probably conservative as it omits to include drivers such as the impact of invasive alien species, forest fires or the effect of thresholds and tipping points.

To date the main drivers of biodiversity loss have been land use change and management through the conversion of natural ecosystems for producing food, bioenergy crops and livestock. The OECD reports that this has accounted for a decline of 16 percent in mean species abundance, relative to the baseline state.

Infrastructure, urban encroachment and fragmentation account for a further 10 percent decline. Growing in importance over time will be the impacts on biodiversity through the expansion of food crop production and livestock farming, and this will be particularly focused in Africa and non-BRIC developing countries.

In some regions it is expected that agricultural land will be abandoned, allowing considerable scope for ecosystem recovery and regeneration to take place. These areas will however bear the negative effects on biodiversity of former land use for several decades after land abandonment.

Forestry is projected by the OECD to exert increasing pressure on biodiversity across all three country groups, accounting for close to 15 percent of global mean species abundance loss between 2010 and 2030 and 30 percent of loss between 2030 and 2050.

Climate change (e.g. through effects on temperature and rainfall) is also expected to drive an increasing proportion of biodiversity loss moving towards 2050.

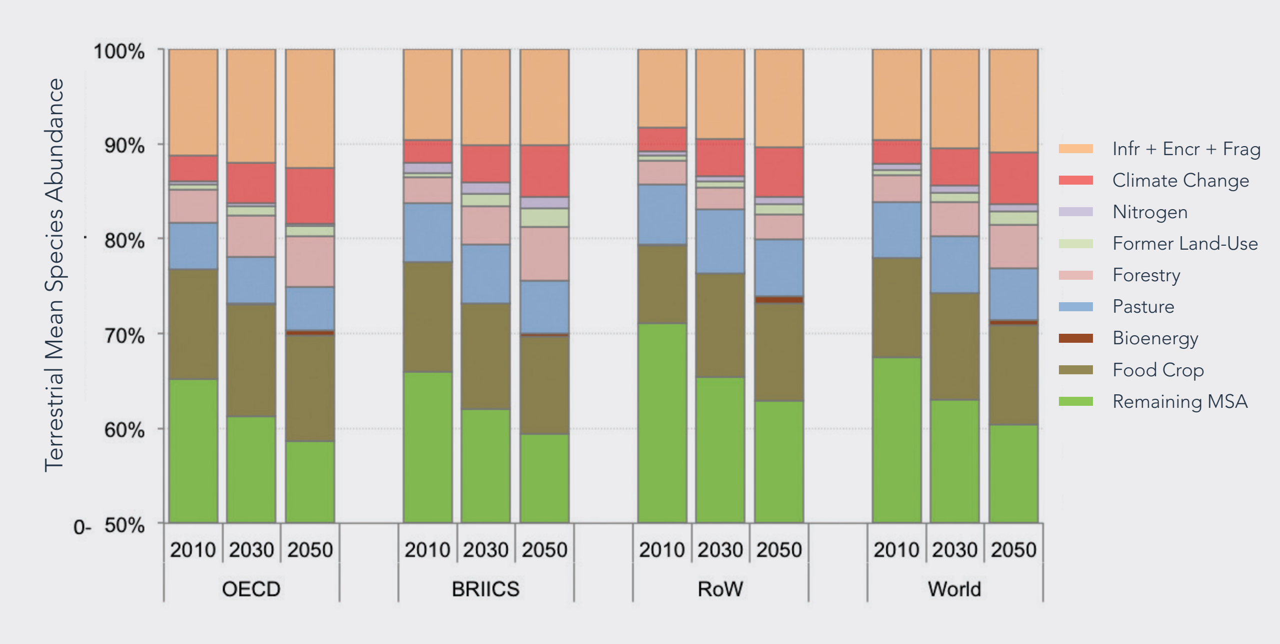
It is interesting that, despite their growing importance and rapid expansion in some regions, bioenergy crops are not expected to have a large negative impact on biodiversity, according to OECD forecasts.

Finally, the deposition of atmospheric nitrogen (e.g. eutrophication and acidification) is expected to have a small negative impact on biodiversity, particularly in the non-BRIC developing world.

Footnote:

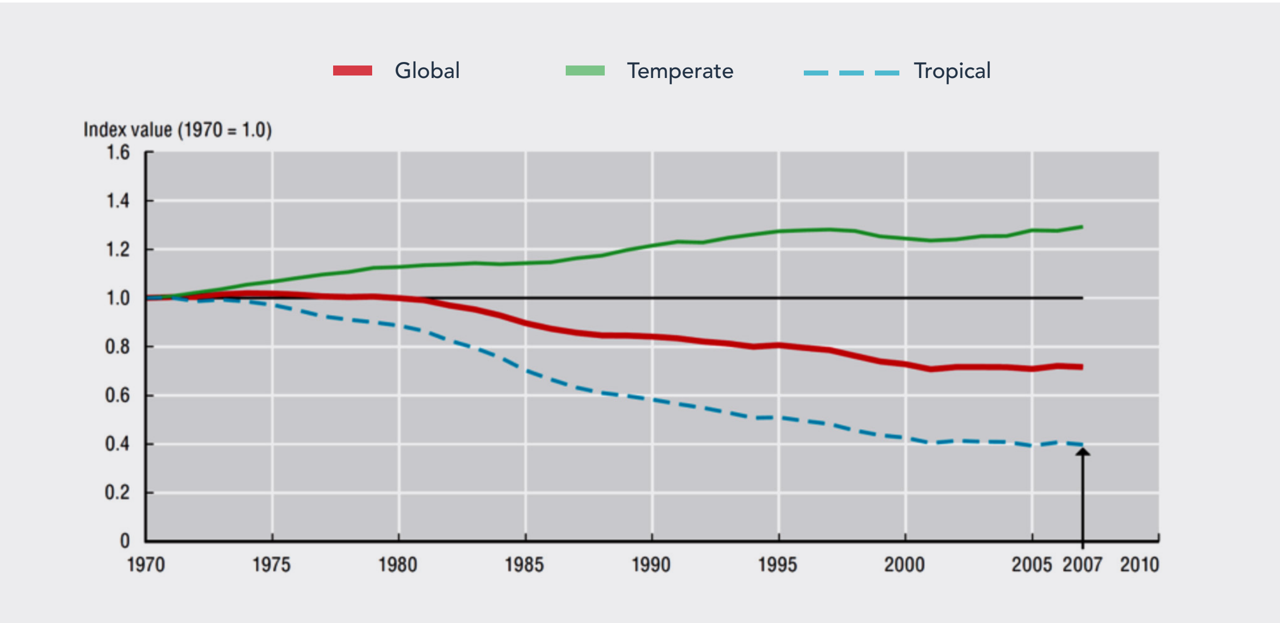
[89] OECD (2012, Chapter 4) *OECD Environmental Outlook to 2050: the consequences of inaction*, OECD Publishing, Paris.

Figure 26: Effects of different pressures on terrestrial mean species abundance



Source: OECD (2012:168) Environmental Outlook Baseline

Figure 27: Global Living Planet Index, 1970-2007



Source: WWF, ZSL and GFN (2010)

The Living Planet Index is an alternative to the Mean Species Abundance indicator which can be used to assess changes in species abundance. It is based on observed trends in almost 8,000 populations of over 2,500 vertebrate species (mammals, birds, reptiles, amphibians, and fish). The index is the aggregated score of changes in the population size of each species since 1970, which is given a value of 1.[90] According to the Living Planet Index, the period 1970-2007 saw massive decline in the abundance of vertebrate species in the tropics, which fell by around 60 percent. This was offset by improving species abundance in temperate regions, which rose around 30 percent, yielding a global average decline of species abundance of 30 percent of vertebrate species.

What are the consequences and responses?

Ecosystems can only absorb pressure up to a certain point before the structure and function of an ecosystem is impaired. Their ability to absorb disturbance is known as ecosystem resilience.[91]

Once these thresholds are crossed it is often very costly, or impossible to reverse. For example, eutrophication of marine and freshwater ecosystems has created 'dead zones' where decomposing algae use up the oxygen in the water making it uninhabitable. This can be seen in the Baltic Sea, Gulf of Mexico and Lake Erie.[92]

Maintaining biodiversity and healthy ecosystems create significant value for the agricultural and wider economy. As discussed, ecosystem services are central to maintaining and enhancing agricultural yield. While some substitution to human and physical capital is possible by using artificial fertilisers, pesticides and other management techniques to compensate for declining ecosystem services, these are likely to be relatively costly.

A biodiverse agricultural crop base is also more resilient to drought, flood, pests and disease, and reduces dependence on any one crop. Diverse food systems can also reduce the risk of famine and help provide a better source of nutrients and vitamins.

The combined effects of different environmental risks such as climate change, pollution, land use change and invasive species often create synergistic effects that act to change system function. Thresholds are expected to be crossed more often in the coming decades due to human perturbations.[93] The complex, non-linear dynamics of ecosystems and their interactions with human systems make it difficult to predict where thresholds lie and what the scale of impact will be.[94]

Footnotes:

[90] WWF (World Wildlife Fund), ZSL (Zoological Society London) and GFN (Global Footprint Network) (2010), *Living Planet Report 2010: biodiversity, biocapacity and development*, WWF, Gland, Switzerland: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/2012_lpr/

[91] Walker, B, Holling, C, Carpenter, S and Knizig, A (2004), 'Resilience, Adaptability and Transformability in Social-Ecological Systems', *Ecology and Society*, 9(2): 5.

[92] Dybas, C (2005), 'Dead Zones Spreading in World Oceans', *Bioscience*, 55, 552-557.

[93] SCBD (2010), *Global Biodiversity Outlook 3*, SCBD, Montreal.

[94] Rockström, J et al (2009), 'Planetary Boundaries: Exploring the safe operating space for humanity', *Ecology and Society*, 14,(2): 32.

The cornerstone of most biodiversity conservation strategies has been to institute a system of protected areas. In the European Union for example, Natura 2000 areas protect around 18 percent of land area and around 130,000km^2 of its seas. *Table 4* below outlines the range of policy instruments that have been used for biodiversity conservation and sustainable use.

Table 4: Policy responses to the problem of biodiversity loss[95]

REGULATORY (COMMAND-AND-CONTROL) APPROACHES	ECONOMIC INSTRUMENTS	INFORMATION AND OTHER INSTRUMENTS
Restrictions or prohibitions on use (e.g. trade in endangered species and CITES)	Price-based instruments: • Taxes (e.g. groundwater, pesticide and fertiliser use) • Charges/fees (e.g. for natural resource use, access to national parks, hunting or fishing license fees) • Subsidies	Eco-labelling and certification (e.g. organic agriculture labelling schemes; labels for sustainability harvested fish or timber)
Access restrictions or prohibitions (e.g. protected areas; legislated buffer zones along waterways)	Reform of environmentally harmful subsidies	Green public procurement (e.g. sustainability harvested timber)
Permits and quotas (e.g. for logging and fishing)	Payment for ecosystem services	Voluntary agreements (e.g. between business and government for nature protection or voluntary offset schemes)
Quality, quantity and design standards (e.g. commercial fishing net mesh-size specifications)	Biodiversity offsets/biobanking	Corporate environmental accounting
Spatial planning (e.g. ecological corridors)	Tradable permits (e.g. individual transferable quotas for fisheries, tradable development credits)	
Planning tolls and requirements (e.g. environmental impact assessments (EIAs) and strategic environmental assessments (SEAs)	• Liability instruments • Non-compliance fines • Performance bonds	

Footnote:

[95] Adapted from OECD (2010), *Paying for Biodiversity: enhancing the cost effectiveness of payments for ecosystem services*, OECD Publishing, Paris.

Markers for future work

Biodiversity loss and the potential collapse of ecosystem services are factors that investors, businesses and policy makers should be building into environmental risk assessments when undertaking investments. Importantly, this should include looking beyond the farm gate, to broader changes in the landscape within the region.

Where problems are identified, local solutions can be facilitated through catchment-based, natural resource management councils. Governments have a critical role to play in helping build and resource local-level institutions that can make devolved decisions drawing on scientific and farm-management expertise.

A range of tools are also available that the financial sector can help develop such as in establishing markets for biodiversity or ecosystems services. These can be used to ensure that local, regional and international conservation goals are being met in a least cost way by recognising the underpriced value in natural capital.

Overfishing and climate change impacts on marine ecosystems

Why are overfishing and climate change impacts on marine ecosystems potential problems for asset stranding?

The earliest occurrence of overfishing in the 1800s saw humans decimate the whale population for blubber. By the beginning of the 1990s, almost 70 percent of the world's conventional fish species were overexploited, fully exploited, or already depleted.[96] In the mid-20th century, international efforts to increase the availability and affordability of protein-rich foods led to concerted government efforts to increase fishing capacity. Favourable policies, loans and subsidies generated a rapid rise of big industrial fishing operations, which quickly supplanted local boatmen as the world's source of seafood.

In 2010, fisheries and aquaculture supplied the world with about 148 million tonnes of fish worth USD 217.5 billion. Fish provides essential nutrition for almost 3 billion people and at least 50 per cent of the animal protein and minerals to 500 million people in the poorest countries.[97] Despite its importance, fisheries management represents a case of tragedy of the commons par excellence. Because of this, many of the world fisheries are in serious trouble from overfishing and poor management.

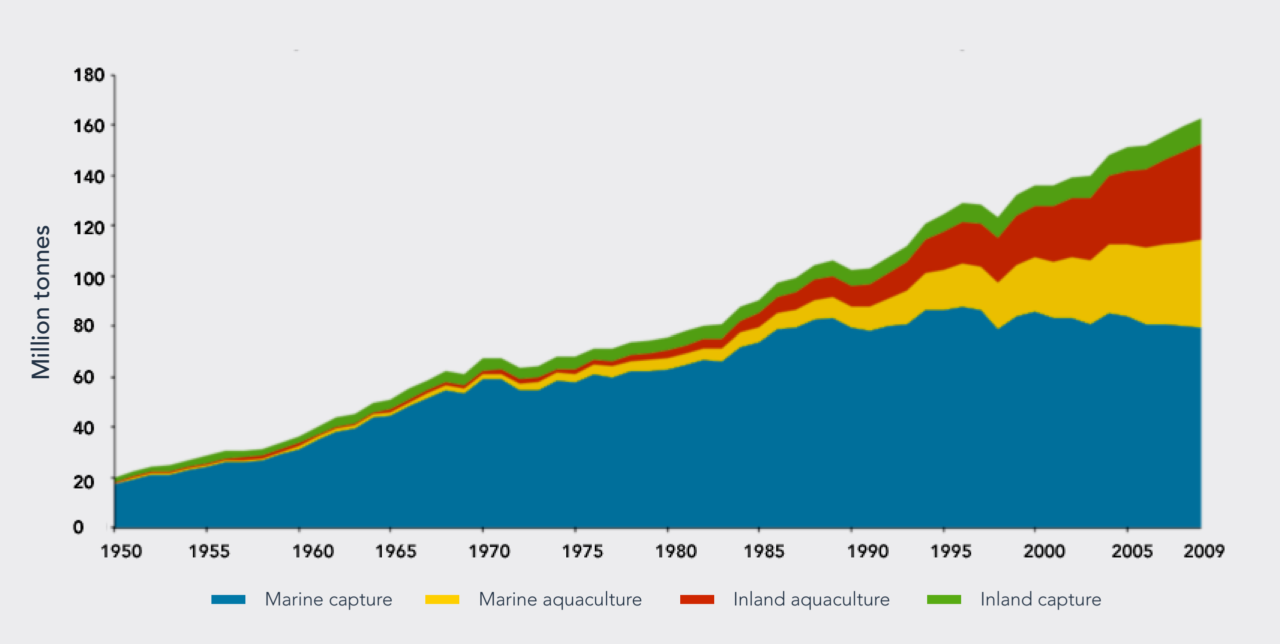
This exposes investors to asset stranding, as once a fishing area can no longer be fished, the industry and communities that depend on it for their livelihood may become non-viable.

Footnotes:

[96] FAO (2012), *The State of World Fisheries and Aquaculture*, FAO Publishing, Rome.

[97] FAO (2011), *Review of the State of World Marine Fisheries Resources*, FAO Publishing, Rome.

Figure 28: World production from different fisheries and aquaculture



Source: FAO (2012)

The industry hit its high-water mark of catch taken from the ocean in 1989 and yields have declined or stagnated ever since. Overall global capture fisheries production continues to remain stable at about 90 million tonnes – though there are significant regional variations. Aquaculture has helped maintain production as oceans are being depleted. Fisheries for the most sought-after species, like orange roughy, Chilean sea bass and bluefin tuna have collapsed.

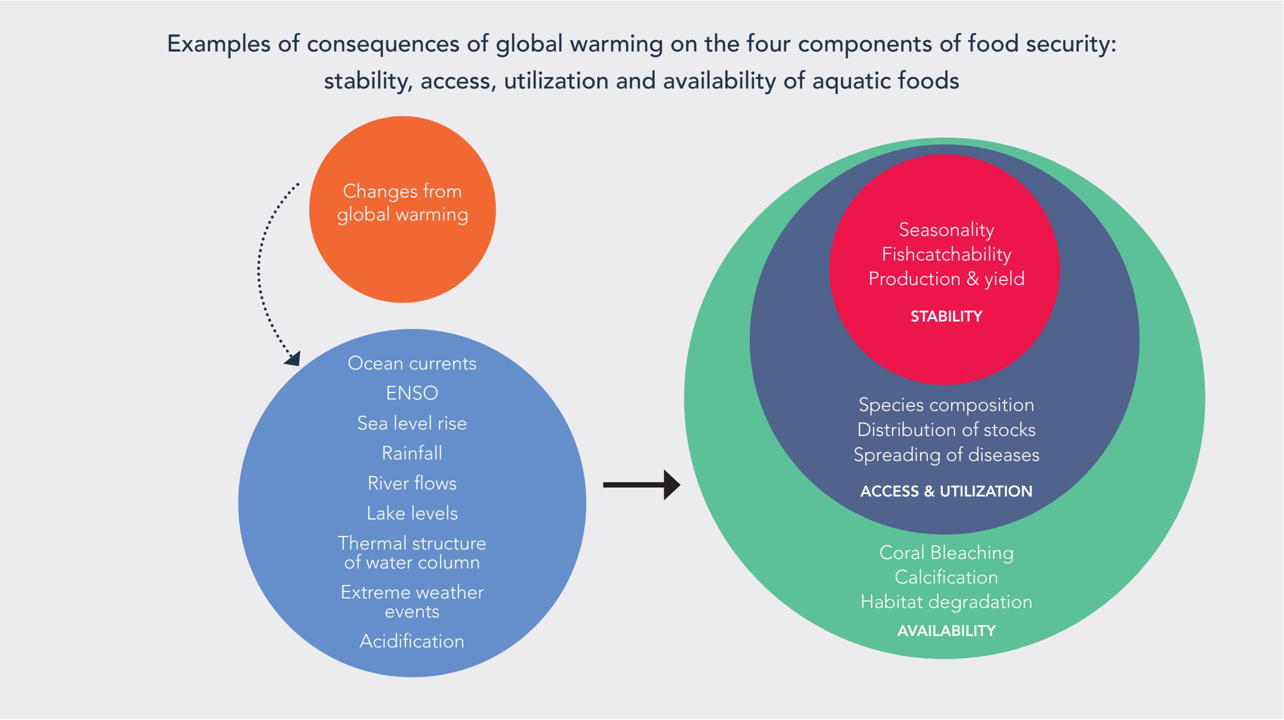
In an example of how humans are substituting human-made capital for natural capital, in the last three decades (1980-2010), world food fish production by aquaculture has expanded almost 12-fold, an average rate of 8.8 percent a year to meet demand. In 2003, a scientific report estimated that industrial fishing had reduced the number of large ocean fish to just 10 percent of their pre-industrial population, a concern considering 97 percent of the biosphere lives in the oceans.

China is responsible for most of the world's per capita fish consumption, owing to the substantial increase in its fish production, particularly from aquaculture. Its share of world fish production grew from 7 percent in 1961 to 35 percent in 2010 and its per capita fish consumption rose by 6 percent annually from 1990 to 2009 to 31.9kg. To put this consumption in perspective, if China is excluded, annual fish supply to the rest of the world in 2009 was on average 15.4kg per capita.

Stock levels are affected not only by fishing patterns but also by environmental factors such as climate variability. These influence spatial distribution, growth, reproduction recruitment and mortality. There is growing evidence of the effect of global warming modifying the distribution of marine species: warm water species are being displaced towards the poles and experiencing changes in the size and productivity of their habitats. Tropical countries could suffer a 40 percent drop in catch potential while high-latitude regions could enjoy as much as a 30 to 70 percent increase in catch potential.

Availability of aquatic foods will vary through changes in habitats for fisheries resources, requiring adaptive measures to exploit opportunities while minimising impacts, as these will have implications on all four dimensions of food security:

Figure 29: Climate change, food security and aquatic foods



Source: FAO (2011). Adapted from Badjeck et al., 2010

A study of catch data published in 2006 in the journal Science predicted that if fishing rates continue on business as usual trends, *all* the world's fisheries will have collapsed by the year 2048.

Box 8: Global fisheries underperform by USD 50 billion annually[98]

Competition between highly subsidised industrial fishing fleets coupled with poor regulation and weak enforcement of existing rules has led to overexploitation of most commercially valuable fish stocks, reducing the income from global marine fisheries by USD 50 billion annually, compared to a more sustainable fishing scenario.

Footnote:

[98] World Bank and FAO (2009), 'The Sunken Billions: The economic justification for fisheries reform', Agriculture and Rural Development Department, The World Bank, Washington, DC: http://siteresources.worldbank.org/ EXTARD/Resources/336681-1224775570533/SunkenBillionsFinal.pdf

What kind of assets are at risk?

The assets most at risk from asset stranding as a result of overfishing will be the natural assets comprising the fish stocks and commercial marine ecosystems themselves.

Figure 30: Assets at risk from overfishing and environmental change

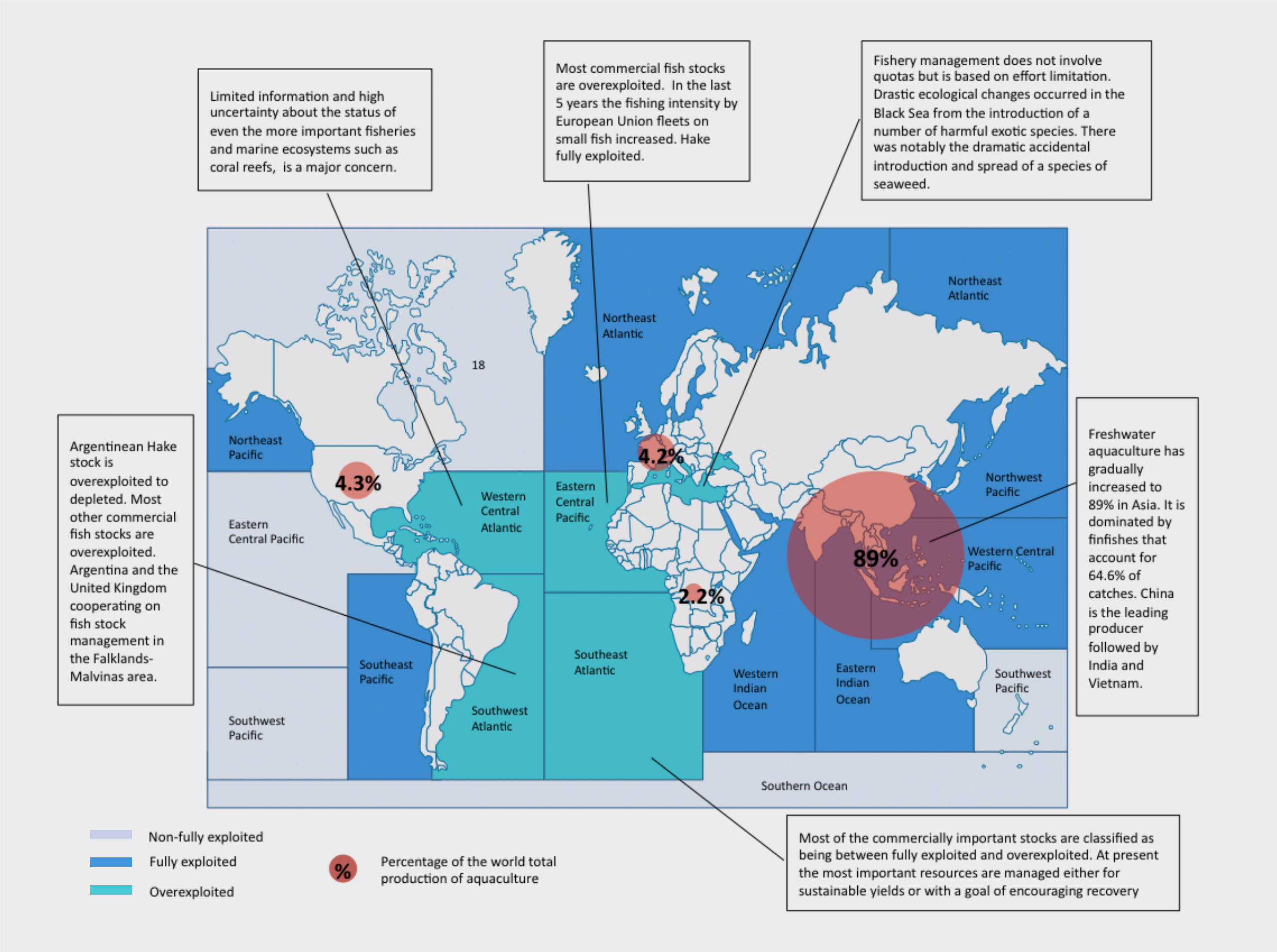
Other highly vulnerable assets will be the physical assets involved with the fishing operations, especially fixed or sunk costs on land, such as processing facilities and port infrastructure. Boats are also vulnerable, although they may be able to retain some of their value through being sold and sent to operate in other fisheries.

Social assets are also likely to be highly vulnerable as fishing communities are usually geographically centred in a region. The desire to maintain social cohesion and cultural identity attached to the fishing sector in the face of declining fish stocks may exacerbate overexploitation, by pushing fishing fleets farther afield.

Human assets are less vulnerable, as people may be able to move their geographic location to a more productive fishery, although the impact on small coastal fishing communities can be drastic as exemplified by the collapse of the northern cod (see *Box 9* on page 64). Financial assets are less vulnerable as they are more fungible, although long-term loans to fisheries assets are likely to underperform in the event of a fishery collapse.

Where is the risk concentrated?

Figure 31: Catch species composition in major fishing areas 2009



Source: based on FAO (2011) Review of the state of world marine fisheries resources, FAO Publishing, Rome.

What are the consequences and responses?

Of the fish stocks assessed by the FAO, 57.4 percent were estimated to be fully exploited in 2009. These stocks produced catches that were already at or very close to their maximum sustainable yield (MSY). They have no room for further expansion in catch, and even some risk of decline if not properly managed. Among the remaining stocks, 29.9 percent were overexploited, and 12.7 percent non-fully exploited in 2009. The overexploited stocks need strict management plans to rebuild their stock abundance to restore full sustainable productivity. The World Summit on Sustainable Development (WSSD) goal demands that all these overfished stocks be restored to the level that can produce MSY by 2015.

The FAO in its most recent review of stocks suggests that this goal is very unlikely to be achieved, despite good progress made in some countries and regions[99]. Nevertheless, according to the FAO, the scientific information currently available on the effects of climate change on fisheries resources points to both negative and positive impacts in the future. It is difficult to forecast whether the productivity of the oceans will increase or decrease. The interaction of the combination of warming, ocean acidification, nutrient flux and other oceanographic phenomena are unforeseeable. As the FAO warns, more information is urgently needed in the tropical and subtropical zones where climate change is expected to have strong impacts and vulnerability is higher.

Under-exploited stocks are under relatively low fishing pressure and have the potential to increase their production. However, proper management plans should be established before increasing the exploitation rate of non-fully exploited stocks in order to avoid following the same track of overfishing.

Box 9: The collapse of the North Atlantic cod fishery

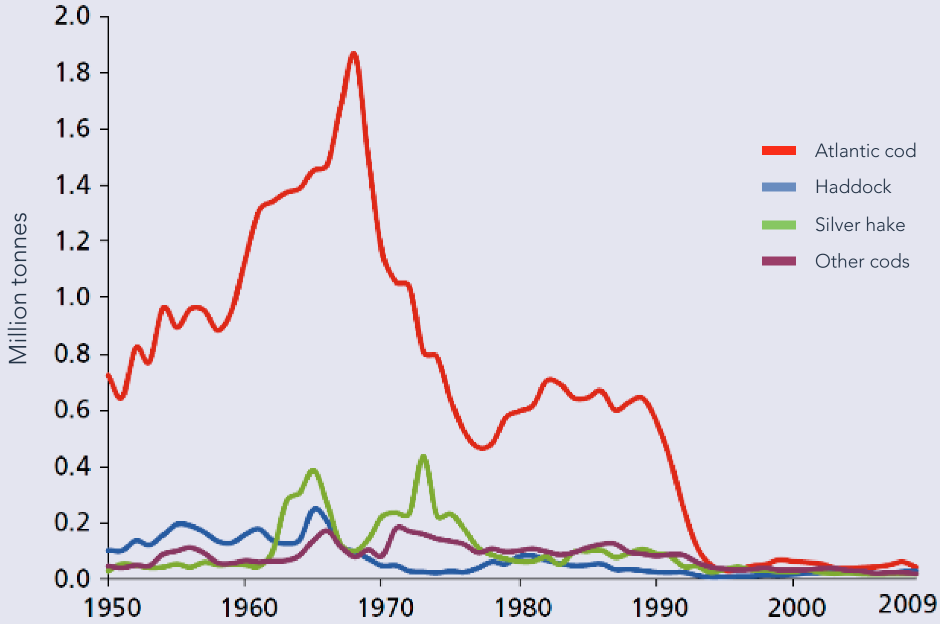
Historic patterns in catch in the North Atlantic are primarily affected by changes in cod (decrease) and shrimp (increase) stocks. Cod catches dominated the fisheries catches prior to the 1950s. They increased in the 1960s to a peak of almost 2 million tonnes, then declined to below 500,000 tonnes in 1977, over the time of the rise of modern ice-reinforced trawlers in the 1960s and 1970s.

The catches from southern Labrador and eastern Newfoundland stock (northern cod) contributed significantly to the overall cod catches in the period 1953-87 and accounted on average for almost 40 percent of the total. It was the largest and most productive fishery in the world. There were ten countries involved in the exploitation of the fisheries that subsequently collapsed to the brink of extinction. The Newfoundland case exemplifies the 'tragedy of the commons' theory whereby a resource can be used by everyone yet no one truly owns it, resulting in intense competition and 'death by a thousand cuts'.

Footnote:

[99] Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S., Jensen, O.P., Lotze, H.K., Mace, P.M., McClanahan, T.R., Minto, C., Palumbi, S.R., Parma, A.M., Ricard, D., Rosenberg, A.A., Watson, R. & Zeller, D. 2009. Rebuilding global fisheries. *Science*, 325: 578–585.

Figure 32: Collapse of the North Atlantic cod fishery



Source: FAO (2011) Review of the state of world marine fisheries resources, FAO Publishing, Rome.

By 1992, northern cod had been driven to the brink of commercial extinction. Canada adopted a moratorium on fishing for the northern cod in the waters surrounding the province of Newfoundland only after cod stocks plummeted by 95 percent over four years.[100] This collapse directly resulted in the devastation of 30,000 livelihoods. The provincial government estimated the indirect effects at ten times as much. The long-term impact on the northwest Atlantic ecosystem remains unknown. There are over 700 coastal communities in Newfoundland, most of which have fishing at the centre of their economies. It is quite likely that the fishery may never recover to its former scale.[101] While the fishers and their families have received a generous compensation package from the government, a way of life has ended. In 2008, catches of cod amounted to 60,000 tonnes.

Markers for future work

The risk of stranded assets from overfishing is a classic public good problem that requires active management. Very much at play here is the tension between maximising short-term profit from the maximum extraction of fish versus the sustainable husbandry of what is a renewable resource. The latter will not occur without the evolution of institutions which can allocate formal or informal property rights to the main fisheries.

Footnotes:

[100] McCay and Finlayson (1998) '*Crossing the threshold of ecosystem resilience: the commercial extinction of the northern cod*' in Berkes, F. and Folke, C. (1998) Linking social and ecological systems: management practices and social mechanisms for building resilience, Cambridge University Press.

[101] McCay and Finlayson, Op Cit.

This may be possible in coastal areas, within a country's exclusive economic zone, but is highly problematic on the high-seas where governance is weak. Without new international treaties or commercial codes of conduct, which challenge the open access of the current arrangement under the international law of the sea, marine fisheries are unlikely to be able to maintain current production levels in the medium to long term.

There is still a lack of reliable information and data with respect to the Southern Pacific and Southern Atlantic fishing areas. Data is needed to assess the diversity of species as well as population estimates to help improve management strategies. There is also a lack of coordination between countries in the management of fish stocks, and concerted efforts between governments to regulate resources would go a long way to improve the sustainability of the catch.

Some modern fishing techniques such as deep sea bottom trawling could be banned in the light of the significant damage caused to marine ecosystems from their use and the more sustainable alternatives available.

Increased risk of agricultural diseases, viruses and pests

Why are agricultural weeds, pests and diseases potential drivers of asset stranding?

Agricultural weeds, pests and diseases are significant production risks that farmers have to manage. Between 26 percent and 40 percent of the world's potential crop production is lost annually because of weeds, pests and diseases, and these losses could double without the use of crop protection practices.[102]

The IPCC Third Assessment Report reviewed the interactions between climate change and the nature of these risks. Evidence suggests that increased climate extremes may promote plant diseases and pest outbreaks.[103]

More recent studies have focused on the potential spread of animal diseases and pests from low to mid latitudes due to warming. For example, it has been suggested that bluetongue, which mostly affects sheep, and occasionally goats and deer, would spread from the tropics to the mid-latitudes[104] and that the Australian beef industry would face increased vulnerability to the cattle tick.[105]

> *Between 26 percent and 40 percent of the world's potential crop production is lost annually because of weeds, pests and diseases, and these losses could double without the use of crop protection practices.*

Footnotes:

102 FAO (2012:75) OECD-FAO *Agricultural Outlook* 2012-2021, FAO Publishing, Rome

103 Alig, R, Adams, D, Joyce, L and Sohngen, B (2004), Climate Change Impacts and Adaptation in Forestry: responses by trees and market choices, American Agricultural Economics Association, Fall, 11.; Gan, J (2004), 'Risk and Damage of Southern Pine Beetle Outbreaks under Global Climate Change', *Forest Ecol. Manag.*, 191, 61-71.

104 Veterinary Record (2006): 'Bluetongue confirmed in France'. News and Reports, 159, 331.

105 White, N, Sutherst, R, Hall, N and Whish-Wilson, P (2003), 'The Vulnerability of the Australian Beef Industry to Impacts of the Cattle Tick (*Boophilus microplus*) under Climate Change', *Climatic Change*, 61, 157-190.

In current production areas, the likely challenge of pests and diseases will mean that an increased focus on integrated management systems, especially host plant resistance and biological control, is essential. Pests and diseases that were once minor problems can turn into major constraints if they change their range of distribution with climate change. Projections illustrate these effects for three major cassava pests: the mealybug, cassava green mite and whitefly.[106]

Invasive alien species can also contribute to the loss of natural capital and increase the costs and lower productivity of agriculture, forestry, fisheries and water management.[107] Important vectors facilitating the spread of invasive species are trade and travel, such as through the ballast water of ships, or seeds and animals carried on vehicles.

What kind of assets are at risk?

The type of assets at risk will depend on the production system. In many cases, the most vulnerable will be physical assets such as plantation crops and animals that may lose some or all of their value as a result of a pest or disease outbreak.

Natural capital through land values may also be adversely affected in the event of a significant new weed outbreak or the invasion of a new pest species. Because of the interactions between plants and animals in the ecosystem, a new species that becomes virulent may lead to declining productivity across the land, as was precipitated by the introduction of rabbits and foxes to Australia.

Figure 33: Assets at risk from agricultural diseases, viruses and pests

Footnotes:

[106] Herrera, B, Hyman, G and Belloti, A (2011), 'Threats to Cassava Production: known and potential geographic distribution of four key biotic constraints', *Food Security* 3(3):329–345.

[107] OECD (2008a), Costs of Inaction on *Key Environmental Challenges*, OECD iLibrary (DOI: 10.1787/9789264045828-en); SCBD (Secretariat of the Convention on Biological Diversity) (2009a), *Invasive Alien Species: A threat to biodiversity*, SCBD, Montreal.

What are the consequences and responses?

For crop production, animal pests and pathogens have been estimated to be responsible for around 18 percent and 15 percent of crop loss respectively. Worldwide, although viruses can cause serious problems in some crops such as potatoes and sugar beets in some areas, the losses due to viruses averaged 6-7 percent in these crops and less than 1-3 percent in other crops[108].

For many countries, animal diseases generally do not cause large-scale production losses, although governments sometimes do order large-scale depopulation efforts to control highly contagious diseases. Rather, the effect of an outbreak of disease is felt through the market, as prices drop, often in response to lower export demand as governments implement import restrictions to protect domestic herds. Depending on whether the disease can be transmitted to humans domestic consumption may decrease significantly as well. As a result all domestic producers are affected by disease outbreak, not just those with infected animals.[109]

Box 10: Bovine Spongiform Encephalopathy outbreak in the United States

In 2003 an outbreak of BSE was limited to one herd of cattle so the production loss due to stock loss was minuscule. However, many countries implemented import bans on US beef, which led to higher beef prices in international markets benefiting countries such as Brazil and Australia, but in the United States to an oversupply. The resulting fall in domestic prices was estimated to have cost US cattle producers USD 500 million in just the first quarter for 2004.[110]

Markers for future work

Actions that can be taken to better understand and mitigate these risks, would be to place extra effort on agricultural disease risk prevention efforts. There will also need to be careful assessment of the risks associated with increasing trade in certain goods, which may act as a vector for the spread of such risks. Financing for customs operations should be carefully assessed in this light to manage the risks.

Many of the problems around the outbreak of agricultural diseases, viruses and pests represent a classic tragedy of the commons, in that an individual business benefits from the risk prevention strategies of others, but it costs them resources to robustly manage risks in their own enterprise. Clear regulation and enforcement involving a cooperative effort from government and industry, as well as education campaigns on the respective risks for farmers may help mitigate some of these risks.

In financing the operations of agricultural enterprises, investors can ensure that such issues are identified and appropriately managed in any environmental risk assessment which is attached to the farm businesses operations. Such assessments can be made broadly available to help engender a culture of best practice.

Footnotes:

[108] Oerke, E and Dehne, H (2004), 'Safegarding Production: losses in major crops and the role of crop protection', Crop Protection, 23:275-285.

[109] OECD (2009), Managing Risk in Agriculture: a holistic approach, OECD Publishing, Paris.

[110] Gramig, B, Horan, R and Wolf, C (2005), A model of incentive compatibility under moral hazard in livestock disease outbreak response. Paper presented at the annual meeting of the American Agricultural Economics Association, Providence, July.

Phosphate availability in the medium to long term

Why is phosphate availability a potential driver of asset stranding?

Along with nitrogen and potassium, phosphorous is essential for healthy plant growth, and its supply through fertiliser is a cornerstone for boosting yield in modern agriculture. Uncertainty over the continued reliable supply of cheap phosphate could become a driver for asset stranding in agriculture, by adding to farm costs, or *in extremis* lowering yield if it becomes unavailable at economically competitive prices.

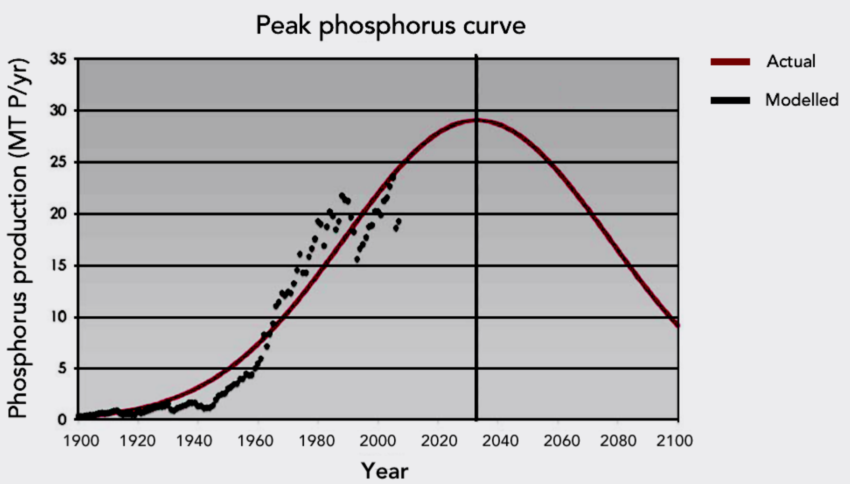
It is important in understanding this debate to distinguish between phosphate rock, which is a non-renewable resource, that takes millions of years to form through geological cycles – and phosphorus, which is a resource that can be recycled subject to economic and technical limits.

The debate around 'peak phosphorous' follows a theory similar to the 'peak oil' hypothesis in that reserves of a finite resource – in this case, a relatively low-value bulk commodity, phosphorus – are likely to peak at some stage, after which declining production will lead to escalating prices and a supply crisis. These concerns are exacerbated by the small number of countries in which phosphate rock, the mineral from which phosphorus is obtained is found.

Some have argued that a 'peak phosphate event' is likely to occur sometime in the next 20 to 25 years, leading to speculation about the strategic value of access to phosphorus for food security.[111] These concerns were given extra impetus by an 800 percent price spike in 2008 due to a short-term lack of supply for phosphate rock.[112]

Uncertainty over the continued reliable supply of cheap phosphate could become a driver for asset stranding in agriculture

Figure 34: Are global supplies of phosphorus running out?



Source: Cordell, D, Drangert, J. and White, S (2009) 'The story of phosphorus: global food security and food for thought', Global Environmental Change, 19:292-305.

Footnotes:

[111] Gilbert, N (2009), 'The Disappearing Nutrient', *Nature,* 46, 8: 716-718.

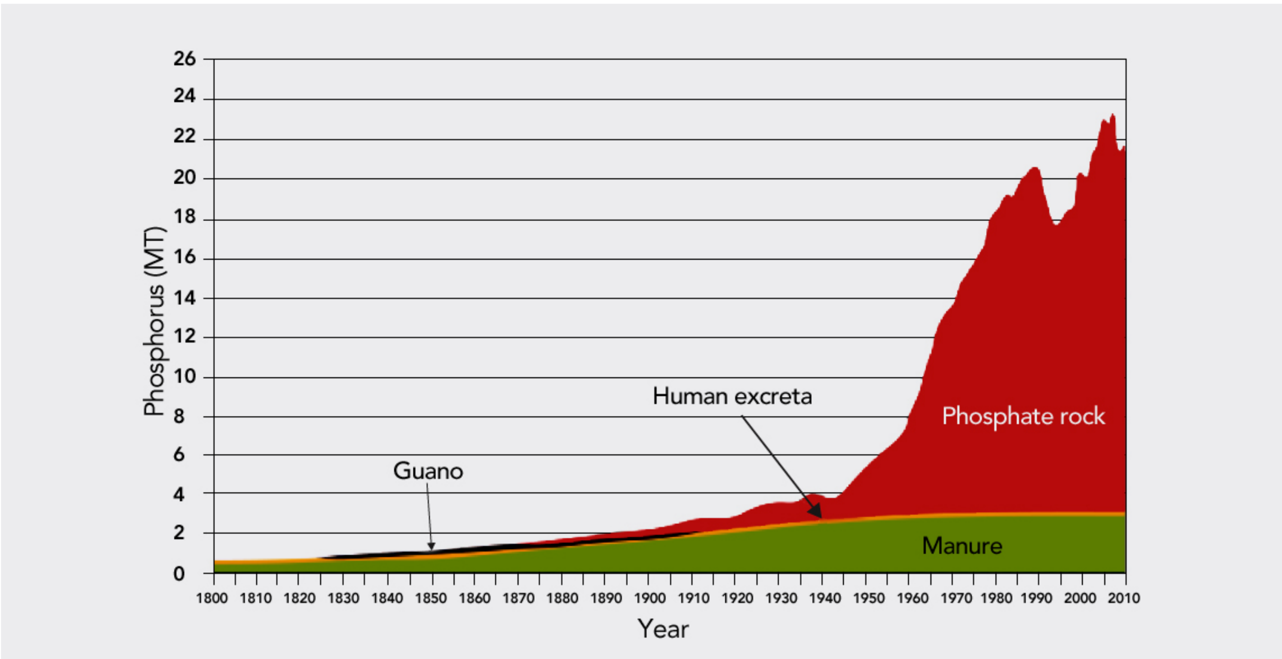
[112] Cho, R (2013), 'Phosphorus: Essential to Life – are we running out?', State of the Planet: blogs from the Earth Institute, Columbia University, *blogs ei.columbia.edu*, 1 April (viewed 8 July, 2013).

Like peak oil, the 'peak phosphorus' theory suffers from the observation that as prices rise for the commodity and extraction technologies improve, estimates of accessible reserves have increased as industry is incentivised to find new sources. The issue is compounded by very poor data, which is owned by companies and not independently verifiable.

For instance, in response to the 'peak phosphorus hypothesis', the International Fertilizer Development Center (IFDC), an industry body for the fertiliser industry, carried out a study in 2010 to reassess reserves.

This study suggested that world phosphate rock resources are approximately 290,000 million tonnes, and may be around 460,000 million tonnes once potential phosphate rock reserves are included. Although this figure does not include estimates for many countries which are yet to be fully explored for potential phosphate reserves, and leaves out many small phosphate deposits, *at current rates of production*, it is enough to supply fertiliser to agriculture for the next 300-400 years.

Figure 35: World production of phosphate peaked in 1987 and again in 2008



Sources: Calculations based on data in Brink, J, (1977), World Resources of Phosphorus, Ciba Foundation Symposium 13; Buckingham, D and Jasinski, S (2004), Phosphate Rock Statistics 1900ics 1900 Statistics 1Survey.,IFA (2006); Production and International Trade Statistics, International Fertilizer Industry Association Paris, available: http://www.fertilizer.org/ifa/statistics/ pit_public/pit_public_statistics.asp; and Smil, V (2000b), 'Phosphorus in the Environment: natural flows and human interferences', Annual Review of Energy and the Environment 25, 53–88

After the release of the IFDC report, the United States Geological Survey, the world's most commonly cited reference for phosphate availability updated its estimates of reserves from 16 billion tonnes to 65 billion tonnes.[113]

What kind of assets are at risk?

The risk of stranded assets from the availability of phosphates will be manifest primarily in the higher prices which farmers may be forced to pay for fertiliser in the event of a supply shortage. This will mean either higher food prices for consumers or lower profit margins for farmers if they cannot pass costs on. In developing countries, such high prices may be more likely to lead to phosphate fertilisers not being applied, and therefore to yield reduction.

While price spikes, such as occurred in 2008, are possible in the short term due to geopolitical and economic events, the risks from a supply shortage due to dwindling reserves is unlikely to impact the valuation of most agricultural assets for many years.

The most vulnerable asset would be the land, as the potential for enhancing the productivity of cropping may become costly or physically limited.

Figure 36: Assets exposed to potential shortage in phosphorus

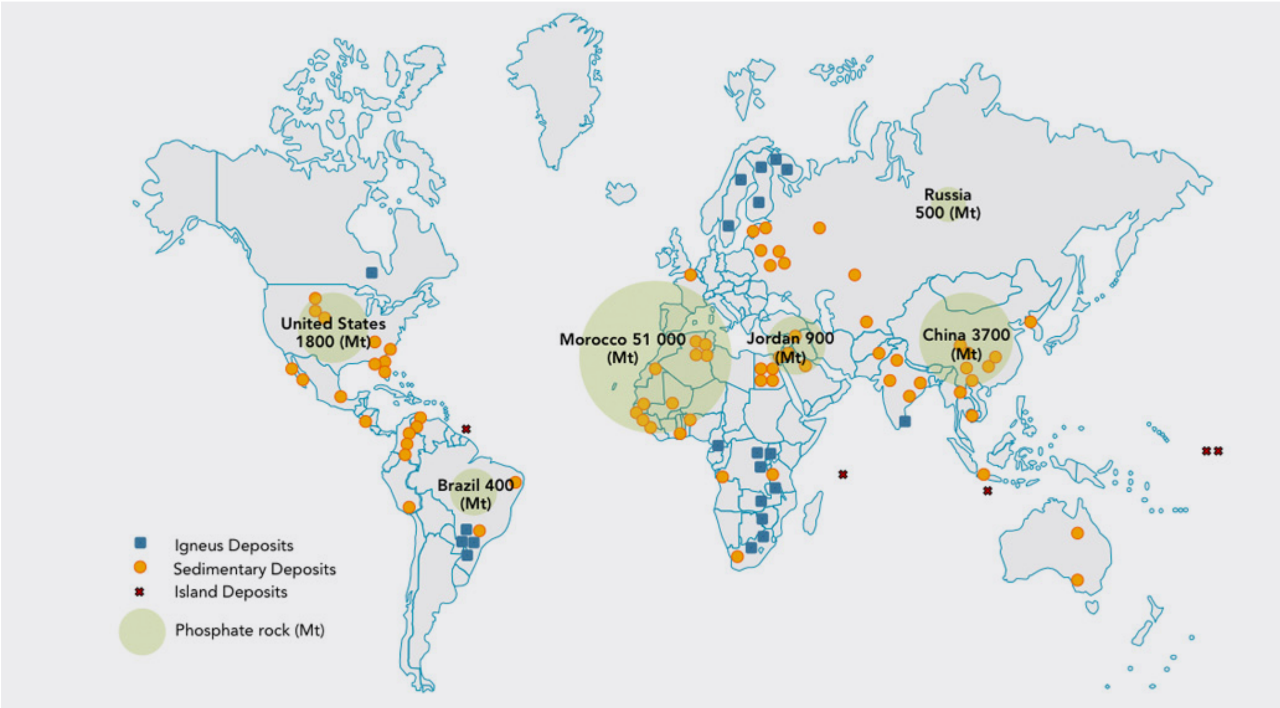
If the predictions of 'peak phosphate' theorists prove correct, holders of phosphate reserves or associated derivatives, and alternative sources of phosphate, such as human and animal excreta, may stand to benefit from significant price upside.

Footnote:

[113] http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/

Where is the risk concentrated?

Figure 37: Geographical distribution of phosphate rock reserves



Sources: Heffer, P and Prud'homme, M (2010), Fertiliser Outlook 2010-2014, 78th AFA Annual Conference, 2012, IFA Paris; and United States Geological Survey Mineral Commodity Summary (2011)

What are the consequences and responses?

While experts disagree on how much phosphate is left and how quickly it will be depleted, it is quite likely that price spikes will recur.

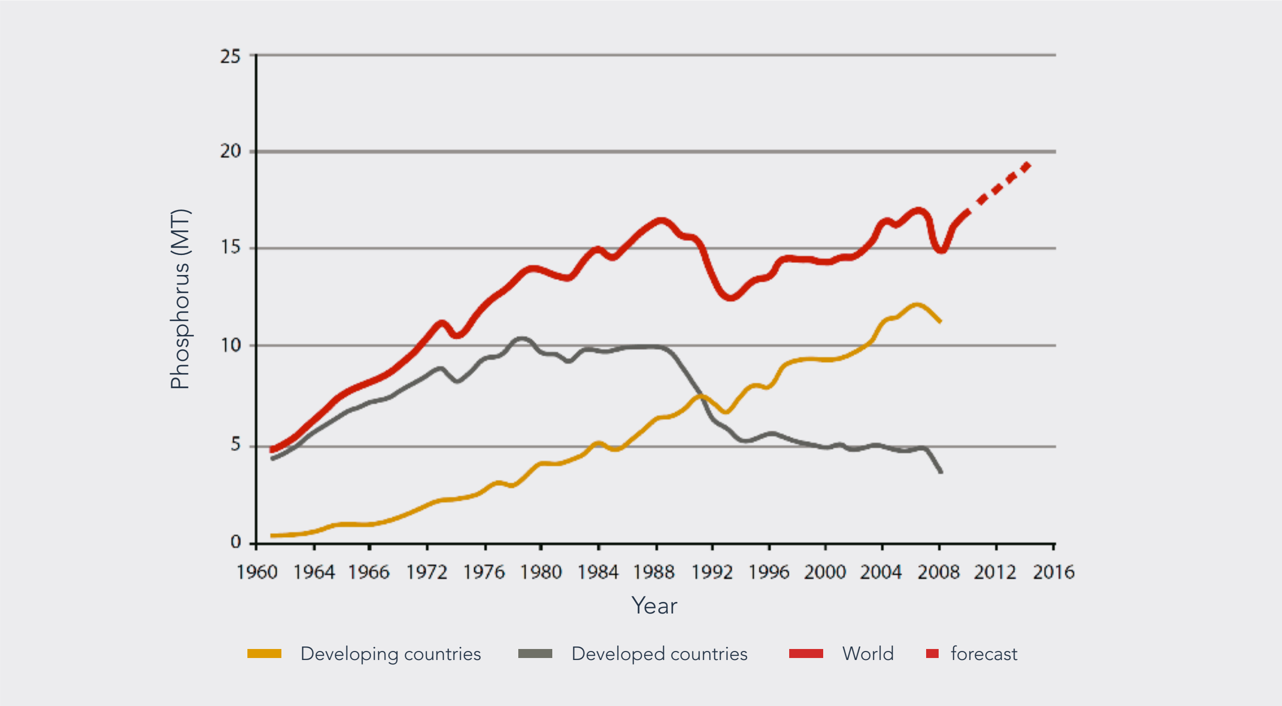
Phosphate supply is vulnerable because importing countries rely on exports from a small group of producers, particularly Morocco. While phosphates application can be optimised, which has led to declining usage in the developed world, and can be recycled from human and animal excreta, ultimately there is no substitute for phosphate in agriculture as there is, say, for oil in transport.

As high-quality reserves are depleted there is also the issue that lower grades of phosphate will need to be exploited which can pollute soils with cadmium, which is toxic to plants and animals.

While experts disagree on how much phosphate is left and how quickly it will be depleted, it is quite likely that price spikes will recur.

Phosphate rock reserves are sensitive to geopolitical concerns. Current estimates place around 90 percent of phosphate rock reserves in only five countries: Morocco, China, South Africa, Jordan and the United States. The United States imports a large amount of phosphate rock from Morocco as it has only 25 years of phosphate reserves left. Morocco has become the world's biggest exporter, geopolitical concerns have been raised over resources based in the disputed territory of Western Sahara.

Figure 38: Global phosphate consumption trends



Source: Heffer, P and Prud'homme, M (2010) Fertiliser Outlook 2010-2014, 78th AFA Annual Conference, 2012, IFA Paris.

One response has been the pursuit of strategic trade agreements to secure supplies from particular countries. For example, in 2004 the United States and Morocco signed a free trade agreement that covered phosphate rock among other commodities and in 2008 Morocco exported to the US around USD 65 million worth of fertiliser.[114]

There is plenty of room to enhance the efficiency of phosphate use on-farm. Of the 14.9 million tonnes of phosphorus mined for agriculture each year, only 6.1 million tonnes are removed as biomass.[115]

Depletion of phosphorous will bring significant disruption to the current industrialised farming system. However, this also poses opportunity for organic, sustainable farming practices that use manure to sustain plant growth and restore soil fertility. For example, biodynamic farming, a branch of organic farming that uses manure from a farm's own animals to fertilise the soil, strives to be completely self-sustaining.

Markers for future work

Whatever the driver of increasing phosphate scarcity – political, economic or physical constraint – it will be prudent to manage the risks and opportunities associated with the reliability of phosphate supply in the agricultural supply chain.

Footnotes:

[114] www.moroccousafta.com/tradedata.htm
[115] FAO (2011), *Looking Ahead in World Food and Agriculture: perspectives to 2050*, FAO Publishing, Rome.

Pressure on phosphate supplies will open up new investment opportunities for business and require improved governance frameworks from policy makers to support more efficient phosphate production and use, as well as the recycling of phosphate from water treatment facilities.

For example, between 40 percent to 60 percent of phosphate is lost when its host rock is converted to fertiliser. In Canada, one industry expert on waste water treatment estimated that attaching phosphate recycling technologies to water treatment plants could supply around 30 percent of the country's phosphate needs. Livestock is an even richer source containing around five times more phosphate than human waste. The increased uptake of such efficiency and recycling technologies would help provide a buffer against any future shortage.

Economic Drivers

Economic water scarcity

Why are water scarcity and increased competition for water rights potential drivers of asset stranding?

Water scarcity has three key dimensions. The first is physical and relates to rainfall or groundwater recharge that shapes a region's hydrological characteristics. The second and third sources of water scarcity are economic and relate to the development of infrastructure to provide access to users and the institutional frameworks which govern the distribution of that water.

In the previous section on physical drivers of water scarcity, we discussed how increased weather variability due to climate change may lead to changes in productivity across production zones, which could lead to stranded assets. While such long-term changes are profound, water scarcity is first likely to be felt through economic drivers such as increased competition for water rights between higher-value users such as industry and urban residents.

The loss of reliable access to water, through either economic or physical drivers, has significant potential to diminish the value of agricultural assets in an affected region. This occurs by lowering the average yields of crops grown in the area, or *in extremis*, by triggering the abandonment of land and agricultural infrastructure if land becomes unviable.

For the agricultural investor, water use patterns are only really meaningful at the basin level, specific to each geographical region. Water resources are very unevenly distributed; some countries having an abundance of water, while others exist in conditions of extreme scarcity.

The social costs and benefits of any change in water use will depend on how scarcity affects potentially competing human water demands, such as between urban use and agricultural use. Agriculture is generally a low-value user of water compared with urban and industrial users. This means that if water users are faced with the costs of water extraction, and if water becomes more of a tradable commodity, other things being equal, water will flow away from agriculture. This has the potential to strand agricultural assets in regions which are particularly reliant on irrigated agriculture. This has been identified as a particular risk for areas reliant on groundwater extraction where extraction is higher than the recharge rate.

What kind of assets are at risk?

The assets most vulnerable to increasing water scarcity and competition for water rights will be those characterised by high fixed and sunk costs and those of low liquidity. For instance, when a farm or a region loses its water entitlements, the value of agricultural land will decline. If rights to water entitlements have not been clearly established, they will be lost, most likely resulting in a significant drop in land value.

If water entitlements are established within a regime of clearly identified property rights, then a farmer or asset owner may benefit from the sale of the water on a temporary or permanent basis to another, high-value, water user. However, while the water right itself may be transferable, fixed assets such as farm buildings and other infrastructure, such as irrigation networks, will be highly vulnerable to water rights leaving a property or region. Network effects are also likely to be important for other community infrastructure and social assets. After a certain amount of water leaves a region, the agricultural community itself may become unviable with closing schools, banks and other services leading to emigration and stranded or ghost towns.

This highlights the importance of a clearly identified property rights system for water in determining the adaptation and resilience of agricultural investments exposed to water risks.

Figure 39: Assets exposed to water scarcity and increased competition for water rights

Where is the risk concentrated?

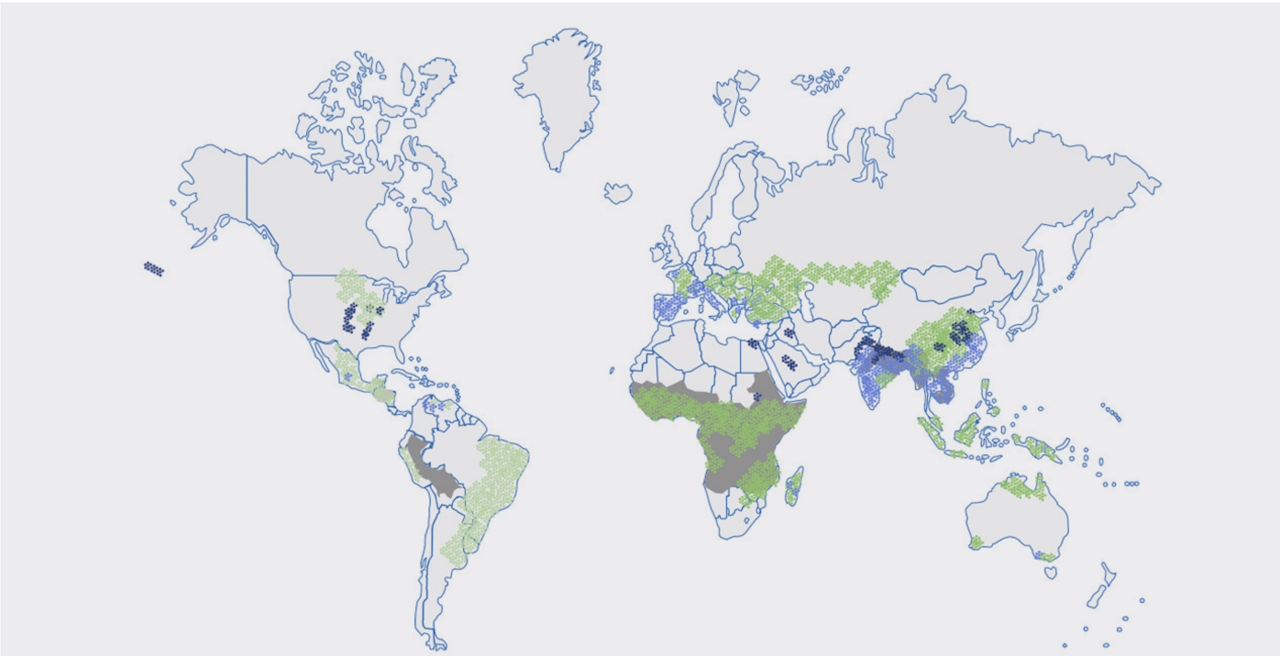
The institutions that govern water allocation will play a significant role in determining the geographical distribution of stranded asset risk. These can differ significantly both within and between countries, resulting in substantial differences in the efficiency, equity and flexibility of water use and infrastructure development.[116]

The IPCC defines basins with water stress as having a per capita water availability below 1,000m^3/year or as having a ratio of withdrawals to long-term average annual runoff above 0.4. These basins are located in Africa, the Mediterranean region, the Near East, South Asia, northern China, Australia, the United States, Mexico, northeastern Brazil and the west coast of South America.

Some regions at greatest risk from water shortages are also agricultural centres such as northwest India, northeast China, northeast Pakistan, California's Central Valley, and the Mid West of the United States.[117]

Exposure to stranded asset risk will depend on the changes in the volume, variability, and seasonality of freshwater runoff and groundwater recharge, as modified by the operation of existing water control infrastructure and investments in new infrastructure.

Figure 40: Economic water scarcity and major irrigation and rain-fed agricultural areas



Source: IWMI (2012); FAO (2012)

In many large water basins, including the Yellow River and the Ganges, the share of water flowing to irrigation is expected to decline due to increased competition from other sectors. As a consequence, as highlighted by one influential study, cereal yields in water scarce basins are expected to decline by 11 to 22 percent by 2025.[118]

Footnotes:

[116] See IPCC (2007), Assessment Report 4, Chapter 3, Freshwater Resources and their Management, Cambridge University Press, Cambridge.

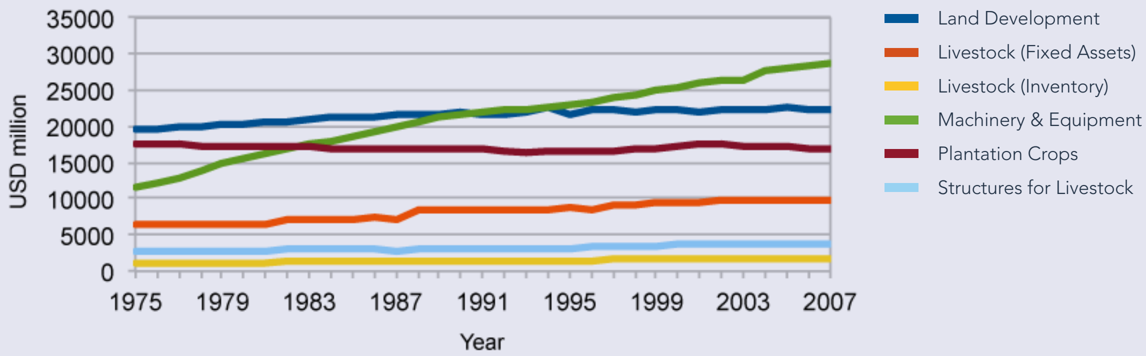
[117] Wada, Y et al, (2010), 'Global Depletion of Ground Water Resources', *Geophysical Research Letters*, 37, L20402, 2.

[118] Rosengrant, M, Cai, X and Cline, S (2002), *World Water and Food to 2025: dealing with scarcity*, IFPRI, Washington, DC.

Box 11: Gross capital investment and economic water scarcity in Spain

As the most semi-arid country in the European Union, Spain has been increasingly featured by the global media for its regional conflicts over water resources. Since agriculture was positioned as a privileged user of water in the late 19th century, irrigation has been promoted as the main rural development policy in Spain. Today Spain accounts for almost a third (32.1 percent) of the total irrigated area in the EU, followed by Italy (24.9 percent) and France (16.2 percent)[119] and uses 75 percent of its available water resources on irrigated agriculture.[120]

Figure 41: Breakdown of gross capital investment in agriculture in Spain



Source: FAOSTAT

The value of gross agricultural capital stock has steadily risen in Spain during the past three decades due to increasing investment in machinery and equipment. This investment has largely been focused on the process of land reclamation – the transformation of dry land into irrigated land as a core element of rural development strategies.[121] Indeed, studies suggest that land reclamation has resulted in the transformation of nearly two million hectares of dry land into irrigated land and led to large public investments in water infrastructure.[122]

Footnotes:

119 Lopez-Gunn, E, Zorrilla, P, Prieto, F and Llamas, M (2012), 'Lost in Translation? Water efficiency in Spanish agriculture', *Agricultural Water Management*, 108: 83-95.

120 INE (2009), cited by Gómez-Limón, J and Picazo-tadeo, A, 'Irrigated Agriculture in Spain: Diagnosis and Prescriptions for Improved Governance'. *International Journal of Water Resources Development*, 28 (1): 57-72.

121 Gómez-Limón, J and Picazo-tadeo, A,,Op cit.

122 Maestu and Gómez, 2010, cited by Gómez-Limón, J and Picazo-tadeo, A, Op cit.

The Common Agricultural Policy (CAP), created in the 1960s, helped drive the shift away from low-yield, rain-fed farming towards more irrigated land and the intensification of production. The resulting expansion of irrigated land necessitated continual investment in machinery and equipment to farm the newly irrigated land areas.[123] The reform of the CAP in 1992 continued to incentivise irrigated agriculture via payments for surface cultivated, which rewarded irrigated agriculture due to its higher productivity compared with rain-fed farming.[124]

With the institution of the 'single farm payment' scheme in 2003 the farm subsidies were made independent of the level of farm output.[125] This, however, has not led to a slowdown in investment in machinery and equipment. The reform has consequently reduced the demand for irrigation water in Spain and imposed on farmers the condition to use water more efficiently in order to be eligible for subsidies.[126]

Reforms to the CAP in 2013 have the potential to strand assets in irrigated agriculture by shifting farm payment support in favour of the dry land regions. Under this new approach, individual farms will receive payments according to the public goods they supply, and dry land regions have supposedly higher potential to supply public goods.[127]

Irrigated agriculture is also a major source of diffuse water pollution in Spain.[128] Irrigated agriculture near the Mediterranean basin in Spain involves the highest irrigation water and chemical consumption rates, concentrating the most intensive farming activities in the country.[129] Thus, increasing water quality standards may also drive asset stranding in agricultural enterprises.

Considering that climate change will worsen water scarcity in certain parts of Spain in the near future by increasing crop water requirements by between 5 percent and 10 percent and decreasing the availability of water resources by between 5 percent and 14 percent in addition to increasing year-to-year variability of the availability of water resources,[130] regions with current water deficits, especially in the south and east of Spain will experience more serious conflicts regarding the use of water.[131]

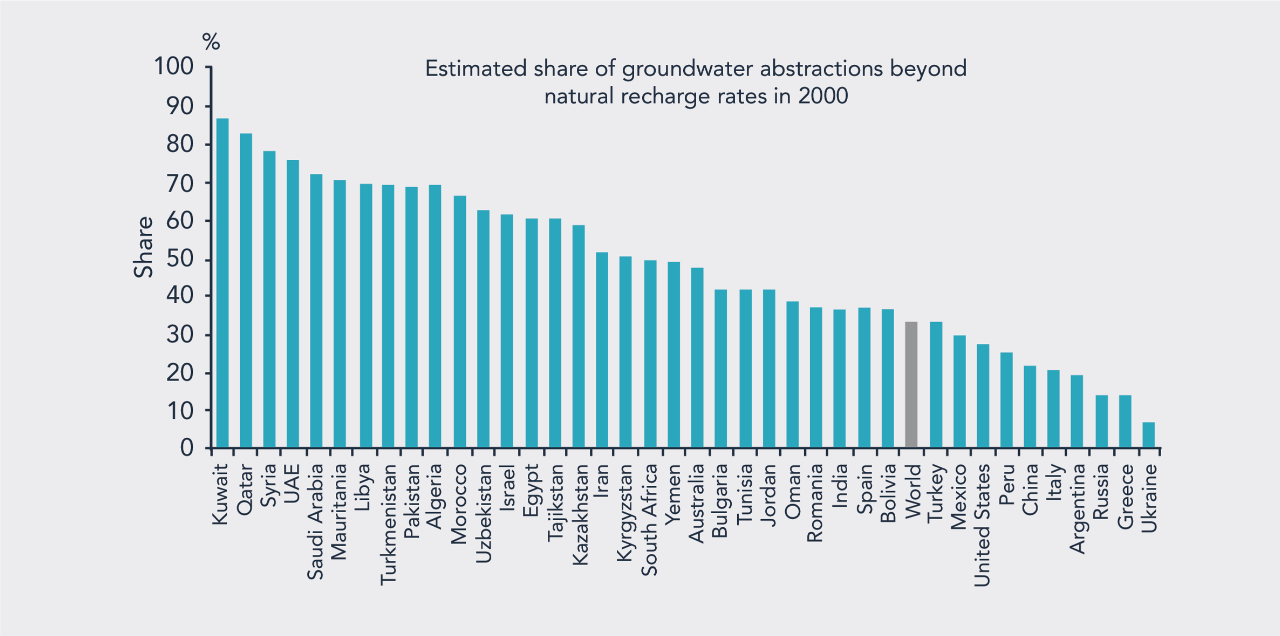
While Spain is one of the leading countries in the world in desalination technology, less than 1 percent of the irrigated surface in Spain utilises desalinated water due to the high costs in obtaining this kind of water resource.[132] The current irrigation policy that focuses on promoting the modernisation of existing irrigation systems, enhancing the efficiency of existing irrigation systems and consolidating irrigated lands,[133] appears to reflect the need for such a paradigm shift to protect water as a natural resource.

Footnotes:

[123] Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[124] Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[125] Schmid and Sinabell, 2007, cited by Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[126] Gómez-Limón, 2006, cited by Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[127] Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[128] Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[129] Gómez-Limón, 2009, cited by Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[130] IPCC, 2007 cited by Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[131] Iglesias, 2009; Iglesias et al, 2010, cited by Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[132] Gómez-Limón, J and Picazo-tadeo, A, Op cit.
[133] Gómez-Limón, J and Picazo-tadeo, A, Op cit.

Of particular concern are irrigated production regions which are reliant on groundwater. These include parts of the United States, Mexico, Saudi Arabia, Libya, Egypt, Australia, northern China, India, Pakistan, and Iran. In many areas extraction rates from aquifers far exceed the natural recharge rates so exposing aquifers to salt water intrusion (see *Figure 42*). Such events may occur suddenly in a non-linear way of decline and thus have the strong potential to strand agricultural assets if not carefully managed.

Figure 42: Vulnerability to stranded assets from groundwater overextraction



Source: Chatham House based on estimates by Wada et al (2012)

What are the consequences and responses?

Stranded asset risk driven by growing water scarcity and competition for water entitlements between users is likely to be material and increasing especially in regions already exposed to economic and physical water scarcity.

One management tool to address these risks is the importing of virtual water from water scarce regions from water rich ones in the form of agricultural products.[134] This closely intersects with the trade agenda, and the 'greening of the agricultural supply chain' discussed elsewhere in this report. Trade offers benefits from realising efficiencies of resource use, improving food security, and providing the engine for yield enhancing investment in countries which are rich in natural assets but poor in financial assets, particularly in parts of the developing world such as Africa.

Footnote:

[134] Allen, J (1998), 'Virtual Water: an essential element in stabilising the political economies of the middle-east', Transformations of Middle-Eastern Natural Environments, Forestry and Environmental Studies Bulletin, 3: 141-149, Yale University Press, New Haven, Connecticut.

Identifying and securing property rights for water use should also be seen as a priority for increasing resilience and mitigating the potential for stranded assets from increasing water scarcity. If water use remains a poorly identified element associated with land value, it may be much more vulnerable to a loss in value if it has been explicitly identified. Furthermore, tradable water entitlements can help meet long-term changes in demand (e.g. due to population growth and urbanisation), as well as short-term needs arising from drought by allowing water to move between sectors and regions. If managed carefully such water markets[135] can not only help provide valuable alternative revenue streams for farmers and investors, but also provide funding for community improvement programmes to guard against stranded social assets from large-scale water transfers out of an agricultural area.[136]

Markers for future work

Increasing water scarcity and competition for water entitlements between users will confront investors and farm businesses with new challenges and opportunities in the coming years. Central to how agricultural enterprises will be able to manage through this period will be the institutions that are put in place by government to recognise water as a property right.

First, defining water property rights will increase efficiency by allowing water to flow to its highest value use within the agricultural sector. This is also likely to free up some water for use outside the sector, such as for industrial and municipal usage. In the event that drought results in a cut in allocations under such entitlements, clear property right regimes will establish a stable set of rules by which water can be rationed. In such times of scarcity water rights are likely to become more valuable, which can compensate farmers for loss of income from selling agricultural products.

Such frameworks are also key political institutions in helping stimulate investment in water infrastructure, such as irrigation. If water rights are poorly defined and fragmented within a region, then such infrastructure investments may end up underperforming.

Footnotes:

[135] Water markets have developed in the United States (e.g. the Metropolitan Water District of southern California), Australia (see the Murray Darling Basin Commission), in Chile and in parts of Canada. In addition some informal water trading occurs in the Middle East, southern Asia and North Africa (see IPCC, AR4 2007)

[136] Miller, K and Yates, D (2006), 'Climate Change and Water Resources: A primer for municipal water providers', 83, AWWA Research Foundation, Denver Colorado.

The greening of the agricultural value chain and new requirements from industry

Why is the greening of the agricultural supply chain a potential driver of asset stranding?

The greening of value chains represents both risk and opportunity for agricultural enterprises. Global value chains (GVCs) refer to the concept that the whole process of producing goods, from raw materials to finished products, has increasingly been 'sliced' and each process can now be carried out wherever the necessary skills and materials are available at competitive cost. A growing emphasis on transparency in GVCs attempts to bridge the gap that many perceive has opened up between consumers and the production systems that create the goods and services they buy.[137]

As a result of growing environmental and social concerns, GVCs are now experiencing a trend towards greener products and processes. For example a range of certification schemes, such as eco-labelling, have gained prominence, as a way of connecting the 'paddock to plate' so that the consumer can more easily assess goods with different quality standards.

Such eco-labelling and product certification are a positive development for providing greater information to consumers about the farming practices used in their production. However, they also represent a risk for some farmers who are unable to achieve certification. This may not always be due to not meeting a specific standard, but rather that such schemes can require a costly certification process, which may be difficult for some farmers to afford. There are also a number of different schemes, with different requirements and quality standards, which if poorly coordinated, could dilute the usefulness of such schemes.

The greatest risk for agricultural assets would be if environmental certification became used as a tool by governments to initiate trade restrictions on environmental or other grounds[138]. This could result in significant, though not necessarily permanent, asset stranding in the target country and sectors.

Box 12: WWF's Better production for a living planet[139]

The World Wide Fund for Nature (WWF) has identified 15 commodities which account for the majority of environmental impact on the planet. About 70 percent of the value of these 15 commodity markets is controlled by fewer than 500 companies. 'Taken together, these commodities include the five largest drivers of deforestation, the main sources of greenhouse gas emissions from land use, and the most important fisheries for aquatic biodiversity and food supply. They also have a critical impact on the livelihoods of hundreds of millions of people, and particularly on many of the poorest on the planet.'

Footnotes:

137 See, for example http://www.idhsustainabletrade.com/

138 http://www.oecd.org/sd-roundtable/papersandpublications/39362947.pdf

139 WWF (2012), 'Better Production for a Living Planet'.

What kind of assets are at risk?

Asset stranding due to new environmental requirements being imposed on industry through a conjunction of consumer driven eco-labelling initiatives and associated potential trade restrictions, represents a medium-term risk for individual farmers, sectors, and even countries.

In one scenario unsuccessful, competing eco-labelling initiatives would have to be abandoned in favour of more popular or officially sanctioned programmes. This means that the social assets built up around competing eco-labelling initiatives are vulnerable to asset stranding.

Fairtrade certification is a high-profile certification scheme, which offers 'a tool for development that ensures disadvantaged farmers and workers in developing countries get a better deal through the use of the international FAIRTRADE Mark.' This scheme also targets environmental sustainability issues such as unsustainable rainforest destruction.

However, the scheme notes that there are risks around the debate on climate change and its intersection with other goals of sustainable development such as providing livelihoods through agriculture. 'The public concern around climate change and carbon emissions has been growing rapidly in recent months and there is no doubt that far-reaching global action has to be taken now to deal with global warming. However if the debate around this issue becomes overly obsessed with the question of food miles, this could severely damage opportunities for sustainable forms of export agriculture to contribute to the economic and social development of poor producers.'[140]

The risk for movements such as Fairtrade is that regulations governing trade and the environment to more accurately reflect the embedded carbon in certain agricultural products could significantly affect the perceived 'greenness' of their own brand. This could result in brand-stranding – a form of reduction in value of social capital.

Footnote:

[140] http://www.fairtrade.org.uk/

Figure 43: Assets exposed to risks from the greening of the agricultural supply chain

In another scenario environmental standards are applied as justification of import bans to keep a certain type of production (such as genetically modified crops) out of a specific market. If such bans become widespread, then farmers who have invested in new farming techniques may be left with smaller markets, which will put downward price pressures on their production.

Natural assets and physical assets may also be vulnerable owing to the type of production process that is required by the eco-labelling system which has come into place and must be complied with. For example, it may take many years to achieve 'organic' certification particularly if synthetic fertilisers and pesticides have been used on a property.

Table 5: Selected market share for sustainability certification (based on current annual reports)[141]

COMMODITY	STANDARD	FOUNDED	PRODUCTION CERTIFIED %
Cotton	BCI	2005	3%
Soy	RTRS	2006	3%
Palm oil	RSPO	2003	14%
Cocoa	Various	n/a	12%
Fish	MSC	1997	7%

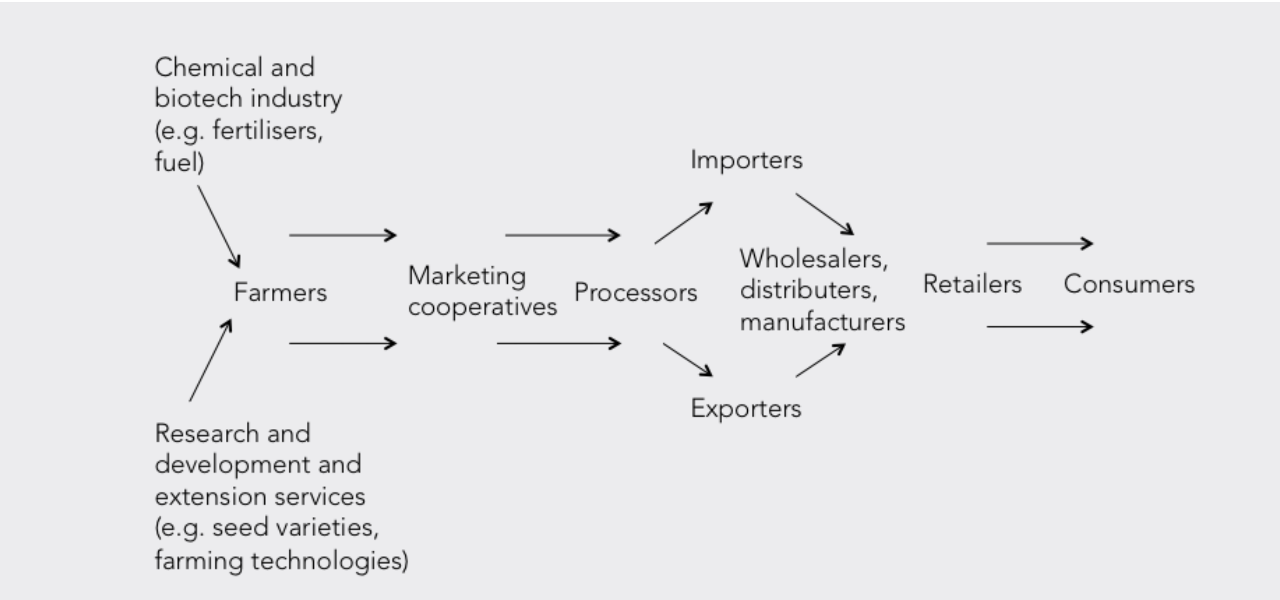
Footnote:

[141] OECD (2013), 'Building Green Growth Value Chains: committed public-private coalitions in agro-commodity markets', OECD Green Growth Papers, OECD Publishing, Paris.

Where is the risk concentrated?

The stranded asset risk from eco-labelling is likely to be concentrated in countries where agricultural operators do not have the resources to comply with the certification requirements, or where certification itself is prohibitively expensive. This is likely to have a disproportionate effect on smaller operators in the supply chain.

Figure 44: Simple schematic of the agricultural supply chain



What are the consequences and responses?

The consequences for the greening of the agricultural supply chain represent a risk for many enterprises due to the potential of increased costs, but more significantly, the risk of losing market access, where standards are used to select producers.

Governments can also play a constructive role in this area in defining the contracting rules which govern the relationships between the producer, their input suppliers, processors, wholesalers and retailers to ensure transparency. This will be particularly important where there is significant imbalance in market concentration between buyers and sellers of agricultural produce, as is especially the case in horticultural markets. Such rules can form an important part of competition framework with respect to preventing the inappropriate use of market power. For example, governments could put in place codes of conduct outlining minimum standards for contract transparency to ensure that farmers receive the promised price for the quality of goods delivered – especially when they are perishable.

Box 13: Unilever's response[142]

'Our Sustainable Living Plan commits us to a common approach across all our value chains. That means we have to work everywhere in the same way. On measuring for sustainability, Europe represents our key challenge because it will introduce the first legislation. This will affect how we operate. What would be a real problem for all companies is if significantly different regulations then emerged in various jurisdictions.'

Nigel Bagley, Director of Industry Affairs, Unilever

Markers for future work

Actions to better understand and mitigate these risks might include the coordination of a database of environmental certification schemes. This will help quantify the scope of the potential problem and identify where asset stranding is likely to take place as a result of any new rules.

The intersection with international trade law is a potential significant risk for businesses that operate in this space, which could result in both winners and losers from changes in regulation. In particular, there is the risk that industry groups may use certification schemes are de facto instruments for trade protection – as highlighted by the problems potentially facing Fairtrade.

Bringing down the transaction costs of certification will be a crucial element in reducing such risks, for if it is easy to switch between schemes, the problem of path dependence and stranded social capital will be significantly mitigated. This is likely to require some element of government intervention, at the very least to set up a registry for such schemes.

Land use regulations

Why are land use regulations potential drivers of asset stranding?

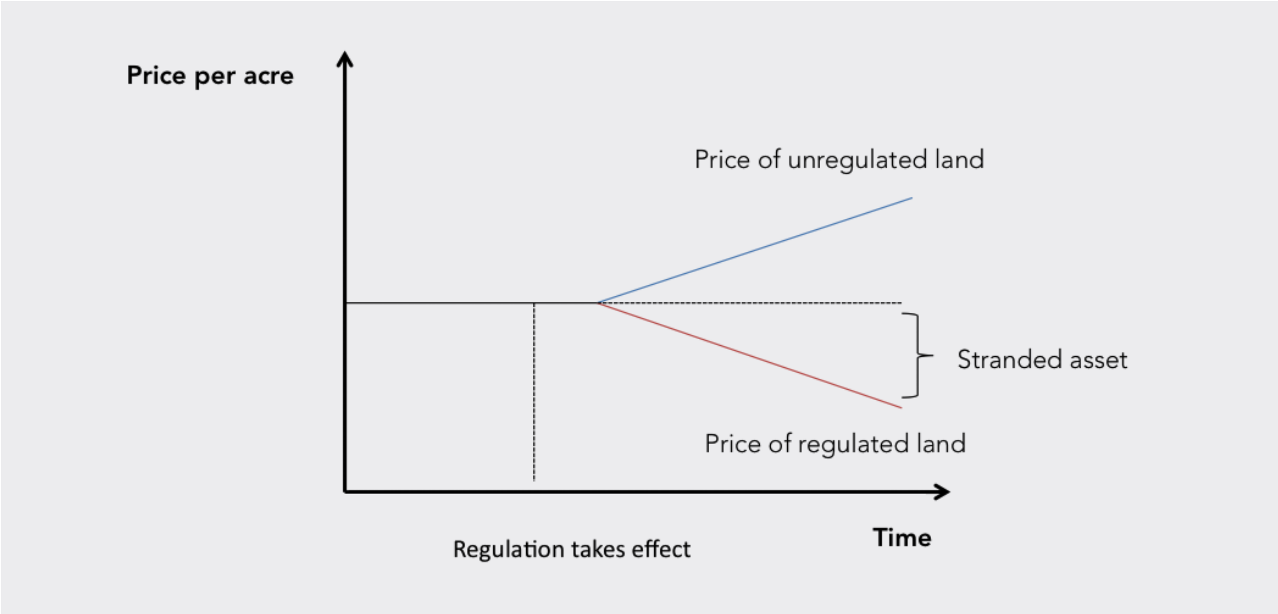
Land use restrictions govern how land can be used and how uses can be changed. Land use typically describes the products and/or benefits obtained from the use of land as well as the land management activities carried out to produce those products and benefits. Land use regulations can affect the market value of farmland in a variety of ways – and thus become a potential driver of asset stranding.

Usually, the basic assumption is that land use regulations reduce property values due to restricting its use, such as by prevention of land clearing, which limits agricultural development and thus the revenue able to be earned from the land.

Footnote:

[142] Quoted in OECD (2013), *Building Green Growth Value Chains: committed public-private coalitions in agro-commodity markets*, OECD Green Growth Papers, OECD Publishing, Paris.

Figure 45: Simple depiction of change in land value due to land-use regulation



Source: Based on Jaeger (2006)

However, land use regulation can also increase property values in a number of ways. First, the regulation may protect, enhance or create amenities or services that benefit the property owners, for example, protecting the ecosystem services such as pollination services and erosion and flood control or reducing environmental pollution in rivers due to fertiliser use or sedimentation. The other way land use regulations may increase property value is through scarcity effects, whereby the restriction of land in one area, increases the prices for similar land in other locations.

Another important area of interaction between land use regulations and agriculture occurs as part of the approximately 19.5 million hectares of land that this converted from agricultural to urban use each year.[143] This often provides a cash windfall to the farmer, as urban land is typically much more valuable than farming land. Thus land use regulations are a double-edged sword for many farming communities – with some farmers receiving a golden parachute to exit a region, which they can use to either reinvest elsewhere, or leave farming altogether.

Certification of land as 'organic' or 'GM free' is also a tool which has been used by some farmers and regulators to differentiate their products and created extra value from their land. Any premium that might be attached to such land may become 'stranded' if it is not managed appropriately, or if there are 'accidental' releases of GM technology in areas designated to be 'GM free'. In this case formal land use regulations for a region can play an important role at either protecting the integrity of a production system or putting it at risk.

Footnote:

[143] http://www.fao.org/nr/land/land-policy-and-planning/en/

What kind of assets are at risk?

The main asset which is highly vulnerable to land use regulations is the value of agricultural land itself. Although there is scope for positive effects on value as discussed above, for the individual landowner, the value of a property as an agricultural enterprise is likely to fall in the event of land use regulation which restricts certain farming practices or limits the scope to obtain revenue from the land. The most typical example is perhaps the implementation of land-clearing controls, which prevents grazing or cropping activities on land intended for development.

Figure 46: Assets exposed to asset stranding from land use regulations

Physical assets may also be vulnerable if a restriction is imposed that limits the use of the land in a way which leaves certain fixed or sunk cost investments unable to be used. For example, farm machinery may become underutilised if a significant proportion of land is taken out of potential production. Human, social and financial assets are less vulnerable as they are more removed from the target of the regulation.

Where is the risk concentrated?

Land use regulation is a risk in most parts of the world, especially in areas with an increasing environmental frontier and where the impetus for the regulation of that land is intense. Geographically, such regulations are likely to focus on areas of biological hotspots, which were mapped in *Figure 25* on page 54.

What are the consequences and responses?

Land use restrictions are widespread. They affect a substantial volume of commerce, through zoning, planning rules, private contracts, location-specific rules and approval processes. The implications of changes in agricultural land-use are complex, because they can impact on other agricultural land-uses; alter the mix of arable crops, permanent crops and pasture; or change property-rights related to land (and water).

Some of these implications might involve: protecting important public good elements of ecosystem service provision; the encouragement of the abandonment of farmland in some rural areas of high nature value and the associated knock-on effects on local communities from declining economic activity and services that result; the reduction of land used in food production and promotion of urban sprawl.

For example, land use regulation also results in significant changes of land value as a result of the possibility for changing use from agricultural to residential purposes. For example, one study found that in 2003, housing land at the outer boundary of an urban settlement permitted for development in the city of Reading, UK cost about £3,000,000 per hectare, while neighbouring agricultural land, not within the urban envelope, had a value of about £7,500 per hectare.[144]

Some jurisdictions have tied the implementation of land use reforms to the implementation of schemes to pay for different aspects of ecosystem services. This may take the form of moving from a system of production subsidies towards payments for environmental services, such as in the case of Europe. In Brazil and Indonesia, there have been steps made towards the implementation of schemes to capture the carbon sequestration benefit of extant rainforest to generate additional revenue streams from environmental protection.

Markers for future work

Actions to mitigate negative risks from biodiversity regulations, would be to purchase farmland which is already in production, rather than on the agricultural frontier. This can prevent concerns that new investment will lead to increased deforestation, such as in the Cerado region of Brazil which faces some intense development pressures.

Governments can also work with potential investors and landowners to identify and clarify property rights where they are unclear. This may free existing land to be put to higher value uses, and encourage productivity enhancing investment in existing areas, thus taking the pressure off frontier development.

One exciting area for future research is the notion of a system of tradable entitlements associated with land use, which would help introduce some flexibility into land use regulation and help agricultural enterprise achieve a conservation objective at least cost.

Footnote:

[144] Cheshire, P and Stephen, S (2005), 'The Introduction of Price Signal into Land Use Planning Decision-making: A proposal', *Urban Studies* 42(4):647-663.

Changing biofuel regulations

Why are changing biofuel regulations potential drivers of asset stranding?

The biofuel industry has grown by nearly 19 percent annually since 2000, helping drive one of the most profound structural shifts within agricultural markets over recent years. In 2010, global biofuel production supplied around 2.7 percent of total road transportation fuel.[145]

Global ethanol production tripled between 2000 and 2007, to reach 62 billion litres,[146] and the production of biodiesel increased more than ten-fold during the same period, to more than 10 billion litres. Brazil and the United States dominate the growth in ethanol production, while the EU has been the major source of growth in biodiesel production. However, many other countries have also begun to increase their output of biofuels.

Currently, around 65 percent of European Union vegetable oil, 50 percent of Brazilian sugar cane and about 40 percent of corn production in the United States is used as feedstock for biofuel production.[147] Nearly 100 percent of the ethanol commercially produced is from first generation feedstocks. These are sourced from food crops such as corn, wheat and sugarcane, which all contain starches and sugars that can be extracted cost-effectively using proven conversion and distilling technology.

In recent years, however, biomass feedstocks have emerged as a promising next generation source of ethanol (i.e. cellulosic ethanol). The most common sources are corn stover, switchgrass, miscanthus and timber, but even cardboard and newspaper have been used. Second generation ethanol differs from first generation ethanol in that it requires the use of special enzymes and chemicals to unlock the starches contained in the lignocellulosic structure of the biomass materials in order to extract the sugars that can then be fermented and distilled to produce ethanol.[148]

Though promising, two major issues still need to be overcome with second generation biofuels to move them closer to commercialisation. First, the feedstocks are not currently available on commercial scales and secondly, the additional enzymatic or chemical treatment process has technical issues that must be resolved for it to become cost-competitive.

Biodiesel is diesel fuel produced by extracting crude oils from oilseeds such as soybeans, rapeseed/canola, and oil palm through a process called crushing. Once extracted the crude oil goes through a process called transesterification, where the lipids within the oils are converted into biodiesel. The same process can be used to convert animal fats into biodiesel.

Changing biofuel regulations are an important source of risk for asset stranding, because they represent a relatively fast moving driver of change. Policy-driven markets are characterised by the potential for policy instability which can open or close markets at short notice.

Footnotes:

[145] Global AgInvesting (2012), *Global Biofuels*, HighQuest Partners, Danvers, MA.

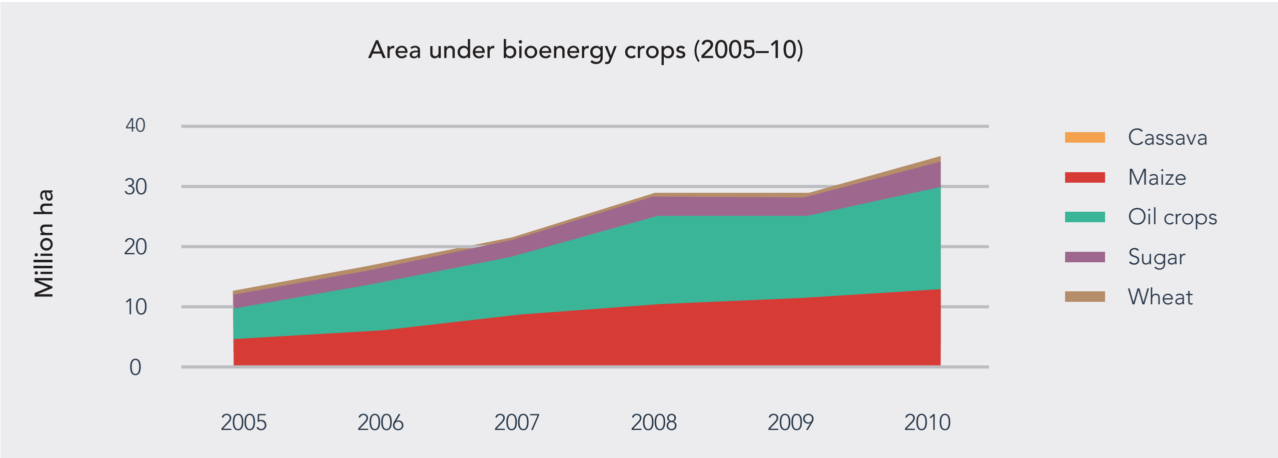
[146] Licht, F (2008), data from the OECD-AO AgLink-Cosimo database.

[147] OECD/FAO (2012) *Agricultural Outlook* 2012-2021, OECD/FAO Publishing, Paris and Rome: http://www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2012_agr_outlook-2012-en

[148] Global AgInvesting (2012), *Global Biofuels*, HighQuest Partners, Danvers, MA.

The different types of biofuel and feedstock also introduce an important element of risk into the sector, with the potential for some types to fall in and out of favour with policy makers as the market evolves and moves from nationally-based markets towards more globalised ones. This also opens up the field of path dependency to locked-in technologies as entrenched industry participants seek to protect their investments in productive assets, in this case by sticking to first generation biofuels, rather than adapting to the new technologies that might be more efficient from a broader social and environmental perspective.

Figure 47: The rapid growth in bioenergy crops



Source: FAOSTAT

Compared with the relatively steady growth in demand for food and fibre from increasing population, income and urbanisation, the demand for energy from the transportation sector is much more volatile. In periods of high crude oil prices, national fuel policies have tended to push for the increased blending of biofuels into the transportation market to reduce the cost of oil imports via the use of subsidies and mandated volumetric targets. This has resulted in the strengthening of the link between agricultural and energy commodity prices, particularly between sugar and crude oil. As can be seen from the commodity price data, sugar has been much more volatile compared with other agricultural commodities as a result.[149]

Footnotes:

[149] See OECD (2011), 'Agricultural Commodity Price Volatility: an overview', OECD Paris, for a discussion on the current price rises and assessment of market volatility in a historical context: http://www.oecd-ilibrary.org/docserver/download/5kg0t00nrthc.pdf?expires=1369910040&id=id&accname=guest&checksum=9633166B7002E552D1E860BEA47718BC

Box 14: Biomass feedstocks for electricity generation

The demand for biomass feedstocks from coal-to-biomass conversions will lead to further expansion of industrial monoculture tree plantations, possibly at the expense of agricultural land for crop production or livestock. In the UK, the Drax power station along with some other large coal burning utilities are seeking to convert half of their existing coal burning facilities to burn wood pellets in order to comply with the new EU sulphur dioxide regulations. These coal-to-biomass conversion plans have generated controversy since the plans not only require burning pellets from millions of green tons of wood every year but also grant rights for the coal power plants to continue their coal-burning operation while being subsidised for using biomass.

The FAO has estimated that about two-thirds of the cereals needed for ethanol production are obtained from increased crop production. The remaining third comes from reduced use of land previously used for grains grown for animal feed (24 percent), and reduced use of land for human food production (10 percent). A review of studies shows that trajectories for the amount of agricultural land that will need to be dedicated to producing crops range from 35 to 166 million hectares, highlighting the disparity of opinions on this topic.[150] Other things being equal, the substitution of production for food and feed to support the expansion of biofuels will increase prices for agricultural commodities as the supply of grain used for food and animal feed contracts.

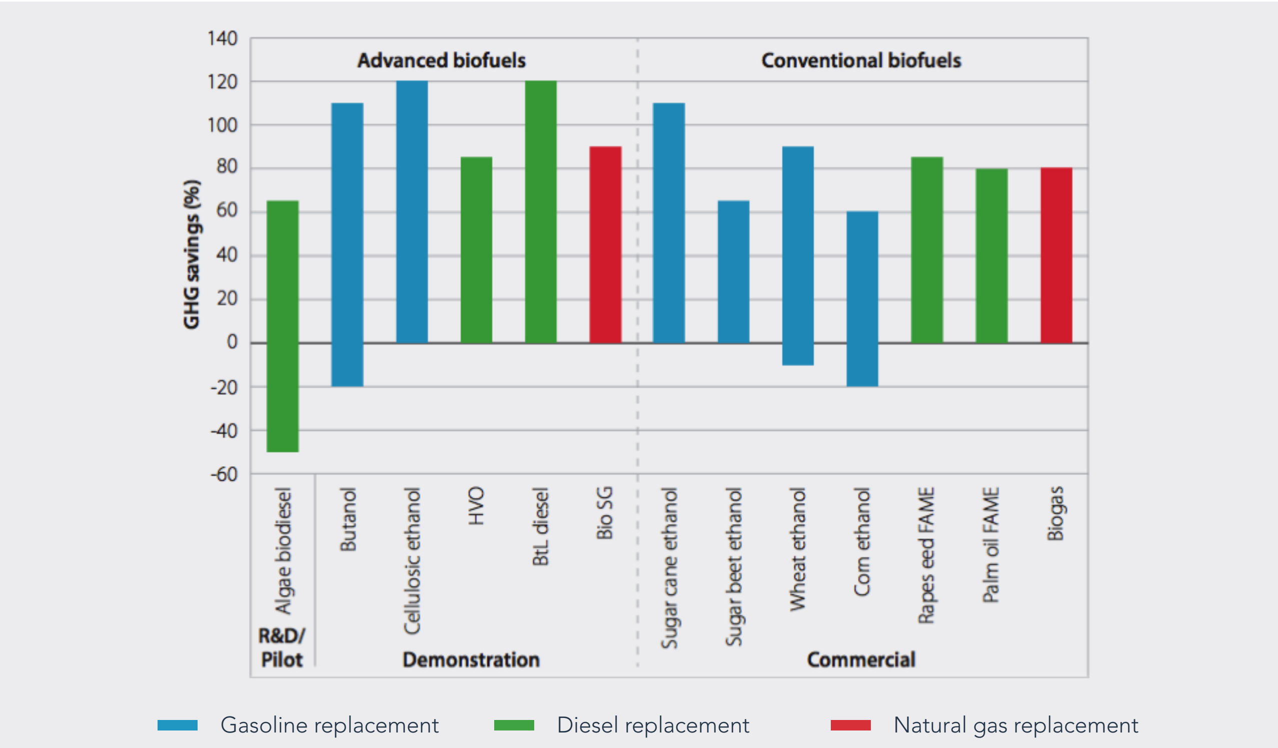
As biofuels become more commonplace they will attract increasing attention from consumers and environmental groups, increasing social and policy risk. Biofuel production that competes with food production will be at particular risk. While higher prices for sugar, grains and other biofuel feedstocks may be good news for farmers, it has led to a backlash against biofuels on the basis of food security concerns. As witnessed by the Arab Spring of 2012, rising food prices can lead to intense political instability, particularly in poorer countries with high unemployment.

Biofuel production that results in the clearing of land with high biodiversity value and biofuels with relatively high lifecycle emissions will also be particularly exposed. Consumer backlash and social pressure are likely to result in increasingly stringent legislation and sustainability criteria. This could impact the entire supply chain regardless of where the legislation is implemented. For example, EU legislation could impact biofuels produced overseas if it is eventually consumed in the EU.

Footnote:

[150] Bringezu, S et al (2009), 'Towards Sustainable Production and Use of Resources: assessing biofuels', UNEP report.

Figure 48: Range of GHG savings of different biofuel chains compared to fossil fuel



Source: OECD/IEA 2011 (in Committee on Climate Change Bioenergy Review: 27) Note: Excludes land use change emissions.

What kind of assets are at risk?

The assets most at risk are those linked to biofuel production that have poor lifecycle emissions or other detrimental environmental effects such as biodiversity loss. Physical assets linked to the production of fuels with lifecycle emissions at the higher end of this range are particularly vulnerable.

Human and social assets which support the biofuel sector will also be vulnerable – for example, the research and development investments in specific biofuel technologies. As the biofuel market is policy dependent and characterised by path dependency, different countries are likely to champion different feedstock technologies. As the biofuel market matures and opens up to trade, such protected technological regimes may come under pressure. This may result in a relatively rapid switch from one technology to another, if a clearly superior alternative emerges.

Figure 49: Assets exposed to changes in biofuel regulation

Financial assets are less vulnerable to asset stranding, as they are characterised by relatively high liquidity when compared say to fixed assets such as plant and equipment. For instance, it should be easier to sell shares in a first-generation biofuel company and move the proceeds into shares in a second-generation biofuel company, than it is to for the company that manages the physical assets of the first-generation processing facility to sell a distilling plant.

Natural assets such as land and water are least vulnerable to stranding as a result of biofuel regulation, as they are likely to be able to be put to alternative uses in the event of a significant biofuel policy change.

Barriers to biofuel diffusion also exist due to problems of supply logistics, warranties on motors as well as liability issues regarding compatibility with different engine technologies and number of flex-fuel vehicles on the road.

Where is the risk concentrated?

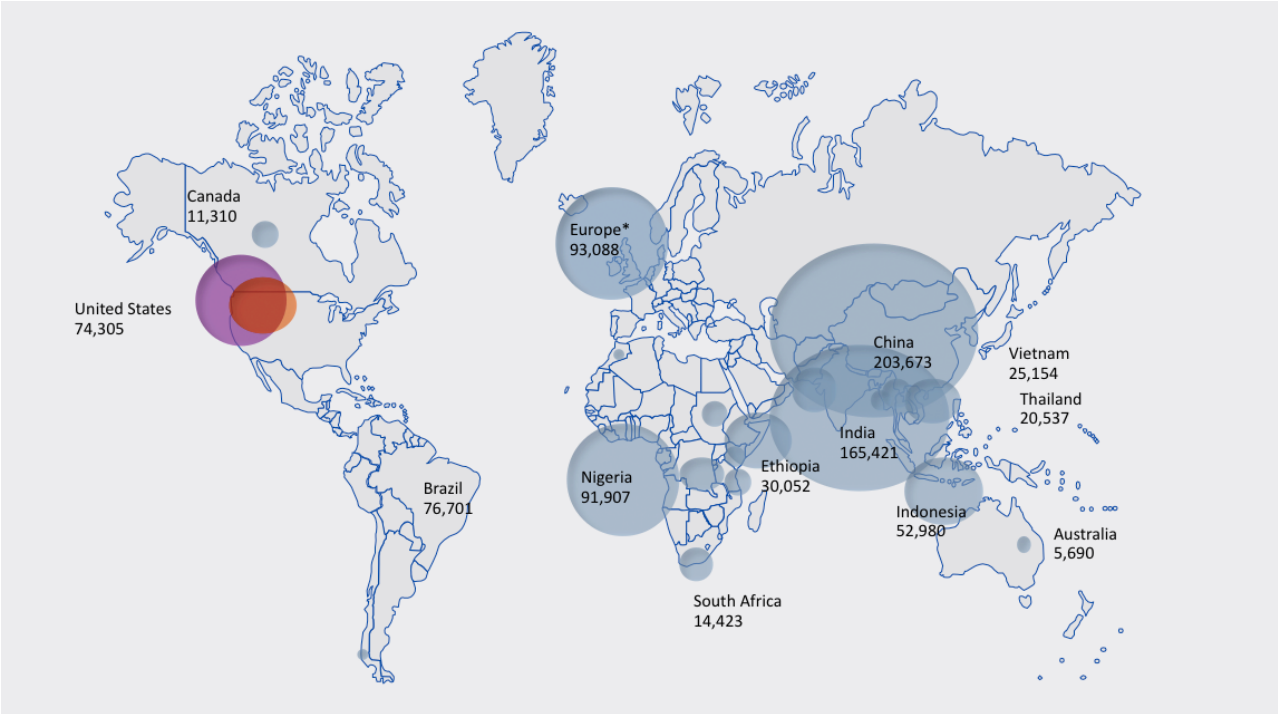
With a global production share of about 50 percent in 2011, and driven by the enactment of the Energy Independence and Security Act of 2007 [151] the United States is currently the world's biggest ethanol producer. This is supported by regulation requiring the blending of ethanol into regular gasoline of up to 15 percent expressed in volume for cars built after 2000. Brazil is the world's second largest ethanol producer, with around 30 billion litres currently produced and consumed and set to grow strongly in production, consumption and exports.[152]

Footnotes:

[151] Public Law (2007: 110–140): www.gpo.gov/fdsys/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf

[152] OECD/FAO (2012:94)

Figure 50: Key biofuel producing countries (kilotonnes of oil equivalent, 2009)



Source: IEA (in FAO 2012 Statistical Yearbook: 316-317)

Unlike the ethanol industry, the global biodiesel industry is less geographically concentrated. The EU is the world's leading biodiesel producer accounting for around 7 billion litres, or 53 percent of 2010 global production. The United States, Malaysia, Indonesia, Thailand, and Brazil as well as a number of other developing countries, make up the remainder. Driven by policy targets, booming private and public investment and increased market adoption, the biodiesel market is expected by some industry analysts to grow around 85 percent annually to reach around 42 billion litres by 2020.[153]

Driven by the imperatives of energy security, increasing domestic employment and value added, several developing countries have also emerged in recent years as significant biofuel producing countries. As potentially important suppliers to international markets, such countries will be exposed to policy decisions regarding biofuel standards taken in import-oriented markets. The United States, Europe, Brazil, India and China have all set mandatory targets for the use of liquid transport fuel.

Footnote:

[153] Global AgInvesting (2012), Global Biofuels, HighQuest Partners, Danvers, MA.

Box 15: Biofuel markets in Europe

In Europe, legislation requires that renewable fuels should increase to 10 percent of total transport fuel use by 2020, however, it also allows for substitution with other renewable sources including electric cars.[154]

The EU is expected to be a major player with total biodiesel use reaching around 24 billion litres by 2019. The world biodiesel price is projected to increase up to 2015 and then to plateau at around USD 144 per hl as second-generation biofuels become available in the EU towards 2019. Biomass second-generation ethanol and biodiesel are only expected to take-off during the next ten years, reaching 7 percent and 9 percent of global production by 2019 respectively.[155] It is expected that much of the increased demand for biofuels will be met by producers outside the European Union, from countries with more favourable growing conditions, such as Brazil.[156]

What are the consequences and responses?

Policy and technological evolution in the biofuels sector is likely to induce a material transition from the first generation of biofuels based on agricultural crops to more advanced biofuels. These include biofuels produced from lignocellulosic biomass, waste material, or other non-food feedstocks and other advanced biofuels such as biobutanol. This may lead to some stranding of the first-generation biofuel technologies.

As discussed, falling crude oil prices would also reduce demand for biofuels. The OECD/FAO suggest a 25 percent fall in the oil price would lead to a 12 percent fall in the world demand for ethanol and a 5 percent fall in biofuel prices. This could lead to asset stranding for producers of higher cost biofuels and have broader consequences along the biofuel supply chain.

In its Agricultural Outlook, the OECD projects world production of ethanol and biodiesel will both increase by 5 percent each year over the next ten years. Despite the developments in second-generation feedstock (i.e. woody crops, agricultural residues or waste), the share of total production of key food crops used for biofuel production is expected to continue to increase each year to 2021: sugarcane by 8 percent, corn by 1.5 percent and vegetable oil by 4.4 percent a year.

Although biofuels are predominately produced in food exporting countries, several low income, food and energy importing countries are also investing in biofuel production facilities.

One of the key immediate uncertainties facing biofuel markets will be the policy choices facing the United States Environmental Protection Agency with regard to meeting an expected shortfall in its cellulosic mandate. This will have material implications in terms of US ethanol production and consumption patterns and for biofuel feedstock supplies, especially coarse grains and sugarcane. Spillover effects into other agricultural commodities and price rises are likely if the mandate is met.

Footnotes:

[154] www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:en:pdf

[155] OECD/FAO (2010) *Agricultural Outlook 2010-2019 – highlights*, OECD Publishing, Paris.

[156] Edwards, R, Mulligan, D and Marelli, L (2010), 'Indirect Land Use Change from Increased Biofuels Demand: comparison of models and results for marginal biofuels production from different feedstocks', JRC Scientific and Technical Reports, EUR 24485.

An important response could be the emergence of a two-way trade in ethanol between the United States and Brazil, as Brazil is the only country likely to be able to adapt to and meet US demand. This is due to the nature of its ethanol production based on sugarcane, its flexibility to switch between ethanol and sugar production, and the rising demand for ethanol for flex-fuel vehicles in Brazil.

Box 16: Transition tensions within the biofuel sector[157]

A coalition of food multinationals and environment and development non-governmental organisations formed to press politicians to end the use of biofuels made from food crops. The group, which includes Unilever, Nestlé, Action Aid, Oxfam and WWF, urged the UK to use its presidency of the G8 major economies, to support a European Commission proposal to impose a 5 percent cap on the use of agricultural biofuels in the EU's overall consumption of transport fuel. The group's position was driven by their concern that biofuels sourced from food-feedstocks are putting upward pressure on agricultural commodity and food prices.

The EU Renewable Energy Directive has set a target to source 10 percent of all transport fuel from renewable sources by 2020, much of which is expected to come from biofuels. As well as the 5 percent cap, the European Commission's proposals released in October 2012, include environmental reporting obligations to account for carbon sinks destroyed by farmland expansion, and the promotion of second generation non-food biofuels.

If bioenergy feedstocks fail to meet sustainability criteria they will not count towards the Renewable Energy Directive target or be eligible for EU subsidies and therefore will not be financially viable.

The Commission's proposals have provoked an angry response from European biofuel producers. For example, the UK's Renewable Energy Association said it 'would mean the destruction of thousands of jobs, see millions of pounds of investment squandered and increase the costs of meeting renewable energy targets.'

Markers for future work

To avoid stranded asset risk in this sector there needs to be a close appreciation of the risks surrounding first and second-generation biofuels.

There are currently quite bullish projections associated with first-generation biofuel use based on the assumption that agricultural commodities will continue to be the source of most feedstocks for ethanol and biodiesel throughout the next decade. Such projections also assume that the technical and economic constraints that currently limit the production and marketing of second-generation biofuels will remain prohibitive.

Footnote:

[157] Bowman, A (2013), 'Unilever and Nestlé join charities to call for biofuel curbs', *Financial Times*, June 6.

These assumptions were brought into question in 2008-09 when many operators of first-generation biofuel plants mothballed or sold their plants for only a fraction of their book value.[158] Many countries are active in research into second generation biofuels and, although prospects for success remain uncertain, it is quite possible that the first commercial production plants for second-generation biofuels could become operational soon. This would significantly change the relationship between biofuel production and agricultural markets, especially with regard to the extent that feedstocks for these fuels would come from either cres or energy crops grown on land not suitable for food production.

Other uncertainties relate to future developments in the markets for fossil energy and agriculture. Feedstock prices represent a large share of total biofuel production costs and have a significant impact on the economic viability of the sector. Should prices for crops fall markedly then biofuels will become commensurately more competitive.

Most attention has been focused on biofuel policy in the United States, the European Union and Brazil, however, as can be seen in *Figure 50* on page 95, China, India, Indonesia and Nigeria are all major producers of biofuels. More attention could therefore be given to understanding the dynamics of biofuel investment and policy in these countries.

Another area of interest for investors and commodity traders as international markets for biofuels open up will be industries which support the trading of biofuels, such as transportation providers.

The regulation and diffusion of biotechnology

Why is biotechnology a potential driver of asset stranding?

One of the most profound transitions in agriculture over the last 50 years has been the boosting of crop yields due to the application of biotechnology and improved chemical herbicides.

According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA), from 1996 to 2011, transgenic crops added USD 98.2 billion to the value of global agricultural output. In 2012, for the first time, developing countries produced nearly USD 1 billion more transgenic crops than their industrial country counterparts. The application of such technologies has helped boost productivity and incomes for nearly 15 million farmers. ISAAA estimates that this has also saved nearly 473 million kg of active pesticide ingredients. It is also suggested that this has contributed to a reduction of about 23 billion kg of carbon dioxide, the equivalent of taking 10.2 million cars off the roads. Without transgenic crops the world would have needed another 108.7 million hectares of land for the same level of output.[159]

Footnotes:

[158] Global AgInvesting (2012), *Global Biofuels*, HighQuest Partners, Danvers, MA.

[159] Juma, C (2013), 'A Plea for Agricultural Innovation', Honorary degree acceptance speech, McGill University, Montreal, Canada, June 3.

However, as is often the case with technological change, these gains have not been made without introducing new risks to the agricultural supply chain.

For example, while genetically modified organisms (GMOs) have been shown to have potential positive production effects, several related environmental risks have also been identified:[160]

- Creating new or more vigorous pests and pathogens;
- Exacerbating the effects of existing pests through hybridisation with related transgenic organisms;
- Harm to non-target species, such as soil organisms, non-pest insects, birds and other animals;
- Disruption of biotic communities, including agro-ecosystems;
- Irreparable loss or changes in species diversity or genetic diversity within species.

It has been suggested that while production has increased as a result of the applications of GMOs, the variability of production may have also increased due to such factors.[161] In addition, research has pointed towards the relatively short-term assessment of biotechnology risk, which may have mischaracterised the long-term economic consequences of environmental uncertainties associated with GMOs.[162] Other research has also pointed to where direct liability can occur in cases of 'accidental' or 'unintentional' releases of GMOs that were not intended for human consumption or commercial planting.[163]

These gains have not been made without introducing new risks to the agricultural supply chain.

These concerns have led some countries to take a precautionary approach and ban GMO technologies. Farmers who have invested in GMO technology and adopted it into their production systems, therefore, may face restricted markets, which limits demand for their production and the prices they can receive. This could drive a reduction in the capital value of their operations.

Footnotes:

[160] Snow, A et al (2005), 'Genetically Modified Organisms and the Environment: current status and recommendations', *Ecological Applications*, 5(2):377-404.

[161] Carew, R and Smith, E (2006), 'Assessing the Contribution of Genetic Enhancements and Fertiliser Application Regimes on Canola yield and Production risk in Manitoba', *Canadian Journal of Agricultural Economics*, 54:215-226.

[162] Aslaksen, I, Natvig, B and Nordal, I (2006), 'Environmental Risk and the Precautionary Principle: "Late lessons from early warnings" applied to genetically modified plants', *Journal of Risk Research*, 9:205-224.

[163] Clapp, J (2008), 'Illegal GMO Releases and Corporate Responsibility: questioning the effectiveness of voluntary measures', *Ecological Economics*, 66:348-358.

Box 17: GMO tensions in Europe

Genetically modified crops were first grown commercially in 1996 and covered around 170 million hectares of the world's farmland in 2012, mostly in the United States, Brazil and Argentina – although, taken together, developing countries grew 52 percent of GMO crops.[164] Less than 0.1 percent of GMO cropland can be found in Europe due to the lack of a supportive regulatory and political climate. The most important 'traits' introduced through genetic modification are herbicide tolerance, which enables the farmer to spray a weed killer without affecting the crop and insect resistance. The four main commercial GM crops are maize, cotton, soyabeans and oilseed rape.

The next big GM development is likely to be the introduction of genes that protect crops against environmental stress such as drought, flooding and frost, with the first drought tolerant maize almost ready for launch in the United States. According to Clive Cookson, writing in the *Financial Times*, blight resistant GM potatoes could be developed soon for the European market, if the regulatory environment changed.

Agricultural biotechnology companies are doing little research, leaving it to universities and governments to fund the basic plant science on which research depends. For example, at Rothamsted Research in Hertfordshire scientists are working in conjunction with Leeds University on cereal crops that fix nitrogen from the air, as peas and beans can, as a substitute for applying chemical fertilisers. Last year anti-GM activists threatened to destroy experimental crops at the institute, but it survived behind strengthened security fencing.

What kind of assets are at risk?

The most vulnerable assets at risk from the regulation and diffusion of biotechnology are the intellectual property, R&D expertise and on-farm management experience that is associated with these new technologies. Shifting regulatory or public attitudes towards GMOs could mean that such assets are left with smaller markets than originally anticipated. Farmland assets that have adopted the use of biotechnology are also highly vulnerable to such shifts in regulation and sentiment. Once a farmer has taken a decision to adopt a GM crop, it may be difficult to revert to non-GM production methods. This may be compounded by the problem of 'super' insects and weeds that have had to evolve to adapt to the GM methods. This raises the issue of biotechnologists starting an 'arms race' against nature.

Shifting regulatory or public attitudes towards GMOs could mean that such assets are left with smaller markets than originally anticipated.

Footnote:

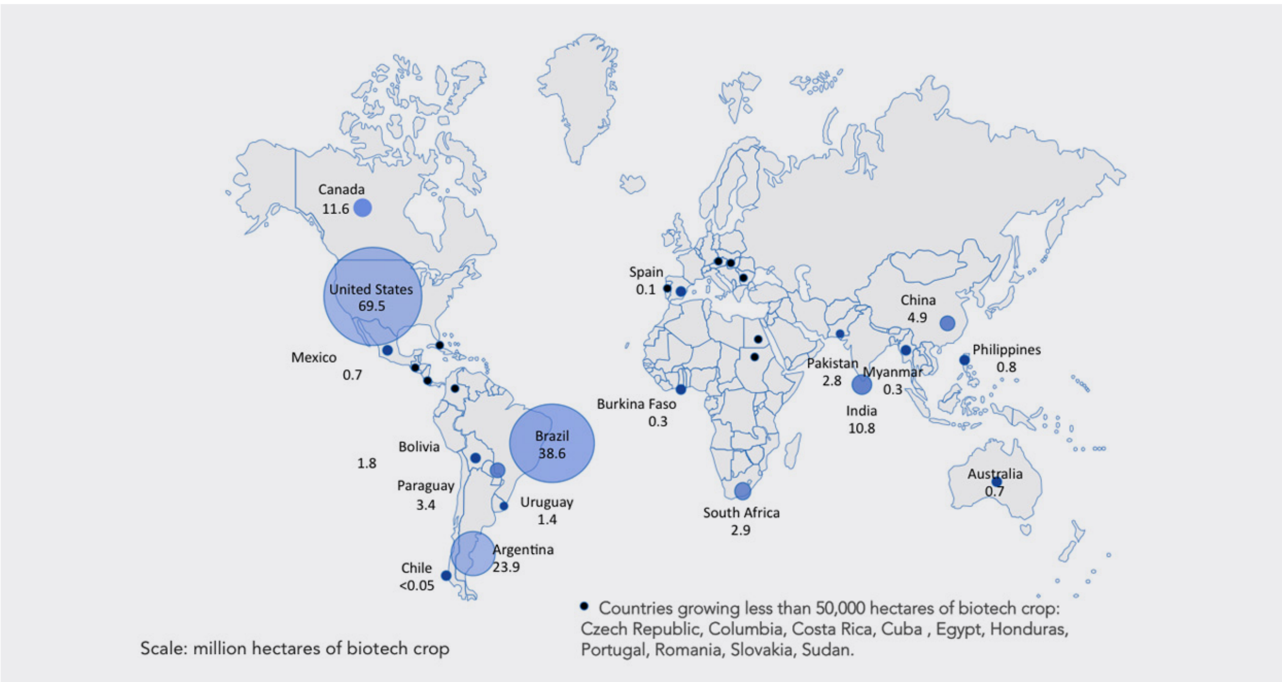
[164] The International Service for the Acquisition of Agri-biotech Applications (2012) Brief 44: 'Global Status of Commercialized Biotech/GM Crops 2012': http://www.isaaa.org/resources/publications/briefs/44/default.asp

Figure 51: Assets exposed to asset stranding risk from the regulation and diffusion of GMOs

Where is the risk concentrated?

The map below highlights the main producers of biotech and GMO crops in 2012. The main biofuel crops include: maize, cotton, soybean, sugarbeet and oilseed rape.

Figure 52: Global Status of Commercialised Biotech/GM Crops: 2012



Source: International Service for the Acquisition of Agri-biotech Applications

What are the consequences and responses?

The consequences of biotechnology risk for investors in the agricultural supply chain are that agricultural commodities are likely to remain differentiated in some markets such as Europe and parts of Africa. This may mean that such differential acts to restrict supply to some markets. This is driven by regulatory standards adopting a precautionary approach to allowing the release of some varieties of GM crops.

Another consequence is that biotechnology firms are less likely to invest in human capital formation in markets such as in Europe, which have adopted a more precautionary approach than elsewhere.

Global anti-GM food campaigns have also targeted developing countries to restrict the adoption or consumption of GM crops, even in the form of food aid. Consumers International has played an important role in this process. For example, in the drought of 2002, Zambia rejected GM crops of any kind, while Zimbabwe, Malawi and Mozambique refused any GM food aid unless it was already milled.[165]

Markers for future work

With rising populations, incomes and intensifying environmental stresses, the application of yield enhancing technologies to boost agricultural output in a sustainable way will be central to meeting the production challenges of the next 50 years. Biotechnology can play a vital role in this transformation.

However, as with most technological innovations, there will be new risks that are introduced to society as a result of the adoption of new technologies – as we make our crops more resilient to insects and weeds, the natural process of evolution is likely to produce stronger pests and weeds – what some have characterised as an arms race between man and nature. If these new 'super' weeds and pests move into production zones without the GM technology they could have much greater impact than their cousins which have not had to adapt to the GM world.

Strong governance and evidence-based decision-making will be required to ensure that the benefits of biotechnology can be captured while minimising the downside risks. For those looking to better understand and mitigate these risks, the issues associated with the regulation and diffusion of GMOs could be built into environmental risk assessments and due diligence procedures at the investment level.

Footnote:

[165] http://www.unep.org/dewa/Africa/publications/AEO-2/content/154.htm

The greenhouse gas regulation of agriculture

Why is greenhouse gas regulation a potential driver of asset stranding in agriculture?

The regulation of greenhouse gas emissions can be thought of intersecting with the agricultural sector in three main domains.[166]

- **The direct emissions of agricultural enterprise and food systems.** Direct emissions from agriculture arise from sources such as the release of nitrous oxide from using fertilisers in soils; methane released in rice cultivation; and the release of methane from enteric fermentation or digestion processes of livestock and from manure management. These non-CO_2 agricultural emissions are about 6,100 million metric tonnes of carbon dioxide equivalent ($MtCO_2e$) a year – about 11 percent of total global greenhouse gas emissions. The food chain, excluding agriculture, contributes 14 to 20 percent of food-related emissions and, at most, 5 percent of global emissions – 9,800 to 16,900 $MtCO_2e$ at 2008 levels a year.
- **Deforestation (or indirect) emissions** arise from land use change as a result of the conversion of forests to farmland, typically for grazing. Deforestation and such land use change account for 2,200 to 6,600 million metric tonnes of carbon dioxide equivalent ($MtCO_2e$) a year, or 30 to 50 percent of agricultural emissions and about 4 to 14 percent of global emissions;[167]
- **The mitigation potential of agriculture.** The mitigation potential of a suite of agricultural practices that reduce emissions associated with farming and increased carbon storage is estimated to be 1,500 to 1,600 million tonnes of carbon dioxide equivalent ($MtCO_2e$) a year at a carbon price of USD 20 per tCO_2e. The mitigation potential through land use change is estimated to be a further 1,550 $MtCO_2e$ a year.[168]

Thus the regulation of greenhouse gasses has the potential both to add to costs, through the application of a 'carbon' price or some other regulation, and also an opportunity for the potential sale of emissions credits, as there are also significant, low-cost mitigation options in the sector.

The greenhouse gas regulation of agriculture therefore may lead to asset stranding where increased costs lower the competitiveness of cropping or livestock below a critical threshold.

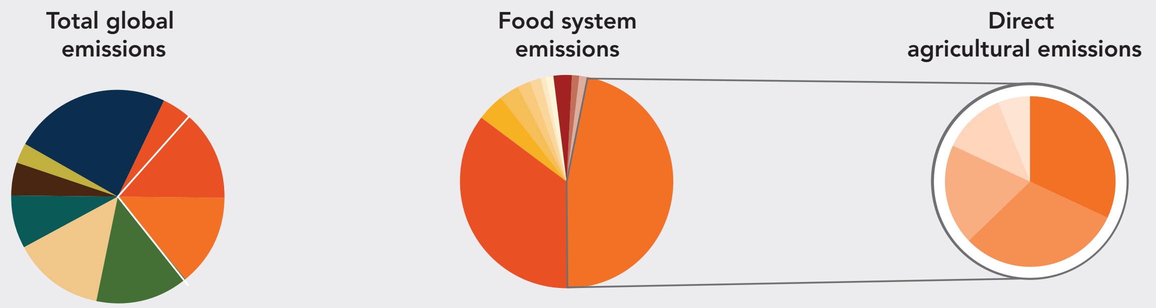
Footnotes:

[166] The data in this section is taken from the Research Programme on Climate Change, Agriculture and Food Security (CCAFS) of the Consultative Group on International Agricultural Research (CGIAR): http://ccafs.cgiar.org/bigfacts/global-agriculture-emissions/

[167] Vermeulen, S, Campbell, B and Ingram, J (2012), 'Climate Change and Food Systems', *Annual Review of Environment and Resources* 37:195–222.

[168] Smith P et al (2008), 'Greenhouse Gas Mitigation in Agriculture', *Philosophical Transactions of the Royal Society* B363:789-813: http://rstb.royalsocietypublishing.org/content/363/1492/789.full

Figure 53: Breakdown of agricultural emissions



- 24% Power
- 18% Land use change*
- 14% Agriculture
- 14% Industry
- 14% Transport
- 8% Buildings
- 5% Other energy related
- 3% Waste

* Approximately 75% of emissions from land use change are attributed to agriculture

PREPRODUCTION
- 3% Fertilizer manufacture
- 0.6% Pesticide production
- 0.5% Energy use in animal feed production

PRODUCTION
- 48.5% Direct emissions
- 35% Indirect emissions (deforestation)

POSTPRODUCTION
- 4% Refrigeration
- 3% Storage, packaging and transport
- 2% Retail activities
- 1.5% Primary and secondary production
- 1.3% Catering and domestic food
- 0.6% Waste disposal

- 32% Agricultural soils
- 31% Enteric fermentation
- 19% Other emissions
- 12% Rice cultivation
- 6% Manure management

Data from Vermeulen et al (2012); US-EPA (2011); and (Stern 2006)[169]

Footnote:
[169] http://ccafs.cgiar.org/bigfacts/global-agriculture-emissions/

What kind of assets are at risk?

The greenhouse gas regulation of agriculture is likely to have the largest impact on physical assets in parts of the agricultural food chain associated with such emissions. This will centre on the clearing of extant primary or secondary forest, emissions from livestock, as in cattle ranching, and the use of nitrogen emitting fertilisers in cropping.

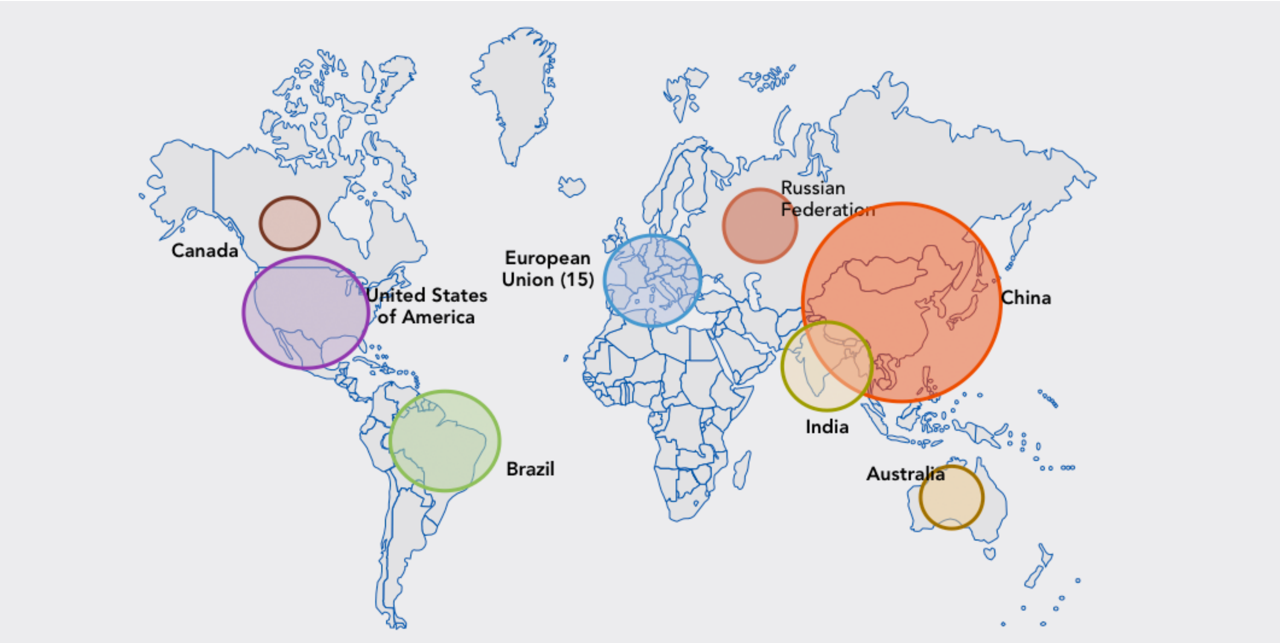
Figure 54: Exposure to asset stranding risk from the green house gas regulation of agriculture

Where is the risk concentrated?

Risk will be concentrated in countries that are considering strong greenhouse gas regulations – and in countries with fast growing agricultural sectors such as Brazil and China.

> *Greenhouse gas regulation of agriculture is likely to have the largest impact on physical assets in parts of the agricultural food chain associated with such emissions.*

Figure 55: Geographical distribution of main agricultural greenhouse gas emissions



Source: UNFCC Database

What are the consequences and responses?

The consequences of greenhouse gas regulation on agriculture are likely to be a shift towards production techniques that manage and control these gases, which could strand assets that are carbon intensive. This will come at a cost for some agricultural enterprises, but will benefit others which are in a position to supply carbon credits for reducing their emissions. However, some of these gains may be dependent on access to an emissions trading scheme and strong emission caps which support a carbon price.

Markers for future work

Many farms can be significant sources of emissions reductions through land use change and reforestation, alternative management practices to applying fertilisers, tilling the land, feeding livestock, and using and producing biofuels.

This presents farmers with a variety of options for engaging with the policy process when it comes to securing new revenue streams for environmental protection. This has particular significance for policy makers in Europe and the United States where the government is still very much in the business of providing environmentally, socially and economically damaging production subsidies. This can help maintain regional development goals, while allowing advances to be made in bilateral and multilateral trade agreements – which are so vital to efficient resource allocation and the productivity of natural capital.

Conclusions

This report has gathered together data on current investment patterns in agriculture and how environment-related risks could result in stranded assets across the agricultural supply chain.

The report has provide an introduction to these risks so as to help inform investors and businesses working in the agricultural supply chain, as well as policy makers and governments who are concerned with the stability and environmental sustainability of the agricultural sector and its contribution to the wider economy. Our aim has been to investigate the issue of stranded assets and the environmental risks involved with agriculture, and set a framework for further in-depth studies in certain sectors and geographies.

There are three main conclusions that are emphasised throughout this report.

First, environment-related risk factors are material and can strand assets throughout the agricultural supply chain. The amount of value potentially at risk globally is significant.

The financial crisis has highlighted how the relationship between the owners of an asset and the actual physical asset can become disconnected in the chase for increasing financial returns. It also highlighted how investments which can be viewed as completely rational within one set of analytical and institutional structures can nevertheless be completely irrational outside those structures. The orthodoxy of not valuing environmental externalities is one such set structure that is coming under increasing pressure for change.

> *Those assets characterised with high fixed or sunk costs will be particularly vulnerable.*

As the unsustainable extraction of environmental capital is increasingly recognised, either explicitly through regulation, or implicitly through breakdown in ecosystem services, assets with the greatest exposure will face increasing risks. Those assets characterised with high fixed or sunk costs will be particularly vulnerable.

Second, the potential challenge of stranded assets in agriculture is currently being exacerbated by an ongoing agricultural boom, which is feeding off high commodity prices and poor investment returns elsewhere in the economy to push farmland values to record highs in many markets.

Over the last decade, the value of agricultural land has risen dramatically, commensurate with other periods of boom and bust.[170] For example, the Savills index of average global farmland values has risen by over 400 percent in the last ten years. At the most extreme end of the spectrum, farmland values in Romania have risen 1,817 percent in the last five years alone, in Brazil farmland values rose by around 550 percent, in Australia by 300 percent, in New Zealand by 262 percent, and in the United States by 75 percent.

> *Potential challenge of stranded assets in agriculture is currently being exacerbated by an ongoing agricultural boom.*

Footnote:

[170] http://www.aei.org/outlook/economics/financial-services/a-bubble-to-remember-and-anticipate/

Many analysts and experts have been reluctant to declare a bubble, citing high commodity prices driven by fundamentals such as strong demand from the rising populations and incomes in developing countries. However, it is also possible that commodity prices will lower, that interest rates will rise and land prices will fall, as they have after similar periods of such growth in the past.

Third, understanding environment-related risks that can induce asset stranding can help investors, businesses and policy makers to develop effective risk-management strategies, which can improve resilience and minimise value at risk.

Businesses, investor and governments are increasingly facing complex risks, embedded in local markets, but with global consequences. This report has looked to shed light on the likelihood, interconnections and impact of significant environmental agricultural risks. Many of these have knock-on effects farther up the supply chain and elsewhere in the economy. For example, the Arab Spring has demonstrated how water supply constraints in North Africa, coupled with extreme weather in Russia can affect food security and prices and contribute to governmental collapse and broader geopolitical tension.

Risks are interconnected, and while you cannot prevent or forecast when many risky events may occur, it is possible to plan for them.

STRANDED
ASSETS
PROGRAMME

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