

SESSIONAL PAPER

Biodiversity & justice

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Abstract

This paper highlights how actuarial thinking could contribute to the development of a justice perspective relating to biodiversity risks and also the implications for actuarial work. The impact of biodiversity loss as well as the use of ecosystem services is not equally distributed across society (both intra and inter generationally). The Biodiversity and Natural Capital Risk Working Party has been setup to proactively take forward a series of activities including think pieces, webinars and external engagement on these risks.

Keywords: Biodiversity; Justice; Fairness

1. Introduction

The purpose of this paper is to introduce and inform actuaries about the concept of justice in relation to decisions that impact on biodiversity and natural resources. To do this we highlight case studies in forestry, fishing, water and farming ecosystems where biodiversity and justice overlap. This is not exhaustive but is intended to serve as a discussion point to explore the issues in greater detail. We note that these cases have led to positive impacts on certain social groups and negative impacts on other social groups. Finally, we draw out key issues from the case studies that are relevant for actuarial work, and we recommend some next steps.

Human interaction with the natural world is leading to a global loss of biodiversity (IPBES, 2019a) at a scale comparable to mass extinction events. This loss is endangering the prosperity and well-being of current and future generations, as measured by the United Nations Sustainability Development Goals (the UN SDGs). To address this loss, we must recognise that our economies and way of life are embedded within nature; they are not external to it (HM Treasury, 2021). Nature must therefore be viewed as a participant in decisions regarding its use, and the sustainable use of natural resources must be incorporated into how we measure economic success alongside wider outcomes. Indeed, we could consider achieving the UN SDGs as a widely accepted standard for minimal global justice.

Whilst the risk associated with biodiversity loss is difficult to quantify (HM Treasury, 2021) it will have a significant impact on the finance sector, and therefore actuaries have a professional duty to consider this risk as part of their work (Jones *et al.*, 2020). As actuaries also have an ethical duty (see for example, Principle 5 – Speaking Up of The Actuaries Code), including a need to consider what may be morally right (Miller, 2017), the issue of justice within the context of biodiversity needs to be considered.

Intergenerational fairness relating to climate change has been explored by actuaries (IFoA, 2017) and similar considerations apply to biodiversity risk. For example, our choice of discount rates could be structured to recognise biodiversity risk in a way that maintains intergenerational fairness. Any quantification of biodiversity risk in the long term is subjective, as it relies on our

views of future pathways, as well as an understanding of very complex systems and their interactions.

However, even when we explore fairness within a shorter timescale, quantification of justice issues can still be subjective as it depends on the, potentially, vastly differing views of those affected (Kenter *et al.*, 2016; Spangenberg & Settele, 2016). Care needs to be taken when incorporating such values into decision-making processes, given the differing ethical, economic, cultural and social considerations of those involved, who may all see their position as justifiable. These considerations include:

- People attributing a different monetary valuation to the same ecosystem. For example, the value of a specific tree to someone who sits under it to read every weekend is likely to be higher than to someone who has never visited that particular site.
- People attributing different types of value (for example, cultural or physical) to the same ecosystem. For example, the significance and the “sacredness” (HM Treasury, 2021) of a particular landscape will be different to people who have lived on that land for generations as compared to a company wishing to extract resources from it.
- In cases where the ownership of land is contested then it may not be clear who the stakeholders are that should be part of the valuation process (Kenner, 2014).

Justice is defined in many different ways (Martin *et al.*, 2013; Miller, 2017) and is often dependent on local social expectations and existing power structures. Justice is also highly influenced by an individual’s political ideology (for example, the weight that one puts on the value of equality in terms of outcomes or opportunities (Steinmetz, 2019). However, bearing in mind the actuarial approach to fairness, that traditionally focuses on recognising the financial claims of different stakeholders, we propose to take the approach outlined by Boelens *et al.* (2018), which requires the following concepts to be considered to achieve a just outcome.

- “recognition” – inequality and discrimination must be recognised and considered;
- “participation”- all those affected must be involved in the decision-making process (Paloniemi *et al.*, 2015);
- “distribution” – resources must be allocated as fairly as possible; and
- “socio-ecological” justice – nature must be considered as a participant. (Shoreman-Ouimet & Kopnina, 2015).

This requires us to allow space for “the embeddedness of particular ideals of justice, and the way these get constituted through social practices” which means we “must understand how diverse people see and define justice within a specific context, history and time” (Boelens *et al.*, 2018). We do not aim to assess the justice of an outcome by measuring an overall level of well-being which is then maximised – rather we incorporate all aspects of justice and approach decision-making taking into account all the inherent complexity.

Actuaries are problem solvers and strategic thinkers who advise on the equitable allocation of resources, albeit traditionally in a financial setting. Actuaries already work with frameworks that bring fairness into decision-making, such as Treating Customers Fairly (“TCF”) and Principles and Practices of Financial Management (“PPFM”). The actuarial profession is viewed as being impartial and competent whilst acting with integrity. Therefore, in a similar way to existing actuarial practices, actuaries can help develop frameworks to categorise risks and calculate values for the monetisation of nature that can be agreed upon by stakeholders with different interests. Justice must be brought into considerations regarding the use of natural resources and biodiversity loss to recognise these different interests.

2. Case Study – Rainforests

The largest area of forest in the world is the Amazon Rainforest which spans over nine countries in South America, the greatest proportion of the Amazon being found in Brazil. It is a “hotspot” of genetic diversity, which is key to medicinal bioprospecting and carbon sequestration, and plays a fundamental function in temperature, humidity and rain pattern regulation (Muller, 2020). Over recent decades the rainforest has been rapidly destroyed so that the land can be used for economic activities such as agriculture and mining. Scientists fear that the mix of deforestation and climate change is pushing us closer to a “tipping point” where much of the Amazon will turn into savannah (Lovejoy & Nobre, 2018).

Brazil is still considered a developing country and its economy is driven by primary industries needing large areas of land. With the Amazon Rainforest making up over half of Brazil’s land cover, there is a balance to be struck between economic growth and forest protection. The following case studies provide examples of where the recognition and participatory concepts of justice could be applied.

The Imposto sobre Circulação de Mercadorias e Serviços (ICMS) in Brazil is a state level tax on goods, transportation and communication services. The system requires that 25% of the revenue raised by the ICMS be allocated by the state government to the counties, with the remaining 75% allocated according to the value-added-tax generated by each county (Grieg-Gran, 2000). The Forest Law, first introduced in 1965, requires landowners to set aside a portion of their land as protected native forest. In combination with the ICMS this meant that some municipalities were losing out since land restrictions were limiting their ability to generate value-added-tax, thereby reducing their allocation of ICMS funds. In 1991 the state of Paraná introduced the ICMS Ecologica, an additional criterion for the allocation of funds from the ICMS which meant that 5% of the state’s ICMS revenue would be distributed to areas with protected land or public water supply (Bassani, 2015). It was hoped that the new criterion would compensate counties subject to land use restrictions which could incentivise counties to set more land aside for protection, or improve the management of existing protected areas (Grieg-Gran, 2000).

Evidence that the ICMS Ecologica has been effective in inducing the creation of conservation units includes the example of Paraná which in 2011 had 206 Private Reserves of Natural Heritage at state level; this was an increase of nearly 25% over the prior 5 years. By comparison, conservation areas on federal lands fell by 12% (Silva Junior *et al.*, 2019). However, other states such as Pernambuco have been less successful with a study by Silva Junior *et al.* (2010) concluding that there were no changes in the behaviour of municipalities following implementation of the policy. This was deemed to be because the policy had lost focus and efficiency in the way it was structured and implemented. This resulted in those municipalities maintaining protected areas to receive low payments, causing them to lose interest in creating new protected areas (Silva Junior *et al.*, 2019).

ICMS Ecologica has now been adopted in varying forms across 15 of the 26 Brazilian states to provide a positive incentive by rewarding municipalities who promote biodiversity conservation and sustainable land use (Bassani, 2015). From a justice standpoint, successful implementation has occurred when the costs of holding protected land were well recognised, such that payments to the municipalities equated with the opportunity cost when such units were created satisfactorily. If the amount received by municipalities is not considered sufficient compensation, the policy has been shown to lose its effectiveness (Silva Junior *et al.*, 2019).

Whilst policies like the ICMS Ecologica have had some success at a local level, it is international action which is needed to divert money away from forest risk commodities; that is commodities which directly or indirectly cause deforestation and forest degradation. Scrutiny on companies to act responsibly when it comes to commodity sourcing is increasing but is only effective if accurate information is available for consumers, investors and other stakeholders to be able to make informed decisions. Unfortunately, many companies are failing to report on deforestation risk, failing to provide transparent reports on their activities and failing to take meaningful action

to curtail damaging activities to forests. Participatory justice is pertinent here whereby those affected cannot participate in environmentally conscious decision-making when information is missing or withheld. The non-profit organisation CDP (Carbon Disclosure Project) is just one establishment which aims to tackle this information shortfall by running a global disclosure system for companies and other stakeholders to manage their environmental impacts. In 2018 CDP found that 70% of the 1,500 companies asked to disclose on four forest risk commodities (timber, palm oil, cattle and soy) did so (CDP, 2019). However, of these companies nearly a third did not include forest-related issues in their risk assessments, and of those that did, 92% saw substantial impacts from these risks (CDP, 2019). They also noted that while the number of reputational risks reported were high, it was the financial impact of reported physical risks such as forest fires that was highest (CDP, 2019). Furthermore, only 25% of downstream companies reported this physical risk versus 60% of those upstream who are in control of the land, showing that retailers and manufacturers at the lower end of the supply chain may be less aware of the potential risks (CDP, 2019). In summary, the CDP report highlights how the financial and business risks associated with deforestation are going under-reported and ignored.

The ICMS Ecologica has been shown to be a successful tool in creating a monetary incentive to protect land; however problems have stemmed from the different interpretations of the policy which have failed to create the correct monetary incentives to address the local cost of protecting forest. Whilst further work needs to be done locally it is crucial that global companies fulfil their intentions to act responsibly, with transparency and full assessments of their biodiversity risks. These case studies allude to the need for greater recognition of the inequality which can occur locally when areas are protected, as well as the need to address the information shortfall when it comes to forest risks, so that stakeholders are able to make well informed decisions.

3. Case Study – Fishing

Oceans and coastal areas are a critical source of benefits and poverty alleviation through fisheries and tourism, and of environmental benefits such as carbon sequestration and habitat protection. For centuries they were seen as an infinite source of these benefits. This is no longer the case. Overfishing is leading to a rapid decline of once abundant fish species and acceleration in the loss of ocean biodiversity. The economic and social implications of these changes have not been constant across society, as illustrated by how a collapse in fish stocks had a devastating effect on the coastal towns and villages that were reliant on them. Here we concentrate on two examples which illustrate that to achieve justice, our decision-making needs to:

- Ensure that those affected can participate in decisions regarding the use of natural resources on which their livelihoods are based; and
- Recognise the limited natural resources available, so that these can be appropriately factored into the decision-making process, which will enable a fairer distribution of these resources.

The first example describes how decisions made regarding the northern cod fisheries off the Atlantic Coast of Newfoundland, Canada affected the livelihoods of the coastal communities. In 1992, the Canadian government announced a sudden moratorium on fishing for northern cod in Newfoundland waters following a dramatic collapse in stocks. This was originally intended to be a short-term measure to allow stocks to recover but the closure largely remains in place to this day. The economic and social effect on the local fishing communities was dramatic and devastating. Around 19,000 jobs were lost in the local fishing industry and up to another 20,000 others were affected by the economic downturn, which together resulted in the largest industrial closure in Canadian history (Holly Dolan *et al.*, 2005).

The fact that there have been so many studies into the reasons for the collapse, and how we can learn from it, illustrates the challenge of balancing the management of complex ocean ecosystems with the nutritional, employment and social needs of people. It has been suggested that the collapse was inevitable due to continued increased competition for a common resource, in this case cod – an example of the tragedy of the commons (Hardin, 1968). However, this model appears to be too simplistic (Mason, 2002). The Department of Fisheries and Oceans was involved in the active regulation and management of the fisheries, so this was not an open access fishery. Furthermore, the structure of the methods used by coastal inshore fishermen meant they did not have the capacity to overfish the cod stocks (Sinclair, 1992) so management mistakes must have been made.

It is important to understand that this was not an example of decision-making in the absence of data, as scientists were modelling the fish stocks. The problem was that after foreign vessels were excluded from Canadian waters in 1977, virtual population analysis models used for projecting cod stocks proved to be too optimistic (Walters & Maguire, 1996; Shelton, 2005). These models were relied on to set initial catch quotas and to make capital investment decisions, which included the expansion of the offshore fishing fleet and the building of fish processing plants. However, even as data subsequently emerged showing lower than expected catches, particularly from local inshore fishermen, political and local community pressure resulted in higher than recommended catch quotas being set and the eventual collapse of the industry (Steele *et al.*, 1992). The result was the loss of a way of life and a social crisis for coastal communities that had relied on the fisheries for many years (Palmer & Sinclair, 1997). This did not just affect one generation for a few years as was originally anticipated; it has already impacted the next, although there is now some indication that cod stocks are finally starting to recover (DFO, 2020).

The length of time this has taken, even with a fishing moratorium, illustrates the difficulty in managing delicate marine ecosystems as the collapse in one previously abundant species resulted in changes in the ecosystem that had previously sustained it. In this case, the limitations of nature (in relation to a species of fish and its supporting ecosystem) were not sufficiently considered as an element in decision-making. As a result, economic investments were made on the basis of insufficient information, and the outcome was a loss of a natural resource and biodiversity that has already affected another under-represented participant in the decision-making process – a future generation.

The second example illustrates the impact of foreign fishing fleets on the coastal communities in West Africa. To satisfy demand from European Union (EU) consumers and the EU's measures to protect fish stocks in its own waters in accordance with its Commons Fisheries Policy, the EU entered into agreements with developing countries in West Africa to provide access for its fishing vessels. The entry of EU industrial fishing fleets with more sophisticated technology resulted in the overfishing and the depletion of fragile stocks, affecting both their target fish and non-target fish, as a result of excess by-catch (World Wildlife Fund, *n.d.*). EU fishing fleets also benefited from EU subsidies, which meant that they have been able to keep fishing, even when catches were uneconomical. Small scale local fishermen have been drawn into this competitive, industrial and largely uncontrolled market in which they struggle to compete (Brown, 2005; Pauly, 2006).

The EU may point to the price it has paid in the access agreements. However, the prices paid are market prices negotiated between signatories with unequal power. On the one hand there is the EU looking to keep its subsidised industrial fishing fleet employed and make up for the shortfall in fish supply from EU waters, and on the other hand, there is a developing country's government faced with adverse economic constraints and the need for investment and foreign exchange (Transnational Institute, 2017). As a result, the prices paid by the EU cover a fraction of the value of the fish caught by EU vessels (Orlowski, 2020) and do not reflect the potential social and economic value lost by marginalised local fishermen, who had little or no input into the agreements. More recent agreements include measures intended to sustain the region's marine ecosystems and

fishing stocks, in accordance with the updated EU Common Fisheries Policy. However, catch quotas have not been sufficiently limited and the resources needed to regulate overfishing were not provided for.

The impact on West African coastal communities has been severe. They are reliant on fish for income and as a crucial source of food, providing more than 50% of protein intake in some countries. The result has been poverty, unemployment, declining health and social stress in the local communities and forced migration of young people in the search for work (Brown, 2005; Jonsson, 2019).

4. Case Study – Water

Justice issues associated with water have a long history. Access to clean and affordable water is a basic human need and is the focus of Goal 6 within the UN SDGs. Alongside access to clean water and sanitation, Goal 6 includes access to the governance of water as well as protecting and restoring the ecosystems that rely on the water sources that we exploit.

There are many case studies that explore justice and water including the allocation of water rights to indigenous people in Australia (Nikolakis & Quentin Grafton, 2014), virtual water¹ (Rulli & D’Odorico, 2013), dams (Hommes *et al.*, 2016), or the transfer of water from rural areas into urban areas (Colloff, *et al.*, 2020). Water has often been subject to natural capital valuation techniques and monetisation, leading to governance processes being set up, including (most commonly) payment for ecosystem services. Some have been effective in reducing damage to biodiversity such as payments to local communities to improve water catchment areas (Temel *et al.*, 2018).

Here we focus on one example of biodiversity and water justice – that of mining. Mining companies around the world use water to transport minerals in slurries, enhance mineral extraction, separate minerals in chemical processes, control dust, and cooling. This water is extracted from local catchment areas and when water is returned it can be polluted or diverted into different areas (Boelens *et al.*, 2018). Mining is a globally important industry, in particular to Canada where, in 2015, Canadian mining assets abroad reached \$170.8 billion, with \$20 billion in subsidised financing and insurance from Export Development Canada (Annand, 2019).

In Central and South America, the problems associated with the extractive industries and water rights are particularly large. Bebbington *et al.* (2010) found that in the Amazon region approximately half of the total area in Ecuador and three quarters in Peru are allocated to hydrocarbon companies. In Guatemala, where natural resource decisions are made entirely by the central government, and collective property rights are not recognised by law (Aldana & Abate, 2015), problems within indigenous and local resident populations, associated with mining, have led to conflict. For example, the Escobal mine contains gold, zinc and lead as well as the world’s second largest silver deposit (Basov, 2017), and since 2010 was owned by the Canadian firm Tahoe Resources. In 2011 local community groups protested at Escobal and the Canadian embassy to oppose the mine, and local referenda in 2012 rejected the development of a new mine with a vast majority voting against it. In 2013 security guards for the mine were killed or injured and local indigenous political leaders were kidnapped or killed (Amnesty International, 2013; Diaz, 2013; Solano, 2015; Tobias, 2015). In 2017 operations at the mine were halted following a ruling by the Guatemala Supreme Court.

The Cerro San Pedro mine, in Mexico, (owned by New Gold, a Canadian firm) has received the Socially Responsible Company of the year award for 11 years, up to and including 2019, from the Mexican Philanthropy Centre (New Gold, 2019a). However, regional impacts are not accounted

¹Virtual water refers to water that is used to make products which are subsequently exported. For example, a region facing water scarcity could use a substantial amount of water within farming and then “virtually” export that water when the food product is exported.

for within New Gold's Corporate Social Responsibility report (New Gold, 2019a). These local impacts take place in an area that has unique environmental and historical importance for Mexican citizens. In 2009 a Mexican court ordered the mine to be closed down on environmental grounds following a campaign by a local group over the previous 10 years (MAC, 2009). The local group also prepared criminal charges and civil suits against the company and proposed a "Mega-remediation project" to remove cyanide with an estimated cost of \$300 million (MAC, 2009). Following this ruling, shares in New Gold fell 15%. However, the open cast mine did not shut down and continued operating until 2018 when it entered into the reclamation phase (New Gold, 2019b). In addition to the environmental damage and the leaching of cyanide (Boelens *et al.*, 2018), there were "rumours of sickness that locals were hesitant to speak of" (Annand, 2019). Following the mine closure New Gold is now supporting local businesses to create new economic opportunities through tourism (Annand, 2019) as part of the shutdown process.

New Gold (2019b) lists a number of risks to its finances including government regulation and permitting risks; environmental damage risk and associated legal liabilities; hazards such as equipment failure of retaining dams around tailings disposal areas; and title claims and rights of indigenous peoples. These risks need to be considered alongside changing environmental and human rights legislation. As biodiversity losses increase around the world it is likely that stricter enforcement and regulations will be introduced to reduce these losses. Indeed, even if local jurisdictions do not act, then national jurisdictions in the countries where companies are based may act. This was seen in 2017 around human rights where a court ruling means Canadian mining companies can now face charges (Annand, 2019) in Canada for offences overseas.

Therefore, where mining activities impact on water we see that local stakeholders are often not involved in decision-making, or are excluded through a lack of property rights, leading to a lack of participatory justice. Without participation, these stakeholders are not fully considered in the granting of mining rights such that recognition, and then distributive, justice is also ignored. Even where the impacts are in locations with unique environmental importance, and local courts have taken into account socio-ecological justice, it appears mines have still operated.

Mining activities in Latin America include defective installation of dams resulting in contamination to water resources (such as aluminium, iron, arsenic and cyanide), acid infiltration, underground water contamination, and felling of forests and trees which cause erosion and sedimentation in water sources. Impacts include degradation of local ecosystems, lower crop harvests and livestock farming, as well as adverse health impacts on local populations including elevated levels of mercury, arsenic and zinc from contaminated water (Working Group on Mining and Human Rights in Latin America, 2014).

As New Gold (2019b, 51) highlight "The Company cannot give any assurance that, notwithstanding any precautionary measures taken, environmental pollution or breaches of environmental laws (whether inadvertent or not), will not materially and adversely affect its financial condition and results from operations."

5. Case Study – Farming

Over a third of the world's land is currently used for crop or livestock production and since 1970 the conversion of natural habitats to agricultural areas has been the biggest driver of global biodiversity loss (IPBES, 2019b). The impacts on biodiversity loss have been exacerbated by the intensification of agriculture, in other words, increasing output by using more inputs such as pesticides (Chatham House, 2021) and therefore negatively impacting UN SDG Goal 15 (life on land). Lower biodiversity reduces the many agricultural benefits it provides such as, pollination of crops, soil regulation, natural hazard regulation, pest and disease regulation (FAO, 2019). In what is a compounding cycle, lower biodiversity therefore reduces crop and animal resilience to shocks and

stress, therefore putting food security and nutrition at risk, and negatively impacting UN SDG Goal 2 (zero hunger).

In many parts of the world, agriculture has been a necessity in order to provide food and income to rural communities, and therefore fair outcomes are an essential consideration for any approaches to reducing the contributions of agriculture to biodiversity loss. We illustrate some of the justice issues that arise from one approach to monetising nature, with the use of payments for ecosystem services.

The Grain to Green Program (GTGP) in China was one of the largest examples of payments for ecosystem services in the world (Liu *et al.*, 2008). GTGP was launched in 2002 and worked by incentivising the conversion of cropland on steep highland slopes into forests and grassland by providing farmers with grain and cash subsidies. The programme was driven by severe floods in the late 1990's with an estimated cost of ¥248bn (Liu & Wu, 2010). High levels of existing grain production and China's growing economy ensured sufficient funds were available for the programme. The programme aim was to reduce environmental degradation and soil erosion by improving vegetative cover on sloping land.

The government specified payments of subsidies for the amount of converted land, depending on the location of the land within the Yangtze or Yellow River Basins. The duration and size of the subsidies was outcome linked, with better managed land resulting in higher subsidies.

The GTGP resulted in many environmental successes, such as reduced surface water run-off, soil erosion and desertification. By the end of 2013 the programme had cost ¥300bn and converted 27.8 m hectares of land (Hua *et al.*, 2016). By 2008 alone, the programme impacted over 2.5 m rural households (Liu & Wu, 2010). However, these successes were not felt equally in communities.

- Lower income households received lower subsidies despite occupying the highest proportion of sloping farmland (Liu & Wu, 2010). This unintended result was due to the duration of subsidies being outcome linked, with higher income households being more able to manage converted cropland.
- The subsidies were only partially financed by the central government, putting a strain on local government finances and resources, yet many other stakeholders benefitted from the GTGP and could have contributed to the subsidies (e.g. insurance companies with flood or drought risk exposure or organisations downstream the Yellow and Yangtze rivers).
- The payments enabled many farmers and farm workers to move to cities and obtain jobs in other industries. In this specific case study some farmers and farm workers may have had more sustainable personal outcomes if they were given training and access to job information which could provide better opportunities instead of only financial payments.

Overall, the GTGP was an environmental and economic success. However, the case study highlights participatory and distributive justice issues, as lower income farmers did not participate in the design of the programme and the distribution of benefits from the GTGP could have been structured to be more equitable. This case study highlights the need to have justice as an integral part of any solution to improving biodiversity outcomes.

6. Implications for Actuaries

Our understanding and assessment of justice relating to the use of nature and the impact on biodiversity focuses on the four concepts of recognition, participation, distribution and socio-ecological issues. The case studies above highlight how justice relating to the use of natural resources and measured through achieving the UN SDGs, can be considered in this context. For example, the failure to sufficiently recognise stakeholder groups and allow them to participate in

decision-making (indigenous groups affected by mines and forestry use, coastal fishermen facing depleted fish stocks) resulted in unfair distribution of the value of the resource used. However, recognising the value of nature and the sustained use of it helped to develop the payment for ecosystem services in the farming case study.

The implications for actuaries are substantial and wide ranging. Continued biodiversity loss will affect our economies and livelihoods. As recommended in the Dasgupta Review (HM Treasury, 2021) a rethink is needed to ensure that we consider our economies and lives as embedded within nature. To do this we need to reconsider how we measure economic success, in particular, the difference between a business case that draws on nature in a sustainable way and one that is reliant on short term profit at the expense of future generations.

Biodiversity risk is now being factored into international treaties and national regulation. As a result financial exposure and reputational risk relating to environmental damage and hazards, especially where they impact on justice issues, is expected to significantly increase. Agreements for access to natural resources requires a balance to be struck that is seen as being fair to local communities by sustaining the biodiversity of the natural resources at a managed and monitored level but also allowing a country to benefit financially from them.

The case studies highlight a number of important issues that may impact actuarial work:

- **Liability risks:** In certain situations, local groups have instigated criminal charges and civil suits against international companies and recent moves in Canada and the UK (Shell/Nigeria) now allow international companies to be sued in Canadian or UK courts for activities carried out abroad – this could substantially increase litigation risk.
- **Catastrophe risks:** Agricultural practices can have a direct impact on natural catastrophes, such as floods, as shown in the China farming case study. For example, insurance companies with flood risk exposure will need to factor in agricultural practices and biodiversity impacts to its decision-making frameworks.
- **Health risks:** Developments in agricultural practice have led to the increased use of chemicals, such as pesticides. The impact of pesticides on human health may be realised over longer time frames and therefore needs to be considered when assessing mortality and morbidity risk. There are further justice implications, as different outcomes may also impact the mortality and morbidity risks in different ways for different groups of people.
- **Systemic risks:** If the current rate of deforestation, for purely economic reasons, continues this may destroy important biomes which could have been used in medicine for reducing mortality rates, as well as contributing to the risk of an increase in severe weather events. It is important that policies such as ICMS Ecologica, which look at the economics of the environmental conservation options, are adopted.
- **Supply chain risks:** Companies associated with forest risk commodities may face increasing reputational risk from heightened public interest, and financial risks from claims arising from biodiversity loss. Legal requirements to disclose forest risks and provide financial reserves may come in time, however some companies may see benefit in acting sooner.
- **Investment risks:** Even where a natural resource is actively managed, the northern cod case study illustrates the difficulty in understanding how complex ecosystems are affected by our actions. Improved disclosure of biodiversity related risks will only tell us so much and we will need to question investment and business models that are reliant on continued abundance of a natural resource.
- **Valuation risks:** Where all other aspects of risks are well managed it may still be possible to under (or over) estimate risk exposures by incorrectly assuming valuation metrics have been used appropriately. Deliberative valuation methodologies could help mitigate this risk by taking into account different monetary valuation perspectives, especially cultural, spiritual or social, of certain ecosystems.

7. Opportunities for Actuaries

- As well as the required data analysis, actuaries could use their experience to factor in the views of the different stakeholders on the value of natural resources being used. One of these stakeholders is future generations who have an important stake that cannot be ignored. How this stake is valued may be complicated by philosophical considerations but is one that we should be able to consider.
- Actuarial input into ecosystem governance models and effective communication of the results could be useful, particularly to illustrate the sensitivity of projections to changes in inputs and assumptions.

8. Next Steps

We recommend that a deeper and more involved study is urgently needed to investigate how we can incorporate nature into our economic and business models. This may involve a different way of thinking about economic gains and investment success. The challenge is to consider and understand the value of nature so that its resources can be justly distributed between current and future generations and the need to reconcile different notions of justice with the current understanding of the actuarial approach to fairness. This will involve issues that do not normally fall within our area of work such as philosophical considerations relating to the values placed on resources by different people and how we can assess values to future generations. However, given our mathematical and problem solving background, we are well placed to embrace this challenge.

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