



DO IT
FOR YOUR
PLANET

AVOIDING TRIPLE JEOPARDY:

DEVELOPING A JOINED-UP FUTURE FOR CLIMATE, FOOD AND NATURE



This report was written by Bernadette Fischler on behalf of WWF-UK. We would like to thank Tony Juniper, Lucy Young, Karen Ellis, Stephen Cornelius, James Beard, Duncan Williamson, Richard Perkins, and Dave Tickner from WWF-UK for their valuable contributions.

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Further information: wwf.org.uk/triple-jeopardy

About WWF-UK: At WWF, we want a world with a future where people and wildlife can thrive. We're finding ways to help transform the future for the world's wildlife, rivers, forests and seas in areas we regard as particular priorities. We're pushing for the reduction in carbon emissions needed to avoid catastrophic climate change. And we're pressing for measures to help people live sustainably, within the means of our one amazing planet.

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⁴ Workers toiling in the fields in Shanxi Province, northern China. Unless it rains, any crops they are preparing the ground for are unlikely to grow. Climate change is bringing more severe droughts, threatening food production in many regions. China is in the middle of the worst drought in 50 years.

FOREWORD

2020 will be a pivotal moment for the future of our world. During that year the challenges of climate change, the health of our natural world and how to sustain development will take centre stage, as world leaders meet to take critical decisions under the auspices of the United Nations Convention on Biological Diversity, the Paris climate agreement and the UN's Sustainable Development Goals.



Tony Juniper
Executive director of advocacy
and campaigns, WWF-UK

All three areas are utterly fundamental for our future and all three are fundamentally related to one another. As we gather more and more information signalling the profound nature of human impacts on the natural systems that sustain our civilisations, so it becomes ever clearer that without complementary action across all three areas at once it will not be possible to achieve success in any of them. The information we have to hand tells of grave and worsening threats.

Perhaps most troubling is the fact that our species is on the brink of triggering a mass extinction event, the sixth in the Earth's long history. Considering the fifth was when the dinosaurs went extinct, this reveals the scale and scope of the impacts we are causing to the life-support systems of our planet. Global populations of wild animals have more than halved over the last 40 years, and ecosystems have been devastated by development. This is not only a problem for wild species, of course, for like everything else we too depend on the natural world and we simply cannot continue to destroy it without suffering consequences. This is why in 2020 it is essential that a new global framework to restore nature must be agreed at the critical global meeting that will take place in Beijing.

The climate, too, is on a knife-edge. The Paris climate agreement was a bold step in the right direction, but unless nations commit to doing a lot more than they have so far, there's no hope of limiting carbon dioxide emissions to safe levels. This would be disastrous on so many levels.

Along with this, the world is struggling to feed everybody adequately – and this will become only more difficult as the global population grows. Providing sufficient food for everyone will be a huge challenge, requiring radical changes to what we eat and how we produce it.

Each of these three areas – climate change, the destruction of nature and threats to food security – poses grave perils to our collective future. In rising to these challenges, however, the biggest mistake we could make would be to treat them as three separate problems that require three separate sets of solutions.

That's why this report makes a call for an integrated response to the challenges at hand. It reveals on the basis of a vast body of data how if we address any of these issues in isolation, we risk missing the bigger picture and could make the overall situation worse.

By contrast, if we take a truly holistic approach that looks right across nature, climate and food security and which can see the deep and fundamental connections between them, then we do still have a chance of managing all three to lay the foundations for a sustainable future for our world.

This will, however, require real vision, hard work and commitment to the long term. Everyone will have a role to play, from world leaders to corporate decision-makers, from grassroots activists to subsistence farmers, and from investors to voters and consumers.

As 2020 approaches, it's time for governments all over the world to step up and take the lead, working together to take an integrated approach to solving the great challenges of our time.

This report shows just how urgent and important the situation is, and leaves us in no doubt that it's time to do something about it.

WHAT MAKES 2020 A 'SUPER YEAR'?

There are two reasons why 2020 is a special opportunity to ensure a world where people and nature thrive in harmony:

- **Decision-making:** In 2020, world leaders have the opportunity to make crucial global decisions about nature, climate and development and declare that it is no longer acceptable to continue degrading our planet.
- **Action-taking:** Making decisions alone will not help save the planet. Governments, business and communities need to take transformative action in 2020, if we want to stop the loss and start the restoration of nature by 2030.

PART 1

AVOIDING TRIPLE JEOPARDY - SUMMARY

Our world is under greater pressure than at any point in history, and humanity faces some truly daunting challenges. We'll need to feed a global population that's likely to be approaching 10 billion by 2050. We must limit global temperature rises and improve resilience to bring climate change under control. And we need to halt and reverse the loss of nature, the life-support system that we all depend on. Failure to address all three of these potentially competing demands could lead to catastrophic social, environmental and economic consequences. But achieving these goals promises great reward for our health and prosperity.

Each of these three imperatives presents a formidable task in its own right – but none can be tackled in isolation. Converting forests to cropland could increase food production in the short term, but at the expense of increased carbon emissions and further loss of biodiversity. While hydropower provides low-carbon electricity, dams in the wrong places can have drastic impacts on river systems, fisheries and agricultural land, undermining food security. Policies aimed at protecting nature and reducing carbon emissions may increase food prices.

So how can we square this circle? Is it possible to achieve food security for all, while tackling climate change and keeping within our planet's natural limits? What are the choices we face, now and in the years ahead? And how do these choices vary from region to region?

To begin to answer these questions, WWF commissioned an analysis of existing literature in each of these fields. This looked at around 80 studies outlining various development scenarios, and their projected implications for food production, climate and nature – including land use, freshwater demand, biodiversity and nutrient cycles.

Interestingly, most studies out there have tended to concentrate on one or two of these areas – but all three areas are closely connected and impact on each other, so we need to take an integrated view of the challenges we face if we really want to address them in the best interests of both people and planet.

There's a lot more to do before we fully understand how the triple trade-offs work. Nevertheless, this overview reveals a number of clear themes that can help guide policymakers in the run-up to 2020. Addressing these issues today is crucial if we're to maintain a habitable planet where people and nature can thrive tomorrow.



Mass soybean harvesting at a farm in Campo Verde, Brazil. Vast areas of natural habitats in Brazil have been cleared to grow soy for animal feed - enabling cheap meat production, but with major impacts on biodiversity and the climate.

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SOME USEFUL DEFINITIONS

Biodiversity is the variety among living organisms – including plants and animals – in different habitats, such as forests, grasslands, oceans and freshwater. This includes diversity within species, between species and of ecosystems.¹

Ecosystems include all living things in a given area, as well as their interactions with each other, and with their non-living environments, including rock, water and air. Each organism has a role to play and contributes to the health and productivity of the ecosystem as a whole.²

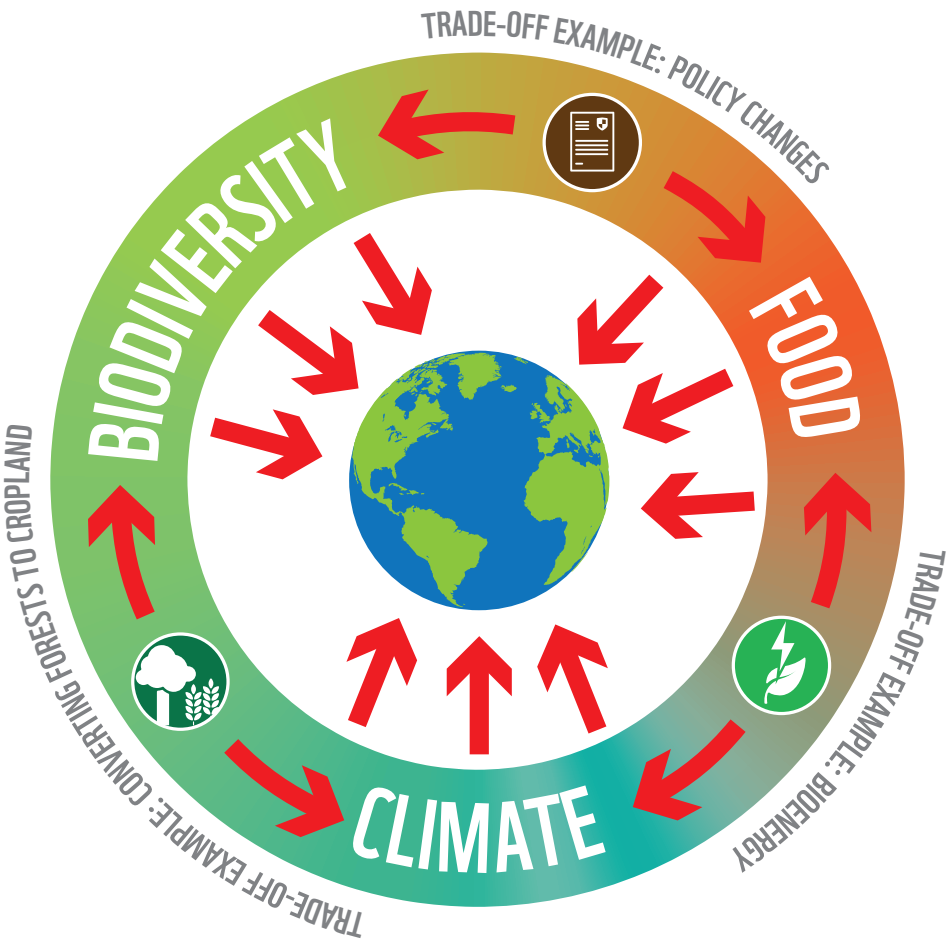
Wildlife is both animals and plants that grow independently from people, usually in a natural environment.³

Nature is a wider term that encompasses plants, animals and their products but also ecosystems, air and water.⁴

TRIPLE TRADE-OFFS – TOUGH DECISIONS IN THE REAL WORLD

The concept of the trade-off is fundamentally important to this report – and indeed to our future on the planet. In essence, it means that positive actions taken to enhance one service can have negative consequences on another.

Our review of the literature reveals how much these three core priorities – food, climate and biodiversity – influence each other, and how many of the decisions we make regarding any of them could involve some form of triple trade-off. If we continue to develop as we have in the past, these trade-offs will become more severe. But this is not inevitable: in nearly all cases there are measures we can put in place to manage the triple trade-offs and avoid their worst potential effects, provided we understand that every detail is part of a bigger picture.



EXAMPLES OF TRADE-OFFS BETWEEN ACTION ON CLIMATE, FOOD SECURITY AND BIODIVERSITY

 POLICY CHANGES Policies aimed at protecting nature and reducing carbon emissions may increase food prices.	 CONVERTING FORESTS TO CROPLAND Converting forests to cropland could increase food production in the short term, but at the expense of increased carbon emissions and further loss of biodiversity.	 BIOENERGY Bioenergy can play an important role in our energy system and contribute to climate change mitigation efforts. But increased bioenergy may also result in increased competition for land (and water) between biofuels and food production, undermining food security.
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KEY CONCLUSIONS

These are the key conclusions from the literature review:

Business as usual is not an option. Human actions have already pushed our planet into unknown territory. A rapidly warming climate, vast changes in land use, huge pressure on water resources, precipitous declines in biodiversity: we're making large-scale alterations to the conditions and processes that have so far helped us to thrive on Earth. If we continue to develop in the way we have to date then, as the global population grows, the pressure on our planetary support systems will continue to mount, taking us into increasingly dangerous situations.

Technology can't be relied upon to solve the problem. While technological innovation will make significant contributions, it cannot alone achieve what is required, not least because some of the fundamental functions performed by natural systems cannot be replicated by technology, at least not in any economically rational manner. In addition to limited scope, there are sometimes also unintended consequences from new technological solutions.

A healthy diet, climate and planet is possible – but will require significant changes, especially to the way we produce and consume food. We can feed a population of 9-10 billion by 2050 while keeping global warming well below 2°C and taking pressure off nature – but it will mean some fundamental changes to our food system and diets. Improvements in agricultural productivity are part of the solution; more significant, however, is reducing food losses and food waste, and reducing the amount of meat and dairy we consume globally: vegetarian diets low on dairy or vegan diets have the lowest impacts on land use and greenhouse gas emissions. This means certain places or parts of societies where the consumption of animal products is high need to eat less of them – which will allow space for consumption in other places to rise to healthy levels.

Decisions on climate, development and nature can't be made in isolation – a holistic approach is needed. Food, climate and nature restoration are interlinked, and efforts to fix one area can create problems elsewhere. Increasing biofuel production could reduce fossil fuel use but threaten food security and biodiversity; intensifying agriculture could boost food production while also increasing water use, chemical pollutants and greenhouse gas emissions; and so on. There's currently limited coordination between various UN processes, government departments and civil society initiatives: what's needed is a holistic approach that encompasses food security, climate and nature together.

Trade-offs are inevitable, but can be managed. As we've seen, there are trade-offs between achieving improved food security, stabilising climate change and conserving nature. There will be tough choices ahead. The first step is to be aware of the trade-offs involved, to make better-informed decisions and to avoid unintended consequences. The second step is to find solutions, to highlight areas where measures can be put in place to manage potential conflicts, where synergies can be pursued, and where innovation is most needed.

These trade-offs will have social implications. Societies will need to make social, economic and political choices that could have profound impacts on people's lives – for example, managing a just transition from subsistence to industrialised farming, or persuading people to make significant changes to their diets. As competition for basic resources such as food and water intensifies, there's a risk of increased inequity and inequality. There could also be conflicts over the use and control of resources, particularly water, at local and national levels. The use of social policy and welfare investments can help to mitigate the impacts during the transition.

Global models don't always reflect local realities. Much of the research to date takes a global view, but many of these issues play out at a local or regional level. Global food and biofuel production, for example, may be constrained by the availability of water at a river basin level, while areas with potential to increase crop production may have particularly high levels of biodiversity. Trade-offs must be managed within a global framework, but it's essential we maintain focus on their local implications and how they may affect the population that can be supported in a particular region. This is likely to prove particularly testing in sub-Saharan Africa, the Middle East, north Africa and south Asia.

Many choices made globally will impact developing countries the hardest, but finding solutions is a global responsibility and we all have a part to play. Sub-Saharan Africa, where regional food security is already seriously threatened, will absorb over half the projected global population growth between now and 2050. Tropical regions face the highest rates of deforestation and biodiversity loss, and developing countries are disproportionately affected by climate change and thus stand to suffer the most if the triple trade-off is not managed well. The world must work together to develop a new pathway that diverges from the unsustainable, high-carbon, resource-intensive development models of the past, and instead facilitates sustainable development patterns.

GLOBAL CHALLENGES, LOCAL IMPACTS

The challenges involved in managing the triple trade-offs vary considerably around the world depending on a host of inter-related local factors. This means that certain regions will be impacted, even if trade-offs are managed successfully at the global level. This map shows some (not all) of the global hotspots identified in the literature review, but it would be wrong to conclude that these will be the only areas affected. For example, we know that the Middle East will be seriously affected by water scarcity. All countries will be directly affected by the economic and social problems that environmental degradation causes, through its impacts on trade, the price of food and key commodities, migration and reduced global economic growth.



CARRYING CAPACITY

Carrying capacity is the maximum population of a given species that can survive indefinitely in a given environment. In short, how many people the Earth's resources can reasonably support on an ongoing basis.⁵

An identified problem in:
South Asia, sub-Saharan Africa, north Africa, Middle East.



DESERTIFICATION

Desertification is land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities.⁶

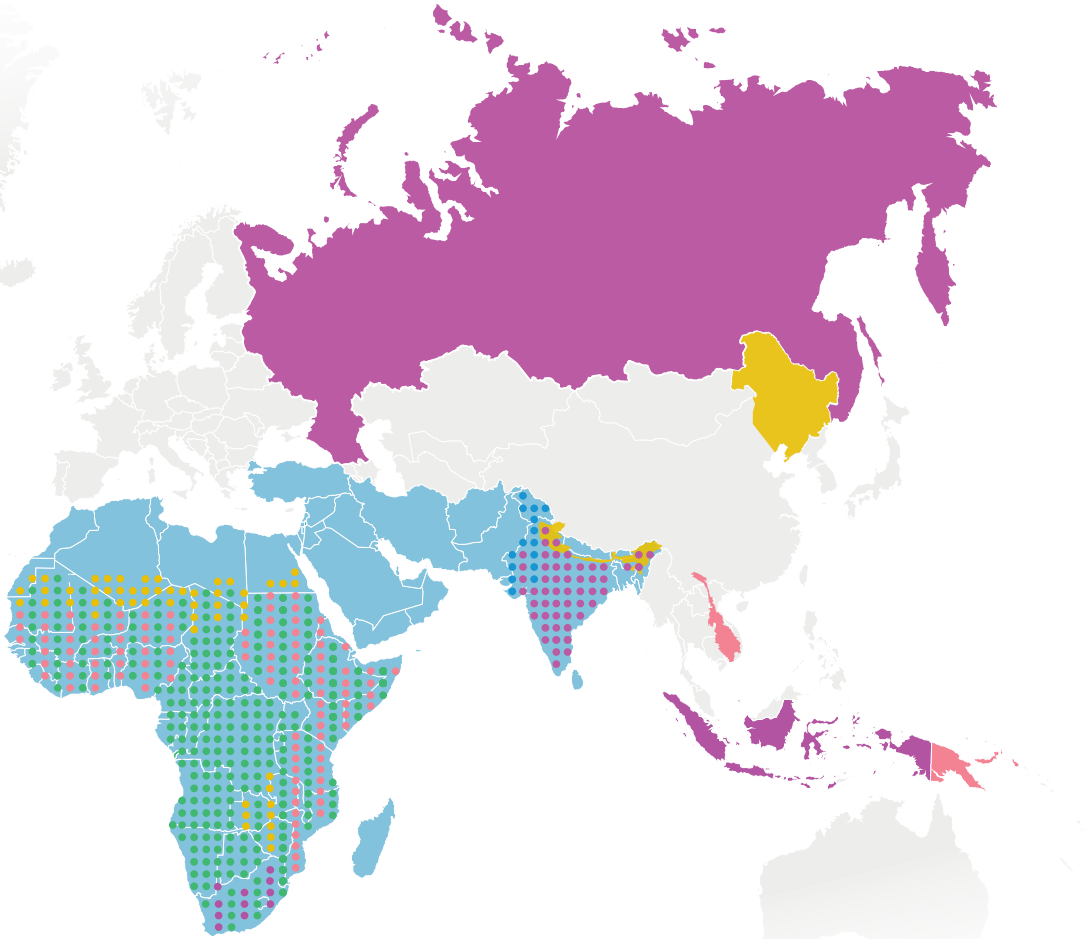
An identified problem in:
North-eastern Brazil, south-western Argentina, southern Sahel, Zambia and Zimbabwe, sub-Himalayan India, north-eastern China.



WATER SCARCITY

Water scarcity can be physical or economic. Physical water scarcity occurs when water resources development is approaching or has exceeded sustainable limits. Economic water scarcity occurs when human, institutional and financial capital limit access to water even though water in nature is available locally to meet human demands.⁷

An identified problem in:
Brazil, Russia, Indonesia, India, South Africa.



WATER RISK TO FOOD PRODUCTION

Water risk to food production describes the limited availability of freshwater needed to produce enough food under our current farming systems.

An identified problem in:
North-east China, north-west India, south-west United States.



LAND CONVERSION TO AGRICULTURE

Land conversion to agriculture describes the adaptation of land to make it suitable for producing goods and services such as food, fibre, fuel and livestock feed.⁸ Conversion to pasture or to grow feed crops, notably soy, is the main driver of deforestation and natural habitat loss globally.

An identified problem in:
Sub-Saharan Africa, South America.



CONFLICTS BETWEEN BIODIVERSITY AND FOOD PRODUCTION

Conflicts between biodiversity and food production refer to the competition for land and natural resources.

An identified problem in:
Central America and the Caribbean; tropical Andes and south-western Brazil; west and east Africa; Madagascar; Greater Mekong; Indonesia; Papua New Guinea.

KEY RECOMMENDATIONS

Based on the findings of the literature review discussed above, WWF has developed the following recommendations.

BETTER INTEGRATION OF ACTION ON CLIMATE, FOOD SECURITY AND BIODIVERSITY

The literature review shows that continuing with business as usual is not an option: we have to get to grips with global challenges. But addressing them in separate silos won't work. Given the finite resources we have to work with, and given the fact that every action in one area can have a knock-on effect in another, the best way forward is to take an integrated approach to climate, food security and nature. On the basis of this review, WWF is making a number of recommendations.

Integrated action is both more efficient and more effective:

- It's more efficient because pooled resources go further and cut out duplication.
- It's more effective because it lessens negative trade-offs and encourages positive synergies between initiatives in different fields.

Nevertheless, while integration makes a lot of sense in theory, it can be difficult to achieve in practice. This is largely because governance structures – at the UN, in governments and even civil society organisations – are at nearly every level reinforcing siloed approaches.

We must start to address this siloed approach as we implement the next round of international agreements in 2020. Three decisions and one anniversary in 2020 offer a unique opportunity to take an integrated approach to the challenges that will define our future:

- 1. A strong post-2020 CBD framework.** The so-called Aichi targets expire in 2020, but the international community still has a long way to go to halt the loss of biodiversity. The new framework should include an inspirational mission to galvanise political and public support, goals and targets for restoring nature, and a robust implementation mechanism. The new Convention on Biological Diversity (CBD) framework must also contribute to the achievement of the Sustainable Development Goals (SDGs) and the Paris climate agreement.

- 2. Enhanced national action plans for the Paris climate agreement.**

Current Nationally Determined Contributions (NDCs) fall far short of the levels needed to limit temperature rises to 1.5 or 2°C. In 2020, nations must strengthen their commitments. In doing so, national action on climate change can be linked with actions on the SDGs and CBD, enhancing both by including nature-based solutions to mitigation and adaptation.

- 3. Extension for environmental SDG targets with 2020 deadlines.**

Many of the environmental targets of the SDGs expire in 2020 and need to be extended. This must be done in alignment with the post-2020 CBD framework, to maintain the integrated character of the SDGs.

- 4. The 75th anniversary of the UN in 2020** will provide a great opportunity for world leaders to promote integration and declare that it is no longer acceptable to continue degrading our planet.

Looking further into the future, we need to develop a set of targets which deliver on all of these issues at once, in a new more joined-up global agreement. As the NDCs, SDGs and the post-2020 CBD framework all have a deadline of 2030, it's the perfect moment to agree and start implementing an integrated set of targets.

FIRST STEPS TO MANAGING THE TRADE-OFFS: POLICIES ON FOOD, CLIMATE CHANGE AND NATURE RESTORATION

In relation to policies addressing food security, the evidence is clear: we need to **shift dietary preferences** away from meat and dairy to ease the growing pressure on land. We also need to **improve agricultural productivity and reduce waste**. However, when taking steps to reduce post-harvest losses and waste we also need to take account of other consequences of potential solutions, such as the energy impacts of increased refrigeration or the pollution risks of increased packaging. A holistic approach is required for prioritising policy responses. In addition, we should **promote food security solutions which also have biodiversity and climate benefits**, like encouraging greater agricultural diversity.

Climate change mitigation should be implemented in a way that does not cause greater damage to ecosystems than climate change itself. The more we can achieve emissions reductions through a swift transition to low-carbon energy generation the better, as this would reduce pressure on land-intensive methods of carbon dioxide removal and thus ease the triple trade-off. Methods of carbon dioxide removal from land which have biodiversity co-benefits should be prioritised; for example via ecosystem restoration on degraded lands. Biofuels policies should take account of land and water pressures and potential negative impacts on food security and nature.

Nature needs to be protected and restored in ways that maximise food security and climate mitigation. This requires stronger understanding of the links between biodiversity and ecosystem services, and for environmental policy to be designed in a way that maximises both. To do this, tools that facilitate integrated policymaking and landscape-based approaches must be employed. For example, natural capital assessments can determine how different aspects of the environment are contributing towards different ecosystem services in a particular location (e.g. food production, or water provision for local communities), and can assess the impacts that changes in their use could have: this knowledge can be used to inform policy decision-making to maximise overall benefits. Analysis of this kind should be incorporated into multi-stakeholder land-use planning approaches, to facilitate the mapping, negotiation and implementation of activities across the whole landscape.

There is a need for more research on (i) the links between natural assets and the ecosystem services they provide; (ii) the impacts different interventions will have; and (iii) the economic and social impacts of changes in ecosystem services. This will help guide decision-making and prioritise policy responses – these themes constitute a growing but still patchy area of academic research. We also need to understand the global economic impact of the triple challenge – how things will play out in economic terms, globally and nationally, under business-as-usual versus alternative scenarios. The **lack of evidence** on the macroeconomic implications of the threats we face, what they mean for different parts of the world, and their implications for development, security, conflict and migration, **has been repeatedly highlighted and urgently needs to be addressed.**

However, we must **not let the need for more research slow us down in developing policy responses, as the problem is urgent.** We know where the future stress points are likely to be, and we should begin planning policy frameworks and response mechanisms to address them right now – not when it's too late.

PART 2

GROWING DEMANDS ON A FINITE PLANET – AND HOW TO MANAGE THEM

The central issue discussed in this literature review is simple: we're consuming more than ever, and every day there are more of us. If humanity continues to develop as we have in the past and our consumption keeps growing at the same rate, then we'll need more resources to support ourselves as a species in the future – more food, more water, more land, more energy. Those resources, however, are not infinite, and if we push the planet too far it won't be able to supply the goods and services we currently take for granted.

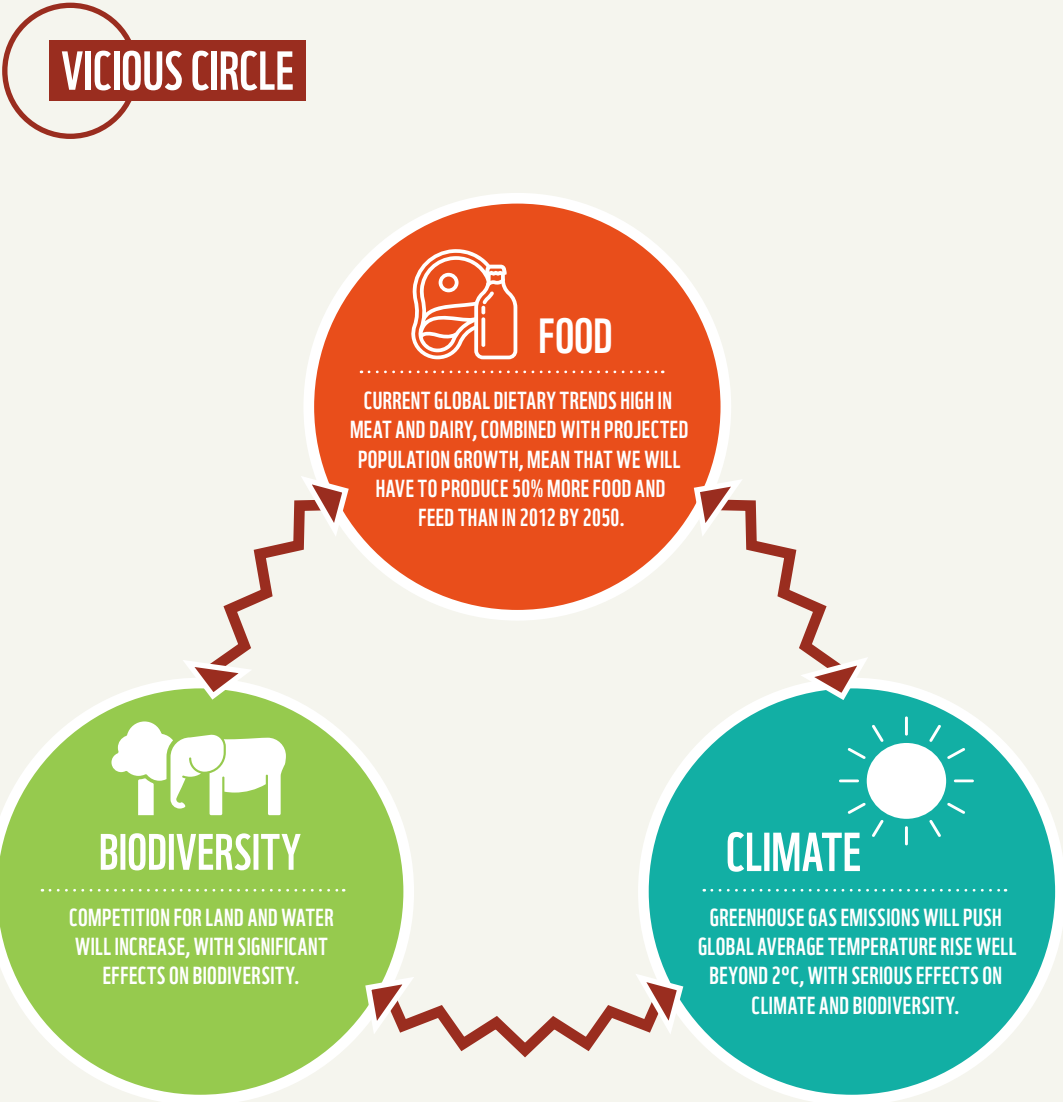
Biodiversity underpins the ecosystem services upon which all life depends, so ongoing biodiversity loss represents an existential threat. That we are increasingly hitting environmental limits at the local level is becoming ever more visible, causing significant negative impacts to the livelihoods, economies, health and wellbeing of affected communities. Over time, if current trends continue, we can expect increased conflict over resources, food insecurity, and migration. The risk of ecosystem collapse, which can be unpredictable, reinforces the need for us to take a precautionary approach.

Taking a global perspective, we need to be clear about two things: what resources will humanity require, and how far will they be available to us in future? Understanding what we'll need and what we'll have is essential in creating real solutions for living within the finite means of our one planet. These questions become increasingly complex the more we look into them: consumption patterns, resource distribution and trade-offs between different development paths can all radically alter future projections.

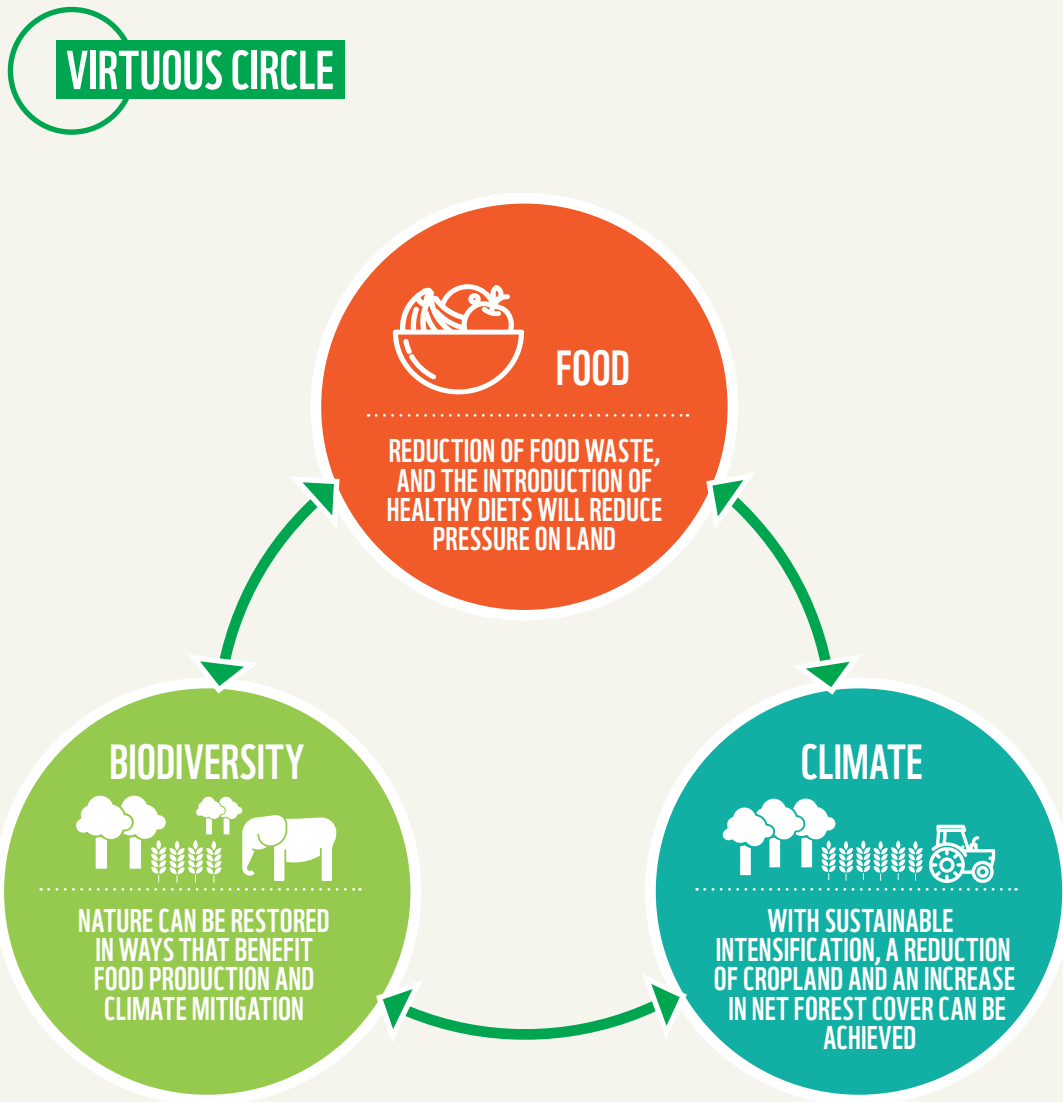
This report summarises the key findings of our review of the relevant literature.

We've set out our analysis under three headings: food security, climate change and nature. For each, we look at the impacts and changes projected over the coming decades. Importantly, we also examine what impacts projected developments in one area may have across the other two.

TACKLING THESE THREE ISSUES IN ISOLATION WILL LEAD TO PROBLEMS.



BUT IT'S POSSIBLE TO FEED 9.6 BILLION PEOPLE BY 2050 IF WE LOOK AT FOOD SECURITY, CLIMATE CHANGE AND BIODIVERSITY HOLISTICALLY.



1. ENSURING FOOD SECURITY

Simply increasing food production can threaten nature and the climate – but changing what we eat and reducing waste could ease the pressure.

This chapter looks at the challenge of feeding a global population of nearly 10 billion by 2050. The research suggests that if current trends continue in line with population growth, there will be drastic consequences for climate and nature. However, even with a significantly larger global population, changes in diet and improvements in efficiency may still offer a route to a sustainable future.

Around 37% of the world's land area is used for food production – either for growing crops or grazing livestock.⁹ Agriculture is, of course, essential for feeding the world. But it's also the biggest driver of land-use change and biodiversity loss, and a significant contributor to climate change.

If current global dietary trends continue alongside population growth, by 2050 we'll need to produce 50% more food and feed than was used in 2012.¹⁰ Competition for land and water would increase still further, and – even with drastic reductions in other sectors – associated greenhouse gas emissions would push the global average temperature rise well beyond 2°C.

That means we need to reduce the impact of our current global food system. One of the biggest things we can do is to change what we eat. Specifically, we need to eat less meat and dairy.¹¹

Livestock is the world's largest user of land resources, with pasture and cropland for animal feed taking up almost 80% of total agricultural land. Animal feed accounts for more than 40% of the world's cereal production, while 26% of the Earth's ice-free land surface is used for grazing.¹² Conversion to pasture or to grow feed crops, notably soy, is the main driver of deforestation and natural habitat loss globally.

And the livestock sector puts more than just habitats under pressure: it's also responsible for 14.5% of greenhouse gas emissions,¹³ which is roughly equal to those of the entire transport sector. The emissions come direct from the animals via methane produced by digestion, and more broadly through land-use change.



A variety of orphan crops for sale in Arusha Market, Tanzania. Reducing food waste is key to ensuring future food security on a global scale.



Brazil's savannah region, the Cerrado, is home to 5% of the world's biodiversity, and is an important carbon store. It's currently being deforested at a rate 10 times faster than the Amazon for production of soy and beef. But if farmers used the 40 million hectares of already degraded land in Brazil, production of beef or soy could triple without the need to clear more native vegetation.

© Adriano Gambarini / WWF-Brazil

HEALTHY DIETS, HEALTHY PLANET

As societies grow in economic terms, people eat more meat and dairy – so global animal protein consumption is likely to continue to rise as more people in developing countries adopt the diet of the developed world. As we've seen, however, the trade-offs that would be required to increase meat production in line with current Western consumption patterns would have disastrous impacts on climate change and biodiversity.

But what would happen if the world's rich meat and dairy eaters ate differently? Several studies¹⁴ – notably WWF's own Livewell review¹⁵ – have looked at what could be achieved if we restricted meat and dairy consumption to levels deemed healthy by the World Health Organization: this amounts to 2,500 calories per day per individual, with a maximum of 57 of these daily calories coming from red meat.¹⁶ Most countries would see a significant reduction in the amounts of meat and dairy currently consumed, but the modelling does also leave room for increases in those countries that need it.

The modelling suggests that the nutritional difference could be made up by including more vegetables and grains in our diet. These require far less land to produce than meat and dairy, and have the added bonus of being healthier options.¹⁷ Vegan diets and vegetarian diets that are low in dairy have the lowest impacts of all.

Of course, bringing about such a change in global diet is a daunting challenge, both in terms of practical logistics and societal attitudes. Also, some low-impact production techniques may lead to higher food prices¹⁸ – carbon taxation on food could help to address this problem, but would also push up some food prices, so attention would need to be paid to protecting the poorest populations.¹⁹

WASTE NOT, WANT NOT

It's not just what we eat, it's how we produce it. If we can be more efficient – grow more per unit of land and waste less – then we can improve food security while minimising the impacts on nature and the climate.

Food loss and food waste occur in different parts of the agricultural supply chain.²¹ In low-income countries, most food is lost early in the supply chain during harvest, storage and distribution, while in medium- and high-income countries food is wasted at the consumption stage, and is often discarded even if it's fit to be eaten.

We can improve on both fronts. Using fertilisers more efficiently and reducing both waste and consumption will ease pressures in terms of land-use change, climate change and disruption of natural chemical flows – but models suggest that these measures will not be enough without a change in diet. However, when taking steps to reduce post-harvest losses and waste we also need to take account of other consequences – e.g. energy impacts associated with solutions such as increased refrigeration, or pollution risks associated with increased packaging. A holistic approach is required for prioritising policy responses.

One study modelled the environmental footprint of feeding 9.6 billion people by 2050 (which is roughly the UN's estimate) under a range of scenarios. It found that sustainable intensification coupled with reduced food waste and the introduction of healthy diets would lead to a reduction of 12% in cropland and an increase in net forest cover.²² However, it's vital that all three measures are included – if not, then across all scenarios forest cover reduces (exacerbating climate change and harming biodiversity).

CASE STUDY:

Diversifying corn and soybean systems by adding crop rotations while reducing tillage can increase yields significantly. A 31-year study in Ontario, Canada saw yield increases of 7% for corn and 22% for soybean in hot and dry years.²⁰



Rice growers in India are getting very encouraging results from the new System of Rice Intensification, which uses alternate cycles of drying and wetting. Not only does the system increase yields, but it requires less water and energy, producing lower emissions.

© Global Warming Images / WWF

2. ADDRESSING CLIMATE CHANGE

While climate change will have negative consequences for food security and biodiversity, poorly chosen or poorly implemented measures to combat climate change could also have negative impacts on both.

Nobody doubts the need to tackle climate change, and bioenergy and afforestation play a role in mitigating carbon emissions. This chapter shows that careful thought must be given to how and where we grow biofuel crops in a world of limited land and water resources; while afforestation may pose its own problems by increasing competition for land and driving up food prices.

Tackling climate change is an accepted international imperative. To avoid the most damaging climate impacts on people and nature we need to keep the global average temperature rise to 1.5°C. This will require a phase-out of fossil fuels by 2050 and a transition to renewable sources of energy and other low-carbon technologies. It will also require some form of carbon dioxide removal through, for example, concerted efforts to protect and restore forests to store carbon.

Cover crops reduce evaporation and improve soil. Agrocaribe, a Guatemalan company, was awarded the Roundtable on Sustainable Palm Oil (RSPO) certificate for using this technique.

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Climate change mitigation should be implemented in a way that does not cause greater damage to ecosystems than climate change itself. The more that emissions reductions can be achieved through a swift transition to low-carbon energy generation and sustainable consumption habits the better, as this would reduce the need for land-intensive methods of carbon dioxide removal and thus ease the pressure on biodiversity. After emissions cuts, methods of carbon dioxide removal from land which have biodiversity co-benefits should be prioritised; for example via ecosystem restoration on degraded lands. Biofuels policies should take account of land pressures and potential negative impacts on food security and nature.

Bioenergy can play an important role in our energy system and contribute to climate change mitigation efforts. But increased bioenergy may also result in increased competition for land (and water) between biofuels and food production.²³ Some claim that biofuel production supports food security by making farming more profitable, but others contend that biofuel production diverts land, water and crops away from food production, reducing the supply of food and hence raising food prices. The use of cropland to grow fuel can therefore come with trade-offs against food security, as well as nature protection.

Estimates of how much cropland is needed to grow bioenergy crops vary widely: from 30 million hectares, where biofuels provide 8% of global energy needs, to as much as one billion hectares – an area the size of Europe.²⁴ Much of this cropland expansion is projected to come at the expense of forests, which would further exacerbate climate change and lead to severe biodiversity losses; as well as pasture areas, which could put pressure on food security. The highest level of biodiversity loss is from scenarios with limited greenhouse gas mitigation and therefore the highest temperature changes. However, if there is ambitious greenhouse gas mitigation without action to limit land-use change then biodiversity loss will also be high.

CASE STUDY:

Forests in the Yangtze watershed help moderate the flow of river water, decreasing it in the wet season and increasing it in the dry season. This allows the Gezhouba hydroelectric plant to generate an extra 40 million kW/h of power each year, worth US\$610,000 – or the equivalent of 40% of the region's forestry income.

Biofuel crops need water too. Some climate mitigation scenarios project a doubling of agricultural withdrawals of water²⁵ by the end of the century if both rain-fed and irrigated land are used in biofuel production, putting severe pressure on limited resources which are also needed to support food security and biodiversity. Alternatively withdrawals could be restricted to rain-fed land, but this would potentially increase the extra land needed by 200 million hectares.

Like biofuels, afforestation to mitigate climate change could also lead to food price hikes by increasing competition for land. One study modelled the impact of a global incentive for afforestation to absorb carbon: this resulted in a massive growth of forests (2.58 billion hectares) and carbon sequestration (860 Gt CO₂) up to the end of the century, but an increase in food prices of about 80% by 2050 and a more than fourfold increase by 2100. However, when afforestation was restricted to the tropics, the food price rise was substantially reduced, while still capturing nearly 60% of the carbon.²⁶

UNDERSTANDING BIOENERGY

Bioenergy (or biofuels) describes energy sourced from organic matter. It can be used directly as a fuel (e.g. wood) or converted into fuels (e.g. charcoal or biodiesel). There are a wide range of technologies which can loosely be grouped into three generations depending on the source from which the fuel is derived:

First generation biofuels extract sugar, lipids or starch directly from **food crops** such as corn or sugar cane. As such there are potential trade-offs with food security and pressure on agricultural land, with knock-on effects for biodiversity.

Second generation biofuels are generally not derived from food crops but can be taken from **agricultural and forestry wastes**, as well as purpose-grown feedstocks such as short rotation coppice and energy grasses. While trade-offs are less direct, second generation biofuels can still cause displacement effects if, for example, short rotation coppice is grown on land that could support food production, or agricultural wastes are diverted away from improving soil fertility leading to an increased use of artificial fertilisers.

Third generation biofuels are derived from **algae** and are very much in an R&D phase. If they prove viable and environmentally sustainable at scale it could be a major step forwards as the lower requirement for land and other inputs will limit pressure on cropland and biodiversity.

3. RESTORING NATURE

Efforts to increase food security and climate change mitigation will have impacts on nature, including forests, biodiversity, and rivers and wetlands.

This chapter highlights how we depend on nature for our survival, economic prosperity, health and wellbeing, and discusses the pressure that nature will come under in the next few decades, particularly as a result of climate change and increased food production. It also shows how these global problems manifest on a regional level, pinpointing some of the areas where we'll need to make the hardest choices in managing the triple-trade-offs.

THE VALUE OF NATURE IN ECONOMIC AND SOCIAL TERMS

Nature is vital to life on Earth. The planet's ecosystems, species, water, minerals, land and atmosphere provide a wide range of essential benefits that underpin our economies, our wellbeing, and ultimately our very survival – these include the supply of food, raw materials, pollination of crops, purification of water and air, and protection from storms, floods, disease and other hazards.

Estimating the value of the contribution that nature makes to our economy is difficult, particularly at the global level, but it has been attempted. One study put the global value in 2011 at US\$125 trillion per year.²⁷ More recently, in 2018, in a global assessment by more than 100 leading experts from 45 countries, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reported that the economic value of nature's land-based benefits in North and South America is worth the equivalent of more than US\$24 trillion per year – equivalent to the region's GDP.²⁸

Yet, despite nature's value, we're degrading and overusing these vital assets at such an unprecedented rate that we're significantly reducing the planet's capacity to support human wellbeing. Thirteen years ago, the Millennium Ecosystem Assessment reported that more than 60% of nature's benefits were being degraded or used unsustainably.²⁹ In 2018, IPBES has shown that nature's decline has continued in every region of the world, driving a sixth mass extinction, and presenting profound implications for humanity.



Sumatran orangutan (*Pongo abelli*) in the Gunung Leuser National Park, Indonesia. This critically endangered species plays a vital role in seed dispersal, but deforestation and climate change threaten its future survival.

Land degradation alone is estimated to have cost the equivalent of 10% of the world's annual gross product in 2010 through the loss of biodiversity and nature's benefits, undermining the prosperity and wellbeing of 3.2 billion people.³⁰ These changes have serious social consequences, such as increased incidence of food and water insecurity, poor health, involuntary migration and conflict. Research has shown that every 5% loss of GDP (itself partly caused by land degradation and its effects) is associated with a 12% increase in the likelihood of violent conflict.³¹

No region of the world is immune. IPBES reports that 65% of land-based benefits in the Americas are in decline, with 21% declining strongly.³² Similar patterns are repeated in Africa, Asia Pacific and Europe. As the global population increases, demand for food, energy, land and other resources will intensify, placing further pressure on natural systems. Reversing these trends will be critical to the achievement of global policy commitments, including the SDGs, the CBD's Aichi targets, and the Paris climate agreement.

PRESSURES ON WATER

Freshwater ecosystems – including rivers, lakes and wetlands – take up less than 1% of the surface of the planet, but are home to disproportionately high biodiversity (including nearly half of the world's known fish species). Increasing pressure on these systems means that they're experiencing declines in wildlife at twice the rate of those seen in forests and oceans.³³

Pressures on water resources are only going to grow in the decades to come. The pressures will build both through physical water scarcity, when there's simply not enough water to meet demand; and economic water scarcity, which means a lack of investment in water infrastructure prevents demand from being met. The former is most common in arid regions, while the latter is more of an issue in the developing world, particularly sub-Saharan Africa.

This year, the UN reported³⁴ that about 1.9 billion people (27% of the global population) lived in potential severely water-scarce areas throughout the early to mid-2010s. By 2050 this could increase to some 2.7 to 3.2 billion, and over 40% of the global population could face water stress.

The OECD's figures are lower,³⁵ but they tell a similar story: water stress is expected to affect 3.9 billion people by 2050, more than 40% of the world's projected population.

Other sources estimate that by 2030 demand will exceed current sustainable water supplies by 40%.³⁶ Some project that water withdrawals will begin to stabilise or decrease in 41% of world river basin areas by 2025, mainly in the developed world – but others will come under increasing pressure, notably the Ganges, the Huang Ho (Yellow River), the Limpopo and the Nile.³⁷

ENVIRONMENTAL FLOWS AND FOOD PRODUCTION

For rivers and aquatic ecosystems to continue to function and provide the services that people and nature rely on, they need enough water at the right times: these requirements are referred to as environmental flows.

Many rivers, however, don't currently receive these environmental flows – and food production is a key reason. An estimated 41% of global irrigation water comes at the expense of environmental flow requirements.³⁸ Given the projected increase in food demand, the tension between environmental flows and irrigation is likely to increase.

Conversely, if water from irrigated cropland was reallocated to meet environmental flow requirements, we could see losses of agricultural productivity of between 20-30% in Central and South Asia.³⁹ The trade-off between nutritional needs and aquatic ecosystems is stark.

Nevertheless, there are an increasing number of instances of environmental flows being successfully implemented. Some of these were documented in a recent WWF report, *Listen to the River: Lessons from a Global Review of Environmental Flow Success Stories*.⁴⁰ In many cases, implementation of environmental flows was stimulated by better engagement with stakeholders (including water users) and by improved understanding of the trade-offs and consequences of different river management options.

WATER QUALITY

In addition to water stress, the need to produce more food to feed a growing population is likely to have serious impacts on water quality. Under even the most optimistic economic growth and climate change scenarios, discharges of nitrogen into water bodies are projected to increase by 35-46% between 2000 and 2050.⁴¹

The risk of nutrient loading and eutrophication will escalate globally: although it may stabilise by 2030 in OECD countries, Russia and Ukraine, it's expected to increase after this date in Brazil, China, India, Indonesia and other emerging economies.⁴²

A 20% rise⁴³ in harmful algal blooms is projected for Africa, Asia and Brazil between 2000 and 2050.

Algal blooms arise when there are too many nutrients in rivers, lakes or coastal waters. They can be toxic to humans and animals and can have economic impacts through reduced tourist revenues, or through physical impacts such as the clogging of intake pipes. They can also cause major damage to ecosystems as algae block light and thus reduce growth of aquatic plants, and as a result of oxygen deprivation caused by increased numbers of bacteria (which use up more oxygen) feeding on dead algae.

Water will also be further contaminated by chemicals, pharmaceuticals (such as antibiotics and hormones from birth control pills), plastics and other pollutants: their impact on water quality is not yet fully understood.

BIODIVERSITY AND HABITAT LOSS

As discussed above, increasing production of food (and potentially bioenergy for climate change mitigation) is a major driver of land-use change. This can have significant negative impacts on biodiversity – particularly the loss of tropical forests and other natural ecosystems such as grasslands and savannahs.

Primary forests and other habitats could shrink by 13-20% by 2050 due to land-use change for pasture, food crops and bioenergy. This could also result in 10-15% terrestrial biodiversity loss between 2010 and 2050 globally, with most of this decline occurring before 2030, impacting ecosystem functioning and resilience to climate change. Species play a fundamental role in ecosystems: their loss alters the functioning of ecosystems, as well as the potential of ecosystems to respond and adapt to climate change impacts and other shocks.⁴⁴

Developing countries face the biggest potential biodiversity losses: they're home to many of the most biodiverse areas on the planet, but face intense pressures to convert land for other uses, while being least able to finance conservation measures.

Hotspots of future conflict between biodiversity and agriculture will be Central America and the Caribbean; the tropical Andes and south-western Brazil; west and east Africa, including Madagascar; and several parts of tropical Asia, in particular the Greater Mekong, Indonesia and Papua New Guinea.⁴⁵ A major expansion and intensification is expected in tropical agriculture, most of all in South America and sub-Saharan Africa.⁴⁶ Both regions have large land reserves that could in theory be converted to arable land, from the humid forests of the Amazon and Congo basins, to semi-arid expanses across South America's Cerrado and Pantanal regions, and Africa's Miombo and Guinea savannah-woodlands. However, these are also hugely important habitats for biodiversity, as well as significant carbon sinks.

CASE STUDY:

The establishment of the Mara Siana and Oloisukut conservancies in the Maasai Mara National Reserve, Kenya, has led to benefits for people and planet. With greater habitat protection and security, numbers of elephant, lion and African wild dog have increased. The livelihoods of local communities have been enhanced through annual land lease fees, employment, increased food security due to greater availability of grazing for their cattle during drought periods, and beekeeping and honey sales, which are providing extra income for women.

In some regions, land-use change is putting natural systems under intense pressure. In south Asia, continued deforestation, increasingly intensive industrial agriculture and major water stress could push ecosystems to breaking point. Scarce land and declining water will put huge pressure on ecosystems in the Middle East and north Africa.⁴⁷

Climate change poses an additional risk to biodiversity, and we can expect to see further impacts of a warming world on species and habitats. As temperatures on the tundra become continental in Canada and Siberia, more temperate regimes emerge in North America and central Europe and the tropical belt widens southwards, desertification is likely to increase and biodiversity will be at risk.⁴⁸ In scattered cases a changing climate may bring some benefits for biodiversity, but these are few and far between.

WILDLIFE IN A WARMING WORLD

The stark reality of what climate change could mean for biodiversity is set out in a recent WWF report, *Wildlife in a Warming World*.⁴⁹

This ground-breaking research examines the impact of climate change on nearly 80,000 plant and animal species in 35 of the world's most biodiverse areas, and finds that unchecked carbon emissions could lead to local extinction for almost half of them by the end of the century. Some regions see rates of losses above 80%.

Even if we succeed in keeping global warming below 2°C, some 25% of the species studied could disappear locally.

The research focuses purely on climatic factors. In reality – and as we can see in this report – there will also be other serious pressures on biodiversity, and the cumulative consequences are likely to be even more devastating.

Wildlife in a Warming World shows it's imperative we act to mitigate climate change for the sake of biodiversity – but as this current report illustrates, the challenge is to do so without threatening our food security or destroying the ecosystems which support the biodiversity in the first place.



Mbiwo Constantine Kusebahasa, WWF Climate Witness, planting pine tree sapling on his land in the Rwenzori mountains, Uganda. WWF has helped 574 farmers in the region plant 700,000 trees in its five-year programme to replenish the bare hills. Many farmers in the region are switching to 'drought-resistant' crops that include pineapple, mangoes, bananas, oranges and upland rice.

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CONCLUSION: AN INTEGRATED FUTURE FOR CLIMATE CHANGE, FOOD SECURITY AND NATURE

The literature clearly shows that pressures on our planet will continue to increase over the coming decades, under almost all of the studies reviewed.

Tough decisions will need to be made as we seek to feed a growing population, limit global warming to well below 2°C and halt the loss of nature across the world. At times there will be direct competition between these objectives, where achieving more of one comes at a cost to another. But if we are able to develop more integrated policy, many of these trade-offs could be avoided.

While today our efforts to tackle climate change, food security and biodiversity loss tend to be developed in silos, by governments and NGOs alike, decisions in the future must be integrated across these three objectives. The three are intimately related, and what happens in one will directly affect some or all of the others.

The good news is that it's not too late. Despite the complexities and tough choices, we do have a realistic chance of feeding the world while maintaining a healthy planet, even as the population approaches 10 billion by 2050. While the literature suggests that dietary changes are key, reducing food waste, improving agricultural productivity and making more effective use of available land will also help to ease the pressure. At the same time, climate mitigation must take place in all sectors, but in a way that doesn't undermine nature and food security.

Recommendations for policy-makers can be found at the beginning of this publication.

REFERENCES

1. www.cbd.int/convention/articles/default.shtml?a=cbd-02

2. www.unenvironment.org/explore-topics/ecosystems/why-do-ecosystems-matter

3. https://dictionary.cambridge.org/dictionary/english/wildlife

4. https://en.oxforddictionaries.com/definition/nature

5. http://sustainableScale.org/ConceptualFramework/UnderstandingScale/MeasuringScale/CarryingCapacity.aspx

6. UN Convention to Combat Desertification, 1994.

7. Comprehensive Assessment of Water Management in Agriculture, 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London, Earthscan and Colombo: International Water Management Institute.

8. Gardiner, A and Gulati, M. 2018. *Population, consumption and planetary limits – final report*. [Original unpublished research available on request from WWF.]

9. https://data.worldbank.org/indicator/AG.LND.AGRI.ZS

10. Kim et al, 2015. *The Importance of Reducing Animal Product Consumption and Wasted Food in Mitigating Catastrophic Climate Change*. John Hopkins Paper.

11. Gardiner, A and Gulati, M. 2018. *Population, consumption and planetary limits – final report*. [Original unpublished research available on request from WWF.]

12. From www.globalagriculture.org/report-topics/meat-and-animal-feed.html , referencing FAO 2014.

13. Gerber PJ, Steinfeld H, Henderson B, Mottet A, Opio C, Dijkman J, Faluccci A and G Tempio. 2013. *Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*. FAO, Rome, Italy.

14. Conijn et al. 2018. Can our global food system meet food demand within planetary boundaries? *Agriculture, Ecosystems and Environment* 251 pp244–256; Bajzelj et al. 2014. Importance of food-demand management for climate mitigation. *Nature Climate Change* 4, 924–92; Stefanovic et al. 2017. Mitigation Strategies for Greenhouse Gas Emissions from Agriculture and Land-Use Change: Consequences for Food Prices. *Environ. Sci. Technol.*, 51, 365–374.

15. www.wwf.org.uk/sites/default/files/2017-09/WWF_Livewell_Plates_Full_Report_Sept2017_Web.pdf

16. Bajzelj et al. 2014. Importance of food-demand management for climate mitigation. *Nature Climate Change* 4, 924–92.

17. Springmann et al. 2017. Mitigation potential and global health impacts from emissions pricing of food commodities. *Nature Climate Change* Vol 17.

18. Timilsina, GR, Shrestha, A. 2010. Biofuels: Markets, Targets and Impacts. World Bank; Springmann et al. 2017. Mitigation potential and global health impacts from emissions pricing of food commodities. *Nature Climate Change* Vol 17; Stefanovic et al. 2017. Mitigation Strategies for Greenhouse Gas Emissions from Agriculture and Land-Use Change: Consequences for Food Prices. *Environ. Sci. Technol.*, 51, 365–374; Obersteiner et al. 2016. Assessing the land resource-food price nexus of the SDGs. *Science* 2016 2; Frank et al. 2017. *Environmental research letters* vol 12 105004.

19. Springmann et al. 2017. Mitigation potential and global health impacts from emissions pricing of food commodities. *Nature Climate Change* Vol 17.

20. Gaudin ACM, Tolhurst TN, Ker AP, Janovicek K, Tortora C, Martin RC, et al. (2015) Increasing Crop Diversity Mitigates Weather Variations and Improves Yield Stability. *PLoS ONE* 10(2): e0113261. https://doi.org/10.1371/journal.pone.0113261

21. Conijn et al. 2018. Can our global food system meet food demand within planetary boundaries? *Agriculture, Ecosystems and Environment* 251 pp244–256; Bajzelj et al. 2014. Importance of food-demand management for climate mitigation. *Nature Climate Change* 4, 924–92; Stefanovic et al. 2017. Mitigation Strategies for Greenhouse Gas Emissions from Agriculture and Land-Use Change: Consequences for Food Prices. *Environ. Sci. Technol.*, 51, 365–374.

22. Bajzelj et al. 2014. Importance of food-demand management for climate mitigation. *Nature Climate Change* 4, 924–92.

23. Souza, G. M., Victoria, R., Joly, C., & Verdade, L., (Eds.), (2015). *Bioenergy and Sustainability: Bridging the Gaps* (Vol. 72, p.779). Paris: SCOPE. ISBN 978-2-9545557-0-6; Kline, K. L., et al. Reconciling food security and bioenergy: priorities for action. *GCB Bioenergy* (2017) 9, 557–576, doi: 10.1111/gcbb.12366.

24. Bonsch, M et al. 2016. Trade-offs between land and water requirements for large-scale bioenergy production. *GCB Bioenergy* 8, 11–24, doi: 10.1111/gcbb.12226.

25. Bonsch, M et al. 2016. Trade-offs between land and water requirements for large-scale bioenergy production. *GCB Bioenergy* 8, 11–24, doi: 10.1111/gcbb.12226.

26. Kreidenweis, U. 2016. *Afforestation to mitigate climate change: impacts on food prices under consideration of albedo effects*. *Environ. Res. Lett.* 11 085001.

27. Costanza, R; de Groot, R; Sutton, P; van der Ploeg, S; Anderson, S.J; Kubiszewski, I; Farber, S; Turner, R.K. (2014) Changes in the global value of ecosystem services. *Global Environmental Change* 26: 152–158.

28. www.ipbes.net/news/media-release-biodiversity-nature%E2%80%99s-contributions-continue-%C2%A0dangerous-decline-scientists-warn

29. Millennium Ecosystem Assessment, 2005. *Ecosystems and human wellbeing: synthesis*. Washington, DC: Island Press.

30. www.ipbes.net/news/media-release-worsening-worldwide-land-degradation-now-%E2%80%98critical%E2%80%99-undermining-well-being-32

31. www.ipbes.net/news/media-release-worsening-worldwide-land-degradation-now-%E2%80%98critical%E2%80%99-undermining-well-being-32

32. www.ipbes.net/news/media-release-biodiversity-nature%E2%80%99s-contributions-continue-%C2%A0dangerous-decline-scientists-warn

33. Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z., Knowler, D. J., Leveque, C., Naiman, R. J., Prieur-Richard, A. H., Soto, D.

34. The United Nations World Water Development Report 2018, p.13.

35. Mountford, H. 2011. *Water: The Environmental Outlook to 2050*. OECD Global Forum on Environment: Making Water Reform Happen 25-26 October. Paris. Hanjra, MA and Qureshi, ME. 2010. Global water crisis and future food security in an era of climate change. *Food Policy* 35, pp 365–377; OECD. 2012. OECD Environmental Outlook to 2050. *The Consequences of Inaction*, OECD Publishing.

36. Beringer, T, Lucht, W, and S Schaphoff. 2011. Bioenergy production potential of global biomass plantations under environmental and agricultural constraints. *GCB Bio-energy* 3, 299–312.

37. Alcamo, J, Döll, P, Henrichs, T, Kaspar, F, Lehner, B, Rösch, T and S Siebert. 2003. Global estimates of water withdrawals and availability under current and future “business-as-usual” conditions. *Hydrological Sciences Journal*, 48:3, 339–348, DOI: 10.1623/hysj.48.3.339.45278.

38. Jagermeyr et al. 2017. Reconciling irrigated food production with environmental flows for Sustainable Development Goals implementation. *Nature Communications* 19 July 2017.

39. Immerzeel, DEJ et al. 2014. Biodiversity impacts of bioenergy crop production: a state-of-the-art review. *GCB Bioenergy*. 6:183–209.

40. Harwood, A., Johnson, S., Richter, B., Locke, A., Yu, X. and Tickner, D. 2017. Listen to the river: Lessons from a global review of environmental flow success stories, WWF-UK, Woking, UK.

41. OECD. 2012. OECD Environmental Outlook to 2050. *The Consequences of Inaction*, OECD Publishing.

42. Alcamo, J, van Vuuren, D, Ringler, C, Cramer, W, Masui, T, Alder, J and K Schulze. 2005. Changes in nature's balance sheet: model-based estimates of future worldwide ecosystem services. *Ecology and Society* 10(2): 19.

43. Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Biodiversity Synthesis*. World Resources Institute, Washington, DC; OECD. 2012. OECD Environmental Outlook to 2050. *The Consequences of Inaction*, OECD Publishing.

44. Delzeit et al. 2017. Addressing future trade-offs between biodiversity and cropland expansion to improve food security. *Regional Environmental Change*. Volume 17, Issue 5, pp 1429–1441.

45. African Development Bank. *Water Sector Governance in Africa. Volume 1 Theory and Practice*. Tunisia. ISBN 978-9973-071-48-4.

46. Alcamo, J, van Vuuren, D, Ringler, C, Cramer, W, Masui, T, Alder, J and K Schulze. 2005. Changes in nature's balance sheet: model-based estimates of future worldwide ecosystem services. *Ecology and Society* 10(2): 19.

47. Alcamo, J., D. van Vuuren, C. Ringler, W. Cramer, T. Masui, J. Alder, and K. Schulze. 2005. *Changes in nature's balance sheet: model-based estimates of future worldwide ecosystem services*. *Ecology and Society* 10(2): 19.

48. WWAP (United Nations World Water Assessment Programme). 2016. *The United Nations World Water Development Report 2016: Water and Jobs*. Paris, UNESCO.

49. www.wwf.org.uk/sites/default/files/2018-03/WWF_Wildlife_in_a_Warming_World.pdf



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