Global Metabolism

the impact of Food Systems on Planetary health

focus of Biodiversity for Food and Agriculture

BIO-413 Planetary Health

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About me…

1998-2003 M.S. in Medical Biotechnology, University of Naples, School of Medicine, Italy

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2009-2012 Postdoctoral fellow. Telethon Institute for Genetics and Medicine, Naples, Italy.

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Main Interests:

Lipid Metabolism , Membrane Cell Biology

Prof. Giovanni D'Angelo
Teaching: Module 4

A Trip to Malaysia

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A Sanctuary for Biodiversity

A Trip to Malaysia

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A Trip to Malaysia

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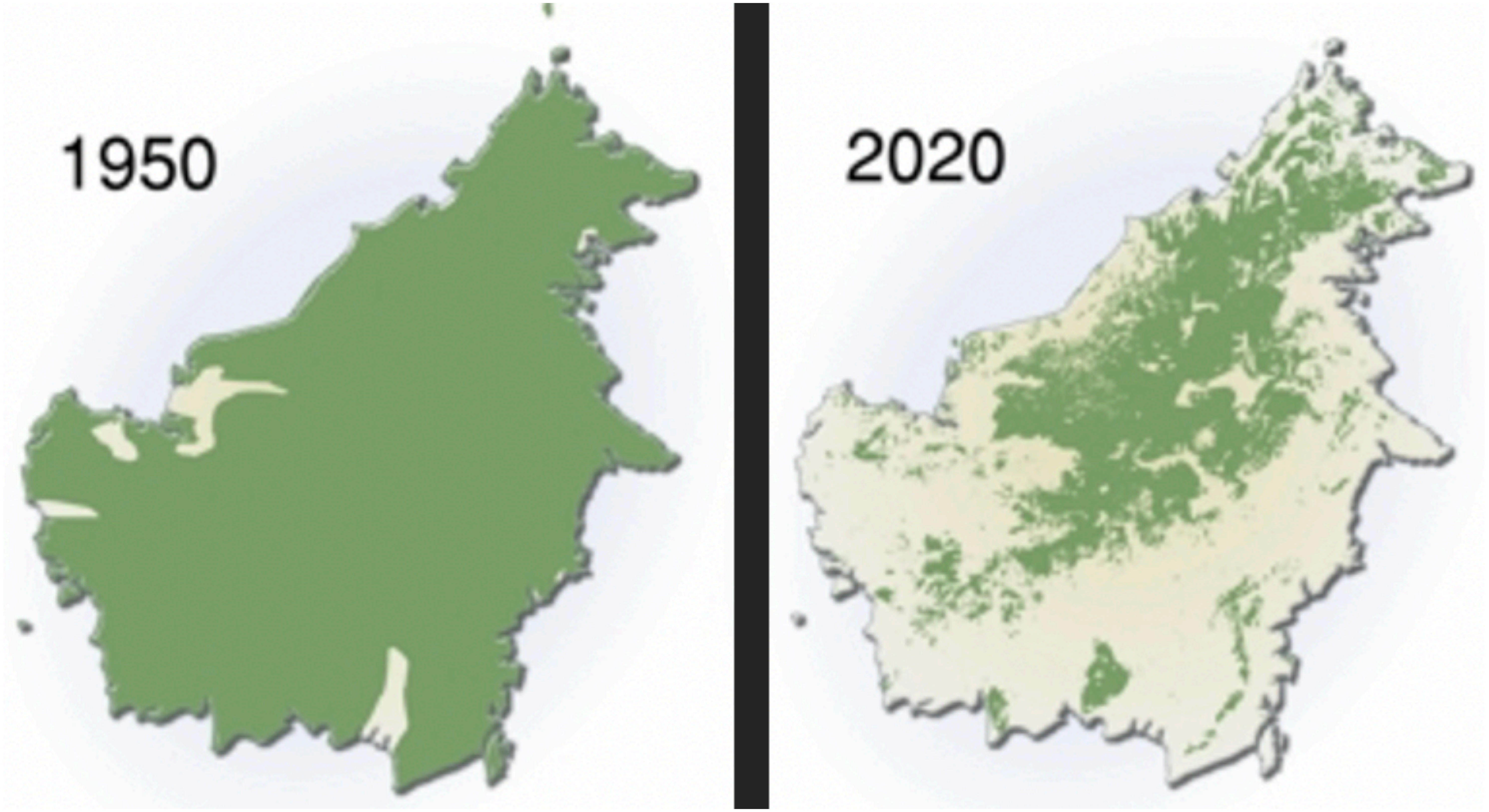
A Trip to Malaysia



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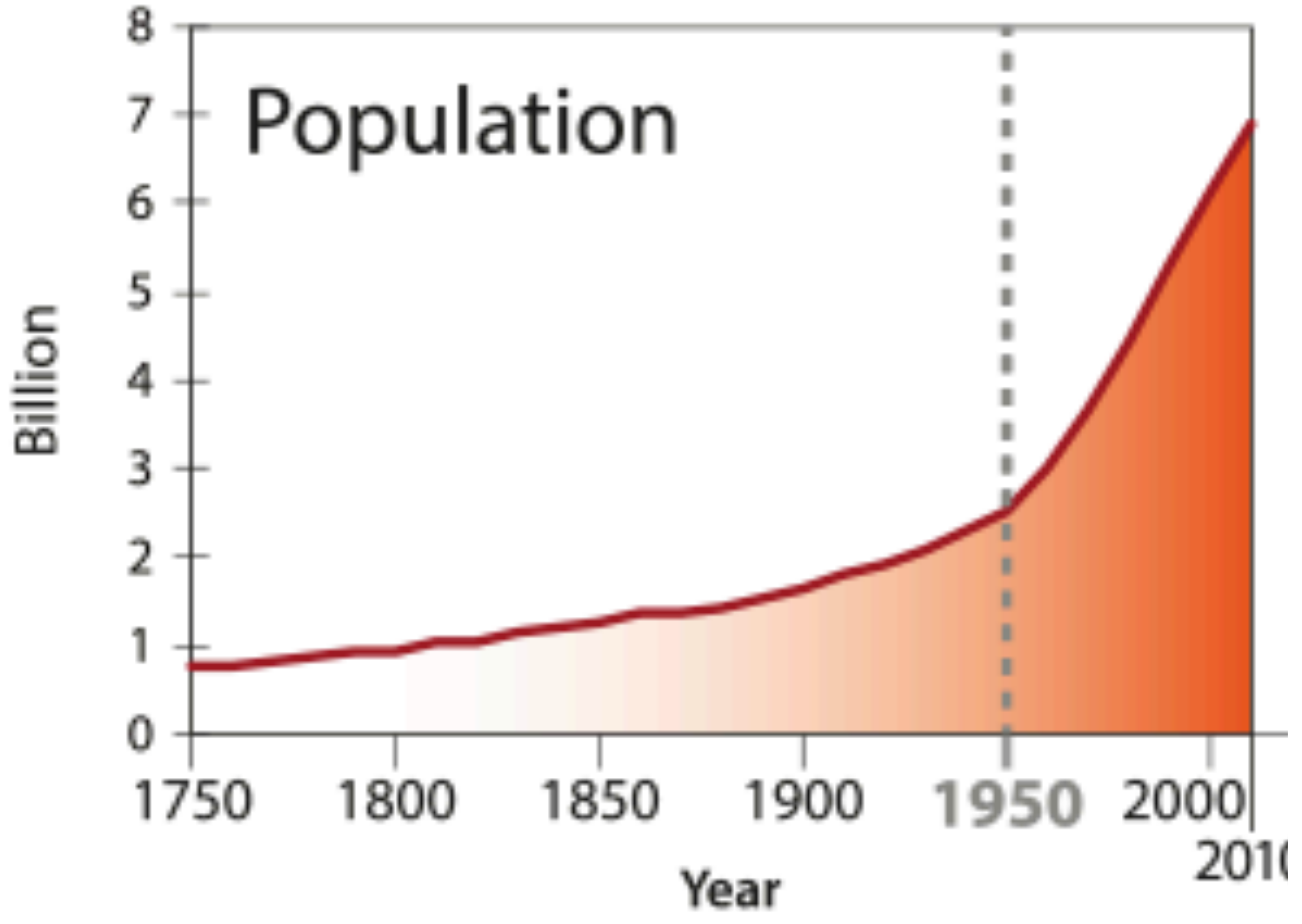
Global Metabolism

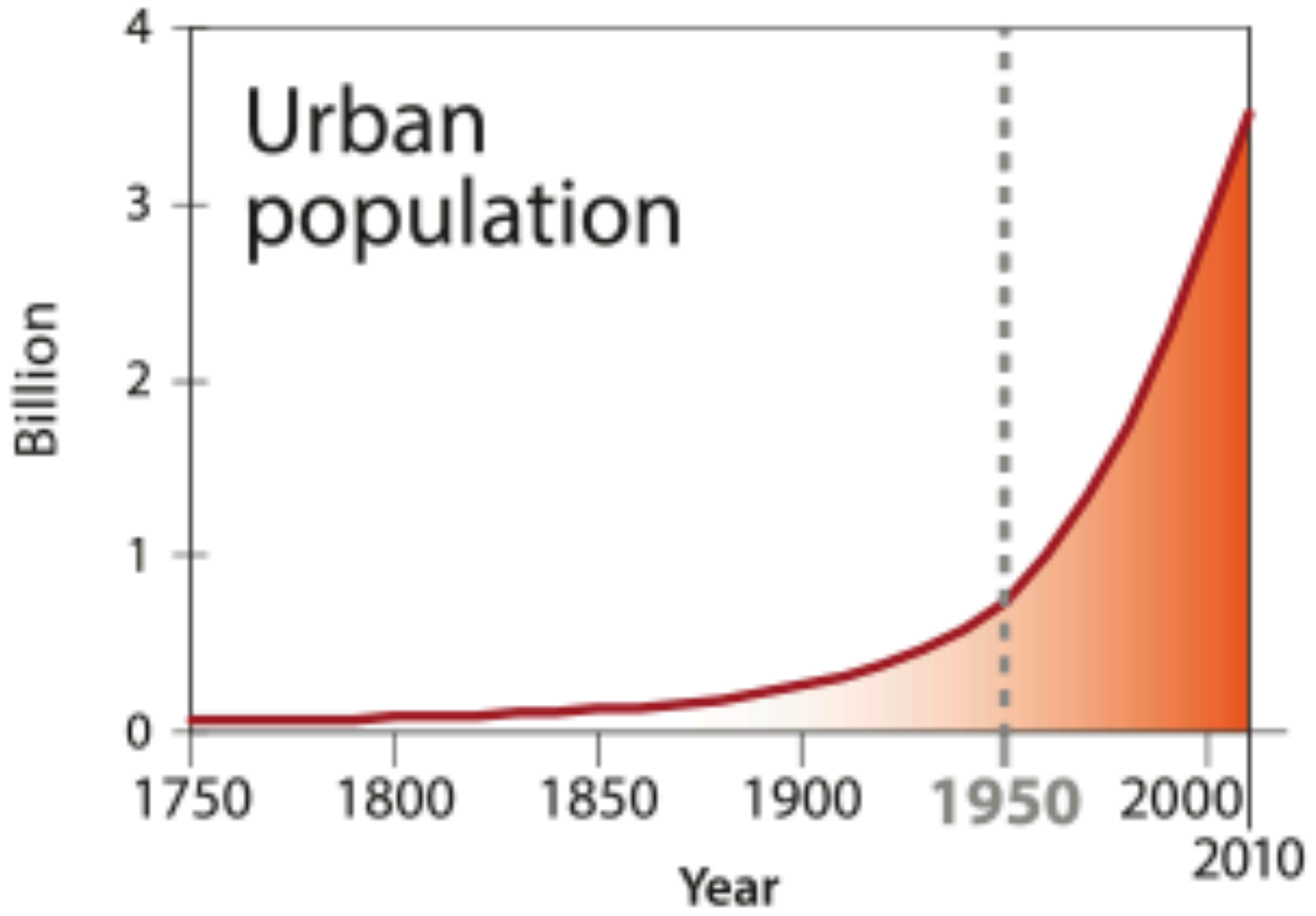
Learning outcomes for today

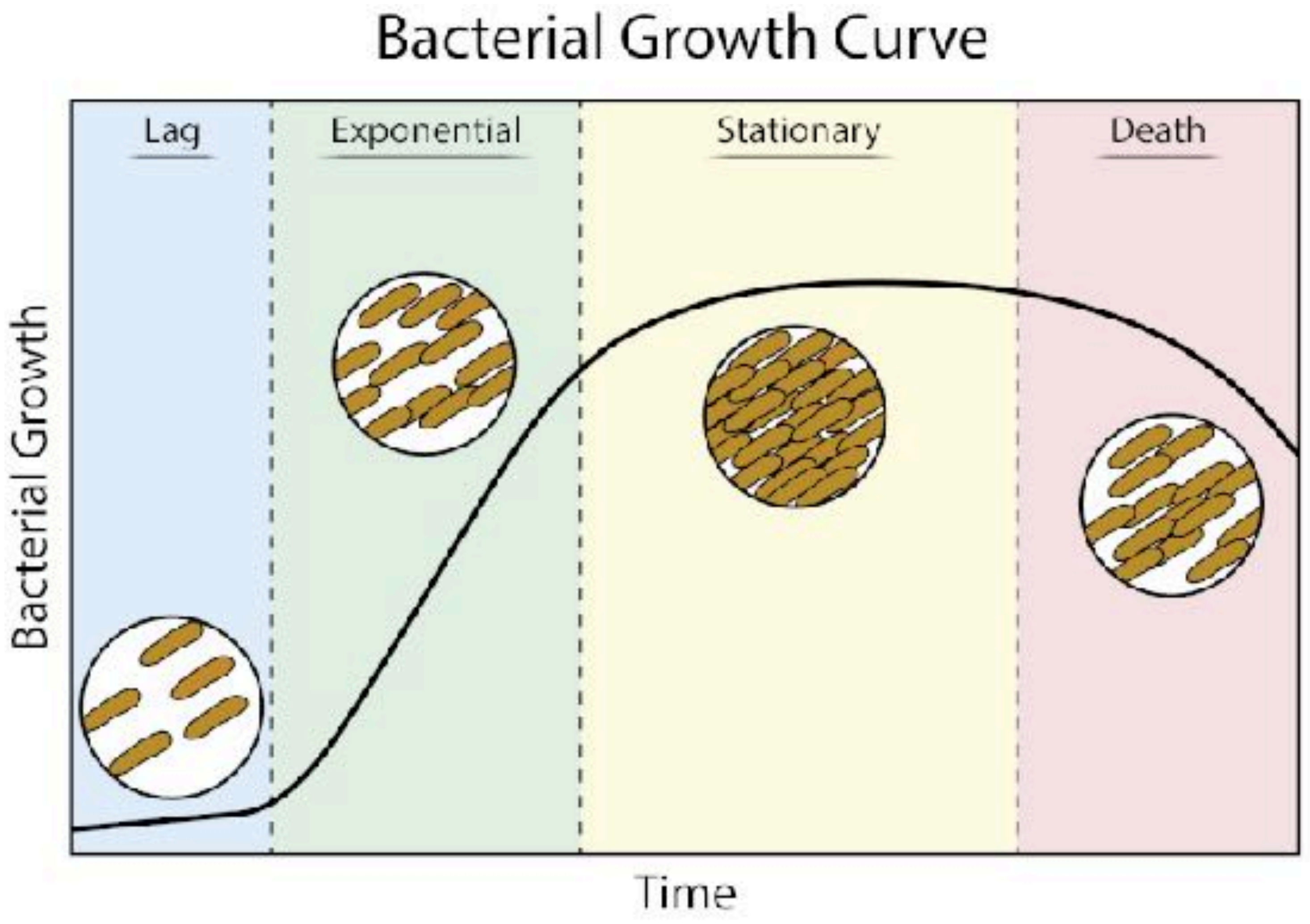
- Familiarise yourselves with the concepts of **food systems**, and **biodiversity for food and agriculture**
- Critically analyse the **state and trends** of functional biodiversity in food systems

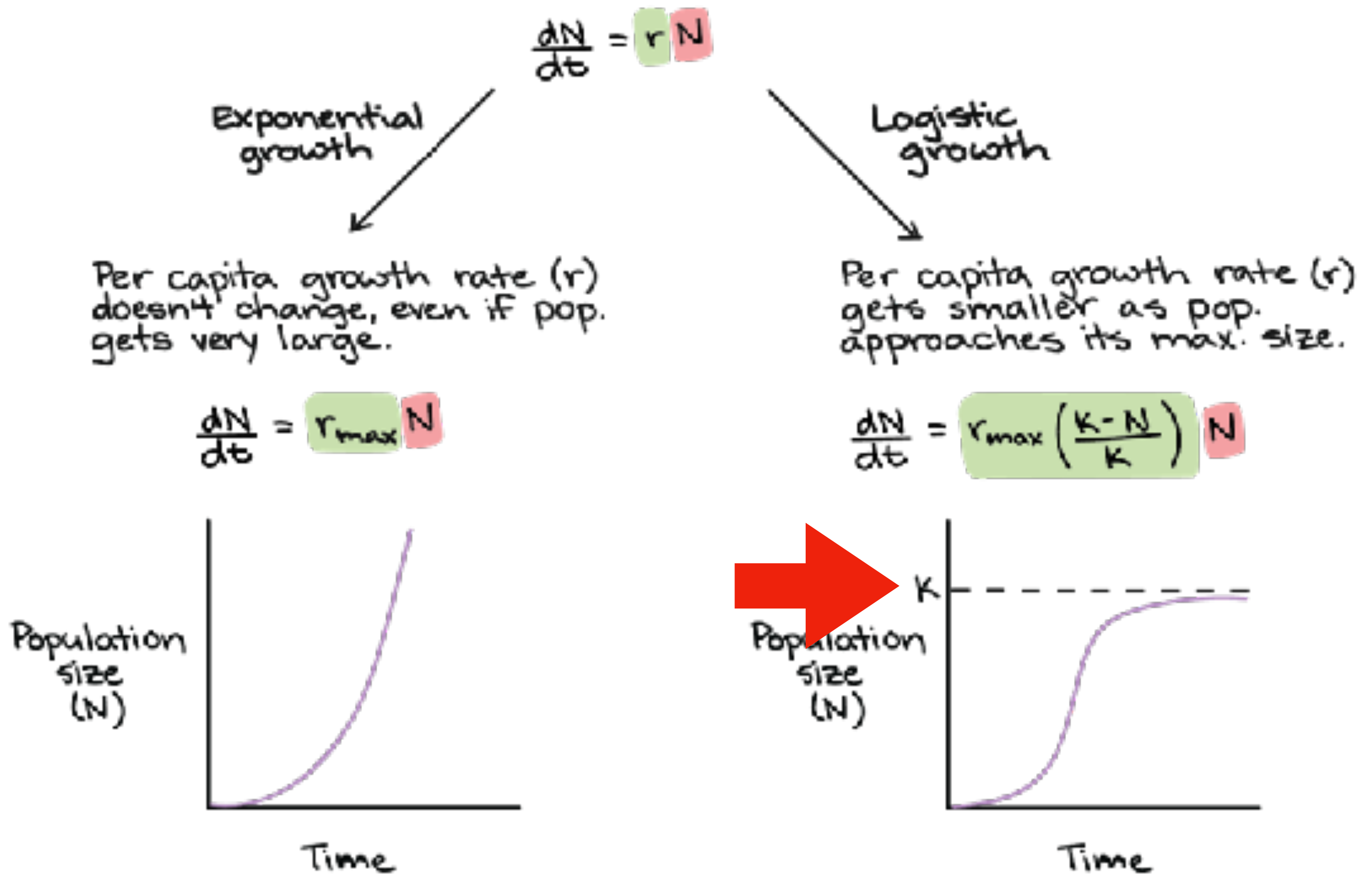
Population Growth

Global Metabolism









Food Systems

Food Systems

Human built systems devoted to production, transportation, processing, and distribution of food.

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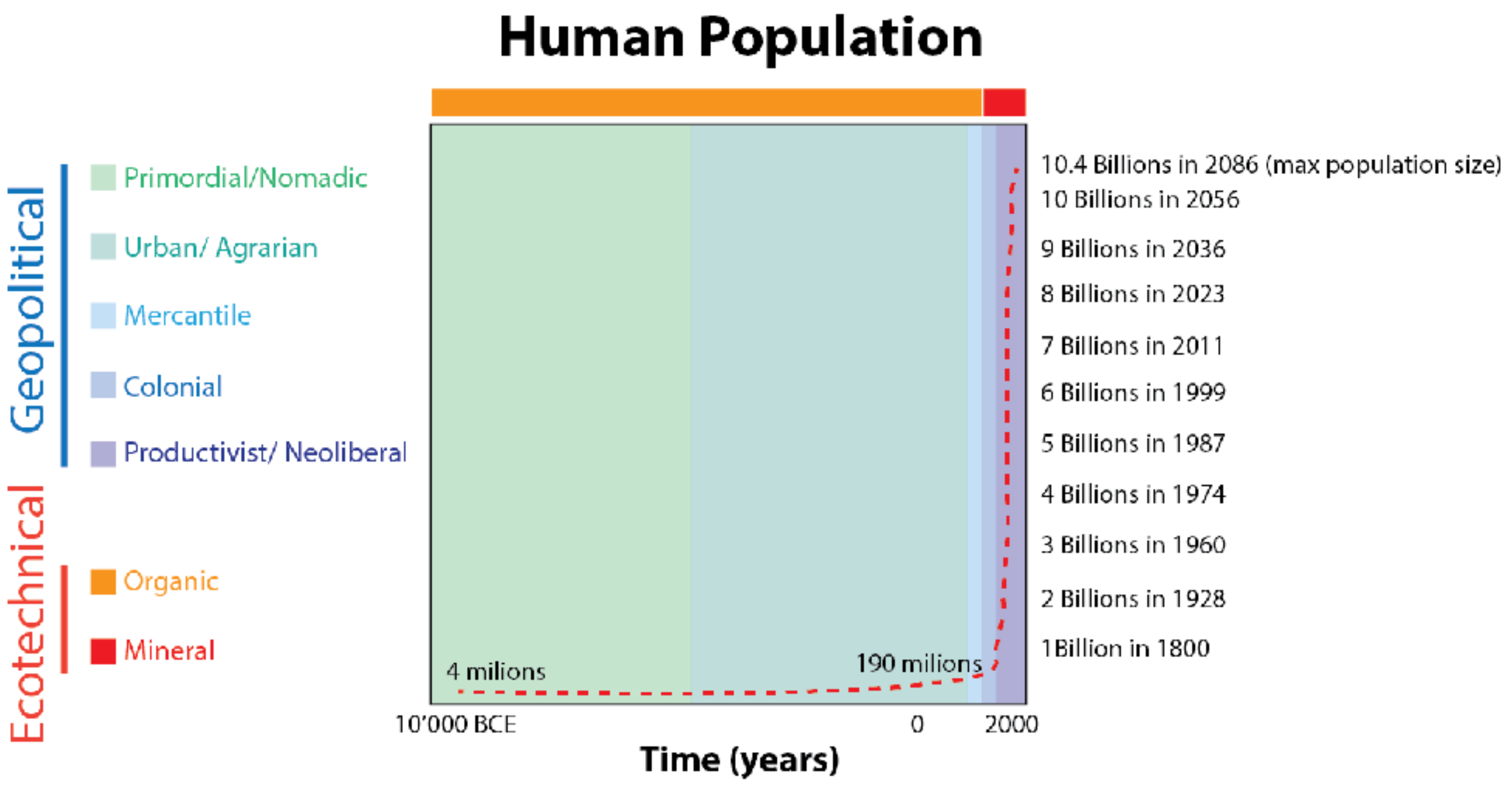

Food Systems

Human built systems devoted to production, transportation, processing, and distribution of food.

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Problem !!!

ensure food security and proper nutrition
for a massively growing population

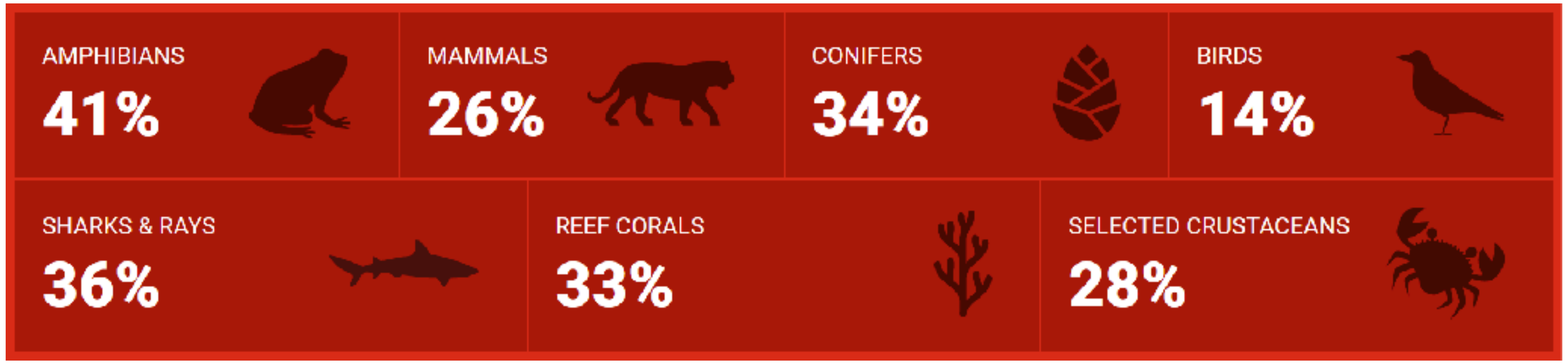
while

preserving the planet

Biodiversity

Biodiversity is the variability that exists among living organisms (both within and between species) and the ecosystems of which they are part.

Problem !!!



Food systems critically contribute to the erosion of Biodiversity.

But Biodiversity is required for effective and sustainable food production!!!

Biodiversity for Food

BFA

Biodiversity for food and agriculture (BFA) is the biodiversity that in one way or another contributes to agriculture and food production

The State of the World's Biodiversity for Food and Agriculture (SoW-BFA) addresses the sustainable use, development and conservation of BFA worldwide. BFA is taken to include the diversity of animals, plants and micro-organisms at the genetic, species and ecosystem levels that sustain structures, functions and processes in and around production systems and provide food and non-food agricultural products.

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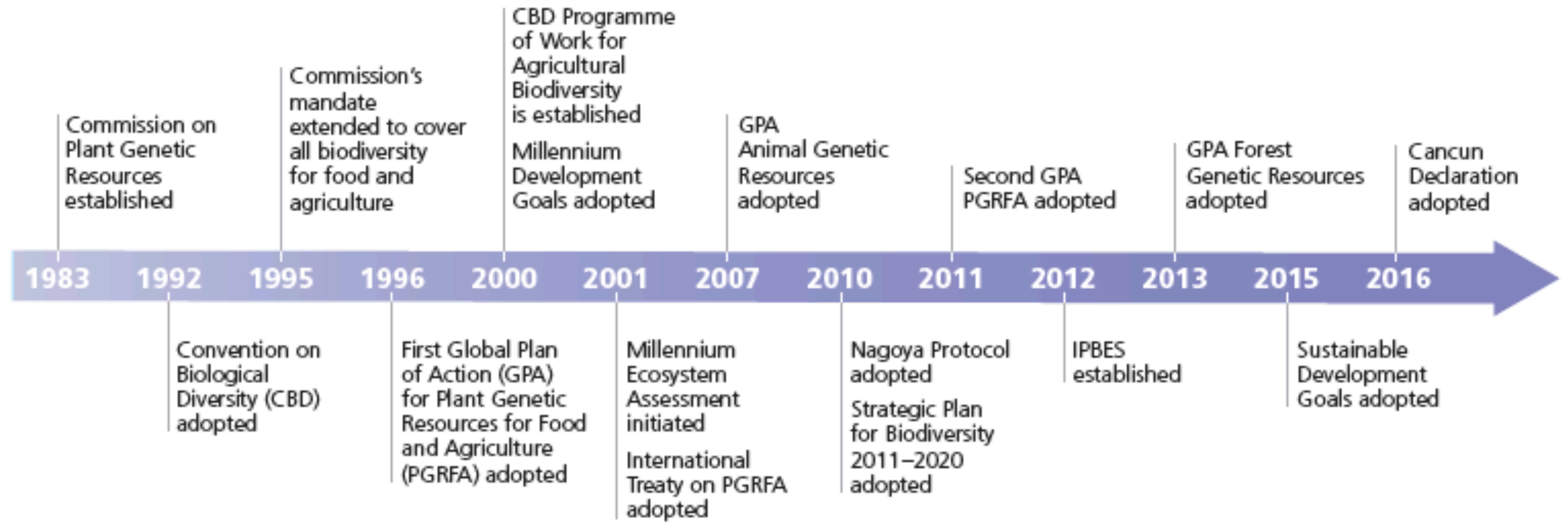
Key developments in the international recognition of the importance of biodiversity for food and agriculture



Ecosystem services for Food Systems

Diverse biological resources – domesticated and non-domesticated, and at every level from genes to ecosystems – are fundamental to food production and to the supply of many essential non-food products

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Biodiversity for Food

Human well-being depends i on the Earth's ecosystems and the biodiversity within them. In recent decades, it has become common to describe this dependence in terms of a set of "**services**" provided by ecosystems. This ecosystem service concept provided the framework for the Millennium Ecosystem Assessment, a major study of the state of the world's ecosystems and their influence on human well-being undertaken between 2001 and 2005. Ecosystem services were defined in this case as "the benefits humans derive from ecosystems"

Ecosystem services

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Biodiversity for Food

Biodiversity for food and agriculture (BFA) delivers multiple supporting and regulating ecosystem services including pollination, formation and maintenance of soils, nutrient cycling, climate regulation, maintenance of water supplies, and control of pests and diseases that are vital to production and to human well-being more broadly.

BFA contributes in many ways to the supply of cultural ecosystem services, i.e. the aesthetic, recreational, inspirational, spiritual and educational benefits that people obtain from contact with nature.

Ecosystem services for Food Systems

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Pollination

An estimated **87.5 percent** of all flowering plant species are pollinated by animals. Crops at least partially pollinated by animals account for **35 percent of global food production** and are particularly significant in the supply of micronutrients for human consumption, for example accounting for more than 90 percent of available vitamin C and more than 70 percent of available vitamin A . Bees, including both managed and wild species are generally the main providers of pollination services. Other insects, birds, bats and some other animals also contribute.

Ollerton, Winfree and Tarrant, 2011
Klein et al., 2007
Eilers et al., 2011

Ecosystem services for Food Systems

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Soil-related services

Soil formation and maintenance are inextricably linked to biodiversity. Micro organisms and invertebrates, in particular, are vital to soil health. Studies have shown that reducing soil biodiversity can impair various soil processes, including decomposition, nutrient retention and nutrient cycling, and reduce resilience to shocks

Beed et al., 2011
Cock et al., 2011
Schulz et al., 2013
Wagg et al., 2014

Ecosystem services for Food Systems

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Air-quality and climate

Soil Ecosystems used for food and agriculture and the biodiversity within them can affect the climate at global, continental and local scales. Forests, grasslands and freshwater, marine and coastal ecosystems play key roles in the Earth's carbon cycle and hence in regulating greenhouse-gas concentrations in the atmosphere. In all cases, the uptake and release of carbon depend on complex processes involving an enormous range of interacting species.

Beed et al., 2011
Cock et al., 2011
Laffoley and Grimsditch, 2009
Nellemann et al., 2009
Pullin and White, 2011

Ecosystem services for Food Systems

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Natural-hazard regulation

The frequency of several kinds of extreme weather events is predicted to increase under climate change, and thus one way in which BFA can contribute to reducing the threat posed by natural disasters is via its above-mentioned contributions to climate change mitigation. However, it can also play a more direct protective role. For example, a number of coastal ecosystems (mangroves, coral reefs, seagrass meadows, kelp forests, etc.) provide protection against coastal storms and flooding.

Ecosystem services for Food Systems

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Pest and disease regulation

The Many different components of biodiversity found in and around production systems help to control species that may attack crops, livestock, trees or aquatic species, cause or spread diseases or otherwise disrupt human activities or the supply of ecosystem services. The direct providers of these services (e.g. predators, parasitoids and herbivores that consume pests, disease vectors or weeds) are referred to as **biological control agents**.

Ecosystem services for Food Systems

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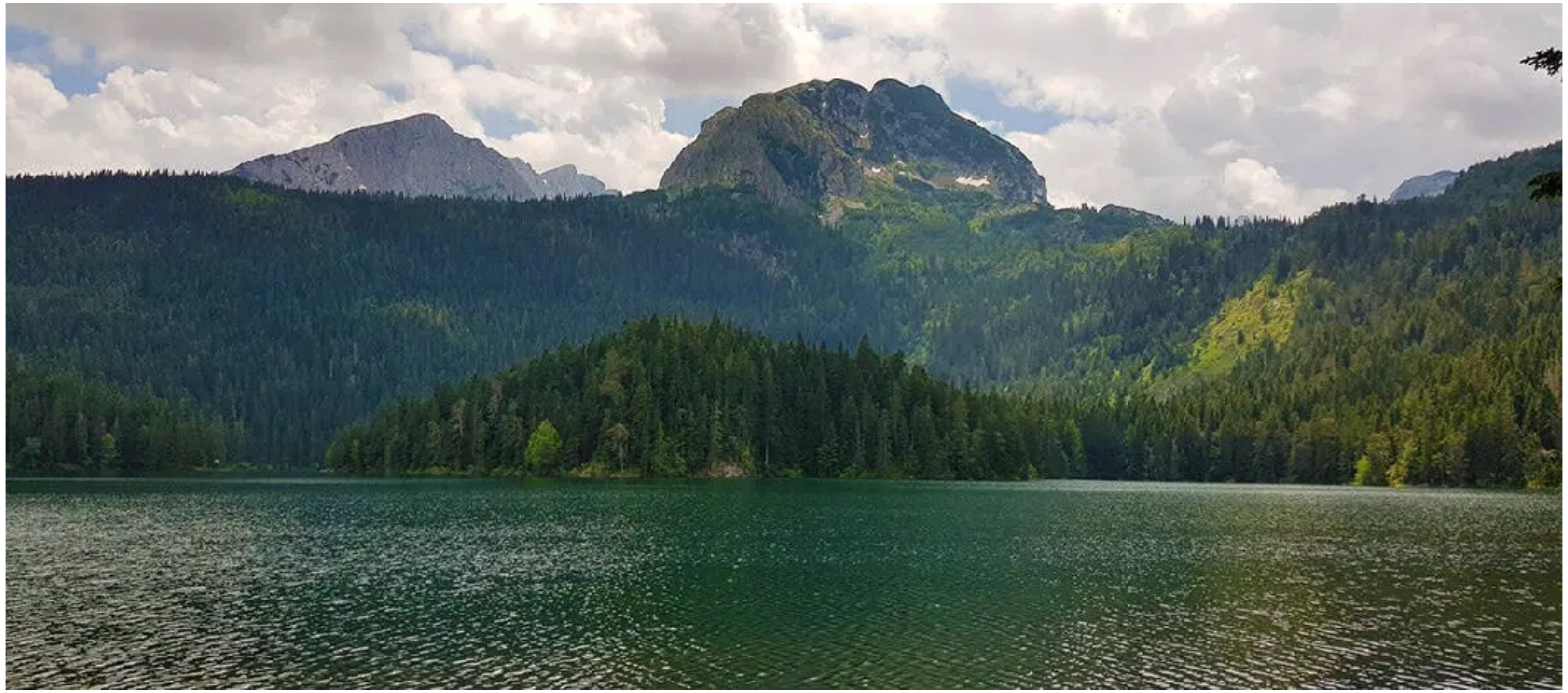
Water-related services

The Ecosystems used for food and agriculture affect both the quantity and the quality of water supplies. Healthy soils and vegetation, whether in forests, grasslands, wetlands or crop fields, help to regulate the run-off of water into downstream areas. This can both help to reduce the risk of flooding and to keep streams and rivers flowing during dry periods of the year. Where water quality is concerned, a range of different physical, chemical and biological processes contribute to removing contaminants (harmful organic and inorganic substances, pathogenic microbes, etc.)



Ecosystem services for Food Systems

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Habitat provisioning

The Food and agricultural production systems are, on the one hand, major drivers of habitat loss, but on the other are often significant habitats in their own right. In the case of forestry and fishing, it is clear that many production systems are diverse natural or semi-natural ecosystems that provide habitats for a vast range of species. At the other end of the spectrum, many crop, tree plantation and livestock systems raise only one, or only a very few, domesticated species and have largely been stripped even of semi-natural landscape remnants that would contribute to habitat diversity.

Ecosystem services for Food Systems

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Cultural services

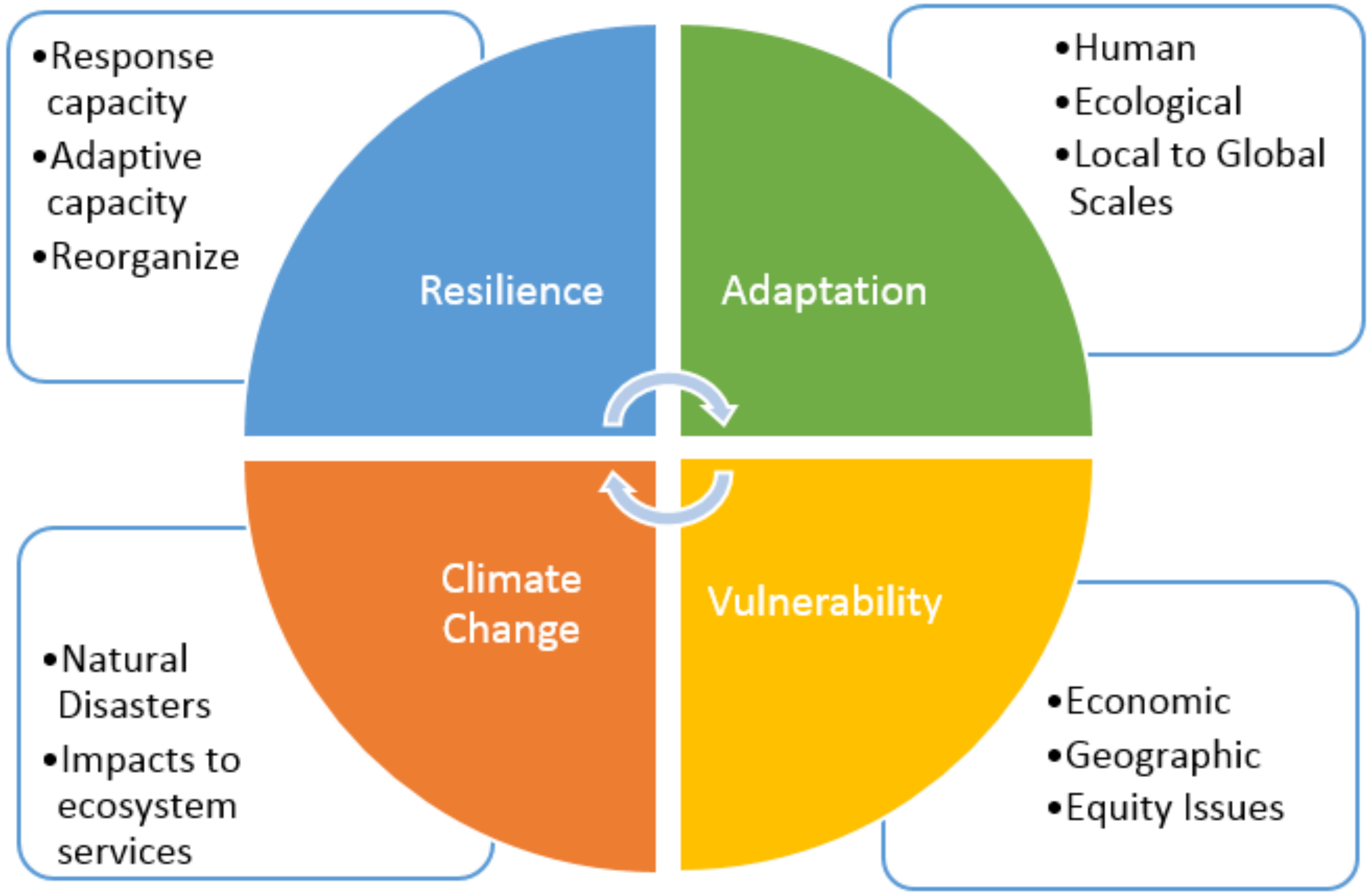
The Both production systems as a whole and their components (including species, varieties or breeds of crops, livestock, trees and aquatic organisms) can contribute to cultural ecosystem services, i.e. the aesthetic, recreational, inspirational, spiritual and educational benefits that people obtain from contact with ecosystems. Biodiversity has a major influence on the aesthetic appearance of many ecosystems, their capacity to inspire, their suitability for various recreational activities and their educational significance.

Resilience

BFA can improve the resilience of production systems by decreasing vulnerability to stresses and shocks, reducing their impacts and supporting recovery and adaptation

Resilience

The BFA provides options for adapting production systems to the threats posed by climate change and other environmental changes, strengthening disaster prevention, response and rehabilitation measures and combating threats posed by invasive alien species.



Resilience

BFA can improve the resilience of production systems by decreasing vulnerability to stresses and shocks, reducing their impacts and supporting recovery and adaptation

Climate change

The The significance of BFA in efforts to cope with the effects of climate change has received increasing attention in recent years. For example, the Resilience Outcome Document of the twenty-third session of the Conference of the Parties to the United Nations Framework Convention on Climate Change in 2017 recognized that "**nature is central to climate resilience**". The protection, sustainable management and restoration of terrestrial and marine ecosystems are the main elements for adaptation and resilience to a changing climate

Resilience

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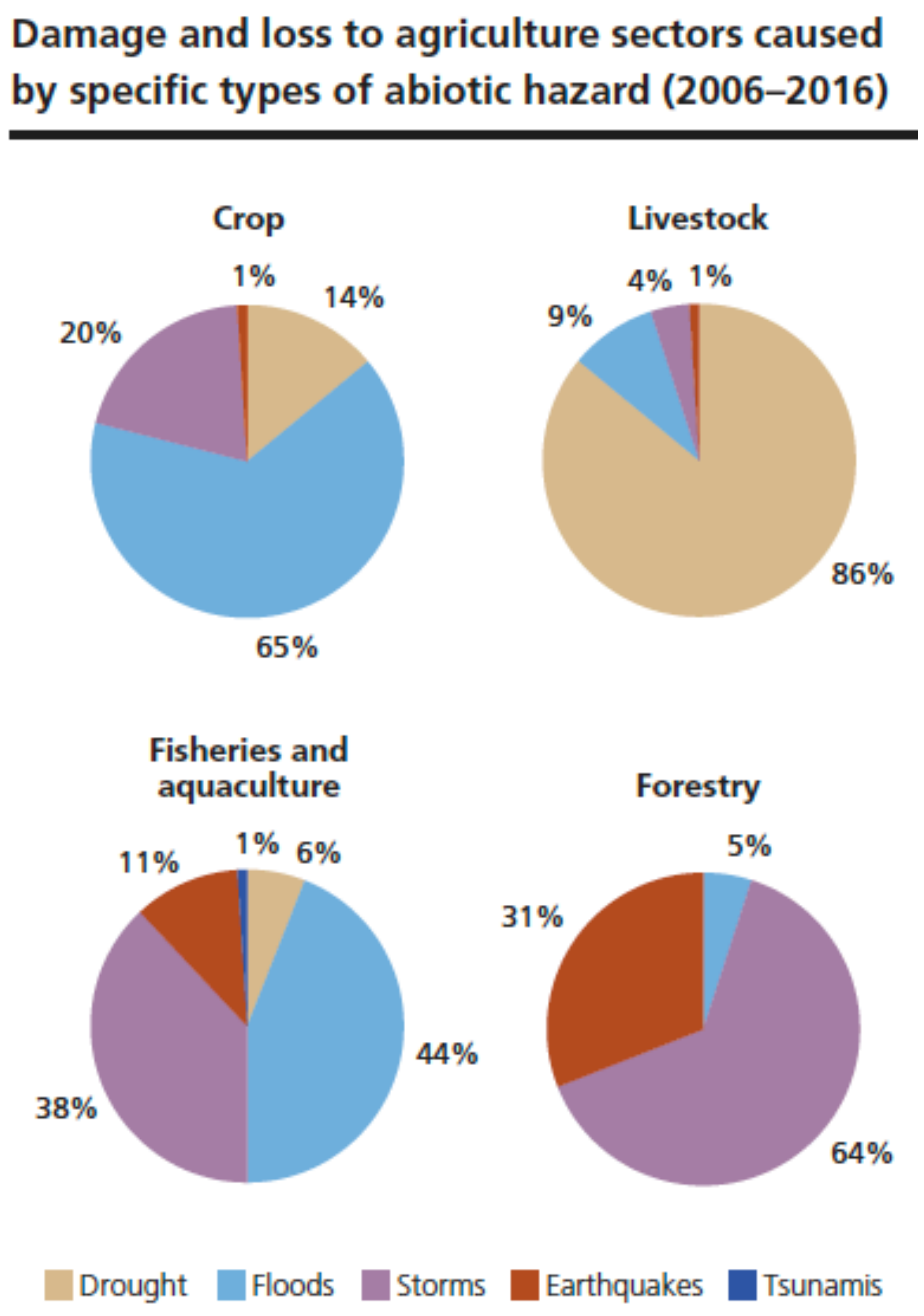
Disasters and their impacts



Bangladesh reports that in response to increased soil salinity following cyclones, researchers have screened for salinity-tolerant varieties of rice and other crops, which have then been multiplied and supplied to farmers. The United States of America mentions the Seeds of Success16 programme, which helps to re-establish stable native plant communities on land being rehabilitated after disasters such as wildfires. Argentina and Panama highlight the importance of genebanks in supporting producers in recovering genetic resources lost in disasters.

Invasive alien species

Resilience

BFA can improve the resilience of production systems by decreasing vulnerability to stresses and shocks, reducing their impacts and supporting recovery and adaptation

Invasive alien species are non-native organisms that have been introduced accidently or deliberately into a new location and are causing economic or environmental harm or adversely affecting human health.

Destabilized ecosystems, including systems used for food and agricultural production, tend to be more vulnerable to the spread of invasive alien species .

Various species are used as biological control agents to control invasive alien species. However, this strategy can carry some risk and needs to be carefully planned and monitored. It has sometimes had negative effects on native biodiversity.

Biological control of invasive alien species through predation, parasitism and herbivory – examples from the country reports

Invasive alien species	Controlling species	Countries reporting
Plants		
Eichhornia crassipes (water hyacinth)	*Neochetina bruchi* (chevroned water hyacinth weevil) *Neochetina eichorniae* (water hyacinth weevil)	Papua New Guinea Sudan
Mimosa diplotricha *Mimosa invisa* (giant sensitive plant)	*Heteropsylla spinulosa* (sensitive plant psyllid)	Niue Palau
Chromolaena odorata (Siam weed)	*Cecidochares connexa* (a gall fly)	Palau Papua New Guinea
Salvinia molesta (Kariba weed)	*Cyrtobagous salviniae* (giant salvinia)	Papua New Guinea
Pistia stratiotes (water lettuce)	*Neohydronomus affinis* (water lettuce weevil)	Papua New Guinea
Mikania micrantha (bitter vine)	*Puccinia spegazzini* (a rust fungus)	Papua New Guinea
Sida rhombifolia (flannel weed broom stick)	*Calligrapha pantherina* (sida leafbeetle)	Papua New Guinea
Impatiens glandulifera (Himalayan balsam)	Rust fungus	United Kingdom
Fallopia japonica (Japanese knotweed)	*Aphalara itadori* (Japanese knotweed psyllid)	United Kingdom (research ongoing)
Amorpha fruticosa (desert false indigo)	Cattle	Croatia (reintroduction of grazing cattle and traditional livestock farming; however, *Amorpha fruticosa* is reported to be widely spread and its eradication considered unlikely)
Insects		
Tuta absoluta (tomato leafminer)	*Bracon concolorans* (a parasitic wasp)	Jordan
Papuana huebneri (taro beetle)	*Metarhizium anisopliae* (a fungus)	Kiribati (reported as unsuccessful)
Molluscs		
Giant African snail	Flat worm	Solomon Islands
Other		
Not specified	Parasite or predator insects: *Trichogramma evanescens* (a wasp) *Bracon hebetor* *Podisus maculiventris* (spined soldier bug) Entemopathological nematodes	Georgia
Perccottus glenii (Amur sleeper) and other invasive alien fish species	*Silurus glanis* (Wels catfish) *Sander lucioperca* (pike-perch)	Hungary (effect reported to be insufficient to slow spread and proliferation or to offset negative effects on the native fish fauna)
River weed	Grass carp	Fiji
Sciurus carolinensis (grey squirrel)	*Martes martes* (pine marten)	Ireland

Source: Selected from the 91 country reports prepared for *The State of the World's Biodiversity for Food and Agriculture*.

Resilience

BFA can improve the resilience of production systems by decreasing vulnerability to stresses and shocks, reducing their impacts and supporting recovery and adaptation

Food-chain crises

Human food chains are affected by a range of shocks including pest and disease outbreaks and food-safety and pollution events. The report highlights the importance of **the conservation and availability of species and genetic diversity** in and around production systems, diversifying the use of crops, livestock, forest trees and aquaculture species, and restoring habitats to increase landscape and seascape complexity

Sustainable intensification

Efforts to increase the quantity and the nutritional quality of food products using less land, water and other inputs per unit output.

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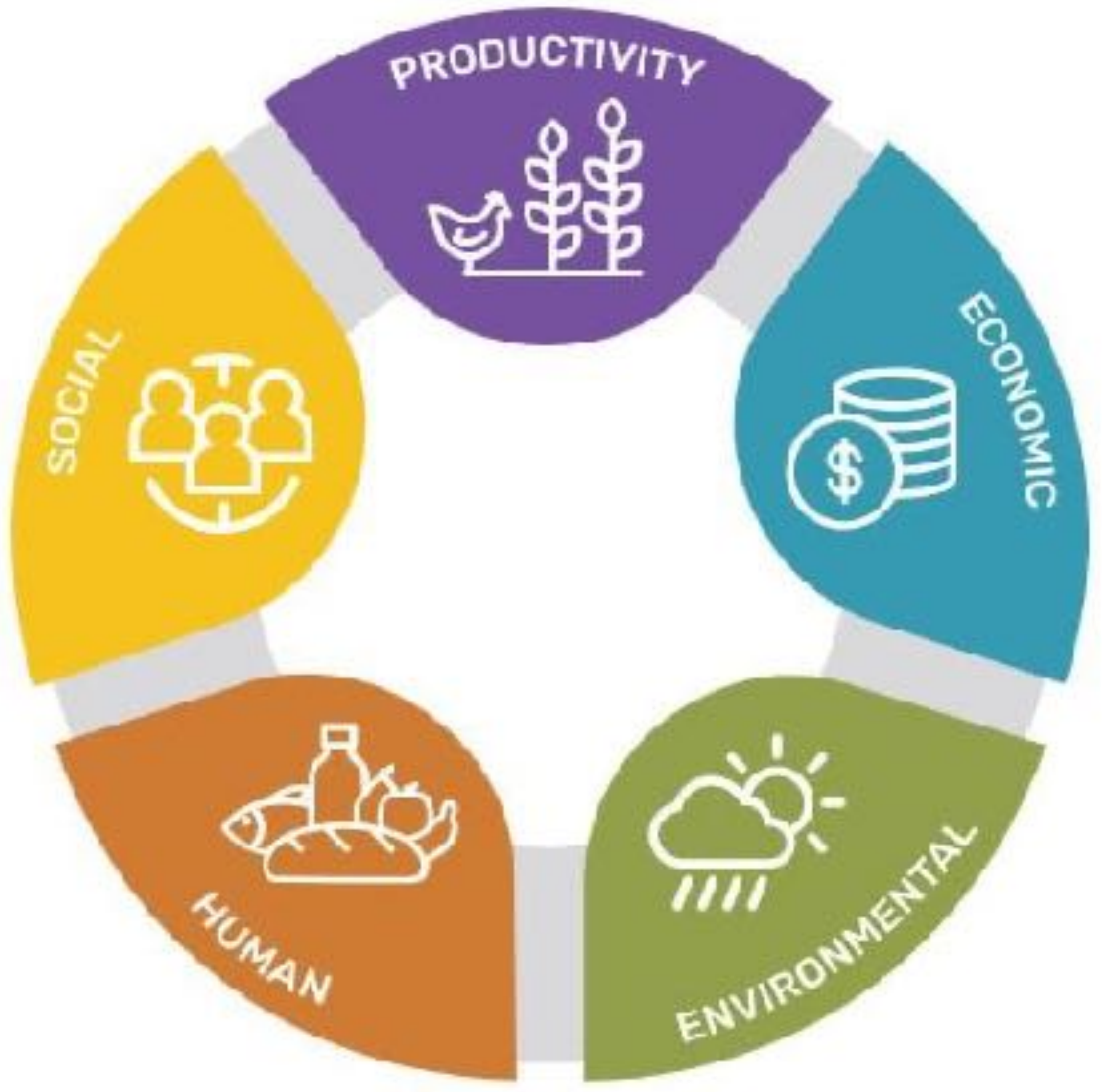
Sustainable intensification

The need to ensure the food security and nutrition of a world population predicted to increase to almost **9.8 billion by 2050** means that food supplies and their nutritional quality will need to increase substantially over the coming years and decades. it has been estimated that global food production will need to increase by 50 percent by 2050.

Appropriate diversification of the species, varieties and breeds present in and around production systems can promote positive interactions that reduce the need for external inputs.

Well-planned genetic-improvement programmes can produce plant and animal populations that have the characteristics needed to produce efficiently in specific production environments



Sustainable Diversification

Sustainable intensification

Efforts to increase the quantity and the nutritional quality of food products using less land, water and other inputs per unit output.

Utilizing a wider range of species, varieties or breeds from within a given sector (crops, livestock, forest, aquaculture, etc.), **promoting positive interactions**.

Potential measures involving associated biodiversity include increasing the availability of pollinator habitat by planting strips of wild flowers or trees within agricultural landscapes to promote pollinator abundance and diversity, and hence the supply of pollination services

Potential interventions to support positive interactions in food production systems

Component of biodiversity	Interventions	Approaches to measuring impacts	Knowledge gaps/research needs
Annual crops	Breed and select crops for more positive crop–crop interactions in production systems, exploiting wild and landrace gene pools (Litrico and Violle, 2015). Exploit species and within-species combinations to improve disease resistance and climate resilience (Döring et al., 2015; Hinrich et al., 2000). Explore the integration of a wider range of crops (including new and orphan crops) that may be able to interact positively with other components into cropping systems, over spatial (intercrop) and temporal (rotation) scales (AOCC, 2018; Dawson et al., 2018b).	Land equivalent ratio, stability and quality of production (direct measures). Rate of artificial fertilizer application, soil fertility, crop-species diversity in intercrops and rotations (indirect measures)	Interactions among annual crops are some of the best researched in food production systems. However, developing breeding methods that effectively account for these interactions requires a paradigm shift from current breeding methods, and this is still in its infancy (Litrico and Violle, 2015). A better understanding of genetic variation in important interaction traits in the crop gene pools available for breeding is required, exploring landraces and wild germplasm where variation in important traits may be more evident than in advanced crop cultivars grown in high-input monocultures (Palmgren et al., 2015). To integrate new and orphan crops into production systems, more research is needed on effective cropping options in combination with major crops, using cropping system modelling frameworks and based on knowledge of existing production systems (Reckling et al., 2016).
Trees in farmland and forests	Protect remaining forest/farm landscape mosaics. Further integrate trees, including leguminous species, into farms, with a focus on soil rehabilitation and improvement. Domesticate a wider range of tree species to increase productivity and allow them to compete successfully with annual crops and thereby contribute to agricultural diversification. Develop new markets for additional tree products and "shade-produced" commodities. Adopt more effective systems for delivering tree-planting materials to smallholder growers. (Sources: Leakey, 2010; Lillesø et al., 2011, 2018)	Land equivalent ratio, production resilience, life-cycle analysis (direct measures). Soil fertility, soil retention, niche occupation, species and market diversity (indirect measures). Many trees provide important habitat for animal pollinators, so distance-related effects on agricultural production from tree habitat can be measured (pollinator effects measured as indicated below).	Longer-term and larger-scale research on forest- and tree-based ecosystem services and associated impacts on food production is required (Reed et al., 2017). Positive spillovers from farms to forests are generally not well understood; further research on them is needed, for example on farm-habitat pollination services for forest food production (Blitzer et al., 2012). The impacts of agroforestry in terms of land-use changes and food security are only partially understood and require further study (van Noordwijk et al., 2014). The best approaches to bringing trees into cultivation to support agricultural diversification are often unknown; further research is needed on participatory tree domestication in particular, giving due attention to the specific needs of both women and men, and with particular emphasis on farm niches (Mulyoutami et al., 2015).
BFA in livestock production systems	Restore degraded pastures to support overall production and increase resilience. Adjust and diversify the breeds raised, the plants grown as feed and the composition of ruminal gut flora and fauna to enhance productivity/synergies and minimize environmental costs. Implement improved methods of manuring (Sources: Dawson et al., 2014; Dijkstra, Oenema and Bannink, 2011; Hayes, Lewin and Goddard, 2013)	Animal weight change and milk yield, crop yield and yield stability from manuring, life-cycle analysis (direct measures). Soil fertility, animal health, animal gut microflora and fauna composition, fodder diversity (indirect measures).	There is currently only limited detailed understanding of the interactions between animals and other components of production systems, including under climate change; further research on animal–crop(–tree) interactions is required (Thornton and Herrero, 2015). Methods for analysing greenhouse-gas balances to determine appropriate mitigation interventions in the context of other production components are available but need to be refined (de Boer et al., 2011).
BFA in aquatic production systems	Promote a wider range of production systems involving diverse components (algae, cleaner fish, etc.). Promote a greater range of crops capable of tolerating flooding and salinity in aquatic agriculture systems and that have greater complementarity in broader floodplain management. Domesticate a range of fish to increase the productivity and support the diversification and resilience of aquaculture and to increase the nutritional diversity of production. Diversify animal- and plant-based fish-feed resources. (Sources: FAO, 2016b; Faruque et al., 2017; Hall et al., 2011; Olesen et al., 2015; Thilsted et al., 2016; Wijkström, 2012).	Fish catch and catch stability, fish growth rate, crop yield and yield stability (direct measures). Fish diversity, fish-feed diversity and conversion efficiency, fish-pest and crop-pest prevalence (indirect measures). Many fish are important for nutritionally balanced diets, so increases in production can be modelled as human nutritional benefits.	There is frequently little information on interactions in aquatic agriculture systems and aquaculture, including interactions between terrestrial and aquatic components, and between aquaculture and fisheries; further research is needed in order to allow the development of more-effective integrated production strategies (Attwood et al., 2017b; Soto et al., 2012). The development of multitrophic aquaculture systems – i.e. systems in which organisms from different trophic levels (carnivores, filter feeders, autotrophes, etc.) are grown in combination – has received limited attention; further research is needed on the creation or enhancement of synergistic relationships in resource use and recycling (Barrington, Chopin and Robinson, 2009). Addressing the negative on- and off-site environmental impacts of aquaculture has received only limited attention and further research is needed.
Animal pollinators	Reintroduce a range of native pollinators into agricultural landscapes. Protect remaining natural habitat/habitat mosaics and further improve and expand animal-pollinator habitat in farmland through agroforestry, border planting, fallow practices, etc. Implement joint management plans for wild and introduced pollinators in landscapes. Reduce insecticide use in farmland. Adopt integrated, pollinator-friendly "environmental certification" approaches for animal-pollinated crops. (Sources: FAO, 2008a; Garibaldi et al., 2013; IPBES, 2016a; Klein et al., 2007; Kovács-Hostyánszki et al., 2017)	Yield, yield stability and quality of animal-pollinated crops (direct measures). Number, range and stability of pollinators/pollinator populations in agricultural landscapes, especially over the crop flowering period (indirect measures). Many animal-pollinated crops are of particular nutritional significance, so increases in crop production may be modelled as human nutritional benefits.	There are gaps in understanding of the levels of pollinator dependency of different crops; more realistic estimates of pollinator dependency in different production contexts are required especially for important staples (e.g. soybean) where the range of quoted effects is large, new and orphan crops, and low- and middle-income country production contexts (Klein et al., 2007; Melathopoulos, Cutler and Tyedmers, 2015; Teichroew et al., 2017). Climate change impacts on pollinator–crop mutualisms (e.g. impacts caused by loss of life-cycle synchronies) are often unknown and require elucidation, especially for major animal-pollinated crops (Giannini et al., 2012; Kerr et al., 2015).
Soil micro-organisms	Implement soil/farm-management practices that enhance beneficial microbe populations and support nutrient cycling and soil fertility, such as greater use of intercrops, rotations and appropriate tillage methods, and more incorporation of crop residues. Directly inoculate with microbial populations. Breed crops for more effective beneficial interactions with micro-organisms by exploiting wild and landrace crop gene pools. (Sources: Brooker et al., 2015; FAO, 2003a; Kapulnik and Kushnir, 1991; Mutch and Young, 2004)	Crop yield and yield stability (direct measures). Rate of artificial fertilizer application, soil fertility, soil texture, soil biomass quantity and composition, water run-off quality (indirect measures).	The role of below-ground biodiversity in nutrient cycling is often poorly characterized; more research is required on the mechanisms involved in shaping complex soil communities and their functions (Bardgett and Van Der Putten, 2014). The effectiveness of inoculation methods is often limited; research is needed to address colonization problems (Compant, Clément and Sessitsch, 2010). There is limited knowledge of how to create more effective crop–microbe interactions at the genotype-to-genotype level; research is required on a range of genotype combinations (Tikhonovich and Provorov, 2011). Research needs to address the question of how domestication and selective breeding have affected the ability of crops to establish beneficial interactions with rhizosphere microbes (Pérez-Jaramillo, Mendes and Raaijmakers, 2016).

Sustainable intensification

Efforts to increase the quantity and the nutritional quality of food products using less land, water and other inputs per unit output.

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Genetic improvement

Genetic-improvement programmes are among the main tools that can be drawn upon to increase the productivity and stability of food and agricultural systems, whether by increasing output, increasing product quality, enabling production to be maintained in harsh conditions or reducing harmful environmental impacts per unit of output. In many cases, however, plants and animals are **currently bred for use in production systems that are in one way or another unsustainable,** for example polluting, highly dependent on non-renewable resources or vulnerable to being undermined by the negative effects of various drivers of change. Breeding in support of sustainable intensification thus requires **adjusting breeding goals** so that the outputs are better adapted to systems that meet the overall objectives of the approach.

Breeding plants for attributes other than yield may be a means of promoting the supply of a wider range of ecosystem services, for example increasing carbon sequestration or water capture.

Food Security

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food

Food Security

Ending food insecurity and malnutrition remains one of the most fundamental challenges facing the world. According to the latest estimates, about 821 million people in the world are chronically undernourished. In 2017 151 million children under five years of age suffered from stunted growth, while 50 million suffered from wasting (a low weight-for-height ratio). Over 38 million children under five were estimated to be overweight and more than 672 million adults to be suffering from obesity.

BFA) contributes to food security and nutrition in many ways, including by enabling food to be produced in a wide range of environments, helping to maintain the stability of food supplies through the year and through shocks such as droughts and pest outbreaks, supplying a wide variety of nutritionally diverse foods and contributing to the supply of water and fuel used in food preparation.

availability, access, utilization, and stability are the four dimensions of food security

Availability

Increased output may require the domestication of additional food-producing species and increasing the use of **underutilized and neglected species**. It will certainly require efforts to ensure that the natural resources upon which food production depends, including all categories of BFA, are conserved and that the ecosystem services they provide are nurtured. For example, it has been estimated that about 30 percent of the increase in global production of food crops since the 1960s has come from pollinator-dependent crops.

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Utilisation

Utilization refers to the way in which food is used in order to create a state of nutritional well-being. This involves selecting a nutritionally balanced diet and storing, processing and preparing foods safely. A healthy diet will require **a range of different foods and hence a range of different plants and animals.** Studies have shown that dietary diversity is a good predictor of diet quality, particularly in the case of children's diets

Food Security

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food

Stability

Food stability exists when adequate food is available to all individuals at all times, for example with no seasonal shortages or shortages in years when harvests are poor. Diversity is significant to stability, whether in that the presence of a range of different food-producing species, varieties and breeds that have different life cycles and different adaptive characteristics helps to maintain food supplies through the seasons of the year and through inter-year variations in rainfall, temperature, disease challenge, etc.

Biodiversity plays an important and positive role for Food Systems

What is the state of BFA?

BFA DoC

BFA is affected by major global trends such as changes in climate, international markets and demography.

G. D'Angelo BIO-413 Planetary Health

Drivers of change of BFA

Demographic changes, urbanization, markets, trade and consumer preferences are reported to have strong influence on food systems, often with negative consequences for BFA and the ecosystem services it provides. Many of the drivers that have negative impacts on BFA, including overexploitation, overharvesting, pollution, overuse of external inputs, and changes in land and water management, are at least partially caused by inappropriate agricultural practices.

Drivers of change of BFA

Drivers of change explored in the country-reporting guidelines

Drivers	Explanatory notes provided in the guidelines
Population growth and urbanization	Population – changes in population metrics (e.g. growth, fertility, composition, mortality, migration, health and disease, including different effects on men and women) Urbanization – for example, shifts in proportion of urban and rural populations; change in urbanization trends, including different effects on men and women
Markets, trade and the private sector	Trade – changing terms of trade, globalization of markets, commercialization of products, retailing, the separate capacities of men and women to commercialize products, etc. Markets and consumption – demand-driven changes in production or practices, including the tastes, values or ethics of consumers that may directly or indirectly impact biodiversity for food and agriculture, product quantity or quality Private sector – the changing role and influence of the private sector and corporate interests
Changing economic, sociopolitical and cultural factors	Economic development – changes in economic circumstances of countries, industries, households (e.g. change in GDP and economic growth, structural change of economy, income diversification, and the different economic circumstances of men and women) Changing sociopolitical, cultural or religious factors – variation in the forces influencing the decision-making of men and women (e.g. public participation, shifts in the influence of the state vs the private sector, changes in levels of education and knowledge, shifts in the beliefs, values and norms held by groups of people) Participatory actions – the role of collective action towards conservation and use of biodiversity by stakeholders
Climate change	The impacts and effects of progressive climate change (alterations in precipitation regimes, temperature changes, loss of water supply, increased variability, sea-level rise, shifts in flowering time or seasonality, etc.)
Natural disasters	Climate shocks, extreme weather events and other natural disasters that threaten agricultural production and the resilience of production systems (e.g. hurricanes, earthquakes, floods and fires)
Pests, diseases and invasive alien species	New and emerging threats from pests, diseases and invasive species affecting biodiversity for food and agriculture (shifting ranges, introductions, increased suitability, loss of predators, etc.)
Advancements and innovations in science and technology	Development and diffusion of scientific knowledge and technologies (e.g. advances in breeding, improvements in mobile extension, tools for monitoring, biotechnology applications and access of men and women to information)
Changes in land and water use and management	Changes in use, management and practices around land and water (deforestation, fragmentation, modification of water regimes, forest degradation, land conversion for agriculture, ecosystem restoration, the role of women and men in land and water use and management, etc.)
Pollution and external inputs	Mismanaged, excessive or inappropriate use of external inputs (overapplication of fertilizer and pesticides, excessive use of antibiotics or hormones, nutrient loading, including from use of imported feed, ocean acidification, CO_2 fertilization, chemical and particulate pollutants, etc.)
Overexploitation and overharvesting	Unsustainable extraction practices (overfishing, overhunting, overgrazing, logging and extractive activities exceeding replacement rates or affecting species of uncertain and at-risk conservation status, etc.)
Policies	Policies – global, regional, national and subnational legislation and regulations (e.g. conservation regulations, and participation and compliance with international treaties and conventions) Economic and policy interventions – interventions that impact biodiversity for food and agriculture directly or indirectly (e.g. taxes, subsidies, charges for resource use and payments for ecosystem services) Intellectual property rights (IPR), access and benefit-sharing (ABS) – direct or indirect impacts of IPR and ABS policy and regulations on biodiversity for food and agriculture

BFA DoC

BFA is affected by major global trends such as changes in climate, international markets and demography.

Drivers of change of BFA

BFA DoC

BFA is affected by major global trends such as changes in climate, international markets and demography.

Number of countries reporting negative, neutral and positive effects of drivers of change on the diversity, availability and knowledge of wild foods

Driver	Negative			Neutral			Positive		
	Diversity	Availability	Knowledge	Diversity	Availability	Knowledge	Diversity	Availability	Knowledge
Population growth and urbanization	29	37	22	9	6	8	1	2	4
Markets, trade and the private sector	18	20	10	9	6	6	11	16	21
Changing economic, sociopolitical and cultural factors	19	18	9	8	8	8	12	14	18
Climate change	31	35	13	7	5	13	3	2	2
Natural disasters	22	29	11	8	6	11	2	2	3
Pests, diseases and invasive alien species	34	40	15	6	2	9	2	2	2
Advancements and innovations in science and technology	5	8	3	9	9	6	20	24	28
Changes in land and water use and management	32	41	21	8	5	10	5	6	7
Pollution and external inputs	29	35	13	8	5	9	1	1	6
Overexploitation and overharvesting	36	45	18	6	4	10	1	2	5
Policies	9	9	4	11	7	8	23	34	26

Notes: The numbers in the table represent counts of country reports. Sixty-one out of 91 country reports provided information.
Source: Country reports prepared for *The State of the World's Biodiversity for Food and Agriculture*.

Economic and social drivers

Information from countries indicates that population growth and urbanization, and associated habitat destruction and land conversion, are having a negative effect on BFA and ecosystem services, with forests and coastal habitats appearing to be particularly threatened. Outmigration from rural areas is tending to lead to changes in management practices and land use, in some cases leading to the decline of traditional, biodiverse production systems. Markets and trade have a generally homogenizing effect globally, and international trade, urbanization and increasing regulation of markets are considered by countries to have a largely negative effect on BFA

BFA DoC

BFA is affected by major global trends such as changes in climate, international markets and demography.

Population growth

Reported effects of population growth and urbanization on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of population growth and urbanization on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	-	-	-	-	-	-	-	-	-
Livestock landless systems	-	-	-	-	-	-	-	-	-
Naturally regenerated forests	-	-	-	-	-	-	-	-	-
Planted forests	-	-	-	-	-	-	-	-	-
Self-recruiting capture fisheries	-	-	-	-	-	-	-	-	-
Culture-based fisheries	-	-	-	-	-	-	-	-	-
Fed aquaculture	+/-	-	-	-	-	-	-	-	-
Non-fed aquaculture	-	-	-	-	-	-	-	-	-
Irrigated crop systems (rice)	-	-	-	-	-	-	-	-	-
Irrigated crop systems (other)	-	-	-	-	-	-	-	-	-
Rainfed crop systems	-	-	-	-	-	-	-	-	-
Mixed systems	-	-	-	-	-	-	-	-	-

Proportion of countries reporting the PS that report any effect of the driver (%)

13–20
21–27
28–34
35–41

People living in cities outnumber those living in rural areas. Projections indicate that population growth in cities will continue to increase. As people move to cities they tend to **depend increasingly on purchased foods**, often from a few supermarket chains. They also lose ties with rural areas and rural foods, and increasingly opt for processed foods rather than fresh foods.

Economic and social drivers

Economic and social drivers

Cultural factors

Reported effects of changing economic, sociopolitical and cultural factors on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of changing economic, sociopolitical and cultural factors on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	+/-	+/-	+/-	+/-	-	-	-	-	-
Livestock landless systems	+/-	+	+	+/-	+/-	+/-	+	-	+/-
Naturally regenerated forests	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
Planted forests	+/-	+/-	+/-	+/-	+/-	-	+/-	-	-
Self-recruiting capture fisheries	+/-	+/-	+/-	+/-	-	+/-	-	-	-
Culture-based fisheries	+	+	+	+	-	+	-	-	+/-
Fed aquaculture	+	+/-	+/-	+/-	+/-	+/-	-	+/-	+/-
Non-fed aquaculture	+/-	+	+/-	+/-	-	+/-	-	-	-
Irrigated crop systems (rice)	-	+/-	+/-	+/-	+/-	+/-	-	-	-
Irrigated crop systems (other)	+/-	+/-	+/-	+/-	+/-	+/-	-	-	-
Rainfed crop systems	-	+/-	+/-	+/-	+/-	+/-	-	-	+/-
Mixed systems	+/-	+/-	+/-	+/-	+/-	+/-	+/-	-	+/-

Proportion of countries reporting the PS that report any impact of the driver (%)

- 9–15
- 16–22
- 23–29
- 30–36

In many developing countries people tend to perceive traditional food crops as poor people's food. For example, in much of sub-Saharan Africa maize is perceived to be a "modern" crop and is promoted over traditional small grains by governmental extension services or private input suppliers.

Environmental drivers

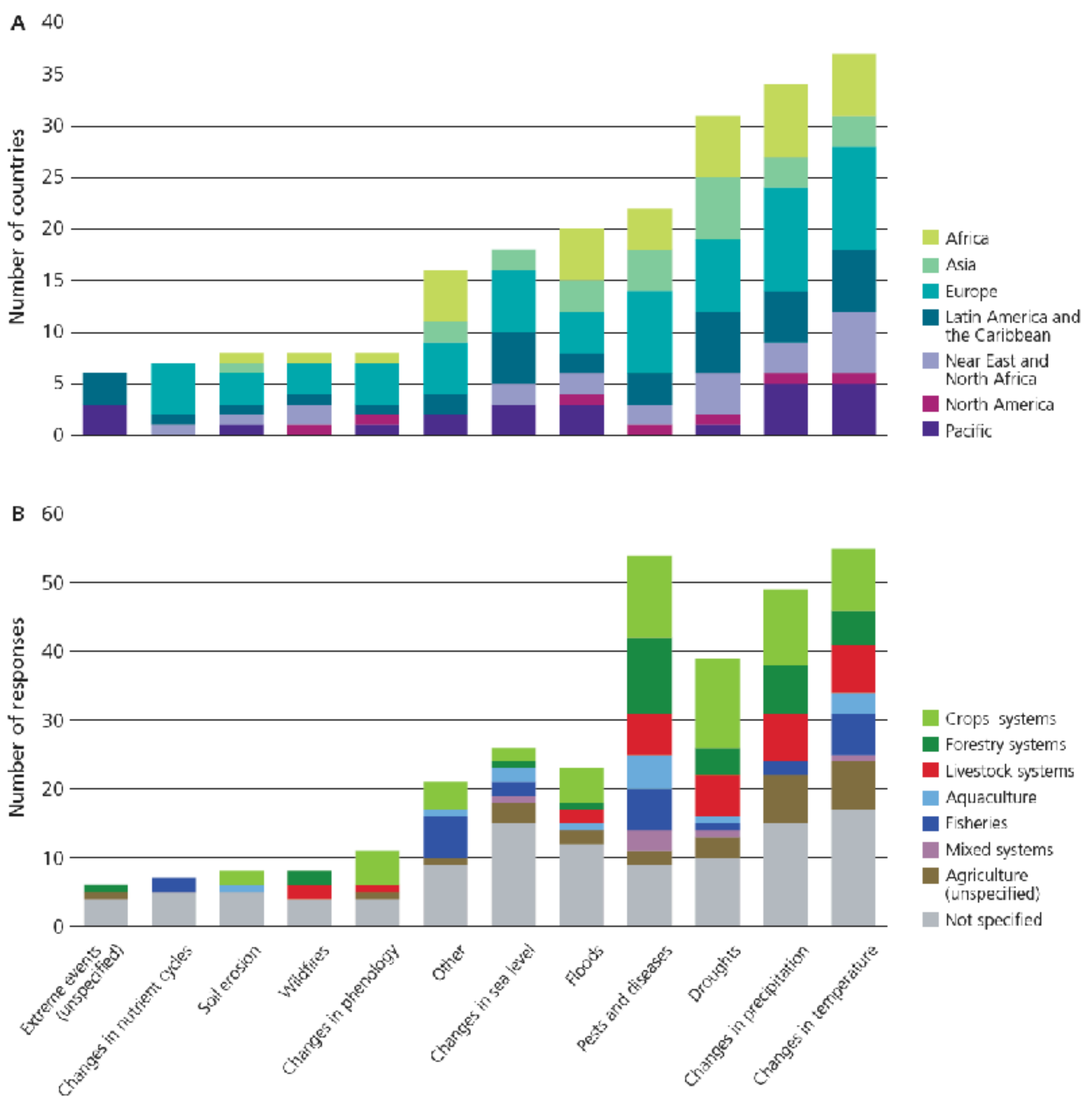
The distribution and phenology of important associated-biodiversity species are expected to change as a result of **climate change**, with negative effects on many production systems, especially on ecosystem services such as pollination and pest and disease control. **Meteorological disasters** can have severe long-term effects on BFA, with forest production systems and coastal areas appearing to be particularly vulnerable.

Environmental drivers

Environmental drivers

Environmental drivers

Reported climate change-related threats to associated biodiversity, (A) by region and (B) by production system



Environmental drivers

Climate change

Reported effects of climate change on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of climate change on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	-	-	-	-	-	-	-	-	-
Livestock landless systems	-	-	-	-	-	-	-	-	-
Naturally regenerated forests	-	-	-	-	-	-	-	-	-
Planted forests	-	-	-	-	-	-	-	-	-
Self-recruiting capture fisheries	-	-	-	-	-	-	-	-	-
Culture-based fisheries	-	-	-	-	-	-	-	-	-
Fed aquaculture	+/-	-	-	-	-	-	-	-	-
Non-fed aquaculture	-	-	-	-	-	-	-	-	-
Irrigated crop systems (rice)	-	-	-	-	-	-	-	-	-
Irrigated crop systems (other)	-	-	-	-	-	-	-	-	-
Rainfed crop systems	-	-	-	-	-	-	-	-	-
Mixed systems	-	-	-	-	-	-	-	-	-

Proportion of countries reporting the PS that report any effect of the driver (%)

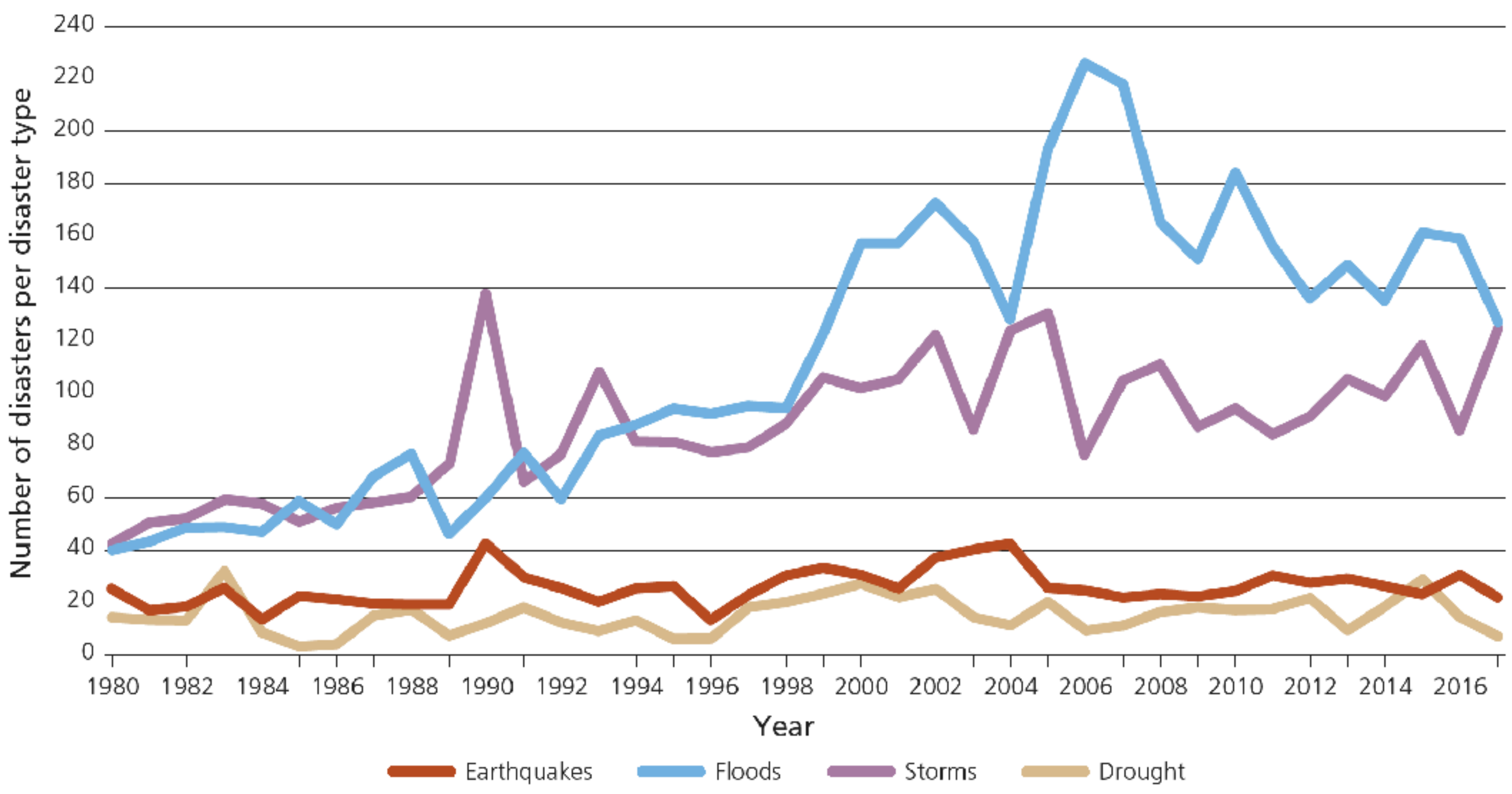
- 10–17
- 18–25
- 26–33
- 34–42

Climate change affects BFA and ecosystem services by changes in rainfall, temperature and the frequencies of events such as droughts, cyclones/hurricanes, floods, fires and early or late frosts and by changes in plant flowering seasons and growing periods, animal breeding seasons, the oxidation rate of soil organic matter and the ranges and population dynamics of invasive species, pests, pathogens and disease vectors.

Natural disasters

Environmental drivers

Global trends in the occurrence of natural disasters – 1980 to 2017



Natural disasters

Reported effects of natural disasters on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of natural disasters on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	-	-	-	-	-	-	-	-	-
Livestock landless systems	-	-	-	-	-	-	-	-	-
Naturally regenerated forests	-	-	-	-	-	-	-	-	-
Planted forests	-	-	-	-	-	-	-	-	-
Self-recruiting capture fisheries	-	-	-	-	-	-	-	-	-
Culture-based fisheries	-	-	-	-	-	-	-	-	-
Fed aquaculture	+/-	-	-	-	-	-	-	-	-
Non-fed aquaculture	-	-	-	-	-	-	-	-	-
Irrigated crop systems (rice)	-	-	-	-	-	-	-	-	-
Irrigated crop systems (other)	-	-	-	-	-	-	-	-	-
Rainfed crop systems	-	-	-	-	-	-	-	-	-
Mixed systems	-	-	-	-	-	-	-	-	-

Proportion of countries reporting the PS that report any effect of the driver (%)

10–16
17–23
24–30
31–38

Post-disaster needs assessments covering 74 medium- to large-scale disasters in 53 developing countries between 2006 and 2016 showed that **agriculture accounted for 23 percent of all losses and damage incurred.** Where droughts are concerned, agriculture absorbed 83 percent of the economic impact.

Environmental drivers

Invasive alien species

Environmental drivers

Reported effects of pests, diseases and invasive alien species on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of pests, diseases and invasive alien species on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/gas regulation
Livestock grassland–based systems	-	-	-	-	-	+/-	+/-	-	+/-
Livestock landless systems	+/-	-	-	-	-	+/-	-	-	-
Naturally regenerated forests	-	-	-	-	-	-	-	-	-
Planted forests	-	-	-	-	-	-	-	-	-
Self-recruiting capture fisheries	-	-	-	-	-	0	-	-	-
Culture-based fisheries	-	-	-	-	-	-	+/-	-	-
Fed aquaculture	-	-	-	-	-	+/-	-	-	-
Non-fed aquaculture	-	-	-	-	-	-	-	-	-
Irrigated crop systems (rice)	-	-	-	-	-	-	-	-	-
Irrigated crop systems (other)	-	-	-	-	-	0	+/-	-	-
Rainfed crop systems	-	-	-	-	-	-	-	-	-
Mixed systems	-	-	-	-	0	0	0	-	0

Proportion of countries reporting the PS that report any effect of the driver (%)

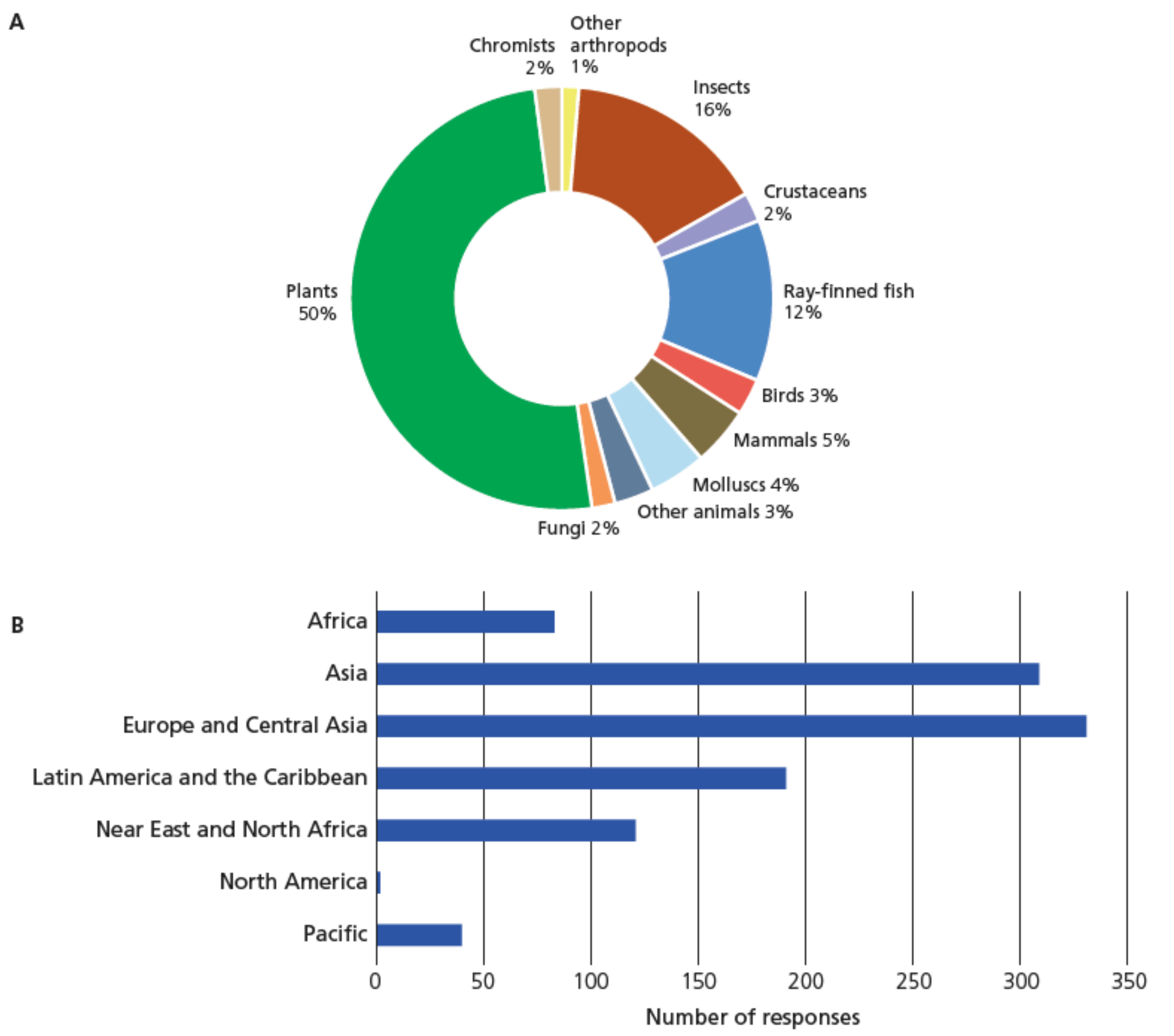
- 9–17
- 18–25
- 26–33
- 34–41

Pests and diseases affect food and agriculture worldwide and can pose a threat to the supply of ecosystem services and to the survival of some components of BFA, particularly **species or within-species populations confined to small geographical areas.**

Environmental drivers

Invasive alien species

Invasive alien species reported by countries to be impacting biodiversity for food and agriculture, (A) by type of organism and (B) by region



Advances in science and technology

Advances in science

Advances in science and technology are largely seen as **positive** by countries and as ways of reducing negative effects of other drivers on BFA. Science and technology are crucial to the **generation of knowledge related to genes, species and ecosystems and hence to the sustainable use and conservation of BFA**. Some technologies have negative effects on BFA and its role in the supply of ecosystem services.

Advances in science and technology

Advances in science

Reported effects of advances and innovations in science and technology on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of advancements and innovations in science and technology on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	+	+	+	+	+	+	+	+	+
Livestock landless systems	+	+	+	+	+	+	+	+	+
Naturally regenerated forests	+	+	+	+	+	+	+	+	+
Planted forests	+	+	+	+	+	+	+	+	+
Self-recruiting capture fisheries	+	+	+	+	+	+	+	+	+
Culture-based fisheries	+	+	+	+	+	+	+	+	+
Fed aquaculture	+	+	+	+	+	+	+	+	+
Non-fed aquaculture	+	+	+	+	+	+	+	+	+
Irrigated crop systems (rice)	+	+	+	+	+	+	+	+	+
Irrigated crop systems (other)	+	+	+	+	+	+	+	+	+
Rainfed crop systems	+	+	+	+	+	+	+	+	+
Mixed systems	+	+	+	+	+	+	+	+	+

Proportion of countries reporting the PS that report any effect of the driver (%)

- 11–18
- 19–26
- 27–34
- 35–41

Technologies that have positive effects on BFA include nanotechnology, which can improve detection and monitoring and thus support rational decision-making, resource-use efficiency and precision targeting. For example, the use of nanosensors allows **detection of plant diseases before symptoms become evident**, meaning that infected plants can be removed to prevent the spread of disease and reduce or eliminate the need to use pesticides

Production-system level

Loss and degradation of forest and aquatic ecosystems and, in many production systems, **transition to intensive production of a reduced number of species**, breeds and varieties, often coupled with inappropriate management practices, remain major drivers of loss of BFA and ecosystem services.

Drivers at production-system level

Drivers at production-system level

Land and water use

TABLE 3.13

Reported effects of changes in land and water use and management on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of changes in land and water use management on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	-	-	-	-	-	-	-	-	-
Livestock landless systems	-	-	-	-	-	-	-	-	-
Naturally regenerated forests	-	-	-	-	-	-	-	-	-
Planted forests	-	+/-	+/-	-	+/-	-	+/-	+/-	+
Self-recruiting capture fisheries	+/-	-	-	-	-	+/-	-	-	-
Culture-based fisheries	+/-	-	+/-	+/-	-	+/-	+/-	-	+
Fed aquaculture	+/-	-	-	-	+/-	+/-	+/-	-	+/-
Non-fed aquaculture	0	-	+/-	-	+/-	+/-	+/-	+	+/-
Irrigated crop systems (rice)	-	+/-	-	+	+/-	+	-	-	-
Irrigated crop systems (other)	-	-	-	-	-	-	+/-	-	-
Rainfed crop systems	-	-	-	-	-	-	-	-	-
Mixed systems	-	+/-	+/-	+/-	+	+	+/-	+/-	+/-

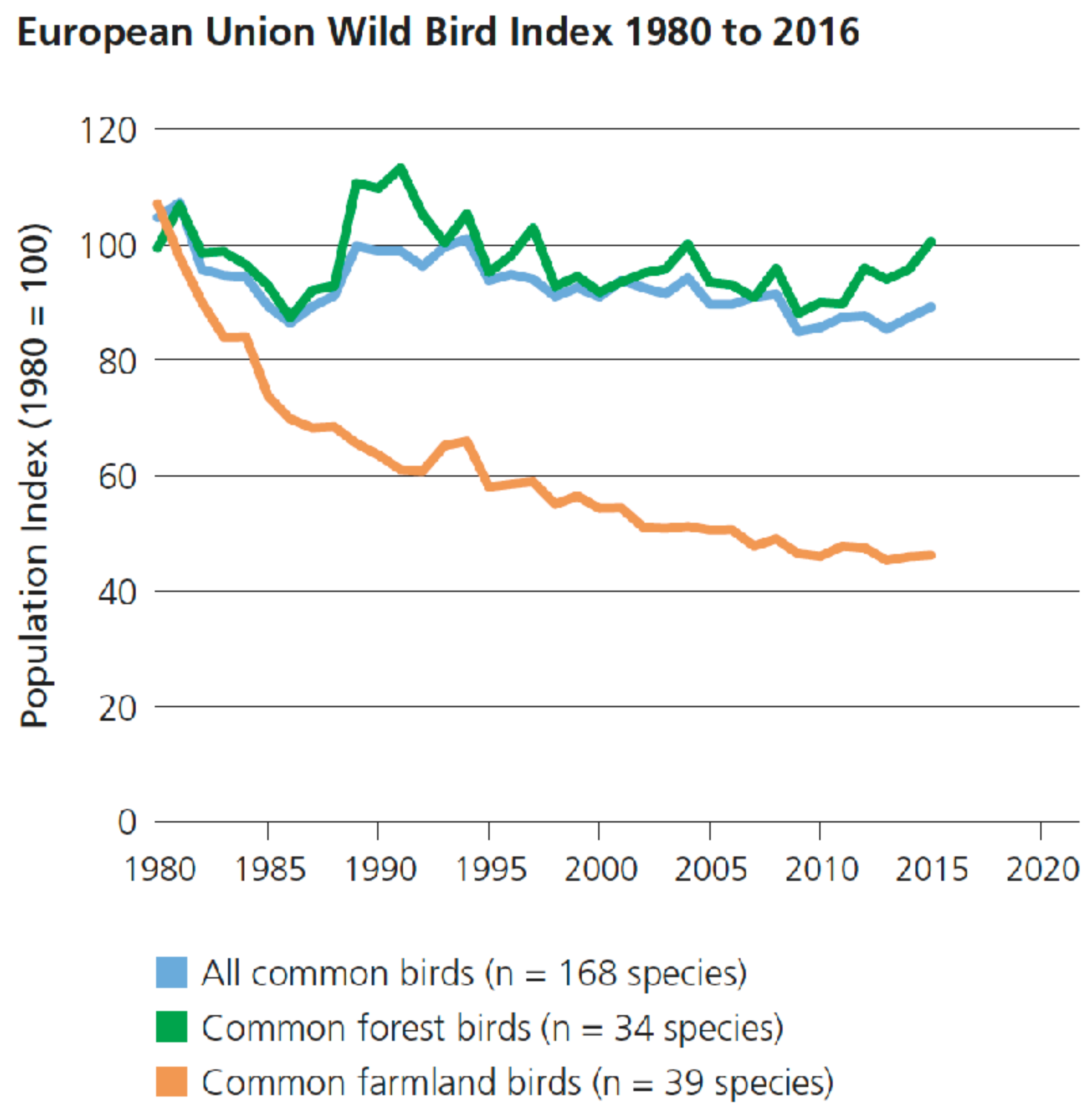
Proportion of countries reporting the PS that report any effect of the driver (%)

- 10–17
- 18–25
- 26–33
- 34–42

The world's **total forest area has declined** in recent years. In addition to reductions in the absolute extent of forest area, **forest fragmentation** is a major threat to biodiversity and ecosystem-service provision, as is conversion from natural forests to monoculture forest plantations in some parts of the world. It has been estimated that 70 percent of the world's remaining forest area is within 1 km of a forest edge. Also agriculture accounts for the largest share of water withdrawals worldwide (approximately 70 percent of the total).

Land and water use

Drivers at production-system level



Pollution

Drivers at production-system level

Reported effects of pollution and external input use on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of pollution and external inputs on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	-	+/-	-	-	-	-	-	-	-
Livestock landless systems	-	-	-	-	-	-	-	-	-
Naturally regenerated forests	-	-	-	-	-	-	-	-	-
Planted forests	-	-	-	-	-	-	-	-	-
Self-recruiting capture fisheries	-	-	-	-	-	-	-	-	-
Culture-based fisheries	-	-	-	-	-	-	-	-	-
Fed aquaculture	+/-	-	-	-	-	+/-	-	-	-
Non-fed aquaculture	+/-	-	-	-	-	+/-	+/-	-	-
Irrigated crop systems (rice)	-	-	-	-	-	-	-	-	-
Irrigated crop systems (other)	-	-	-	-	-	-	-	-	-
Rainfed crop systems	-	-	-	-	-	-	-	-	-
Mixed systems	-	-	-	-	-	-	-	-	-

Proportion of countries reporting the PS that report any effect of the driver (%)

- 10–17
- 18–25
- 26–33
- 34–43

There is abundant evidence that intensification of crop, livestock and aquaculture systems through **excessive use of synthetic inputs adversely affects BFA** and particularly associated biodiversity. Contamination of soils with pesticide residues is also a major concern in intensive crop-production systems.

Drivers at production-system level

Overexploitation

Reported effects of overexploitation and overharvesting on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of overexploitation and overharvesting on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	-	-	-	-	-	-	-	-	-
Livestock landless systems	-	-	-	-	-	-	-	-	-
Naturally regenerated forests	-	-	-	-	-	-	-	-	-
Planted forests	-	-	-	-	-	-	-	-	-
Self-recruiting capture fisheries	-	-	-	-	-	-	-	-	-
Culture-based fisheries	-	-	-	-	-	-	-	-	-
Fed aquaculture	+/-	-	-	-	-	-	-	-	-
Non-fed aquaculture	-	+/-	0	0	-	0	-	-	-
Irrigated crop systems (rice)	-	-	-	-	-	-	-	-	-
Irrigated crop systems (other)	-	-	-	-	-	-	-	-	-
Rainfed crop systems	-	-	-	-	-	-	-	-	-
Mixed systems	-	+/-	-	-	-	-	-	-	-

Proportion of countries reporting the PS that report any effect of the driver (%)

12–18
19–25
26–32
33–40

As well as affecting target populations directly through removal, overharvesting can affect them indirectly by modifying their habitats. **33.1 % of marine fish stocks are classified as overfished**. The bluefin tuna of the Northern Pacific Ocean provides an emblematic example. By 2016, overfishing had led to a fall of about 97 % in its population relative to estimated unfished levels; a large majority of the catch were young fish that had not yet reached reproductive age

Policies

Policies

Policies directly addressing the management of BFA, and particularly those that r**estrict unsustainable practices**, are considered by many countries to have positive effects on diversity and the supply of ecosystem services. However, negative impacts are also reported, for example in the case of policies **favouring inappropriate mining, dam or reservoir construction or road building**.

Policies

Policies

Reported effects of policies on the provision of regulating and supporting ecosystem services, by production system

Production systems (PS)	Effects of policies on ecosystem services								
	Pollination	Pest and disease regulation	Water purification and waste treatment	Natural-hazard regulation	Nutrient cycling	Soil formation and protection	Water cycling	Habitat provisioning	Production of oxygen/ gas regulation
Livestock grassland-based systems	+/-	+	+	+/-	+	+	+	+	+/-
Livestock landless systems	+	+	+	+	+	+	+	+	+
Naturally regenerated forests	+	+	+	+	+	+	+	+	+
Planted forests	+	+	+	+	+	+	+	+	+
Self-recruiting capture fisheries	+	+	+	+	+	+	+	+	+
Culture-based fisheries	+	+	+	+	+	+	+	+	+
Fed aquaculture	+	+	+	+	+	+	+	+	+
Non-fed aquaculture	+	+	+	+	+	+	+	+	+
Irrigated crop systems (rice)	+	+	+	+	+	+	+	+	+
Irrigated crop systems (other)	+	+	+	+	+	+	+	+	+
Rainfed crop systems	+	+	+	+	+	+	+	+	+
Mixed systems	+	+	+	+	+	+	+	+	+

Proportion of countries reporting the PS that report any effect of the driver (%)

- 10–17
- 18–25
- 26–33
- 34–43

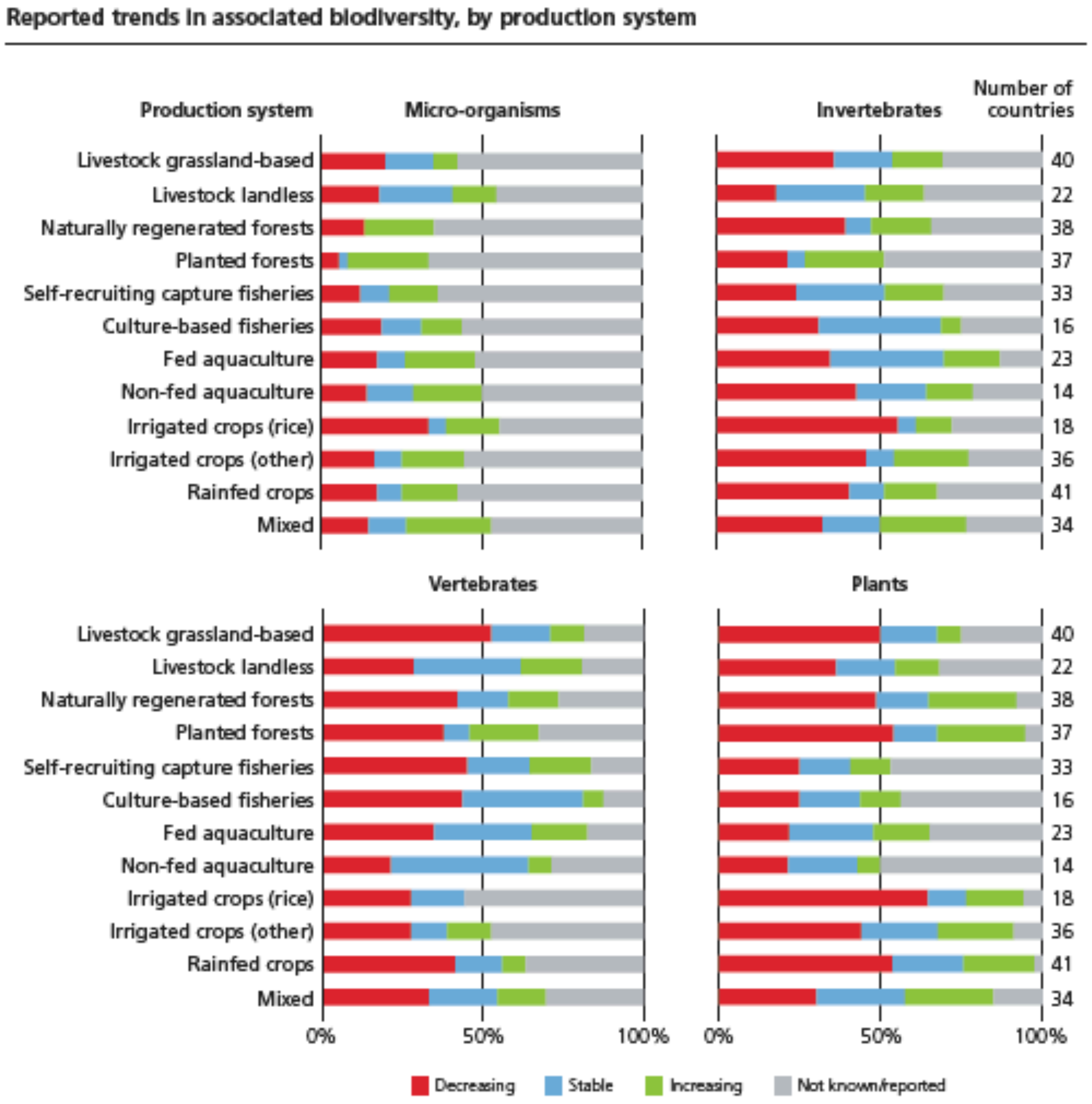
The status and trends of biodiversity for food and agriculture

Status of BFA

- Many key components of BFA at genetic, species and ecosystem levels are in decline
- The proportion of animal breeds at risk of extinction is increasing.
- Nearly a third of fish stocks are overfished and a third of freshwater fish species assessed are classed as threatened.
- Many species that contribute to vital ecosystem services, including pollinators, natural enemies of pests, soil organisms, and wild food species, are in decline.
- Forests, rangelands, mangroves, seagrasses, coral reefs and wetlands in general – key ecosystems that deliver many essential services to food and agriculture, including supply of freshwater, protection against storms, floods and other hazards, carbon sequestration and provision of habitat for countless species – are declining rapidly.

The status and trends of biodiversity for food and agriculture

Status of BFA



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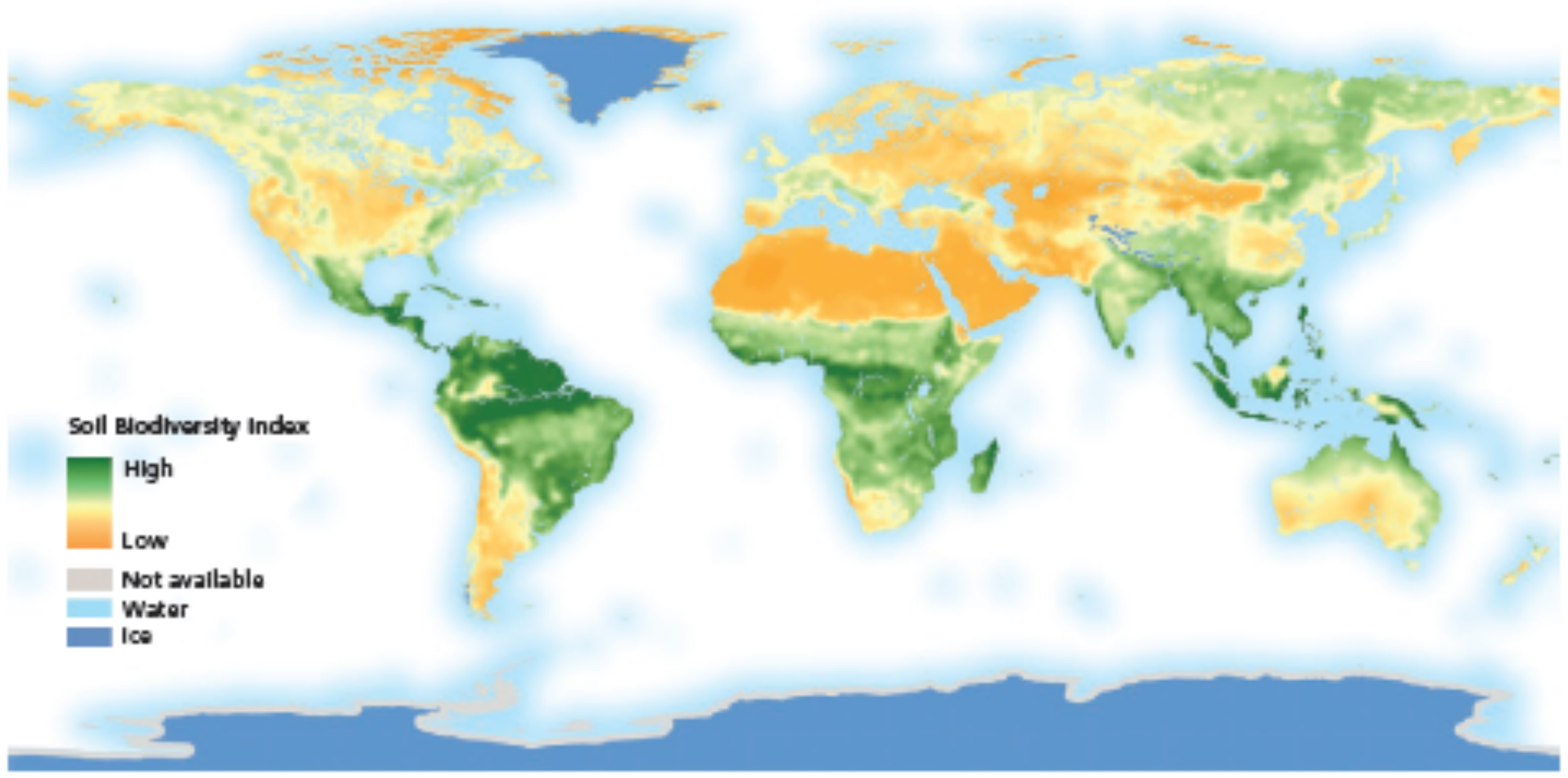
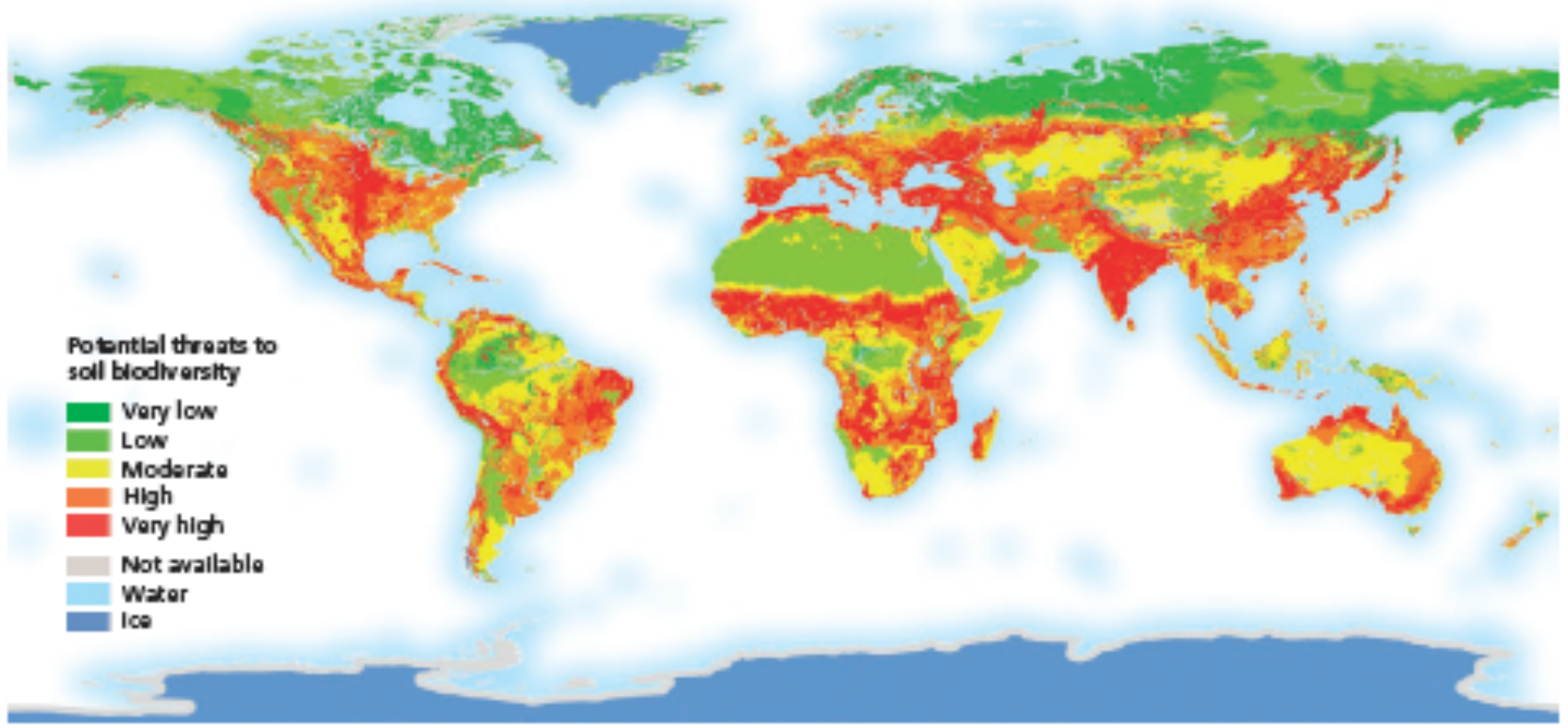
Map of the Soil Biodiversity Index



Map of potential threats to soil biodiversity



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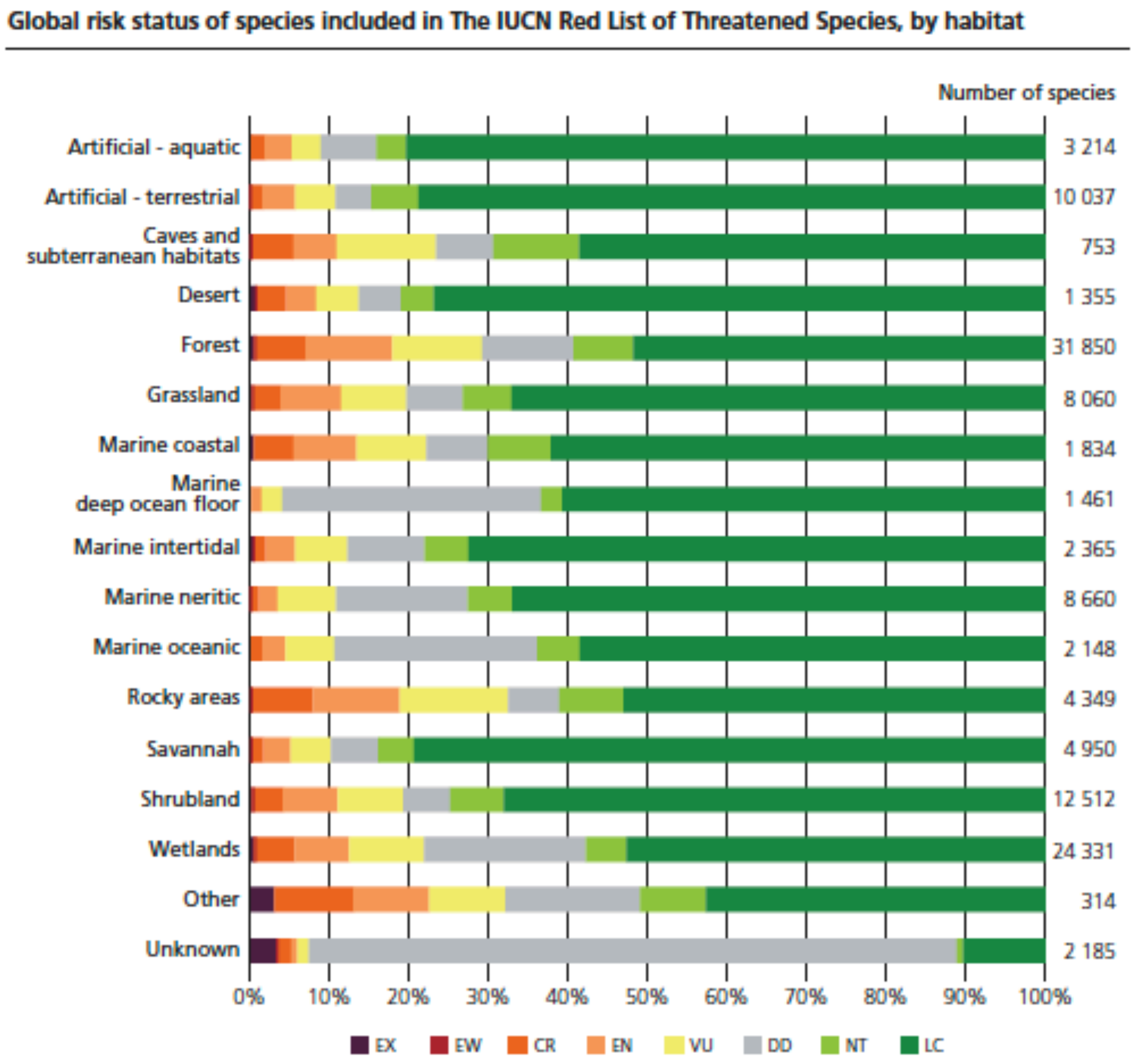

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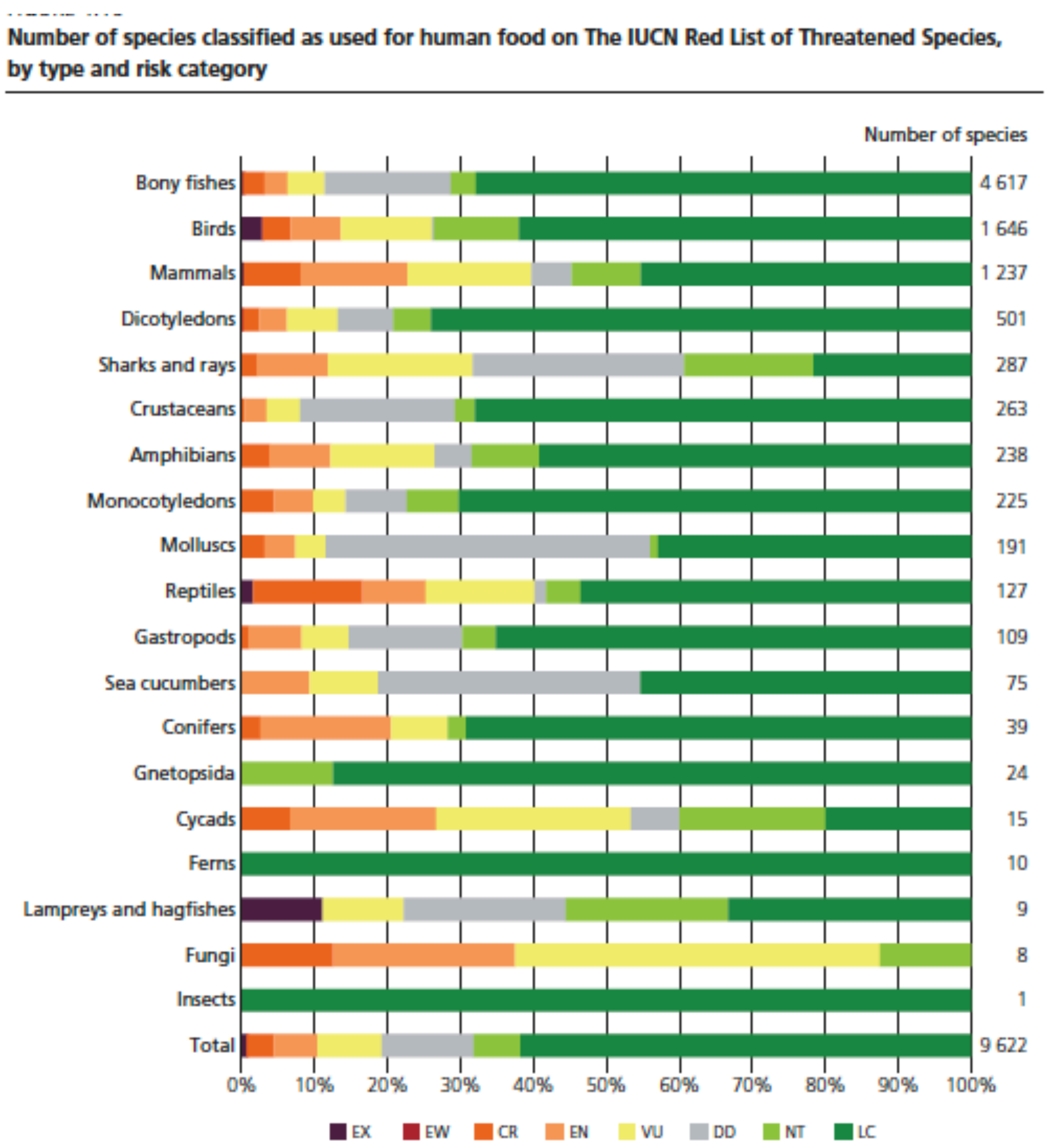
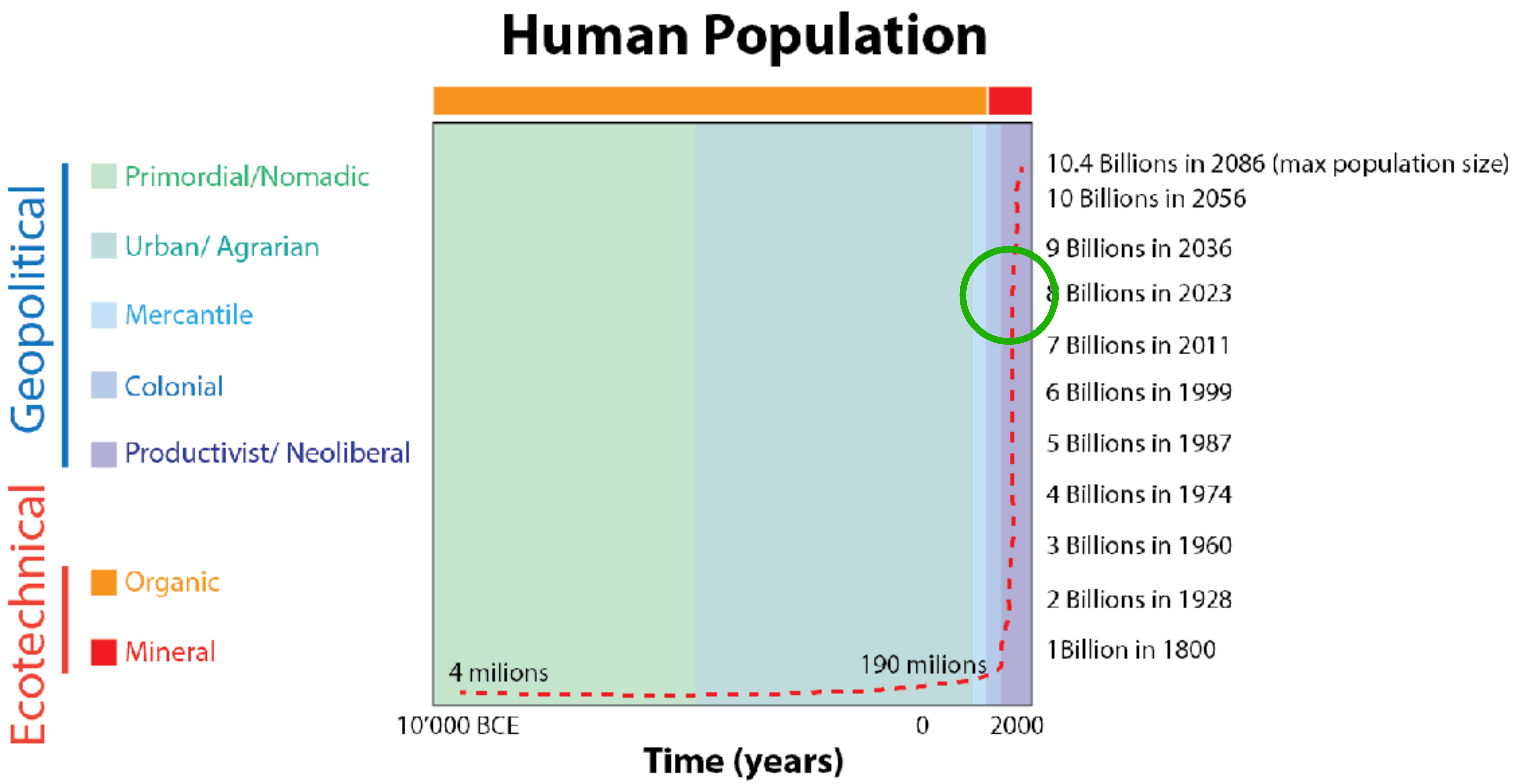


What should we do?

Global Metabolism



Discussion