IFMSA Policy Document
Food for Health and Sustainability

Proposed by AMSA-Australia & Sf-GH UK
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Policy Statement

Introduction:
Nutritional health and environmental sustainability are critical to human health, yet accumulated evidence shows our food system is threatening both. Low quality diets and food insecurity directly threaten health through malnutrition and diet-related non-communicable diseases. Agriculture, biodiversity, food loss and food waste have environmental implications, that indirectly affect health through changing ecosystems, social structures, economies and access to healthcare.
Whilst food is the single greatest risk for death and disability globally, it is also our greatest lever to optimise human and planetary health. Thus, to support an estimated population of 10 billion people in 2050, a global food transformation is required, with an approach that will stabilise the climate, improve global nutrition and combat non-communicable diseases, whilst ensuring economic development and poverty alleviation.

IFMSA position:
As future health professionals, the International Federation of Medical Students' Associations (IFMSA), affirms the importance of driving local, national and global shifts in our food system, in the interests of improving future public health outcomes. IFMSA stresses the co-benefits of addressing our food system for both human and planetary health; recognising that a transition to nutritious and sustainable food systems will have a direct impact on health through increased food security, provision of adequate nutrition and cessation of hunger. IFMSA also recognises that by addressing sustainable agriculture and building climate resilient food systems, we will indirectly protect and promote health for all. Health must be placed at the centre of any negations on our food system.

Call to Action:
Therefore, the IFMSA calls on:

IFMSA National Member Organisations, medical students, and other health care professionals to:

- Advocate for positive food recommendation guidelines and public health regulations, in a manner contextually appropriate to their country.
- Educate and engage patients and the wider population about food choices; taking into consideration a planetary health diet.
- Role model healthy and sustainable food choices; to patients and in all professional settings
- Support the development and translation of educational materials on food sustainability and its interaction with health; including within medical school curricula, public health campaigns and wider community education.

Education providers and health facilities (inclusive of universities, schools, hospitals):

- Create sustainable health facilities through increasing availability of sustainable food sources, careful procurement and food waste reduction; including but not limited to partnering with sustainable food providers on university and hospital campuses (with consideration of sourcing and provision of food).

- Prioritise providing healthy and sustainable foods to workforce, students and patients to meet their dietary requirements
- Integrate food sustainability and nutrition into medical school curricula globally; including Planetary and One Health approaches, and antimicrobial resistance.
- Facilitate further research on the relationship between food, sustainability, biodiversity and health, with the aim of translating this research into public health strategies.

International Organisations (WHO, FAO, and/or World Bank) to work with Governments to:

- Establish a new convention or agreement regarding healthy and sustainable food systems, drawing on the IPCC or IBPES as examples.
- Integrate food sustainability as a key factor in government dietary guidelines and food provision
- Develop contextually-appropriate food labelling systems to enable people to make informed choices about the health and sustainability of products.
- Implement taxes, subsidies and other forms of regulation on food and beverages, inclusive of sugar sweetened beverages and targeted meat taxes.
- Protect consumers, especially children, from inappropriate marketing and publicity of food; limiting advertisements that promote unhealthy diets, processed foods and sugar; and promote healthy dietary practices.
- Prioritise sustainable food provision within schools, to minimise food being a barrier to accessing education.
- Integrating nutrition and physiology science basics in schools; to ensure understanding of its impact on NCDs.
- Establish national goals for food production, consumption, loss and waste in line with SDG Target 12.1 and 12.3. Including introducing education campaigns to promote reduction in consumer level food waste, focusing on understanding of storage techniques, food labelling and purchase planning.
- Develop public policy, financial incentives, and incorporate food production, loss and waste into national waste programs to target other aspects of the supply chain.
- Legislate policy to minimise food wastage by selling rather than rejecting edible, yet cosmetically imperfect products through a law that mandates that supermarkets do not waste food on the grounds of cosmetic appearance
- Work with the food and agriculture industry to develop cost-efficient ways to store and transport fresh produce to rural and remote communities.
- Invest in farmers in developing countries for post-harvest infrastructure, processing and packaging processes in line with the Save Food Initiative.
- Develop and effectively implement regulations for sustainable agricultural practices and limit the use (and necessity of use) of antibiotics in animal agriculture, in the interests of human public health.
- Commit to the Half Earth strategy of land-use change, recognising its crucial importance for climate and biodiversity goals.
- Encourage crop diversification rather than monocultures through subsidies, policies and research, but also through measures to encourage demand of diverse food products.
- Incorporate climate and biodiversity into national public health strategies, develop biodiversity targets and action plans, with recognition of importance to human health.
- Encourage international organisations to foster multi-sectoral cooperation and provide a platform for climate change and biodiversity decision making; recognising the need for a precautionary approach to risk management, alongside meeting competing requirements for land use, such as land for preservation, biofuels and crops.

Position Paper

Background information:
In 2015, 193 countries adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SGD's); with SDG 2 dedicated to ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture (1). Yet, as the FAO's "The State of Food Security and Nutrition in the World" (2018) report highlights, over 821 million people globally are currently undernourished (2). Our current diet trends are unhealthy and unsustainable, and without significant change we are unlikely to meet the targets set for SDG 2 by 2030. Global shifts to unhealthy diets, which are high in calories, processed foods and foods derived from animal sources, are driven by rapid urbanisation, increasing incomes, and inadequate accessibility of nutritious foods. Transitions to unhealthy diets are increasing, corresponding to a rise in obesity and diet-related NCDs, including cardiovascular disease, diabetes and cancer. In 2019, the EAT-Lancet commission titled "Food in the Anthropocene" highlighted that "Unhealthy diets pose a greater risk to morbidity and mortality than does unsafe sex, and alcohol, drug, and tobacco use combined" (3).

Our food systems are not only failing to sustain us nutritionally, but current methods of food production have resulted in the agriculture sector being the single largest driver of environmental degradation (3, 4). It is a key contributor to global greenhouse gas emissions, biodiversity loss, and environmental pollution through land and water usage, farming and fishing, agricultural waste, and use of antimicrobial agents. These factors contribute to changes in climate and in turn climate change threatens global food security and endangers the livelihood and health of millions of people globally.

The EAT-Lancet's commission concluded that "Food is the single strongest lever to optimise human health and environmental sustainability on earth" (3). In order to feed the projected population of 10 billion people by 2050 and to prevent further environmental degradation, we require urgent change in our global food system.

Discussion:

The State of our Nutrition Globally

Nutrition transition
The nutrition transition describes shifts in dietary intake, physical activity and obesity as a result of social, economic, demographic and technological changes, largely as a result of globalisation (5). These changes have exposed people to markets of mass-produced processed food and beverages, beef and dairy products, that have shifted the state of global nutrition and contributed to the rapid rise of non-communicable diseases (NCD's) (6). The nutrition transition describes these changes across five patterns. In the first and second patterns, food is primarily derived from plant sources; sourced from home food production that requires extensive physical activity to harvest and produce. The third and fourth patterns includes more animal source foods, higher fat and sugar intake, and more processed foods. The fifth and final pattern describes a shift back to a diet with less saturated fat and decreased dependency on processed foods; a desirable dietary change. The diets of populations in North America and northern and southern of Europe sit within patterns four and five, meanwhile low and middle income countries (LMICs) are rapidly moving from primarily plant-based or home production based diets (high in starch, low variety and low in fat; patterns one and two) to diets with greater proportions of energy derived from meat, dairy, animal fats and vegetable oils (6). This shift characterises the transition from receding famine to rising prevalence of NCDs, and has been a key contributor to the obesity epidemic occurring in LMICs (7). Although it was once only considered a problem in high-income countries, obesity prevalence continues to rise in LMICs; requiring direct action and global leadership (8).

Double burden of malnutrition

The World Health Organisation (WHO) defines the double burden of malnutrition as the "coexistence of undernutrition along with overweight and obesity, or diet-related non-communicable diseases, within individuals, households and populations, and across the life course" (9). On an individual level, people may simultaneously experience the presence of multiple forms of malnutrition during their lifetime; in household's, family members may be affected by different forms of malnutrition; and globally, we observe the presence of undernutrition and overnutrition across communities, regions and nations. The WHO concludes that one in three individuals globally suffers form of malnutrition including stunting, wasting, vitamin and mineral deficiencies, overweight or obesity and diet related NCDs (9). The United Nations Decade of Action on Nutrition, adopted in 2016, declares 159 million children under 5 years of age are stunted and more than 2 billion people are affected by micronutrient deficiencies (10). Globally, over 1.9 billion individuals are overweight, and more than one in eight individuals are obese (11). Poor nutrition causes 45% of deaths in children under five each year, with LMICs carrying the greatest burden of malnutrition (12).The 2019 Lancet Commission "The global syndemic of obesity, undernutrition, and climate change" reported that wasting and stunting worldwide are decreasing, but decline of undernutrition for children and adults is too slow to reach SDGs by 2030 (13).

The drivers of the double burden of malnutrition can be summarised by the nutrition transition, epidemiological transition and demographic transition (9). Due to improvements in water and sanitation, and more effective public health services, rates of undernutrition and infectious disease are declining globally. This has led to a shift in disease burden from high rates of infectious disease to increasing NCDs, which now account for 71% of deaths globally (14). Historically, undernutrition has been associated with a higher prevalence of infectious diseases, but this is no longer the case. Furthermore, as life expectancy increases and the demographic profile shifts towards a greater proportion of elderly people, NCDs become more predominant (15). Countries transitioning from lower to higher incomes will experience rapid urbanisation and its health-related consequences. Increasing rates of chronic diseases are associated with significant health care costs, in addition to reduction in productivity which perpetuates the cycle of poverty and ill health through slower economic development (9). Addressing the double burden of malnutrition will be of critical importance in achieving the ambitions of the United Nations Decade of Action on Nutrition and Sustainable Development Goals.

Current diet trends and associated health risks

The Lancet "Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017", concluded that in 2017, 255 million disability adjusted life years (DALY's) and 11 million deaths were attributable to dietary risk factors (16). Diet-related deaths were attributed to high intake of sodium, and low intake of whole grains, nuts, seeds and fruits. The leading causes of diet-related deaths are cardiovascular disease, followed by cancer and type 2 diabetes. LMICs had the highest rates of deaths from cardiovascular diseases, whereas high income countries have their greatest mortality burden from cancers. The highest rates of dietary-related deaths and DALYs was in Oceania, and lowest rates in high-income Asia Pacific and Australasia. In low income countries the lowest incidence of deaths were from cancer.

Consumption of red meat such as beef, pork or lamb is associated with increased risk of death from cardiovascular diseases, stroke, type 2 diabetes and certain types of cancers, such as colorectal cancer (3). Systematic analysis of the Global Burden of Disease study suggests the global intake of red meat is 27g per day, 18% greater than the recommended 'optimal' intake (16). Similarly, global consumption of processed meat is 4g per day, 90% greater than the optimal amount; and sodium intake is 6g per day, 86% greater than the suggested optimal. The consumption of sugar-sweetened beverages, at 49g per day, is also suggested to be far higher than the optimal intake. Consumption of ruminant meat (beef, lamb and goat) is projected to rise around 88% by 2050, due to the nutrition transition in LMICs (4). The most commonly consumed ruminant meat is beef. Processed red meat is widely consumed in high-income countries and is also visibly increasing in diet shift patterns in LMICs (16). The International Agency for Research on Cancer classifies processed meat as a type one carcinogen, and red meat a type two carcinogen (17).

Transition to healthy and sustainable diets

In 2019, the EAT-Lancet commission "Food in the Anthropocene" evaluated current scientific evidence to develop recommended intakes of specific food groups, to optimize human health and focus on sustainable food production, ensuring stable earth systems (3). This resulted in the development of the planetary health diet- a diet rich in plant-based foods, containing fewer animal source foods, processed foods and foods high in sugar content. In 2015, the US Dietary Guidelines Advisory Committee undertook the largest ever prospective study of vegetarian diets, concluding that in contrast to omnivorous diets, diets that are vegan, vegetarian, semi-vegetarian or pescatarian are associated with an overall 12% reduction in mortality (18). Limiting ruminant meat consumption and improving the marketing of plant-based foods should be considered a priority on global, national and local levels in order to reduce rates of NCDs and overall diet-related public health outcomes (3, 19). It is estimated that by global adoption of EAT-Lancet's recommendations for a planetary health diet, 11.1 million deaths per year could be prevented; this number represents between 19-24% of total annual deaths in adults (3). These findings suggest that a shift towards a dietary pattern emphasising whole grains, fruits, vegetables, nuts, and legumes will be beneficial not only in lowering rates of NCDs but also reducing greenhouse gas emissions and environmental impact of the agriculture sector. Attention must also be given to the health and environmental implications of meat consumption and its role in diets globally.

Education

Life-long health behaviours are shaped during childhood and adolescence. As Ban Ki-moon, United Nations 8th General Secretary said in a message for the Scaling up Nutrition Movement and Roadmap (2016-2020) "improved nutrition is the platform for progress in health, education, employment and the reduction of poverty and inequality" (20, 21). Quality education is a significant contributor to health literacy and a key determinant of public health. Education level is positively correlated with health outcomes, and in turn poor health status is a barrier to accessing quality education. As such, the education sector is an essential part of governmental response to reducing NCDs (22, 23). Learning proper care practices, what constitutes a healthy diet, and when to seek medical care is elemental for enabling adequate nutrition. Educational programmes in preschools and schools have a vital role in building children's capabilities to do this. Education fundamentally shapes children's lifelong trajectories and opportunities for health. In order to stay on track for SDGs goal 4.2 to ensure that all girls and boys have access to quality early childhood development, we need to tackle the double burden of malnutrition and access to proper education in early childhood.

Fiscal Policy

Establishing equal accessibility to healthy foods requires addressing the availability and price of foods. The WHO recommends taxation as a cost-effective strategy to reduce population consumption of specific products; with data suggesting that subsidising healthy food and beverages, and taxing unhealthy products, may not only improve diet, but subsequently improve health outcomes (24). A 10% reduction in the price of fruits and vegetables has been shown to increase intake by 14% and positively affected BMI (25). A UK modelling study concluded that a 40% reduction of added sugars in sweetened beverages over a five-year period would reduce new cases of type two diabetes by 300,000 and the number of obese adults by approximately half a million (26). Similar health benefits are projected for type 2 diabetes, strokes, myocardial infarctions and overall mortality in Mexico, following its implementation of a sugar sweetened beverage tax, that reduced sales by 9.7% in two years (27, 28). The success of sugar-sweetened beverage taxation on population health should prompt further research into taxation and subsidisation of other foods to improve diets and subsequently population health; including fiscal policy on processed and red meat, as a means to reduce global intake.

Dietary recommendations in the Anthropocene

Food systems are a primary determinant of health and environmental welfare. Future food systems are required to adapt to the increased stress of the estimated 10 billion global citizens by 2050. However, contrary to agricultural developments in the past 50 years, which have focused on increased crop yields, production of calorie dense and heavily processed food, future development must focus on provision of nutritious, diverse diets produced in an environmentally sustainable manner. To succeed, dietary recommendations must reflect the impact of food choices on both population level health and the environmental burden of food production. Such diets will have an appropriate caloric intake and deliver

the appropriate amounts of micro and macro nutrients to ensure good health (2,3,4). Most recently, the EAT-Lancet report has suggested a dietary menu, to optimise human and planetary health (3).

Essential to global dietary shifts is the adoption of Food-based Dietary Guidelines (FBDG). Research by the United Nations Food and Agricultural Organisation found that only 83 countries, of a possible 215, have existing FBDGs (29). Implementation of FBDGs provides a clear context of how people should eat to maintain good health. Additionally, FBDGs provide context for policy development that shift food consumption patterns (29, 30).
Current FBDGs that integrate sustainability have broadly consistent themes. These include:

- Choosing mainly plant-based food, including seasonal and locally grown produce.
- Choose lean cuts of meat, white over red, and limit red-meat consumption
- Consume milk and dairy products that are low in fat and unsweetened. Alternatively chose calcium and Vitamin D rich food, such as fortified soy, almond or chickpea drinks.
- Consume seafood at least twice per week, choosing eco-labelled options
- Consume fats in moderation, preferencing unsaturated liquid fats, specifically those from vegetable origins.
- Significantly limit or do not eat processed food

Contribution of Food Systems to Climate Change and Health

Land use and livestock
Agriculture contributes to climate change from two interlinked fronts; land use and livestock. Agricultural land occupies 38% of global land area. Of the 38%, almost 80% of this land is used for livestock in the form of grazing land or cropland for feed; making livestock production the single largest anthropogenic user of land (31). Expansion of livestock is the leading cause of deforestation, with 70% of deforested land in the Amazon is occupied by pastures for livestock, and the majority of remaining deforested land used for feed-production for livestock (29, 32). Industrialisation of animal agriculture has improved the sectors efficiency and decreased land required per unit area, however, this is at the cost of increasing and concentrating subsequent pollution (32). Currently beef requires twenty times more land use and produces twenty times more greenhouse gas (GHG) emissions per gram of protein than plant protein sources such as legumes, beans and peas (4). The agricultural sector is also the single largest driver responsible for the transgression of planetary boundaries (3). The planetary boundaries are quantitative recommendations (with proposed limits) on nine processes which are responsible for regulating the stability and resilience of the earth system. Exceeding the recommendations or the planetary boundaries is associated with an increased risk of irreversible environmental changes (33).

The agriculture sector contributes to GHG emissions through four main categories; carbon dioxide emissions from agriculture-associated deforestation, methane production from both rice cultivation and from enteric fermentation of cattle, and nitrous oxide production from fertilizers (34). In order to avoid increasing the environmental impact of livestock production beyond the present level, moving towards 2050 projections of meat and milk demands, emissions per unit of livestock production must be cut in half (32). The World Resources Institute (WRI) estimates that by 2050 GHG emissions from the agriculture sector will reach 15Gt CO2e annually, approximately 70% of total allowable global GHG emissions limit (4). To hold warming at 2 degrees Celsius since pre-industrial times, we need to reduce GHG emissions from the agriculture sector to 4 Gt CO2e annually by 2050. The recent EAT-Lancet commission “Food in the Anthropocene” similarly proposed that GHGs from the agriculture sector be kept at or less than 5 Gt CO2e per year in 2050 (3). It is important to note that in 2010, the agriculture sector contributed 12ggt CO2e to the annual GHG emissions. Limiting ruminant consumption to 52 calories per person per day, is predicted to reduce GHGs mitigation gap by half and nearly close the land gap (4). In order to address these environmental sustainability issues, contextually-appropriate steps to limiting meat consumption should be addressed through public health campaigns and government dietary guidelines.

There is a bi-directional relationship between agriculture and climate change; where food production is a key driver of GHG emissions, and climate change is also a significant threat to food security. Current environmentally unsustainable agricultural practices jeopardise future food production, posing a public health risk from two fronts - direct impact of climate change on human health and increasing risk to food security (35). As IFMSA's climate change policy outlines, the detrimental effect of climate change on human health is a key public health priority moving forward. Climate-smart agricultural change must address issues such as; reducing environmental impact of current agricultural practices and increasing the resilience of food production to climate change. This could be achievable through more effective management of resources utilised in food production (3, 4, 35).

Pollutants and Waste from the Agriculture Industry:

The production of pollutants and waste from unsustainable agricultural systems is a significant threat to human and environmental health. In many countries, agriculture is the largest consumer of water. Agricultural drainage is the most significant contributor in volume to wastewater, and 80% of global wastewater is released into the environment untreated - leading to millions of tonnes of heavy metals and toxic sludge entering waterways every year (36). Industrial agricultural waste is the most significant factor in the degradation of inland and coastal waters. Agriculture-associated nitrate is the most common chemical contaminant in groundwater aquifers globally, and in China it is almost exclusively responsible for groundwater pollution. It can also cause further threats to the quality of water through eutrophication and harmful algal blooms, which can produce toxins harmful to humans. Air pollution from agriculture poses significant health risks and associated costs. Manure from livestock and fertilizer for crops release ammonia into the atmosphere, which poses significant health risks and chronic exposure is associated with heart and lung diseases (37).

Animal waste is an important source of nutrient pollution and pathogen contamination (38). 85% of global animal faecal waste is produced by domesticated farm animals, which is a far greater amount than the proportion of waste contributed by the human population (39). Approximately two-thirds of human pathogens and three-quarters of emerging pathogens are of zoonotic origin (40). Pathogens in animal faeces can be transmitted to humans via direct contact with humans (common in developing nations where animals live closely to human domestic environments) or water source contamination (via drinking water, sanitation, or hygiene related pathways). Zoonotic pathogens found in animal faeces are associated with acute gastrointestinal symptoms, which can result in long-term growth stunting in children. One-third of diarrhea related deaths of children under five years old can be attributed to pathogens found in animal faeces, such as cryptosporidium, for which there is no vaccine, with only limited treatment in developing nations (41). Sanitation interventions have primarily focused on containment of human excrement, and therefore current interventions may be failing due to persistent exposure to excrement from animal origin (38). Animal excrement has a disproportionately-elevated health risk to people living in low socioeconomic, developing, and rural settings (41). This suggests further innovation in minimising production of animal faeces and preventing it's contact with humans and the water sources in which human populations rely upon is an important area of future global health strategy development.

The human health impacts of pollution from agriculture are profound and unprecedented. Water pollution from agriculture threatens human health on three fronts; reduced quality of drinking water, reduced quality of bathing water, and unsafe and contaminated food (36). Use of certain pesticides, including nitrates, have had widespread bans due to the demonstrated detrimental public health effects of their accumulation in waterways and in the food chain. However, some of these pesticides are still in use in developing nations, causing acute and chronic health effects to the poorest, and therefore the most vulnerable. Governments need to take preventative actions before these pollutants reach widespread harmful levels and threatening public health outcomes. The FAO suggests such actions should include introducing more sustainable farming practices, recommending dietary changes to decrease demand on animal agriculture, and adequate animal waste management (36).

The United States Environmental Protection Agency recommends farming practices shift towards reducing nutrient losses (42).This includes but is not limited to; adopting nutrient management and effective timing techniques, ensuring year-round ground crop cover, planting field buffers to filter out

nutrients before they reach a body of water, implementing conservation tillage, limiting access of livestock to streams/waterways, and engaging in collaborative watershed efforts. Collaboration of stakeholders across an entire watershed is paramount to reducing agriculture-associated pollution, and thereby reducing the detrimental public health effects.

Antibiotic Use and Subsequent Antimicrobial Resistance:

The World Health Organisation ranks antimicrobial resistance (AMR) within the top ten threats to human health in 2019. Without action, by 2050 the global economy may lose more than USD 6 trillion dollars annually as a result of AMR - nearly 4% of Gross Domestic Product (GDP) (43). By 2030, 24 million more people may be forced into extreme poverty due to AMR, many will come from low income countries; increasing the number of people experiencing malnutrition. High volume use of antibiotics in food producing animals is a driving force behind antimicrobial resistance which results in public health risks (44). It is estimated that in some countries the total amount of antibiotics used in animals is four times greater than the amount used in the human population (45). Projected increases in demand for animal food products may lead to further increases in antibiotic usage, due to increased quantity of animals and intensification of farming (46). Intensification of animal agriculture (increased stock densities) has resulted in increase of antibiotic use as prophylaxis, growth promotion, and metaphylaxis (44).

It is expected that the use of antimicrobial agents in agriculture will increase by 67% from 2010-2030 globally, with dissemination of resistant bacteria from livestock to humans (44, 47). It is common for poultry to receive more antibiotics than other livestock animals and resistance is likely to develop in conditions of animal overcrowding and poor sanitation - typical of intensification of farming. Movement of food and animals has led to the global dissemination of antimicrobial resistant pathogens; across continents and between humans, food, farm and wild animals, and aquatic environments (44). As such overuse of antibiotics and subsequent antimicrobial resistance in countries with poor regulations can have detrimental health effects on an international scale.

There are four main drivers behind the overuse of antibiotics by farmers; the belief that antibiotics are necessary in animal agriculture, limited knowledge about antimicrobial resistance, unrestricted access to antibiotics, and weak monitoring systems. However, the antibiotic consumption profiles in developing countries are greatly influenced by the gross abuse and misuse of antibiotics due to their availability over the counter, through unregulated supply chains as well as the ability to purchase without prescriptions (48). Strict biosecurity measures including reducing dissemination of antimicrobials into surrounding environments, regulatory control of veterinary chemicals, and minimisation of animal farming intensification is required (49). Shifts in dietary choices towards reducing consumption of animal products can act as a preventative measure of further intensification of farming, and therefore is a primary preventative measure of antimicrobial resistance.

Biodiversity

Biodiversity refers to the variety of species present in a given level of life (genetic, habitat, ecosystem and planetary)[1] (50). Out of the nine interdependent Planetary Boundaries (PBs), biosphere integrity (biodiversity) is one of two core boundaries alongside climate change. These boundaries are essential as both increase the resilience of the Earth system to changes in other PBs [2](51-53). Due to data paucity and inherent difficulty in measuring biodiversity at different scales, uncertainty persists as to how quickly it is decreasing (54). Also unclear is whether and at what threshold biodiversity loss could trigger non-linear and catastrophic decline in Earth system function (33, 55). Despite these unknowns, it is clear human activity has pushed current extinction rates to 100-1000 times the background rate; indicating biodiversity is one of three PBs that have already been overshot in the Anthropocene (33, 56). 25% of assessed plant and animal species are threatened with extinction. On our current trajectory,

[1] It has been suggested that crossing any Planetary Boundary could trigger "non-linear, abrupt environmental change" with potentially "catastrophic" consequences for humanity (Rockstrom et al. 2009; Steffen et al. 2015)

[2] The uncertainty range for the estimated total number of species is 2 to 13 million (Costello et al. 2012; Scheffers et al. 2012)

1 million species may already face extinction, with many occurring over the coming decades (57). This has prompted some researchers to classify the current epoch as the Sixth Mass Extinction Event (period of high extinction rates) (58, 59).

Impacts of agriculture on biodiversity
Agriculture is the leading cause of biodiversity loss across all ecosystems terrestrial (land), freshwater and oceans. This is mainly due to land-use changes and direct exploitation (mostly fishing and hunting) however, chemical pollution through pesticide and fertilizer over-application also plays a role (60, 61). To put this into scale, land used for livestock covers the equivalent area to Latin and North America and Canada combined (62). As such, agriculture is responsible for up to 80% of extinction threats to mammals and birds (63). However, certain low-intensity grazing practises can preserve biodiversity in some situations (3, 64).

Agricultural Biodiversity
Agricultural biodiversity refers to the plants, animals and microorganisms that contribute either directly (e.g. plants we eat) or indirectly (e.g. pollinators) to food production (50). As dietary diversity is key for health, agricultural diversity is key for food systems (3, 65). It is critical for food security because of its role in regulating the resilience of food systems to pests, disease and climate change but is under threat. Humans have cultivated over 6000 plant species but only 9 account for two thirds of current crop production (50). Further, 26% of livestock breeds are at risk of extinction (50). Declines in biodiversity also includes and affects pollinators, which 75% of global food crop types depend on in some capacity (57).

Broader relevance of biodiversity to human health
Biodiversity is essential for our ability to benefit from ecosystem services such as the provisioning of food, wood fuels and medicines as well as water, air quality and climate regulation (66). These services are most relied upon by Indigenous populations, who are crucial gatekeepers for preservation of biodiversity and transfer of knowledge (67, 68). Biodiversity is intrinsically connected to our ability to combat climate change - forest, soil and ocean life are all significant carbon sinks. Reduced presence of or interaction with microbes in the environments in which we live can compromise immunity and lead to disease. Ecosystem alteration can interfere with natural regulation of pests, increasing transmission of vector-borne diseases. Mangroves and coral reefs are both sources of medicines and food but are key to coastal protection and increasing in importance with climate change (69). The UN Environment's Sixth Flagship Global Environmental Outlook ranked Biodiversity third out of Air, Land, Freshwater, Oceans and Biodiversity in its potential to compromise human health (70). Protection of biodiversity compatible with achieving the SDGs will require a significant global trajectory realignment (57).

Food loss and waste:
Food loss is food that is lost prior to reaching market. For example, it may be destroyed by pests during production. Food waste refers to food that is fit for consumption but is consciously discarded at the level of the retailer or consumer (71). Globally, it is estimated that up to one third of all food produced is lost or wasted (71). This figure is as high as 50% for staples, fruits and vegetables.

Food waste is responsible for up to a quarter of all food related GHGs (72). Further, food sent to landfill can release methane during decomposition, a potent greenhouse gas with 25 times greater warming effect than CO2 over a 100-year time-period (73). Food waste is estimated to cost the global economy over USD 1 trillion per year, excluding environmental and social costs (74).

In developed regions food is mostly wasted at the level of the market or household. Therefore, solutions depend on changing consumer (e.g. education about food storage practises) and retail-level behaviour (such as improved inventory management practises). In developing regions, food losses occur earlier in the supply-chain due to technical, logistical or financial constraints that have been mainly overcome in richer areas, such as farmers having poor access to storage or packaging facilities (4). This reduces incomes of poor smallholder farmers and reduces the total amount of food available for consumption (71).

Sustainable Development Goal 12.3 calls for a halving of per capita food loss and waste by 2030(1). This endpoint was highlighted as a necessary component of a sustainable food system in the EAT-Lancet Commission (3). Reducing food waste by only half of the SDG's and Eat-Lancet's target (25% reduction) would close food, land and GHG mitigation gaps by 12, 27 and 15 percent respectively (4).

Food security and climate change:
Food security varies globally due to environmental, social and economic determinants. The forecast increase in the world's population, coupled with the impact of climate change on agricultural production threatens to increase food insecurity (75). Climate change will cause direct and indirect impacts to food systems through environmental changes in temperature, water availability, atmospheric gas concentrations combined with altered pest, pathogen and pollinator spread (2). These environmental impacts are hypothesised to reduce the utility of cropping systems and the world's fisheries, threatening global food production and citizens access to safe, nutritious and affordable food. Such changes will have significant impacts on global health and well-being.

Crop yields and nutritional content in the Anthropocene:
Climate change threatens to reduce global crop yields, nutrient content and overall production (4, 76). Accounting for geographical and crop variability, climate modelling identifies that increases to ambient temperature will reduce global crop yields. Temperate regions will experience increases in crop yields while crop yields will reduce in tropical and subtropical zones. Crops, including many varieties of fruits, vegetables and legumes have lower heat tolerance and yields are forecast to diminish in line with increases in ambient temperature and extreme heat events. Alternatively, staple crops perform better at higher temperatures, causing some regional increases in crop yields. Variation in water availability through altered rainfall patterns, glacial melt and increased salinity of irrigation water is expected to negatively impact yields in all crop varieties. Climate change inducing atmospheric gas independently impacts crop growth, increases in atmospheric CO2 levels increase crop yields, however increasing levels of ground level ozone, O3, are detrimental to crop yields due to the toxic impact of ozone on photosynthesis and growth (77).

Environmental changes impacting crop growth patterns concurrently impact their nutritional content. Increased ambient air temperature and CO2 levels both reduce crop nutritional content. Higher growth rates associated with increased CO2 and ambient temperature alter the nutritional composition of crops, reducing protein content by up to 15% (78). Micronutrient availability is similarly impacted, with reduced concentrations of potassium, calcium, magnesium, iron, zinc and other minerals in cereals and legumes (79).

Impact on livestock:
Climate change will significantly challenge the livestock industry for a multitude of reasons. A hotter, drier planet with a greater number of extreme weather events and increased disease spread will impact all factors involved in livestock production. Reduced quality and quantity of animal feed, and water stress will challenge the livestock stock sector to feed, grow animals and process their products (80). Altered environmental conditions, including greater disease spread and heat stress, are likely to reduce the health, and the ability of livestock to reproduce, increasing mortality rates and reducing the output of a resource intensive industry (81, 82).

Impact on fisheries:
World fisheries are already declining, and climate change will increase the strain on this food source. Climate change is expected to cause oceans to warm, de-oxygenate and acidify. Combined with glacial and polar melt and extreme weather events this will significantly alter ocean and freshwater aquaculture (83). All levels of aquaculture are expected to experience a heterogenous impact, as regional changes cause migration of fisheries, altered plankton populations, and changes to aquatic vegetation patterns and invasive species (84, 85). The impacts of climate change and altered sea temperature have resulted in numerous instances of polar migration of fish populations have been recorded in the Atlantic and Pacific (75). Thus, the impact of climate change will challenge the sustainability of current fisheries requiring local and global adaptation to fishing practices.

Food loss and spoilage due to pests, pathogens and pollinators:
A changing climate further reduces food security owing to lost food production and spoilage. Climate change threatens to impact the distribution of pests, pathogens and pollinators. Changes in temperature have already increased the range of many insects. It is expected that warming temperatures will increase survival of pests during winter temperatures, which combined with the increased range will potentiate crop loss at a greater rate than currently occurs (86, 87). Climate change is expected to reduce the abundance of pollinating insects through a number of mechanisms, thus decreasing the yield of pollinator dependent crops, including fruit, vegetables, nuts and seeds (88, 89).

Reduced labour productivity:
Climate change is expected to increase the frequency of extreme weather events globally. Such events reduce productivity of our food systems due to their potential impact on human health. Globally, the average summer temperature and frequency of extreme heat days is expected to rise. Climate modelling suggests that up to 50% of work could be lost in tropical and subtropical regions during the hottest months (90, 91). 26% of the global population are employed in agriculture, therefore changes in climate have the potential to influence the incomes of millions of individuals globally (92).

References:

1. United Nations (UN). Transforming our world: The 2030 agenda for sustainable development. Resolution adopted by the General Assembly. 2015.
2. The Food and Agricultural Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP) and World Health Organisation (WHO). 2018. The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, FAO.
3. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. The Lancet. 2019;393(10170):447-92.
4. Searchinger T, Waite R, Hanson C, Ranganathan J, Dumas P, Matthews E. Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050. World Resource Institute: Washington, DC, USA. 2018.
5. Popkin BM. The nutrition transition and its health implications in lower-income countries. Public Health Nutr. 1998;1(1):5-21.
6. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. Nutr Rev. 2012;70(1):3-21.
7. Abarca-Gómez L, Abdeen ZA, Hamid ZA, Abu-Rmeileh NM, Acosta-Cazares B, Acuin C, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128· 9 million children, adolescents, and adults. The Lancet. 2017;390(10113):2627-42.
8. WHO. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. Geneva. 2013 WHO [cited 2019 May] Available From: http://www.who.int/nmh/events/ncd_action_plan/en/.
9. WHO. The double burden of malnutrition: policy brief. WHO; 2016. Available From: https://apps.who.int/iris/bitstream/handle/10665/255413/WHO-NMH-NHD-17.3-eng.pdf.
10. UN GA. United Nations Decade of Action on Nutrition (2016-2025). United Nations website. https://www.un.org/ga/search/view_doc.asp?symbol=A/70/L.42 Published 26 March, 2016. Accessed May 27, 2019.
11. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. The Lancet. 2016;387(10026):1377-96.

12. WHO. Children: reducing mortality. Factsheet. 2016. Geneva. WHO [cited 2019 May]. Available From: http://www.who.int/mediacentre/factsheets/fs178/en/.
13. Swinburn BA, Kraak VI, Allender S, Atkins VJ, Baker PI, Bogard JR, et al. The global syndemic of obesity, undernutrition, and climate change: The Lancet Commission report. The Lancet. 2019;393(10173):791-846.
14. Forouzanfar MH, Afshin A, Alexander LT, Anderson HR, Bhutta ZA, Biryukov S, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. The Lancet. 2016;388(10053):1659-724.
15. United Nations General Assembly, Sixty-Sixth Session, Resolution 66/2, Political Declaration Of The High-Level Meeting Of The General Assembly On The Prevention and Control of Non-Communicable Diseases, Document 2, p. 95.; 2011, September 19. Available From: https://apps.who.int/iris/bitstream/handle/10665/94384/9789241506236_eng.pdf?sequence=1
16. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, et al. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2019;393(10184):1958-72.
17. Bouvard V, Loomis D, Guyton KZ, Grosse Y, Ghissassi FE, Benbrahim-Tallaa L, et al. Carcinogenicity of consumption of red and processed meat. The Lancet Oncology. 2015;16(16):1599-600.
18. Orlich MJ, Singh PN, Sabate J, Jaceldo-Siegl K, Fan J, Knutsen S, et al. Vegetarian dietary patterns and mortality in Adventist Health Study 2. JAMA Internal medicine. 2013;173(13):1230-8.
19. Springmann M, Wiebe K, Mason-D'Croz D, Sulser TB, Rayner M, Scarborough P. Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail. The Lancet Planetary health. 2018;2(10):e451-e61.
20. Scaling Up Nutrition Movement. Annual Progress Report 2018. 2018 Geneva.
21. Scaling Up Nutrition Movement. A message for the SUN Movement Strategy and Roadmap (2016-2020) from the United Nations Secretary-General. [cited 2019 May]. Available from: https://scalingupnutrition.org/nutrition/nutrition-and-the-sustainable-development-goals/.
22. WHO and United Nations Development Programme. What Ministries of Education Need to Know. 2016 [cited 2019 May]. Available From: https://www.who.int/ncds/un-task-force/policy-briefs/en/.
23. NCD Alliance. A Focus on Children and Non-Communicable Diseases. 2011 [cited 2019 May]. Available From: https://ncdalliance.org/sites/default/files/resource_files/20110627_A_Focus_on_Children_&_NCDs_FINAL_2.pdf.
24. Thow AM, Downs SM, Mayes C, Trevena H, Waqanivalu T, Cawley J. Fiscal policy to improve diets and prevent noncommunicable diseases: from recommendations to action. Bull World Health Organ. 2018;96(3):201.
25. Afshin A, Peñalvo JL, Del Gobbo L, Silva J, Michaelson M, O'Flaherty M, et al. The prospective impact of food pricing on improving dietary consumption: a systematic review and meta-analysis. PLoS One. 2017;12(3):e0172277.
26. Ma Y, He FJ, Yin Y, Hashem KM, MacGregor GA. Gradual reduction of sugar in soft drinks without substitution as a strategy to reduce overweight, obesity, and type 2 diabetes: a modelling study. The Lancet Diabetes & Endocrinology. 2016;4(2):105-14.
27. Sánchez-Romero LM, Penko J, Coxson PG, Fernández A, Mason A, Moran AE, et al. Projected Impact of Mexico's Sugar-Sweetened Beverage Tax Policy on Diabetes and Cardiovascular Disease: A Modeling Study. 2016. PLoS Med 13(11): e1002158. https://doi.org/10.1371/journal.pmed.1002158.
28. Colchero MA, Rivera-Dommarco J, Popkin BM, Ng SW. In Mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. Health Aff (Millwood). 2017;36(3):564-71.
29. FAO. The Food Climate Research Network at The University of Oxford. Plates, pyramids, planet. Developments in national healthy and sustainable dietary guidelines: a state of play assessment. 2016. FAO. Available From: http://www.fao.org/3/a-i5640e.pdf.
30. Blackstone NT, El-Abbadi NH, McCabe MS, Griffin TS, Nelson ME. Linking sustainability to the healthy eating patterns of the Dietary Guidelines for Americans: a modelling study. The Lancet Planetary Health. 2018;2(8):e344-e52.
31. FAO. The State of Food and Agriculture 2009: Livestock in the Balance. 2009. Rome.

32. Steinfeld H, Gerber P, Wassenaar TD, Livestock E, Initiative D, Food, et al. Livestock's Long Shadow: Environmental Issues and Options: Food and Agriculture Organization of the United Nations; 2006.
33. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, et al. Planetary boundaries: Guiding human development on a changing planet. Science. 2015;347(6223):1259855.
34. Intergovernmental Panel on Climate Change (IPCC). Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. 2014. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at: IPCC AR5 Report.
35. Meybeck, A., Laval, E., Lévesque, R., Parent, G. Food Security and Nutrition in the Age of Climate Change.Proceedings of the
International Symposium organized by the Government of Québec in collaboration with FAO. 2018. Québec City, September 24-27, 2017. Rome,
FAO. pp. 132. Licence: CC BY-NC-SA 3.0 IGO.
36. Mateo-Sagasta J, Zadeh S, Turral H. More people, more food, worse water?: a global review of water pollution from agriculture: Rome, Italy: FAO Colombo, Sri Lanka: International Water Management …; 2018.
37. FAO. Identification of indicators for evaluating of sustainable animal diets, by Freija H. van Holsteijn,
Marion de Vries & Harinder P. S. Makkar. 2016. FAO Animal Production and Health Working Paper. No. 15. Rome, Italy.
38. Penakalapati G, Swarthout J, Delahoy MJ, McAliley L, Wodnik B, Levy K, et al. Exposure to Animal Feces and Human Health: A Systematic Review and Proposed Research Priorities. Environ Sci Technol. 2017;51(20):11537-52.
39. WHO. Animal waste, water quality and human health. 2012. Geneva.
40. WHO. The control of neglected zoonotic diseases: a route to poverty alleviation: report of a joint WHO. Geneva: WHO, 2006.
41. GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980-2015: a systematic analysis for the Global Burden of Disease Study 2015 [published correction appears in Lancet. 2017 Jan 7;389(10064):e1]. Lancet. 2016;388(10053):1459–1544. doi:10.1016/S0140-6736(16)31012-1.
42. United States Environmental Protection Agency. The Sources and Solutions: Agriculture. 2019 [cited 2019 June]. Available From: https://www.epa.gov/nutrientpollution/sources-and-solutions-agriculture
43. FAO. Antimicrobial resistance policy review and development framework - A regional guide for governments in Asia and the Pacific to review, update and develop policy to address antimicrobial resistance and antimicrobial use in animal production. Bangkok. 64 pp.
44. Rousham EK, Unicomb L, Islam MA. Human, animal and environmental contributors to antibiotic resistance in low-resource settings: integrating behavioural, epidemiological and One Health approaches. Proceedings Biological sciences. 2018;285(1876):20180332.
45. WHO. Antimicrobial resistance in the food chain. 2017 [cited 2019 June]. Available From: https://www.who.int/foodsafety/areas_work/antimicrobial-resistance/amrfoodchain/en/.
46. WHO. Global Action Plan on Antimicrobial Resistance. 2015. Geneva. WHO.
47. Van Boeckel TP, Brower C, Gilbert M, Grenfell BT, Levin SA, Robinson TP, et al. Global trends in antimicrobial use in food animals. Proc Natl Acad Sci. 2015:201503141.
48. Ayukekbong JA, Ntemgwa M, Atabe AN. The threat of antimicrobial resistance in developing countries: causes and control strategies. Antimicrobial resistance and infection control. 2017;6:47.
49. Marquardt RR, Li S. Antimicrobial resistance in livestock: advances and alternatives to antibiotics. Animal Frontiers. 2018;8(2):30-7.
50. FAO. The State of the World's Biodiversity for Food and Agriculture, J. Bélanger & D. Pilling (eds.) 2019. FAO Commission on Genetic Resources for Food and Agriculture Assessments. Rome. Available From: http://www.fao.org/3/CA3129EN/CA3129EN.pdf

51. Rockström J, Steffen WL, Noone K, Persson Å, Chapin III FS, Lambin E, et al. Planetary boundaries: exploring the safe operating space for humanity. Ecol Soc. 2009.
52. Costello MJ, Wilson S, Houlding B. Predicting total global species richness using rates of species description and estimates of taxonomic effort. Syst Biol. 2011;61(5):871.
53. Scheffers BR, Joppa LN, Pimm SL, Laurance WF. What we know and don't know about Earth's missing biodiversity. Trends Ecol Evol. 2012;27(9):501-10.
54. UN Environment. Global Environment Outlook – GEO-6: Healthy Planet, Healthy People. 2019 Nairobi, Kenya. University Printing House, Cambridge, United Kingdom. p.62.
55. Capon SJ, Lynch AJJ, Bond N, Chessman BC, Davis J, Davidson N, et al. Regime shifts, thresholds and multiple stable states in freshwater ecosystems; a critical appraisal of the evidence. Sci Total Environ. 2015;534:122-30.
56. Mace G, Masundire H, Baillie J. Ecosystems and Human Well-Being: Current State and Trends: Findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment, vol. 1 of The Millennium Ecosystem Assessment Series. 2005.
57. Diaz A, Settele J, Brondizio E, et al. Summar for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Sciece-Policy Platform on Biodiversity and Ecosystem Services: Advanced Unedited Version, 6 May 2019. 2019. Intergovernmental Platform for Biodiversity and Ecosystem Services. [cited 2019 June] Available From: https://www.ipbes.net/sites/default/files/downloads/spm_unedited_advance_for_posting_htn.pdf.
58. Barnosky AD, Matzke N, Tomiya S, Wogan GO, Swartz B, Quental TB, et al. Has the Earth's sixth mass extinction already arrived? Nature. 2011;471(7336):51-7.
59. Ceballos G, Ehrlich PR, Dirzo R. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. Proc Natl Acad Sci U S A. 2017;114(30):E6089-e96.
60. Fowler, D., Steadman, C.E., Stevenson, D., Coyle, M., Rees, R.M., Skiba, U.M. et al. Effects of global change during the 21st century on the nitrogen cycle. 2015. Atmospheric, Chemistry and Physics 15(24), 13849-13893. https://doi.org/10.5194/acp-15-13849-2015.
61. Kok, M., Alkemade, R., Bakkenes, M., Boelee, E., Christensen, V., van Eerdt, M. et al. How sectors can contribute to sustainable use and conservation of biodiversity. 2014. CBD Technical Series No. 7. PBL Netherlands Environmental Assessment Agency.
62. Roser M., Ritchie H., Yields and Land Use in Agriculture. 2019. Published online at OurWorldInData.org [cited 2019 May] Available From: https://ourworldindata.org/yields-and-land-use-in-agriculture'.
63. Tilman D, Clark M, Williams DR, Kimmel K, Polasky S, Packer C. Future threats to biodiversity and pathways to their prevention. Nature. 2017;546(7656):73-81.
64. Nordborg, M. and Röös, E. Holistic Management – A Critical Review Of Allan Savory's Grazing Method. 2016. Uppsala: SLU/EPOK - Centre for Organic Food and Farming & Chalmers. .
65. Cook, S. The spice of life: The fundamental role of diversity on the farm and on the plate. 2018. Discussion Paper. IIED and Hivos, London and The Hague.
66. Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC 2005.
67. IPCC. Summary for policymakers. 2014. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32.
68. Kuhnlein, H., Erasmus, B., Spigelski, D. Indigenous Peoples' Food Systems: the many dimensions of culture, diversity and environment for nutrition and health. 2019. FAO and CINE, Rome.
69. Das S, Vincent JR. Mangroves protected villages and reduced death toll during Indian super cyclone. Proc Natl Acad Sci. 2009;106(18):7357-60.
70. Gupta J, Hurley F, Grobicki A, Keating T, Stoett P, Baker E, et al. Communicating the health of the planet and its links to human health. The Lancet Planetary Health. 2019;3(5):e204-e6.
71. FAO. Global food losses and food waste – Extent, causes and prevention. Rome.
72. FAO. Food Wastage Footprint & Climate Change. 2015 Rome.
73. IPCC. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. 2007 IPCC, Geneva, Switzerland, 104 pp.

74. FAO. Food Wastage Footprint: Full-Cost Accounting, Final Report. 2014. FAO.
75. Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, et al. Food security and food production systems. 2014.
76. Nelson GC, Rosegrant MW, Koo J, Robertson R, Sulser T, Zhu T, et al. Climate change: Impact on agriculture and costs of adaptation: Intl Food Policy Res Inst; 2009.
77. Mills G, Buse A, Gimeno B, Bermejo V, Holland M, Emberson L, et al. A synthesis of AOT40-based response functions and critical levels of ozone for agricultural and horticultural crops. Atmos Environ. 2007;41(12):2630-43.
78. Myers SS, Zanobetti A, Kloog I, Huybers P, Leakey AD, Bloom AJ, et al. Increasing CO 2 threatens human nutrition. Nature. 2014;510(7503):139.
79. Zhu C, Kobayashi K, Loladze I, Zhu J, Jiang Q, Xu X, et al. Carbon dioxide (CO2) levels this century will alter the protein, micronutrients, and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries. Science advances. 2018;4(5):eaaq1012.
80. Rojas-Downing MM, Nejadhashemi AP, Harrigan T, Woznicki SA. Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management. 2017;16:145-63.
81. Howden S, Crimp S, Stokes C. Climate change and Australian livestock systems: impacts, research and policy issues. Australian journal of experimental agriculture. 2008;48(7):780-8.
82. Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U. Effects of climate change on animal production and sustainability of livestock systems. Livestock Science. 2010;130(1-3):57-69.
83. Gattuso J-P, Magnan A, Billé R, Cheung WW, Howes EL, Joos F, et al. Contrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios. Science. 2015;349(6243):aac4722.
84. Lloret J, Rätz H-J, Lleonart J, Demestre M. Challenging the links between seafood and human health in the context of global change. J Mar Biol Assoc UK. 2016;96(1):29-42.
85. Boyd PW, Lennartz ST, Glover DM, Doney SC. Biological ramifications of climate-change-mediated oceanic multi-stressors. Nature Climate Change. 2015;5(1):71.
86. Bebber DP, Ramotowski MA, Gurr SJ. Crop pests and pathogens move polewards in a warming world. Nature climate change. 2013;3(11):985.
87. Bale JS, Masters GJ, Hodkinson ID, Awmack C, Bezemer TM, Brown VK, et al. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Glob Chang Biol. 2002;8(1):1-16.
88. Potts SG, Imperatriz-Fonseca V, Ngo H, Biesmeijer JC, Breeze T, Dicks L, et al. Summary for policymakers of the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on pollinators, pollination and food production. 2016.
89. Smith MR, Singh GM, Mozaffarian D, Myers SS. Effects of decreases of animal pollinators on human nutrition and global health: a modelling analysis. The Lancet. 2015;386(10007):1964-72.
90. Kjellstrom T, Briggs D, Freyberg C, Lemke B, Otto M, Hyatt O. Heat, human performance, and occupational health: a key issue for the assessment of global climate change impacts. Annu Rev Public Health. 2016;37:97-112.
91. Dunne JP, Stouffer RJ, John JG. Reductions in labour capacity from heat stress under climate warming. Nature Climate Change. 2013;3(6):563.
92. The World Bank. Employment in agriculture, % of total employment, 2018. [cited 2019 June]. Available From: https://www.theglobaleconomy.com/rankings/Employment_in_agriculture/